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OF THE

UNITED STATES GEOLOGICAL SURVEY

PART VII.—EXPLORATIONS IN ALASKA IN 1898

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A RECONNAISSANCE IN THE SUSHITNA BASIN AND ADJACENT TERRITORY, ALASKA, IN 1898.

By George H. Eldridge.

INTRODUCTION.

The portion of Alaska assigned for reconnaissance to the party of which the writer had charge embraces the area "within the divides delimiting the Sushitna river system, and beyond to the Yukon." The object of the reconnaissance was to ascertain the general topographic features; the distribution of the rock masses; their relations and characteristics; the occurrences of valuable minerals, especially gold; and, in addition, the practicable passes between the Sushitna and Tanana rivers, with reference to the location of a railroad or wagon route from Cook Inlet to the Tanana. The topographic survey was to embrace a continuous stadia line over the whole route traversed, with triangulation as a substitute if found practicable, starting from a position in latitude, longitude, and elevation as nearly exact as could be determined, and closing in the same way. Latitude stations were to be established at intervals of 25 miles. The topography, not only adjacent to the route, but, so far as feasible, at a distance, was to be sketched by means of the plane table. Other observations, for magnetic declination, temperature, climate, character and extent of timber, and navigability of streams, were also to be made. The topographic work was committed to Mr. Robert Muldrow, of the Survey.

TOPOGRAPHY.

SUSHITNA DRAINAGE BASIN.

Cook Inlet is a structural mountain basin of vast size, open to the North Pacific at its southern end. At present the sea occupies about half its total area, the remaining portion having been gradually filled and elevated until it now forms a broad valley, 75 to 100 miles wide by 150 to 175 miles long, drained by the Sushitna river system.

INCLOSING MOUNTAIN RANGES.

The inclosing mountain ranges are of intricate and rugged topography, of an approximate average height of 8,000 to 10,000 feet, sharply serrated and relieved by numerous peaks 12,000, 15,000, and 20,000 feet in altitude. The loftiest and most rugged range is the Alaskan, constituting the Sushitna-Tanana divide. This carries the highest peak on the North American continent, Mount McKinley (*Bolshaya*, Russian; *Traleyka*, Sushitna Indian), 20,464 feet in altitude (Pl. II, *A*).[1] West of Mount McKinley about 30 and 50 miles, respectively, in the same range, are two other peaks, approximately 14,000 and 16,000 feet in altitude. The sawtooth profile is the common crest line of the range, while its face is carved with gorges 4,000 to 8,000 feet deep, with walls precipitous and upper courses glacier filled.

The Chigmit and Tordrillo ranges, which lie west of Cook Inlet and the Sushitna Valley, resemble the Alaskan Range in their bold and rugged nature. Both carry lofty, unnamed peaks 10,000 to 15,000 feet in altitude, the Chigmit bearing in its southern half the two well-known volcanoes, Redoubt and Iliamna, 11,000 and 12,000 feet in altitude, respectively. Iliamna is still steaming. The two ranges are separated by a deep cut, from which, it is said, flows the Beluga River.

East of the Sushitna Valley and Cook Inlet the mountains have again great ruggedness, and there are many points with altitudes but little less than those in the Alaskan, Tordrillo, and Chigmit ranges. Their southern half occupies the Kenai Peninsula, while northward they form the divide between the Sushitna and Copper rivers, though deeply cut by the Knik and Matanuska rivers, which flow into Cook Inlet. For this northern half, bordering the Sushitna Valley, the name Talkeetna has been suggested.

At the head of Cook Inlet and just west of the Sushitna River is Mount Sushitna, 4,280 feet in altitude (Pl. II, *B*). It forms the south-eastern extremity of a low ridge extending well toward the Tordrillo Range and separating the waters of the Yentna, the chief western tributary of the Sushitna, from the streams entering the inlet farther to the south.

The higher peaks of the Alaskan and other ranges are snow capped the entire summer, but the lower elevations are bare from June to September. Glaciers of various sizes occupy the majority of the higher valleys, and in some instances reach well down to the main stream courses.

RIVER SYSTEM.

The vast watershed referred to above drains southward through the Sushitna river system. What is locally regarded as the main stream, though little larger than its two principal tributaries, the Chulitna and Yentna, rises far in the interior, in the angle of the Talkeetna

[1] Continued cloudy skies and a rapid succession of storms during the entire season prevented a more satisfactory photographic exhibit of the physical features of the region traversed. That no views appear of the Upper Chulitna and the Cantwell valleys is also due to continued rains and to the impossibility of carrying cameras on the forced march over this portion of the route.

and Alaskan ranges, having a course irregular but in the main south-southwest. The Chulitna enters the main stream about 80 miles from the mouth, in latitude 62° 20′ N., longitude 150° 32′ W. It has many forks rising in the Alaskan Range, some of them originating in the canyons of Mount McKinley. The volume of water in the Sushitna below the entrance of this stream is very great, the channel being 1½ miles across—more than twice the width of either stream above. A mile below the Chulitna the main stream receives another important branch, from the northeast, the Talkeetna. Though rising far back in the Talkeetna Range, its volume of water is much smaller than that of either tributary of the Sushitna above. The Yentna enters the main river 20 miles above the mouth. The region drained by this tributary is vast, embracing the country lying in the angle between the Alaskan and Tordrillo ranges. The Sushitna, Chulitna, and Yentna carry vast amounts of sediment derived from glaciers and from the banks, which are constantly wearing away. Their currents are probably between 4 and 5 miles an hour. The main channels are deep. All receive great numbers of creeks, many of them large and important, many running the clearest mountain water. A description of the Yentna, which was ascended by Mr. Spurr en route to the Kuskokwim, will be found in an accompanying report.

GENERAL FEATURES OF THE LOWER VALLEY.

The valley of the main Sushitna, below its confluence with the Chulitna, merges with that of its tributary, the Yentna, forming a broad, gently undulating scope of country, 100 to 125 miles in diameter, and rising gradually from 4 or 5 feet above mean high tide at the mouth of the river to 300 and 400 feet at the border of the foothills. Here and there, as opposite Mount Sushitna and just below the Yentna, the general level is relieved by low, yet conspicuous, ridges of eruptive rock; at other points, by especially heavy deposits of gravel, which have been sufficient to form local prominences; and yet again, as opposite and a little below the Yentna, by a ridge of hard conglomerate, with sandstone, clay, and coal seams near by. The valley is generally well timbered with cottonwood, spruce, and birch, the latter upon the ridges and other elevated portions. Meadows and swamps are freely interspersed, and lakes are a conspicuous feature. At the periphery of the valley the country is generally high and rolling, forming foothills to the adjacent ranges.

The Sushitna River has formed a large delta, which is now cut by three or four channels of considerable size, the westernmost being used by the Indians and traders on account of shortness, depth, and the opportunity afforded, in reaching it, of landing on the shore of the inlet in case of storm or high winds, the latter being of common occurrence. The channels, well defined and permanent through the land portion of the delta, offshore frequently change, now becoming choked with the sediments brought down, now being scoured by the strengthening currents. The delta, above general tide level, is a vast body of marsh land, relieved along the channels by fringes of timber that become heavier as distance from the inlet is gained. At first only alder and cottonwood prevail, but 8 or 10 miles upstream spruce appears, increasing rapidly to Alexander (*Taguntna*, Indian) Creek, from which point northward it is an important growth both in quantity and in size. The Sushitna delta is continuous southward, along the west side of the inlet, with what is locally known as the Beluga Flats (Pl. II, *B*), a strip of marsh land 10 or 12 miles long by 4 or 5 wide, lying between the uplands of glacial sands and bowlder clays and the inlet's waters. The Beluga and Theodore rivers, draining the contiguous portions of the Tordrillo Range and the high lands along its base, cross the flat and enter the inlet by channels as blind as those of the Sushitna. The waters of the inlet are very shallow off the flats, low tides exposing a belt of mud and sand a mile or more in width. The tides of the inlet have a rise and fall of 30 feet and are exceedingly strong.

Between the delta and the mouth of the Chulitna the Sushitna maintains a width of from one-half to 2 miles and is, for the greater portion of the distance, studded with islands, though just below the Yentna, and again about 14 miles below the Chulitna, there is a single broad, deep channel, one-half to three-quarters of a mile wide. The stage of the water causes marked variation in the relative proportion of islands and bars exposed, seriously affecting the ease with which the river is ascended, since, on account of the swiftness of the current, the greater portion of the distance above the Yentna has to be made by towing along bar or island or on the main shores (Pl. I, *A*, *B*, and *C*). There are, however, many minor channels of greater or less length where comparatively easy progress can be made with oars and paddles. The main channel of the river for 130 miles from its mouth is generally well defined and of considerable depth, sufficient, it is believed, for the passage at all points of light-draft stern-wheel steamers.

The banks of the Sushitna River for the lower 12 miles rise but 5 or 6 feet above ordinary water level. They consist of alluvial mud or fine gray to yellow sand. At Alexander Creek gravel banks appear, but not until a mile or two above the Yentna do they become a pronounced feature of the river (Pl. I, *D*). From this point to the Chulitna they form banks 10 to 200 feet high, with but scant bottom lands along either main river or tributaries. The sands and gravels probably underlie the larger part of the general valley of the Sushitna and its branches, their generally level surface, with its accumulated soil, offering vast areas of land well adapted to agriculture.

GENERAL FEATURES OF THE UPPER VALLEY.

Between 5 and 10 miles above the mouth of the Chulitna the character of the main Sushitna Valley begins to change. The river here lies in the foothills and a little beyond is inclosed between ridges of 3,000 to 4,000 feet elevation that separate it on the southeast from the Talkeetna and on the northwest from the Chulitna. The stream itself now runs in a most picturesque gorge, 400 to 500 feet deep, which has been cut in the bottom of an earlier though still comparatively recent valley. About 50 miles above the mouth of the Chulitna, rapids, with falls above, are reported, impeding further progress upstream by boat. By a portage of about 25 miles, however, made on the northwest side of the river, boats may again be utilized for transportation of supplies, nearly to the great glaciers at the head of the stream; but the current is much swifter than from the rapids down. The early valley of the Sushitna (see Pl. V) is nearly closed at its lower end, 10 miles above the Chulitna; it opens to a breadth of 6 or 8 miles within the next 10 miles, and thence maintains this width in a general way as far as the great bend in the river about 70 miles above the Chulitna. Beyond this it is said to broaden still further and to take on the character of an open highland country, yet with mountains at a distance, along its periphery. From 10 to 15 miles above the Chulitna the north side of the valley is marked with terraces that succeed one another well toward the summit of the ridge. The origin of these terraces was not investigated, but they may have been due to a difference in successive strata or, perhaps, to the effects of early erosion and changes in water levels.

Although this early valley of the Sushitna had once a general and well-defined base-level, it has since been deeply cut by mountain torrents, and its floor rendered further uneven by general erosion of the underlying, highly folded slates. The region is now one of hills and dales, beautiful in the extreme, with growths of spruce and birch interspersed with open, grassy or moss-covered parks and lakes of great picturesqueness. The soil in the hollows of this high bench land is deep and rich, but the ground, especially the moss-covered portion, is uneven with tussocks and difficult to traverse. Timber line in the Alaskan Range lies approximately at 3,000 feet above sea level; beyond this for 500 to 600 feet alders extend, succeeded finally by moss-covered slopes or the bare rocks themselves.

The head of the main Sushitna is said to embrace three or four large branches that spring from glaciers well up in the mountains forming the eastern extremity of the Alaskan Range.

THE CHULITNA AND THE MOUNTAIN PASSES AT ITS HEAD.

The Chulitna was not ascended in our exploration, but was observed from the range separating it from the Sushitna, at a point opposite the mouth of Indian Creek. The distance between the streams is here 12 or 15 miles. The course of the main Chulitna is a little west of south, but it receives numerous large tributaries, glacial and others, from Mount McKinley and adjacent peaks to the west, while from icy amphitheaters high in the spurs to the east flow several others of considerable importance. At its head the Chulitna has several prominent forks, which rise far back in the range, some of them leading to passes less than 4,000 feet in altitude. Two of these forks were ascended last season, and the passes at their heads crossed, by independent parties from the Geological Survey and the Army. The Survey party crossed at the head of the easternmost fork, finding there two passes to the waters of the Tanana about 1½ miles apart, one 3,700 feet in altitude, the other 4,200 feet, the lower lying to the east of the other, with an approach of gentle grade on both sides quite to the summit. In the immediate vicinity of these are two other passes, one leading from what is probably an upper fork of the Sushitna, the other from the tributary of the Chulitna next west of that ascended by the Survey party. The latter pass is the lowest of the four in this vicinity and bears a small lake at its summit. Its elevation is probably about 3,500 feet. The approach to it appears to be easy. The four passes just described lead directly to the same tributary of the Tanana.

The detail from the Army, from a detachment of the Fourteenth Infantry under Captain Glenn, consisting of Sergeant Yanert and a private, under the pilotage of an Indian, ascended what is possibly the main tributary of the Chulitna and crossed the range at a point perhaps 20 miles west of that at which the Survey party crossed, by a pass estimated to be about 2,700 feet in altitude and affording a more direct route than that taken by the Survey party. This pass, or at least the valley leading north from it, the Survey party saw on its journey toward the Tanana. The existence of still other passes in the Alaskan Range is possible to the east of the foregoing, indeed, quite probable, though to the west questionable.

The general valley of the Chulitna is even more a mountain valley than that of the Sushitna, for it lies directly at the base of Mount McKinley and the peaks to the northeast. Notwithstanding this, it is comparatively broad, has the same character of bench lands as described for the Sushitna, and appears fairly easy of access. It is well timbered and watered and there are hundreds of acres of meadow and grass lands similar to those seen in the Sushitna Valley. The upper portion of the valley is basin shaped, with the spurs of the inclosing ranges extending well to the center. Even the lofty ridge which farther south separates the Chulitna from the Sushitna River and Indian Creek is continued several miles into the basin, making in its southeastern quadrant a deep cove of high, rolling meadow and moss-covered lands. The southern end of this cove is drained by a deep gorge cut entirely across the median ridge, while the northern portion drains around the end of this ridge into an upper branch of the Chulitna.

Magnetic variations, Sushitna River, Alaska. (Robert Muldrow, 1898.)

Latitude.	Longitude.	Place.	Date.	Variation.
61° 19′	150° 38′	Mouth Sushitna River.	May 12–15	27° 15′ E.
61° 35′	150° 27′	Mouth Yentna River.	May 26, 9.45 a. m	27° 20′ E.
61° 54′	150° 07′	Sushitna River	June 3, 4.30 p. m	27° 50′ E.
62° 20′	150° 10′	Forks Sushitna River.	June 26, 4.30 p. m	29° 30′ E.
62° 49′	149° 39′	Sushitna River, mouth of Indian Creek.	July 5, 4.33 p. m	29° 30′ E.

CANTWELL RIVER.

The tributary of the Tanana descended by the Survey party is probably the Cantwell River. Sergeant Yanert encountered the same stream well down. Though it was not followed to the mouth, the tributary is known to lie considerably to the west of that descended by the main Army party, which was identified as the Delta River.[1] The stream descended by the Survey party is important in size, receiving within the range, for a length of at least 60 miles, many large tributaries, glacial and other. For 20 or 25 miles from its source it is confined to narrow and tortuous canyons, two important tributaries entering it from the east, about 5 and 12 miles from its head, respectively. Twenty-five miles from the source the stream, after passing through a short box canyon, crosses midway an open northeast-southwest valley, 40 or 50 miles in length by 5 or 6 in width, drained from either end by large streams of glacial origin. In passing out of this valley these streams have each cut a deep gorge in the northwest wall, uniting beyond it in a river between 100 and 200 yards wide, flowing a heavy volume of water. The stream descended by the Survey party enters the western branch just above its exit from the valley, about 10 miles above its confluence with the eastern branch. Both east and west branches carry heavy sediments, derived from glaciers that feed their tributaries. Their valleys are locally well timbered with spruce and cottonwood. There are, however, great areas of moss and marsh

[1] See accompanying report by W. C. Mendenhall.

land of irregular surface, and in the valley of the western fork, especially in its upper half, there are numerous lakes, some of them apparently of considerable size. It is this, the western, valley that Sergeant Yanert descended, reporting that he entered it over a low pass directly from the valley of the Chulitna, which he ascended. At the junction of the western branch with the tributary followed down by the Survey party, Sergeant Yanert, deserted by his Indians, decided to retrace his steps. About 40 miles below the confluence of the east and west forks referred to above, for most of which distance the river flows through a narrow, deep canyon, there enters from the east another important tributary, occupying a broad, open valley of great length and of the same general appearance as the upper valleys. This tributary is also glacier fed, and it is difficult to say whether it is inferior or superior in size to that descended by the Survey party. About 15 miles below its entrance into the main river the latter appears to pass out of its mountain-hemmed valley by a sharp gorge 5 or 6 miles in length, through which it was believed the open valley of the Tanana could be seen. From these lower forks the Survey party, short of supplies, retraced its steps over practically the same trail.

GEOLOGY.

STRATIGRAPHY.

The country traversed by the Survey party presents for examination a half dozen formations and a structure broadly simple yet complex in detail. The formations include granite, which it is believed is the basal granite of the country; schists and slates, chloritic and other; a series of conglomerates and coarse sandstones; sandstones and shales in succession, with coal seams, belonging to the Kenai formation; and drift—gravels, sands, and clays or muds. The ages of the formations are undetermined except for the Kenai, which Drs. W. H. Dall and F. H. Knowlton studied several seasons ago and found to be Eocene.

GRANITE.

This is the basal rock of the country traversed and is apparently of the same nature as that found in like positions elsewhere in Alaska. It is bright gray, of moderately coarse texture, and either massive or of a heavy gneissic structure. Its chief components are feldspar, biotite, and quartz, with occasional hornblende. The greatest body encountered was that of Mount Sushitna (Pl. II, *B*), its entire mass above an altitude of 1,200 feet being of this rock; below this altitude the slopes showed no outcrops on our line of ascent. From the summit of the peak the granite appeared to form the core of the ridge that extends for many miles to the northwest.

A second locality of granite is a small faulted area on the east side of the main Sushitna about 18 miles above the mouth of the Chulitna. The granite has a prominent gneissoid structure that imparts to it the appearance at a distance of a heavily bedded quartzite. It forms a characteristic ridge, the smooth, well-rounded top rendering it a conspicuous feature of the landscape. The fault referred to has a northwesterly trend and a throw of perhaps 1,000 feet, the granite uplifted on the northeast against slates on the southwest. To the northeast the granite rapidly passes beneath the slates, its outcrop along the river being less than a mile in width.

A third granite mass is exposed a short distance above the last area, on the opposite side of the river. It forms the core of the ridge between the Chulitna and the Sushitna, and extends, with occasional interruptions, nearly to the head of Indian Creek. At the base of the ridge, on the southeastern side, it is fringed by quartzites and slates. Small remnants of the latter rocks are also to be found at several points along the crest of the ridge, and, indeed, locally, the series may extend quite over the summit, from base to base. The granite is of the same general character as that in the areas already described, but the gneissic structure is not so strongly developed.

Granite also occurs on some of the tributaries of the Chulitna explored by the Survey party, but the areas of exposure seen were comparatively small, separated by others of the overlying series of slates. It was also found in similar isolated patches north of the Tanana-Sushitna divide.

SUSHITNA SLATES.

The Sushitna slates (Pl. VI, *A*) constitute one of the most important of the Alaskan formations. The beds are essentially quartzitic, varying in coarseness of material from an extremely fine homogeneous rock to one of granular structure. In addition to quartz there are occasional orthoclase, plagioclase, biotite, muscovite, scattered grains of iron oxide, and minute fragments of slate—apparently of the same nature as the fine-grained slates of the series itself. The entire series has been extensively sheared, and the sand grains crushed, producing thus the partial schistose or slaty structure that so generally prevails. Mr. Cross, of the Survey, who examined the rock microscopically, found no grains referable to igneous rocks, in spite of the impression from megascopical examination that the rocks were sheared eruptives.

A feature of the formation in localities where great crumpling of the strata has taken place is the presence of large numbers of quartz seams, a half inch to 2 feet thick, reticulating the exposed surface of the series with considerable intricacy. Such seams often show mineralization with sulphide of iron, and it is believed that they constitute the source of much of the gold found in the bars of the Sushitna and in other places where the slate series is present.

In ascending the main Sushitna one finds this great series of slates first exposed about 15 miles above the mouth of the Chulitna. Thence the formation extends up river to a point considerably beyond the mouth of Indian Creek—it is said by a prospector to a little above the falls, or about 50 miles above the lower outcrop. The general trend of the series, east of the Sushitna River, is believed to be parallel with that of the Talkeetna Range—that is, NNW.-SSE.; west of the Sushitna its relations are with the Alaskan Range, the strata veering first to E.-W., and then to NE.-SW. The general dip is away from the range axes at degrees varying between 45 and 85. In the Tordrillo Range the same slates are again said to be found, but this is not on the best authority. Throughout all the ranges there are doubtless many secondary folds, varying in direction and causing serious intricacies in the areal distribution of the rocks involved.

North of the Sushitna-Tanana divide the series of slates is quite as fully developed as south of it. Again their general dip is outward, except where influenced by local secondary folds. The dip on this side is usually below 45°. The series maintains the same general features of composition, schistosity, cleavage, and quartz veinings more or less mineralized as on the south side of the range. The total width of the terrane across this range can not be far from 80 miles.

CANTWELL CONGLOMERATE.

This is a series of conglomerates and coarse sandstones which was encountered in the banks of the Cantwell River about 10 or 15 miles above the lower forks. The matrix is quartz, the pebbles are of dark slate, perhaps derived from the great series of slates described above, on which they presumably rest. The series is, possibly, 600 or 700 feet thick, and may be thicker. The area underlain is not known, but may be 50, 100, or more square miles. The strata outcrop for a mile or two along the river bank, the channel now lying with the strike, now with the dip, of the beds. The general dip is northward.

KENAI FORMATION.

This is the only other sedimentary formation encountered along the route of travel, except the recent bowlder clay, sands, and gravels. The formation is a succession of soft, light-gray sandstones and mud shales, with interspersed coal seams (Pl. I, *E*). Dall[1] and Spurr[2] report conglomerates in the series. Certain conglomerates were found by the writer in the east bank of the Sushitna, a mile below the Yentna, but their relation to associated recognized Kenai beds was obscure. The

[1] Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, p. 789.

[2] Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, pp. 185-209.

age of the Kenai series has been determined from plants and mollusks to be upper Eocene—Oligocene.[1]

From the existence of the Kenai formation along the eastern shore of Cook Inlet, its presence from a point several miles southwest of Tyonek to the vicinity of Mount Sushitna, its appearance on the Sushitna River, first at Sushitna Station and again on the main stream above the mouth of the Chulitna and again on the Talkeetna, it is very probable that the entire Cook Inlet Basin, both above and below water, is underlain by this formation, with its periphery defined by the base of the surrounding ranges. Of the foregoing localities the Kenai Peninsula is doubtless the most important in point of areal outcrop. Next to this is, perhaps, the Tyonek field, which, from reports of the finding of coal by prospectors, must underlie much of the region to the foothills of the Tordrillo and Chigmit ranges. The upper area on the Sushitna is also important, for the formation can be traced along the stream for 3 or 4 miles, and it doubtless extends beyond this, as well as outward on either side, beneath the gravels, earth, and vegetation which constitute the general surface of the land. In all of these localities the same general features of the formation are recognizable.

On the lower east fork of the Cantwell River, about 10 miles above its confluence with that descended by the Survey party, there is an outcrop of shales and sandstones with traces of thin coal seams, which it is believed belong to the Kenai. The areal extent of the formation in this locality, however, was not determined.

The beds of the Kenai are rarely horizontal. Dall reports gentle but broad undulations in the strata on the Kenai Peninsula; in the Tyonek field the dips observed by the writer are between 20° and 40° E.; in the Upper Sushitna a general dip of 5° to 10° downstream (southward) was found; and in other localities similar undulations were met with.

PLEISTOCENE DEPOSITS.

The recent deposits of the Sushitna Valley and adjacent shores of Cook Inlet embrace gravels, sands, and clays. These were laid down in two distinct periods.

In the earlier period was deposited a bluish-gray clay, locally rich in pebbles and small bowlders of materials derived from encircling ranges—granite, slate, and the various eruptives, together with coal derived from the beds of the underlying Kenai series. The clay is of wide distribution, being found at frequent intervals in the bluffs of the Sushitna to the entrance of the Chulitna, along Cook Inlet west of Tyonek, and underlying the bench lands contiguous to the Beluga and Theodore rivers. In each instance the extent of the outcrop indicates a considerable area for the deposit. The clay rests uncon-

[1] Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, p. 837.

formably upon the Kenai formation, and occurs in numerous independent outcrops. Its general thickness it was impossible to determine.

In the later period were laid down heavy deposits of coarse, loosely agglomerated, ferruginous sand and gravel (Pl. I, *D*), also embracing materials derived from the encircling ranges. The proportion of gravel to sand varies between the extremes, even in the same locality. It is noticeable, however, that the general coarseness of the material increases as the river is ascended. Cross bedding is a common feature.

At Tyonek is a heavy deposit of yellow sand, which forms bluffs 150 to 200 feet high. It is believed that this sand belongs to the same period as the younger gravels described above, being the corresponding seaward deposit.

ERUPTIVES.

Several eruptives were encountered along the Survey party's route to the interior. East of Mount Sushitna there is a conspicuous north-south ridge, rising from the valley 400 or 500 feet, and composed entirely of hornblende-andesite. Between this and the mountain is a smaller ridge of the same rock. The general features of the specimens from the two localities are: For the first, a few phenocrysts of hornblende and plagioclase in a strongly predominant groundmass of plagioclase feldspar in short, square prisms and colorless particles, with a fine magnetite dust sprinkled through the mass; for the second, simply a fine-grained mass without the development of phenocrysts. Mr. Cross, of the Survey, made the determinations.

Just below the mouth of the Yentna the west bank of the Sushitna presents a bluff of olivine-diallage-basalt, according to Mr Spurr, who examined it in detail. Mr. Spurr describes the rock constituents as plagioclase, olivine, diallage, all very abundant, some iron oxide, a little colorless augite, and amygdules filled with natrolite.

At the head of Indian Creek, from the peak just east of the pass, was obtained an eruptive which Mr. Cross determined as metadiorite or metadiabase, offering in explanation the following statement: The rock "appears to have been a simple hornblende-diorite of fine-granular structure. So much secondary green hornblende has been formed in the plagioclase and as a fringe about the older hornblende grains that the primary constitution and structure are obscured. It may be altered diabase, the original augite having changed to hornblende, but I think the rock was probably a diorite."

Other eruptives, including a granite, were found in situ in the heart of the Alaskan Range, in the pass crossed by the Survey party.

STRUCTURE.

The structural features of the Sushitna Valley and its inclosing ranges (map 3) could be gathered only in so far as the route of travel and the allotted time permitted. The results attained, therefore, are limited, and in no instance cover an area structurally complete in itself. The feature of chief interest is the Alaskan Range, which, in the region of the Chulitna and Cantwell rivers, shows in the slates which compose it a broad anticlinal structure, the axis NE.-SW., the steeper side of the fold to the south. From the ridge between the Sushitna and Chulitna this side of the range is in full view for 50 or 60 miles, and clearly shows the stratification of the slates and their highly inclined position. In consequence of the steep dip and the variable though always great hardness of the strata, an unexampled ruggedness has been imparted to this face of the range, rendering its lofty points and its high, glacier-filled canyons and amphitheaters utterly inaccessible. No extended general view of the north side of the Alaskan Range was obtained.

In the transverse section of the range many secondary folds of greater or less importance were discovered. Such folds vary materially in the directions assumed by their axes, and in deciphering the structure of the range for a given area many intricacies will be encountered. An instance of a secondary fold occurs in the ridge between the Sushitna River and its tributary, Indian Creek, on the one hand, and the Chulitna on the other—an anticline with granite core and fringing slate and quartzite, the latter locally extending across the summit. Even in this secondary fold unevenness of development has been displayed, for opposite a point midway the length of Indian Creek is a most remarkable structural pass, a veritable synclinal crumple in the anticline of the main ridge. The northern end of the anticline is found in a lofty, rugged mountain mass that extends for 20 miles beyond the head of Indian Creek into the middle of the upper valley of the Chulitna. Secondary folding occurs quite to the crest of the divide, but it is here more completely involved in the central or axial fold of the range and is therefore less individual in character.

North of the divide, also, some very large secondary folds were observed, notably in the vicinity of the upper east and west forks of the Cantwell, and again in the ranges inclosing the valley at the lower forks and the main stream below.

Regarding the structure of the Talkeetna Range, the distant views obtained suggested for it a series of folds of much irregularity of disposition. Mr. Mendenhall, however, passed through the heart of this range, and to his report the reader is referred.

The structure of the Tordrillo Range, which is a synclinorium, Mr. Spurr will discuss. The Chigmit Range is doubtless more or less volcanic.

From the foregoing it will be seen that Cook Inlet and the Sushitna

Valley constitute a great structural basin, modified as to its floor by certain eruptives and by the deposits of recent times, especially the Pleistocene gravels. The Kenai formation was deposited prior to the completion of the mountain uplifts, for its strata dip to the center of the inlet and valley in a pronounced degree.

MINERAL RESOURCES.

The mineral resources of the Sushitna Valley at present known are gold and coal.

GOLD.

The gold found along the route of the Survey party, except traces by assay in the pyritiferous quartz of the slate series, is placer. Placer gold was found in every bar of the Sushitna River prospected, pans being taken every 4 or 5 miles from the Yentna to Indian Creek. Nowhere, however, did the amount exceed a few fine colors. The source of this gold is, doubtless, the innumerable small quartz seams in the Sushitna slate series, and it may have been transferred direct to its present resting place or may have first been deposited in the heavy Pleistocene gravel beds through which the river flows. It was found, in minute grains and in small quantity, at several points in the younger of these gravels; the older gravel, with its matrix of blue clay, yielded no returns. Above the Chulitna the gold is more immediately derived from its original source, the mountain torrents here rushing directly from the slates into the main stream. In the torrential streams the gold is coarser than in the river bars, in a stream entering the river from the east, about 2 miles below Indian Creek, particles of a value of 5 or 6 cents being picked from the rim rock.

The quartz seams rarely exceed 8 inches in width, while perhaps the majority are under 4. Nearly all bear traces of pyrite, and some show small portions rich in this mineral. However, samples chosen for their favorable appearance from the gold standpoint showed none of this mineral by panning, but one or two gave traces of gold and silver by assay. Notwithstanding these results, it is believed that the quartz seams afford the gold for the enrichment of the river bars. It is in the region of the slates that the richer prospects of placer gold are found; also, the gold is here coarser, and in some instances the location of the deposits is such that the gold could not have been derived from any other source than the slates. From the enrichment of the quartz, too, with a mineral so often auriferous, it is thought that the veins are the source.

The localities of special importance, it will be gathered from what has been said, are such areas in the slate belt as have undergone special crumpling and crushing and so have furnished opportunities for the formation of quartz seams and their mineralization. Two of these localities were encountered on the route followed by the Survey party, one in the hills on the southeast side of the Sushitna 2 miles below Indian Creek, and one north of the divide, on the west side of the tributary of the Cantwell descended, about 15 miles from its source. From prospectors a third locality was learned of—on the Chinaldna, a tributary of the Talkeetna, 25 or 30 miles south of the locality first referred to. It is probable, also, that in the ranges encircling the Sushitna Valley many other localities of equal promise will be found.

COAL.

THE FIELDS.

The coal of Cook Inlet and the Sushitna drainage system occurs in the Kenai formation, of Eocene (early Tertiary) age. The beds of the Kenai Peninsula, on the east side of Cook Inlet, were examined by Dr. W. H. Dall in 1895, and are described in Part I of the Seventeenth Annual Report of the United States Geological Survey, page 765 and following. They will not be further referred to here. On the route of the present survey three areas of coal outcrops were encountered—at Tyonek, on the west shore of the inlet; on the east bank of the Sushitna, a mile below the mouth of the Yentna; and on the main fork of the Sushitna, 4 to 10 miles above the mouth of the Chulitna. The Tyonek field is the easiest of access, and its outcrops have for some time afforded coal for use in a small local steamer and for domestic purposes at the agency of the Alaska Commercial Company at this point.

The extent of the Tyonek field was not investigated, but from independent reports by prospectors and Indians it is inferred that it extends for several miles inland, and from a point 7 or 8 miles west of Tyonek along the coast, as far northward at least as Theodore River. From a point 2 miles west of Tyonek to one about 6 miles west there is a continuous outcrop of the Kenai formation—sandstones, shales, and coal seams—along the beach bluffs (Pl. I, *E*). The strata dip from 35° to 60° SE., the amount varying locally. The general strike of the series, NNE., would carry the strata to a point about 10 miles up the Chulitna, where, indeed, coal is reported in veins equaling in size and number those at the beach. Coal is also reported about 30 miles up the Beluga River, nearly in line with the Chulitna and Tyonek exposures. This would make an outcrop on the strike, beneath the superficial deposits of silt and gravel, of approximately 30 miles, with a width, as shown at the beach, of about 4 miles. The number of seams, large and small, exposed along the beach west of Tyonek is 36, but it is possible that some of them are repetitions by faulting, though no actual evidence to this effect was found. The beds vary in thickness from a foot to 15 feet, there being many from 4 to 6 feet thick. As a rule, not only is the coal of low grade, but the seams are many times split by slate, clay, or sand partings. There are, however, three or four seams in which probably one or two 3-foot benches of moderately clear coal might be found.

Of the field near the mouth of the Yentna but little can be learned without boring or other extensive prospecting. One or two small coal seams in a limited outcrop of clays and sandstones, with a conglomerate of undetermined relationship near by, are all that here appear. Across the river the bank is of gravel, beneath which, however the Kenai should again be found.

The third coal field along the main river, 4 to 10 miles above the Chulitna, appears in outcrop for a distance of 6 or 7 miles, and is, perhaps, the exposed portion of an extensive area. The strata form bluffs 100 to 300 feet high, and consist of clays and sandstones—the former predominating—with coal seams from 6 inches to 6 feet thick. There are perhaps ten or fifteen coal beds exposed in the entire length of the outcrop. Their general dip is 5° to 10° SSE., with undulations. The thickness of the series exposed is perhaps 500 feet.

North of the divide, measures similar in appearance to the Kenai series were observed on the lower (east) fork of the Cantwell River, a few miles above its confluence with that descended by the Survey party. Thin coal seams appeared to be present at a distance, but close examination was impossible, because the exposure was across the stream from us. The extent and economic worth of the formation in this valley also remain in question, but it is possible that the measures underlie a considerable area.

PHYSICAL FEATURES OF THE COAL.

The coal of Cook Inlet and the Sushitna Valley, as at present known, is all of the same nature, a low-grade lignite. In appearance it is often hardly more than a compressed mass of carbonized wood, it being possible to pull up from the back of a seam slivers from a few inches to 3 feet in length. Stumps 1 foot to 2 feet in diameter are common, being especially conspicuous along the beach west of Tyonek (Pl. I, *F*). They stand vertical to the bed, and by their appearance, together with the assemblage of slivers and other carbonized material, suggest that the coal seams originated in a mass of decayed swamp vegetation. The color of the coal is black and brown, with a brown streak. There are, as in coal beds generally, joint planes running in two or more directions. Locally, the coal of some layers may have lost its woody and fibrous structure and have taken on the appearance of the higher-grade lignites which shade into the lower divisions of the bituminous series. One of the first impressions, however, on seeing the coal beds is their youth, it being questionable if a younger example of coal can be found anywhere, peat itself excepted. Indeed, in some of the local bogs resting upon the coal measures there are stems and other woody tissues that closely approximate some of the less altered varieties of the lignitic material.

ANALYSES OF THE COAL.

The following analyses are of samples taken from the Tyonek field, and were made for use in studying the coal rather than with a view to its commercial possibilities. They represent the coal at its best, in no instance the average of a seam, which would fall considerably below the results here given.

Analyses of four coals from near Tyonek.

	No. 1.	No. 2.	No. 3.	No. 4.
Moisture	5.41	9.07	9.47	9.44
Volatile matter	65.13	49.41	53.53	48.75
Fixed carbon	27.60	30.84	31.66	33.56
Ash	1.86	10.68	5.34	8.25
	100.00	100.00	100.00	100.00
Sulphur	.26	.41	.36	.49
Coke	None.	None.	None.	None.

No. 1. Portion of a vein crossing beach 4 miles west of Tyonek. (Wood coal; selected.)

No. 2. From best portions of three or four different veins along the beach, 3½ to 3¾ miles west of Tyonek. (Coal.)

No. 3. Portions of a vein crossing beach 2½ miles west of Tyonek—the first vein west of the village. (Represents a layer of coal 1½ feet thick in a 12-foot vein.)

No. 4. Portions of a vein 6 miles west of Tyonek, but from a stock pile at Tyonek for use on the small steamer *Perry*, plying on the waters of Cook Inlet.

By way of comparison, a few analyses of samples collected by Dr. Dall in 1893 from the Kachemak Bay locality are given below. Detailed information regarding them will be found in the Seventeenth Annual Report of the United States Geological Survey, Part I, page 789 and following, from which the extracts given below were taken.

Samples of coal were taken as follows: No. 213 from the Bradley seam; Nos. 218, 219, and 220 from the seams in Eastland Canyon, at 270 feet altitude; No. 222 from the Curtis seam. Analyses give the following results:

Analyses of coal from Bradley seam, Eastland Canyon, and Curtis seam.

	No. 213.	No. 218.	No. 219.	No. 220.	No. 222.
Moisture	12.64	11.72	10.35	11.59	11.67
Volatile matter not moisture	43.36	46.50	52.22	50.70	52.37
Coke	37.14	34.64	34.58	30.84	21.01
Ash	6.86	7.14	2.85	6.87	14.95
	100.00	100.00	100.00	100.00	100.00
Sulphur	.49	.40	.17	.22	.46

No. 213. Luster, brilliant on fresh fracture; break, cuboidal; ash, gray, without clinkers; coke, dull and noncoherent.

No. 218. Coke, dull, noncoherent; ash, yellowish. The coal was dull charcoal-black, with an apparently fibrous structure, breaking into elongated splinters and chips, and giving when scratched a dark reddish-brown streak.

No. 219. Coke, dull, very slightly coherent; appearance resembles No. 218. This specimen was taken from a mass which had been exposed to the weather.

No. 220. Coke, dull and noncoherent.

No. 222. Coke, dull and noncoherent; ash, yellowish.

AGRICULTURE.

VEGETATION.

A portion of the country traversed last season gives promise of an agricultural value little short, it is believed, of many of the more prosperous regions in the United States.

In many localities in the Sushitna Valley native grasses, including the blue-stem of northern United States, grow profusely. There are rich meadows of native hay, and of forage plants the lupines are one of the most conspicuous. At Tyonek, rye and oats grew to full head last season, the grain having been dropped along the gravelly beach by prospectors early in May. Here, also, and at their Sushitna station, just below the mouth of the Yentna, the agents of the Alaska Commercial Company and the Indians raise annually excellent Irish potatoes of moderate size, peas and beans, turnips of finest flavor, lettuce, and radishes. In the wilds of the valley and adjacent mountains berries abound, including cranberries, high and low bush; salmon berries, a berry resembling a dewberry in size and shape but of the color and flavor of a strawberry; blueberries, mossberries, bearberries, and currants, all delicious in flavor. The soils of the valleys are rich in loam and decayed vegetable matter extending to depths of 4 to 10 feet. The marshes are susceptible of drainage, as are also the swamps, while the higher timbered areas are generally dry.

In the Cantwell Valley the conditions differ somewhat from the foregoing, the climate being drier and the atmosphere colder. Moreover, the elevation is generally greater. Grasses are less abundant; mosses more so. Berries and forage plants abound.

SEASONS.

The length of the season in the Sushitna-Tanana country is somewhat limited, but it is to be borne in mind that by reason of the high latitude the summer days are days throughout, and that therefore the growing time of vegetable life, from May to September, must nearly equal that where the twenty-four hours are divided into daylight and darkness. Moreover, the rapidity of growth is remarkable. Last season the Sushitna became practically free of ice on May 22. At that time plant life gave no definite sign of reviving. On June 1 leaves were of sufficient size to impart to the river banks a delicate spring green. On June 6 all nature was in full sway. Berries were abundant by the middle of July. In the latter half of August the leaves and mosses had taken on their autumn tints, rich and brilliant. By the 1st of September many of the trees were losing leaves, and by the 15th of the month the last vestige of foliage had disappeared.

CLIMATE.

The following tables will indicate the climatic conditions of the region traversed.

Temperature and weather observations in the Sushitna Basin in 1898.

Date.	Place.	Mean.	Maximum.	Minimum.	Range.	Remarks; days.
May 11-14	Mouth Sushitna River	45.5	55	39	16	2 cloudy,[1] 1 fair, 1 light rain.
May 15-21	.....do	46.3	54	43	11	3 cloudy, 4 clear.
May 2-28	Mouth Yentna River......	51.0	59	45	14	2 clear, 4 cloudy, 1 rain.
May 28-June 1	45 miles N. of Cook Inlet ..	52.0	64	44	20	1 rain, 4 clear.
June 2-3	....	......	....	....	....	2 clear.
June 4-9	57 miles N. of Cook Inlet..	56.5	65	49	16	1 clear, 5 cloudy.
June 10-16	65 miles N. of Cook Inlet..	67.0	81	57	24	6 clear, 1 rain.
June 17-23	75 miles N. of Cook Inlet..	59.0	69	48	21	2 showery, 2 clear, 3 cloudy.
June 24-30	90 miles N. of Cook Inlet..	59.3	68	52	16	1 rain, 5 cloudy, 1 clear.
July 1-7	110 miles N. of Cook Inlet..	56.2	67	50	17	2 rain, 2 cloudy, 3 clear.
July 8-16	Sushitna River, mouth of Indian Creek.[2]	63.6	84	51	33	3 rain, 2 cloudy, 4 clear.
July 17-22	7 miles NE. of mouth of Indian Creek.[3]	58.7	64	54	10	4 rain, 2 cloudy.
July 23-25	....	......	....	....	....	1 smoky, 1 rain, 1 cloudy.
July 26-Aug. 3	10 miles NE. of mouth of Indian Creek.[4]	53.7	61	47	14	8 rain, 1 cloudy.
August 4-12	15 miles NE. of mouth of Indian Creek.[5]	55.4	64	45	19	4 rain, 5 cloudy and partly cloudy.
August 13-17	18 miles NE. of mouth of Indian Creek.[6]	50.2	54	46	8	4 rain, 1 cloudy.
August 18-27	En route: Indian Creek nearly to Tanana.	49.2	63	35	28	2 rain, 5 cloudy, 3 clear.
Aug. 28-Sept. 5	Return to Tyonek..........	49.5	57	43	14	7 rain, 2 clear.
Sept. 6-15	Tyonek.....................	50.3	54	47	7	5 rain, 5 clear.
Sept. 16-24	.....do	49.0	56	41	15	1 rain, 7 clear, 1 cloudy.

[1] On cloudy days the mists rarely rose much above the foothills. [2] Elevation 700 feet.
[3] Elevation 1,900 feet. [4] Elevation 2,000 feet. [5] Elevation 2,100 feet. [6] Elevation 2,500 feet.

The precipitation in 1898, May to September, is said to have been by far the greatest within the memory of the oldest Indian. In 1897, the data for which have been furnished by Mr. W. G. Jack, a prospector, the precipitation is regarded as more nearly the average.

Weather conditions in the Sushitna Basin in 1897.

Date.	Place.	Weather.
April 2	Tyonek	Clear.
April 3	En route up Sushitna River	Do.
April 4	12 miles north of Cook Inlet	Do.
April 5	En route up river	Do.
April 6	Sushitna Station, 20 miles up river	Cloudy.
April 7–9	En route up river	Do.
April 10	.....do	Rain a. m.
April 11	97 miles up river	Snow and rain all day.
April 12–13	.....do	Do.
April 14	En route up river	Cloudy.
April 15	.....do	Rain.
April 16	.....do	Snow; clear.
April 17	.....do	Cloudy; cold.
April 18	Sushitna River, mouth Indian Creek	Clear.
April 19	Portage Creek	Do.
April 20–23	Portage Creek to Devil Creek; portage	Clear.
April 24–25	.....do	Showers.
April 26–30	.....do	Clear.
May 1	.....do	Rain and snow.
May 2–6	.....do	Clear.
May 7–11	Devil Creek and vicinity, on Sushitna River.	Do.
May 12	.....do	Snow, 3 inches.
May 13	.....do	Rain.
May 14–17	.....do	Clear.
May 18	.....do	Cloudy; rain.
May 19	Vicinity of Devil Creek. River starts breaking up.	Clear and cold, ¾-inch ice.
May 20–25	Vicinity of Devil Creek	Clear.
May 26	.....do	Shower; clear.
May 27–28	.....do	Clear.
May 29–30	.....do	Shower; clear.
May 31	.....do	Rain.
June 1	.....do	Cloudy.
June 2	.....do	Showers.
June 3	Started up river in boats	Clear.
June 4–5	En route	Do.
June 6	.....do	Shower; clear.
June 7	.....do	Cloudy.
June 8–30	.....do	Clear with occasional light showers. Lightning on 14th at Buckley Creek.
July 1–2	.....do	Clear.
July 3	.....do	Rain.
July 4	Independence Creek	Clear.
July 5	En route	Cloudy; warm.
July 6	.....do	Rain.
July 7	.....do	Cloudy.
July 8	.....do	Rain.
July 9–10	.....do	Clear and cool.
July 11–12	.....do	Rain.
July 13	.....do	Clear.
July 14	.....do	Cloudy.
July 15	Mouth Lake Fork	Cloudy and shower.
July 16		Clear.
July 17–26	Head of boating on 26th	Clear with occasional showers each day.

Weather conditions in the Sushitna Basin in 1897—Continued.

Date.	Place.	Weather.
July 27	....	Rain.
July 28	Reached head of river, 4 miles above boating. This below glaciers.	Clear.
July 29	Start back down river	Do.
July 30	Clepser Creek	Do.
July 31	Lake Fork................................	Do.
Aug. 1–5	Devil Creek	Clear with occasional showers.
Aug. 6	Devil Creek to Portage Creek; portage...	Rain.
Aug. 7–10	.....do	Clear with occasional showers.
Aug. 11	Sushitna River, mouth Portage Creek....	Clear.
Aug. 12	Vicinity of Portage Creek. On 15th started down river.	Do.
Aug. 13–15	.....do	Cloudy.
Aug. 16	Sushitna Station, 20 miles north of Cook Inlet.	Do.
Aug. 17–18	On 18th at mouth of river	Clear.
Aug. 19	En route southward.......................	Do.
Aug. 20	Ladds Station	Do.
Aug. 21	Tyonek....................................	Cloudy; rain.

For the year 1896 the precipitation was, according to Mr. Jack, about the same as for 1897.

In the country north of the Sushitna-Tanana divide it is probable that the precipitation is generally less than in the Sushitna Valley. It appeared to have been so for the last season, for the region was noticeably drier than that traversed to the south. Moreover, the vegetation is less luxuriant in the Cantwell Valley than in the Sushitna.

GAME.

The game of the country passed over embraces the moose, caribou, bear, fox, wolf, wolverene, lynx, mink, marten, marmot, and other minor animals, together with geese and ducks in marvelous flocks. The fish include many varieties, halibut, salmon, candle-fish, and trout being foremost among them.

INHABITANTS.

The region traversed is practically uninhabited except along Cook Inlet and at one or two points on the Lower Sushitna, where trading companies have established small agencies. About these have gathered 100 or 200 quiet Indians, living in log cabins and subsisting on fish, game, and such supplies as they are able to purchase through sale of skins. On both the Sushitna and the Cantwell rivers, however, in the heart of the mountains, cabins were seen—the homes of the Indian hunters in winter. On the Cantwell these were particularly numerous and were said to be occupied by the Tananas—reputed great hunters—who come up from their valley when travel over the snow and frozen streams is rendered easy.

THE SUSHITNA AND CANTWELL VALLEYS AS A RAILWAY ROUTE TO THE INTERIOR OF ALASKA.

The route followed by the Survey party lay along the western shore of Cook Inlet from Tyonek to the mouth of the Sushitna River, thence up this river to the mouth of Indian Creek; this far 150 miles, by canoe. From here an old and very obscure Indian trail was taken across the uplands east of Indian Creek to the head of this stream, distant from the mouth about 20 miles. A pass of 3,200 feet elevation leads hence to the valley of the Upper Chulitna, the route now lying at an elevation but slightly lower than the pass itself. The easternmost of the upper and larger forks of the Chulitna was that ascended. About 10 miles from the head it divides into two, a sharp conical hill marking the point. The western, and more directly northward, branch was taken to the pass at its head, the conical hill diverting the trail to the eastward, over a high ridge, for the first half of the way. From the divide the route followed directly down the Cantwell, crossing the two great valleys referred to in describing the topography, at all points keeping relatively near the stream. Although the Survey party remained on the east side of the stream descended for the entire distance traveled, it is probably preferable to take the west side of the stream below the upper forks, to avoid being caught between the second forks lower down. Boats can safely be employed in descending the tributary of the Cantwell followed by the Survey party, notwithstanding the rapid currents for the greater part of the distance.

Nowhere along the foregoing route of travel was an obstacle encountered that would prevent the construction of pack trail, wagon road, or railway. Grades for the latter could easily be found; the streams could be bridged at slight expense; and timber abounds either along the route or in close proximity to it. That the Sushitna-Cantwell valleys afford a feasible railway route to the interior of Alaska is beyond dispute. Yet in any undertaking in this direction the winter snows must not be lost sight of. They would surely entail heavy operating expenses for at least five months in the year, if, indeed, they would not altogether prevent traffic. In the Sushitna Valley the average depth of snow is said to be 4 feet; in the mountains it is, of course, much greater.

The desirable features of such a route are: (1) That the southern terminus be on water, open the year round; (2) that the country traversed yield a large amount of farm produce for those who may dwell in the interior and less agricultural portion of the Territory. The Sushitna-Cantwell route affords both these conditions, and is the only one that does. Moreover, the route is remarkably direct, both to the Birch Creek and Klondike mining regions and to the confluence of the two great navigable rivers of the interior, the Yukon and the Tanana, a point that, from its position, is regarded by many as of prime importance in the future growth and development of the interior.

Cook Inlet, in the winter season, is packed with floating ice as far south as the East and West forelands, a condition that has proved a barrier to navigation for four or five months each year. South of these points the ice is said to be less aggressive and navigation possible, though perhaps a little impeded. Off the shores of Redoubt Bay the charts indicate a depth of water of 10 fathoms, and the coast has protection from the north, as at Tyonek, where, with less water, an excellent harbor is afforded during the summer. This locality, therefore—without actual investigation—would seem to afford a suitable location for the southern terminal of a railway line to the interior.

The second of the desirable features—that the country traversed shall afford a supply of agricultural and farm produce equal to its own demands and to those of the interior—will likely be realized if settlement is attempted, for the possibilities suggested on a preceding page as to the agriculture of this region are most encouraging to the farmer seeking a new home. Moreover, so far as at present known, this is the only area of such capabilities along the entire southern coast of Alaska. In other portions the great extent of arable valley lands is wanting, or the region, where open and level, has too great an altitude for the growing of grains and vegetables. A railway in the Sushitna Valley might have tributary to it many thousand farms from which to draw its traffic. Besides farm produce there would be carried a heavy tonnage of manufactured products, including machinery. The amount of return freight would, however, be considerably smaller than that passing inward.

A feature of the Sushitna-Cantwell route that should not be overlooked is its picturesqueness. The route would lie at the very foot of Mount McKinley, would pass through one of the grandest ranges on the North American continent, and in the valley on either side of the divide would afford ever-changing views equal to those along the most attractive routes in the United States.

There have already been found many routes to the interior available for pack trails or wagon roads, but for a railroad none seems to be so desirable as the Sushitna Valley.

A RECONNAISSANCE IN SOUTHWESTERN ALASKA IN 1898

BY

JOSIAH EDWARD SPURR

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A RECONNAISSANCE IN SOUTHWESTERN ALASKA IN 1898.

By J. E. Spurr.

ITINERARY.

PREPARATIONS.

The party in charge of the writer left Seattle on the 29th of March in company with other parties from the Geological Survey. By the courtesy of the Navy Department the gunboat *Wheeling* was placed at our disposal, and in it we made the entire trip to Cook Inlet, arriving at Tyonek on the 26th of April. During the voyage frequent stops were made along the Alaskan coast, giving opportunity for inspecting the conditions and for forming some idea of the geology, especially at Sitka, where a stop of over a week was made.

The party as landed at Tyonek consisted of the writer as geologist and chief, Mr. W. S. Post, topographer, and Messrs. A. E. Harrell, Oscar Rohn, George Hartman, and F. C. Hinckley, camp hands. Mr. Rohn was also qualified to act as assistant geologist or assistant topographer in case of necessity, while Mr. Hinckley had had considerable experience as a naturalist in general.

The purpose of the expedition was to ascend the western branch of the Sushitna River and to cross from its head waters to those of the Kuskokwim; then, if possible, to descend the Kuskokwim as far as a water route to the Yukon, which was known to exist, and by way of this water route and the Lower Yukon to reach St. Michael, where steamboats could be found to transport the party back to Seattle or San Francisco. Nearly all of this region was entirely unknown, never before having been explored by white men; therefore it could not be foreseen just what conditions we should meet or what provisions we ought to make for overcoming obstacles. From what vague reports we heard from traders, who had gleaned their information from natives, the divide between the Sushitna and the Kuskokwim was supposed to lie in a low, flat country, and there was even said to be a string of lakes connecting the headwaters of the two streams. On reaching it, however, we found this divide to consist of a high range of mountains on whose summits lay snow and whose sides bore glaciers. Nevertheless, our preparations were made with the view of meeting, so far as possible, every condition which might be encountered. As means of transportation for ourselves, our food, and our outfit we depended upon light cedar canoes. These were specially built for the expedition in Peterboro, Ontario, and combined lightness with large carrying capacity, durability, and stanchness of model. They were built in three different lengths, for the purpose of nesting in transportation—18 feet, 18½ feet, and 19 feet. Our object in selecting these boats was to procure a craft which would be equally serviceable in upstream and downstream work, in rapid or in slow water, and on the portage; and the result of our trip showed that, while for any particular phase of the work a different boat might have been better, for all purposes taken together very light craft of large carrying capacity, such as these, is unexcelled. In case we should lose our boats by any accident, we carried along a small but complete outfit of boat-building tools, in charge of Mr. Rohn, who was a skilled carpenter. We planned to travel entirely on waterways, except where portages from stream to stream were necessary. For such portages we made provision in the shape of Minnesota pack sacks, by the aid of which the laborious task of carrying heavy loads is made vastly easier; and we also provided yokes for carrying the canoes. The rest of our outfit was made as simple and as light as possible, every sacrifice being made to secure smallness of bulk and little weight. For cooking we depended entirely upon an open fire built on the ground, and for baking we used a tin reflector such as is common in the Lake Superior woods. Outfits of clothing, boots, etc., were made as light as possible, so that the entire personal baggage of each man probably averaged less than 40 pounds. The item of food being the most important one to an explorer, a great deal of thought was given toward securing the necessary proper nourishment in the lightest possible form. Every article of food containing water was excluded from the list, and therefore all canned goods. After comparison of Major Brooks's ration list, founded on his experience in the Lake Superior woods, with the list as determined by the Geological Survey party in 1897, under the charge of the writer, the following was adopted:

Rations for one man one month.

	Pounds.
Farinaceous food (three-quarters flour)	38¼
Meats and fatty foods (chiefly bacon)	28
Nitrogenous food (three-quarters beans)	6⅔
Sugar	6
Tea	¾
Dried fruits and vegetables (three-fourths dried fruits)	5
Baking powder, 1 pound to each 35 pounds of flour	1
Salt	½
Total	86⅙

Under the head of farinaceous food we carried evaporated potatoes, rice, and rolled oats, all of which we found to be valuable, with the possible exception of the rolled oats, which, when wet, as provisions often become by accident, cakes, so that a large proportion of it is lost. As meats we carried, besides bacon, a small amount of pemmican, which had been specially made for these expeditions in Seattle, and consisted chiefly of beef and suet, with some minor ingredients. We found that this pemmican, when mixed with some other material, such as evaporated potatoes, made a very palatable food, and one so rich that a small can lasted an astonishing length of time. Its use is heartily recommended for all such exploring expeditions. Under the head of nitrogenous food we carried, besides beans, a small amount of pea meal, which is also to be highly recommended as furnishing a very sustaining food with remarkably light weight, and when made into soup it was agreeable as a change, though not to be recommended as a steady diet. We also carried, as an experiment, some pea sausage, or Erbsenwurst, such as is in use by the German army when in the field. This consists of pea meal, with various fatty substances, flavored, and when made into soup it is a wonderfully nutritious food. Among the other foods taken which are out of the general camper's list a preparation of the evaporated yolks of eggs proved very valuable, combining light weight with great food value. Tea was taken as the only drink, both on account of its lighter weight than coffee and also because experience has shown that its qualities are of greater value in this kind of work.

COOK INLET.

The time of our arrival at Cook Inlet was rather unfortunate, it being too late for travel over the ice and snow and too early to travel on the rivers, for these were still covered with soft, spongy ice, while the land still retained much snow, which was generally too soft for traveling. Moreover, a succession of heavy gales prevented us from leaving Tyonek for several days. During this time Mr. Post was temporarily called away from the party, and in his absence Mr. Rohn undertook the duties of topographer. To take Mr. Rohn's place as camp hand John Madison, who had been already several years in Alaska, was engaged. On the 4th of May, the gales having abated, two canoes started for the mouth of the Sushitna, while some of the party proceeded by land along the shore for the purpose of running a continuous line of survey. Mr. Muldrow, topographer with Mr. Eldridge's party, also accompanied us as far as the Sushitna delta. Mr. Hinckley, having been taken sick, was left at Tyonek to superintend the bringing up of the bulk of our provisions later, when the ice on the river had broken. On our arrival at the mouth of the river on the 7th of May we found the ice in the delta broken, but the upper ice still intact, although so rotten that travel over it was impossible. We therefore were obliged to camp on an island.

SUSHITNA RIVER.

The morning of the 20th of May we left the delta of the river and proceeded upstream in our boats, paddling against the current or pulling ourselves up by the bushes along the banks when the current was too strong. Much floating ice was being brought down by the stream, but from the quantity which had come down the day before we judged the river had already broken. After we had gone several miles, however, we were surprised by a solid wall of ice bearing swiftly down upon us, and we had only time to throw our load upon the banks and drag the boats out of the water before the ice jam swept past, piling over upon the banks in places and grinding off trees. As soon as the jam had passed we proceeded on our way, dodging the loose cakes of floating ice; but on this day and the next we had the same experience several times. We found out afterwards that the ice had broken first at the delta and then by successive stages higher up the river, but that most of the river was unbroken at the time we started to ascend. On the first day a floating cake of ice broke a hole in one of our boats, which was promptly beached and repaired. On the 21st of May, arriving at a point just below the Sushitna trading station, the post maintained by the Alaska Commercial Company for the purpose of trading with the Indians, we found that the river was blocked by a tremendous ice jam. The next morning, however, the jam not yet having broken, we succeeded in finding a channel through and arrived at the trading post. At this time the mosquitoes first began to be annoying.

From the trader in charge at Sushitna Station we purchased a stock of provisions to last us until our main supply should be forwarded from Tyonek, according to our agreement with the station keeper at that place, and the next morning continued on our way up the river. We made every effort also to procure a native as guide, since white men had not explored the river we were to ascend; but we were unable to obtain one, although we offered very high wages, the Indians claiming that the river was too rapid and dangerous. A few miles above the station we came to the first forks of the Sushitna, and according to our plan took the left-hand one, known to the natives as the Katcheldat or the Yentna. At the mouth of this river Mr. Rohn began running a continuous line of stadia observations, which was continued until the 8th of June, when the increasing difficulty of traveling rendered advisable its abandonment in favor of more convenient methods.

YENTNA RIVER.

We continued ascending the Yentna without delay, averaging 4 or 5 miles a day, by paddling against the current in the quieter reaches and pulling ourselves forward by means of the brush in the rapid places. We met Indians continually coming down the river in boats made of moose skin stretched over rough wooden frames; they were returning from their spring hunt up the river, but none of them had ever been so far as we wished to go, and had no idea how long the river was. We were unable to persuade any of them to accompany us but obtained from each one a sketch map giving his ideas of the general drainage of the country, and these maps were remarkable for being entirely different from one another except in minor details. The river soon began to split up and flow through many small channels or sloughs, so that it was almost impossible to tell where tributaries joined the main stream.

The weather continued very fine and soon brought about remarkable changes in the landscape. On the 24th of May we had difficulty in finding a bare place to pitch our camp, for the snow still lay deep everywhere, while on the 27th the snow had disappeared almost entirely from the river bottoms and vegetation was already flourishing. In places grass and various plants were 6 inches high and the leaves were bursting forth on the trees; the poplars in particular were already quite green. By the 1st of June the snow was rapidly disappearing on the lower mountains, and near the river flowers were blooming, wild currants were in blossom, and rose bushes in full leaf (Pl. VII, *A*).

As we got higher up the river the current became so rapid that we could make no headway by paddling, and a system of pulling the boat by ropes, or tracking, was adopted. Our method, devised by Mr. Rohn, was to fasten long lines to both bow and stern of the canoe, and while the men carrying these lines walked along the bank of the river, the boat itself was sent out into the current without occupant. By skillful handling of these two lines it was found that the boat could be easily steered, being brought close to the shore or sent out into the middle of the stream, as circumstances demanded, at the same time being pulled onward.

On account of the fine, warm weather and the rapidly disappearing snow the river began to rise rapidly about this time, and on the 1st of June was running over its banks in many places. On this day we reached the main forks of the stream and, thanks to the Indian maps, we chose the correct one, although at first the two channels seemed to be sloughs of the same stream (Pl. VII, *B*). We camped that night on the spruce-covered island between the two branches, and the swollen river kept cutting away the banks so rapidly that large portions of earth and tall trees fell into the water close to our camp. The northernmost or left branch of the river (going downstream), from which we here departed, was called by the natives "Yentna," and was said by them to run close up under the Big Mountains, as they call them, or in their tongue, "Traleyka." The highest of these is the giant mountain variously known to Americans as Mount Allen, Mount McKinley, or Bulshaia, the latter being a corruption of the Russian adjective meaning big. During this fine weather we had one day a splendid view of these lofty mountains, but afterwards either the intervening hills or the mist hid them from our sight.

SKWENTNA RIVER.

The southern or right branch of the river, which we took, is called by the natives the Skwentna, and seemed to be the larger stream of the two. After ascending this branch a few miles we found that the water became so much split up into tiny, shallow streams and spread out so much that progress was very difficult. The current also seemed more rapid than before, and nearly every channel was choked with dead trees, so that we gave the place the name of Snag Flats. The first day after reaching these snag flats we progressed only a mile with our boats, and then not finding any camping place (for the water was everywhere over the banks) we were finally obliged to return to our camp of the night before. It seemed at once evident that the Indians who had been engaged to bring up the bulk of our provisions, according to contract, would not be able to take them through the Snag Flats even had they been willing, and as the supplies that we already had would not last long enough, Madison and Harrell were sent back to help Hinckley bring up additional supplies in canoes. By thus reducing the number of men to three there were provisions enough to last throughout the season, even if the men sent back did not succeed in catching up. The three who were thus left behind then kept on up the river without waiting. The next day the men who had been sent back returned, having met on the way Hinckley, who was bringing up a load of provisions from the station. On the same day Mr. Post returned to the party, having come up in a birch canoe with two Indians. Since the increased size of the party, which now consisted of seven men, rendered our stock of provisions insufficient, even with those which Hinckley had brought, it was thought best to send back another party to bring up what was lacking for the summer's outfit. For this disagreeable work Rohn and Harrell volunteered and went back on the same day. Meanwhile the rest of the party, with two canoes, immediately started up the stream. The next day—the 8th of June—one of the canoes was upset in some rapid water, and when everything possible was saved, it was found that we were still minus some provisions, such as flour and bacon, and that the photographic outfit had been almost entirely ruined. The films had been inclosed, for the sake of protection against water, in tin tubes, but it was found in nearly every case that the soldering was imperfect, so that the water penetrated.

On the 9th of June, having worked up through the Snag Flats, we entered a narrow canyon with perpendicular walls; but here, by taking skillful advantage of the eddies, which were as well marked as the current itself was powerful, we managed to work through with comparative ease. Beyond this canyon we again found snag flats similar to the first, and for many days we laboriously worked our way upward through these, pulling our boats with ropes, often wading in the water nearly all day long, and often obliged to cut the thick-growing brush from the banks in order to work the line.

On the 12th of June the water began to rise again, and on the 14th the river had become a raging torrent, so that we thought best to wait a day in camp. This wait was not disagreeable, as everybody was exhausted. We were by this time close under the high mountains which, we afterwards found, form the divide between the Sushitna and the Kuskokwim waters, as well as the watershed of several other streams. A remarkable thing in the hills close by the river was the difference in vegetation between the north-facing and the south-facing slopes. On the latter was full summer, the abundant vegetation forming a thicket of green leaves; ferns were nearly 2 feet high, and blueberries already in blossom. On the north-facing slopes was winter or the earliest spring; the leaf buds were just bursting from the alders, and deep patches of snow lay everywhere.

On the 16th of June one of our canoes had been broken and patched so many times that the bottom would no longer keep out water, so a stop was made, the bottom was covered with canvas from our provision sacks and smeared with spruce gum which we gathered in the woods, the whole being then covered with a couple of long boards taken from the inside of the boat. The same night a slight flood washed away a large part of the island where we were encamped, forcing us to change the position of our tents. Our average progress at this time and for many days was scarcely over 3 or 4 miles a day.

On the 21st of June one of the boats was again upset in rapid water, from which the chief loss suffered was the case of boat-building tools.

On the 22d of June we entered the second canyon of the river. Here the current was rapid and the walls were high and perpendicular; yet by taking advantage of the little strip of sand which was generally bare on the inside of the curves, and so working up from side to side, we experienced no great difficulty, although in some places where there was no foothold on either side we were obliged to work the boats up by catching hold of the rough rocks of the canyon walls with our fingers. The next day the river again widened out into snag flats as before.

ACROSS THE TORDRILLO MOUNTAINS.

On the 26th of June we entered the third canyon, which was only a third of a mile long, and the same day came to a rapid tributary of pure green water, which we judged from the Indians' maps was the tributary which we should ascend to find the portage to the Kuskokwim. This stream proved to be a raging torrent, which ran in a continuous canyon and was full of great bowlders. On the second day on this stream, which we named Happy River, we worked until nearly the middle of the afternoon, in constant risk of losing our boats and provisions, and succeeded in advancing only about half a mile; and as the stream was growing continually more dangerous and the canyon walls higher, we saw that it would be impossible to make any headway. Camp was therefore made, and the next morning three of us started on a scouting trip on foot. After a trip of 20 miles and back, which occupied twenty-four hours, we succeeded in getting from the tops of various low mountains a better idea of the geography of the country. We discovered that the stream on which we were encamped ran in a continuous canyon for 20 miles or more, and that there was no prospect of its soon heading in a divide, even if we could ascend it. On the other hand, a gap in the high mountains directly opposite seemed to be the shortest route to the drainage of the other side, whatever that might be. On our return to camp, therefore, we immediately dropped down Happy River to the junction with the main stream, and again began ascending the latter. On the 3d of July we camped at the junction of another torrential tributary, where we decided to begin our portage (Pls. VIII and IX). This tributary, which headed in the gap through which we intended to go, ran in its lower part in a very deep and rocky canyon, while its upper part was comparatively slack water, which meandered in an open valley. A trail was blazed through the woods and brush to this slower part, a distance of 7 or 8 miles. The same day Rohn and Harrell arrived, who had only succeeded in catching up with us here, after an absence of twenty-seven days.

After packing our provisions and outfit over the trail to the upper part of the tributary, which we named Portage Creek, two of the boats were also carried over. The third boat was now entirely worn out, and was, therefore, left behind, the nails, screws, and some of the sound boards being taken out as mending material for the survivors. On the little tributary the boats were again launched and were pulled as far up the mountain valley as there was sufficient water to float them. We were now in an extremely picturesque and rugged region, with high mountains, deep valleys, and beautiful glaciers.

On the 9th of July a scouting trip resulted in the discovery of the mountain divide, and the hills and valleys of a new drainage system lay before us. To get our boats and outfit over the pass was, however, slower and more difficult, but was finally accomplished, and we camped by a foaming stream on the other side. The pass itself is about 4,400 feet above sea level, and is guarded on both sides by mountains rising to 8,000 feet (Pl. X). After leaving the small poplar and spruce in the lower valley, we went upward through a dense growth of alder-brush, and finally, leaving the brush line below us, traveled several miles over moss and broken angular fragments of stone to the summit. On the western side of the pass the descent was rather more abrupt, and we found here a small lake almost entirely covered with thick ice; below this were wide stretches of snow, over which we were able to slide our boats. While making these portages we killed many partridges and ptarmigan, which made a welcome change in our diet.

KUSKOKWIM RIVER.

On account of lack of a guide and of previous knowledge of the country, we were much divided in opinion as to the probable course of the stream at whose head waters we then were; but as it was manifestly our best plan to follow it wheresoever it went, we lost no time in beginning. The boats were let down the narrow stream with ropes to a point where the stream entered a broad flat valley. Here the water sprawled through the bowlders so that no channel suitable for a boat was left, and another portage was made to a point where the stream began to cut a canyon in the bottom of the valley. At this point an Indian trail was found which ran over the hills to the lower end of the canyon, and part of the outfit was carried over this trail, while the canoes with a light load were let down the stream, the men wading in the water. This canyon proved very difficult to get through, and during the passage one of the men was nearly drowned.

At this point the stream ran into a larger one, coming out of the canyons to the north, and several miles below the junction another large stream came in from the same direction, making in all a considerable amount of water. The fall of the river was very great, and rapids were almost continuous; but as the state of our provisions did not admit of much delay nearly all of these rapids were run through in the canoes, and in this downstream traveling our progress was as rapid as it had before been slow. Much to our surprise, the river turned and began to run persistently toward the north between two parallel mountain ridges, one of which we named the Teocalli Mountains, from the resemblance to the Aztec temples given by the terraced sides, and the other, from the superb and peculiar coloring, the Terra Cotta Mountains. On this part of the river we made but one quarter-mile portage, which was to avoid a short canyon.

On the 25th of July we emerged from the mountains into a broad, flat, gravelly plateau, and for nearly 100 miles thereafter went through snag flats similar to those we had ascended on the Sushitna, presenting, if possible, even a more formidable aspect to the explorer.

On the 27th of July the water suddenly grew slacker till it entirely changed its aspect and was a slow, placid current flowing through silt banks. On this day we came upon a camp of Indians, who were the first human beings we had seen for nearly two months. They were badly frightened at our unexpected appearance, and it took some time to conciliate them and bring about the desired barter of fish for tobacco. We were obliged to converse entirely by signs with these people, as they knew neither English nor Russian, nor anything except their own dialect.

About this time the prolonged rainy season set in, which lasted six weeks or so, and was perhaps the most disagreeable feature of the trip, the rain falling almost continuously night and day with short intervals.

On the 29th of July the stream joined another of nearly equal size, these two streams together making up the main Kuskokwim River. The stream which we had descended, however, was larger and apparently longer, so that the true head of the Kuskokwim seems to be in the Tordrillo Mountains, which we crossed. Below the junction the current was still slack, and the course of the river was extremely tortuous as it meandered through a broad flat made up of finely stratified silts. We passed two or three Indian camps situated 40 or 50 miles distant from one another, and all containing very few people. On the 1st of August we came to an old trading post known as Vinasale, concerning which we had some previous information, and where we were expecting with pleasure a replenishment of supplies, for we had long been entirely without some important articles of food, and were very short in what was left. We were therefore disappointed in finding the place deserted and empty, as we convinced ourselves by making our way into the storehouses. We therefore embarked without delay and again proceeded downstream.

On leaving Vinasale it was thought best to cut the ration of flour to one-half in order to make it last until a new supply could be obtained. We were likewise now reduced to a diet consisting, besides flour, almost entirely of bacon and pea meal, for most of the other articles taken had been consumed or lost in our various accidents. On the same day we met an Indian coming upstream in a birch canoe who had some tea in his possession. From this we knew that there was a supply farther down the river, although by the most skillful use of signs we could not find out exactly how far. For several days after this we averaged 50 miles a day in our progress down the stream. On the 2d of August we left the broad flats of the upper river and entered a definite valley lying between picturesque timbered mountains, in appearance suggesting the Lower Ramparts of the Yukon. The river continued to run through these mountains for several hundred miles. On the 4th of August, two days after entering the range, the peaks grew higher and bolder and some of them bore patches of snow, while the river flowed past high, perpendicular, rocky bluffs. Just before entering these higher ramparts the largest stream which we had yet observed entering the Kuskokwim came in on the left. It is a wide river of dark-colored water, contrasting in this with the muddy current of the Kuskokwim, and at the time of our passing by the water was alive with leaping salmon. The native name of this stream we afterwards found out to be Holiknuk, and that it heads in the Nushagak divide.

The upper flat portion of the Kuskokwim region is inhabited, so far as we saw, very sparsely, and the natives belong to a general type of Indians similar to the Sushitna natives, the Tananas, and the Upper Yukons. Farther down, the population becomes progressively more numerous, and a marked change in the type also takes place, the stouter frame and the heavier features indicating the relationship to the fish-eating coast tribes. Still lower, the typical Eskimos, or Yut, as the Kuskokwim branch of the Eskimos are called among themselves, began making their appearance in scattered camps. Our best efforts did not succeed in obtaining much information from any of these people, although they were kindly and hospitable, and ready with presents of fish. We were anxious to find out whether provisions could be obtained at Kolmakof, but this name did not appear to be known to them, so that we ourselves almost came to doubt its existence. Several of them explained by signs that a steamboat with white men was coming up the river and was now almost due, and we believed this report so fully that we stood watch all night to intercept this "belihootook," as the natives called it in their language, but in vain.

On the 6th of August, when we had already long passed the astronomical position in which Kolmakof was indicated on the Russian charts, we unexpectedly reached the post, which consists of an old hexagonal log blockhouse with several other log buildings, which were built by the Russians long ago. We found no one here, however, except some natives and one half-breed, from whom we obtained some tea, which was the only article left, the supplies for this year not yet having come up the river. The next day we reached the native village of Oknagamut, where there were several hundred Eskimos. One of these was a sort of native trader, and through him, after considerable difficulty, we managed to obtain 20 pounds of flour, which he had brought from the Yukon. This helped us out considerably, as our own flour was already exhausted. All through this country, however, we obtained from the natives plenty of fish, with occasional delicacies, such as bear meat.

After leaving Kolmakof the river rapidly left the mountains behind and flowed through a perfectly level country, very sparsely timbered, and always growing broader. The channel broadened out in places to a veritable sea, with many large islands, so that, in one place, looking across from bank to bank between the islands, we estimated the distance as 9 miles. The land on both sides grew more and more swampy and treeless until it developed into the typical dreary tundra. Eskimo villages grew more numerous, and at one, Oknavigamut, we found a vacant mission building and schoolroom, welcome signs of civilized man. On the 10th of August we arrived at the native village of Memtrelegamut, where the natives had informed us that provisions could be obtained, and here we were surprised and delighted to find, not only a trading post, but a mission supported by the Moravians. These people made us very welcome, as we were the first white people they had seen that year, and we stopped several days making preparations for our future work.

After ascertaining as nearly as possible the conditions of travel in this lower coast country we decided to attempt to make our way back to Cook Inlet by a partly inland and partly coastal route, this route to be developed as we went forward, since not enough was known of the country to determine it exactly beforehand. Inasmuch, however, as it promised to be difficult to obtain transportation and food for a large party, it was thought best to cut our numbers down, and, by sending some of the party to St. Michael by way of the Yukon portage, at the same time to obtain a knowledge of this route, hitherto unexplored by any who have left records. For this purpose Messrs. Harrell, Madison, and Hinckley were detached and sent back up the river a short distance to go over the portage into the Yukon, and thence down the Yukon to St.Michael, where they were instructed to join the other Geological Survey parties, which, according to previous plans, should be at St. Michael about the time they arrived. Mr. Hinckley was instructed to map the portage and to take other notes of interest. To this party one of the canoes was assigned, leaving us with only one. Dr. Romig, one of the missionaries, was also about to make a trip to the Yukon, and the two parties set out together.

Below this mission the Kuskokwim grows very large and begins to be affected by the tides, and so gradually passes into the broad Kuskokwim Bay. The shores are barren, swampy, and flat, and with no firewood except scattered driftwood. One of the missionaries, Mr. Kilbuck, was about to proceed down the river in a small sloop, and kindly offered to carry our party. We left the mission on the 19th of August and reached our destination at the mouth of the river—Kwinhagamut—on the 25th, our progress having been slow on account of the extreme width and shallowness of the river and the difficulty in finding the proper channel. The tides too, were so high and the bottom was so flat that when we were not in the deepest channel the receding tide left us dry, out of sight of water, while the flood tide lifted us upon a broad sea out of sight of the shore.

KANEKTOK RIVER.

We decided to ascend the river which entered the Kuskokwim at Kwinhagamut—the Kwina or Kanektok River in the native language—and to find, by crossing the divide at the head of this river, a passage to the Togiak or Nushagak drainage. Our plans were naturally rather indefinite, as the river was not shown at all on existing maps and we could get no very accurate information from natives. Through the good offices of Mr. Kilbuck we obtained a couple of Eskimos from Kwinhagamut as guides, although these men did their utmost to dissuade us from the trip, saying that the river was extremely rapid, which we did not believe at the time, but afterwards found to be quite true. We also had brought along from Memtrelegamut a native of that place, who had engaged to go as far as Nushagak. We left Kwinhagamut on the 26th of August and started up the river. By this time the mosquitoes had nearly disappeared, and the black flies, which usually follow the mosquito pest, were not very troublesome.

From the first the river proved difficult to ascend, but owing to our previous experience we made comparatively rapid progress, averaging often 10 miles a day. The current was so rapid, however, that we could not paddle, but were obliged to track the whole distance, often wading in the water nearly all day, as in our ascent of the Skwentna. Each of the natives who accompanied us had his own kayak or seal-skin boat, which he propelled up the river by pushing with small, sharpened sticks against the bottom in shallow places. On the 29th of August, the river having grown continually more rapid and difficult, our Memtrelegamut native gave out and asked permission to go back. We therefore sent him down the river in his kayak, while the other two remained with us. The next day heavy rains set in, which lasted night and day, with short intervals, for two or three weeks. The same day we emerged from the flat tundra, in which the lower part of the river runs, into the mountains again, and the day afterward we came to a place where the river divides into two almost equal forks. These mountains are rather low along their front wall, where they face the tundra, and are nearly bare of timber and other vegetation.

On the 1st of September, our two guides being fatigued and lame from the exertion of pushing their kayaks upstream against the swollen and rapid current, we relieved them of 50 pounds of their load, and a few days afterwards, upon their again becoming exhausted, we took another 50 pounds from them, leaving them with only one package, enough to ballast their craft, while we ourselves carried all the freight in our cedar canoe. The continual rains swelled the river until it overflowed its banks, while the raw, cold weather took the spirits even out of the natives. So difficult was the work of traveling that the natives had no time or strength for supporting themselves by hunting, as they had agreed to do before starting. We were therefore obliged to feed them from our own provisions, which disappeared so rapidly that we feared a shortage in the near future. Frequently, however, red salmon, which the guides speared with their small bone harpoons, and occasionally ducks and geese, shot with the rifle, added much to our supplies.

As we ascended farther up the river the wood grew scarcer until there was only a little scattered brush. The hills were thickly covered with moss, especially the iceland or reindeer moss, a species which the natives eat when they can obtain no other food, and scattered thickly everywhere through the moss were many berries, including, besides blueberries, high and low bush cranberries and a small, black, sweet berry which was not familiar. Repeated forks of the river made the main stream which we ascended continually smaller, and the mountains through which it flowed grew higher until they became very bold and picturesque, with great snow patches on the top and occasionally small glaciers. On the 8th of September we reached a beautiful lake walled in by magnificent jagged mountains covered with fresh snow. In this lake were so many red salmon that in places the water was colored a uniform crimson.

Near the lake a small, very crooked stream was followed for two days, when a portage of half a mile was made to a little lake in the bottom of the mountain valley, whose head we had nearly reached, and another, of a quarter of a mile, to a larger lake, where we camped. The next day, after paddling about 5 miles across this beautiful body of water, we began our long, hard portage over the main mountain divide between the waters of our stream and those of the Togiak. This portage was 20 miles long and occupied us five days, our outfit and provisions being so reduced that we were able to take them and the boat in between two and three trips on each stage of the journey. The mountain pass was comparatively high (2,500 feet), and for several miles of its highest part there was no wood for cooking. On both sides of it rose high mountains (Pl. XI, *A*). On the farther side of the pass we found a heavy growth of alder brush, through which we were obliged to cut a trail before we were able to carry our outfit down the valley.

On the 17th of September we reached a spot where the stream was large enough to float our canoe and the natives' kayaks, and we soon paddled down to a considerable lake, after crossing which we ran down a short stream full of bowlders to a large lake, which we judged might be 30 miles long. This lake, the natives told us, was the chief source of the Togiak River. It is walled in by high and snowy mountains, very picturesque and beautiful. On entering this lake we were met by four of the natives who lived on it, for this region is comparatively well populated. These people, who were clean-looking, mild, and placid men, escorted us for a number of miles before turning back.

TOGIAK RIVER.

From Togiak Lake we ran down the Togiak River to the coast, a journey which took us only three days, since the river is free from obstructions and of moderate swiftness, so that progress was continuous and uninterrupted except for the necessary stops at the numerous Eskimo villages which line the banks of the stream. This is one of the most populous regions of Alaska, since the abundant supply of salmon and other fish affords more food than in most places. We were everywhere welcomed by the natives and treated so hospitably that it became a question of diplomacy how to avoid their attentions and not lose time in continuing our journey. At the first village we passed all the guns which could be mustered were fired as a salute in our honor, to which we responded with our revolvers without stopping. At most villages, however, we sent our native guides ashore to barter for fish in exchange for tea and tobacco. Our provisions were already almost entirely exhausted, except the flour, but having brought a considerable quantity of tea and tobacco along for trading purposes, we were able to exchange this with the natives for large supplies of fresh and sun-dried salmon, and this fish, with the flour, formed our almost sole diet for several weeks. On the 19th of September we arrived at the mouth of the Togiak River and camped at a small native trading post, where we were able to obtain a little more flour and some salt, of which we stood sadly in need. We were now out upon the tundra again, which extended back from the bay to the distant hills.

FROM TOGIAK TO NUSHAGAK.

The next day we were favored by exceptionally calm weather and attempted the usually somewhat hazardous trip along the coast from Togiak Bay to Kululuk Bay. The natives do not attempt this trip in their covered skin boats except in good weather, and for our open canoe it would not have been possible except in the perfect calm which we enjoyed. After paddling 30 or 40 miles without resting, along a bold and rocky shore, we passed a dangerous headland, where the tides make a choppy sea even in calm weather, and entered the bay, where we camped to wait for the tide the next morning; for in all the narrow bays along this coast the tides are so violent that one must travel with them, since no headway can be made in the opposite direction. The next morning we paddled to the head of the bay and then floated with the tide up a tortuous river for 10 miles until we met the real river current flowing in the opposite direction. After pushing our boats up this stream with poles for a short distance we came to a little lake on which was a small native village. The next day we ascended a short, shallow stream from this lake into another, from which a low portage of three-quarters of a mile led us to another 2 miles in length. From this lake a half-mile portage led us to a large lake surrounded by high mountains. After starting out on this lake a severe gale sprang up, so that we could make no headway and were obliged to land again to avoid swamping. This was the first of a series of violent gales which hindered our progress for some time after this.

On the 23d of September, having crossed the lake, we ran down a shallow, rapid stream to another lake several miles in width, crossing which we entered a larger river, which became continually slacker and wider, and finally became tidal. At the same time the spruce and birch timber which had come in with the mountains in the higher part of the route gave way to the dreary tundra again. On the 24th of September we were unable to travel on account of a violent gale, but on the 25th we worked our way downstream, much annoyed by frequent squalls of wind and by the very puzzling and irregular changes of the tides. The river was extremely tortuous, and several times, by short portages, we were able to cut off bends several miles in length. The tidal currents were rapid, and when they were opposed to the winds a very heavy sea was brought about. Farther down, the river became wider and straighter, and we finally approached very near the coast and camped at a spot where the tides had fallen 30 feet and were still going down. The next day, after a short journey, we reached the coast of Nushagak Bay, where we were delayed by fierce gales which rendered it entirely impossible to travel until the 28th, when, taking advantage of a flood tide and a calm at midnight, we paddled along the shore to a point on the bay opposite the Nushagak trading post, which we reached the next morning. The route which we had followed from Kululuk Bay to Nushagak is a convenient one which had long been used by natives and traders, and which was pointed out to us by our Eskimo guides. At Nushagak we found several canneries, now, however, closed for the season. There was also a Greek and a Moravian mission, and a well-furnished trading post.

FROM NUSHAGAK TO KATMAI.

Owing to the delay which we had already experienced, and to the difficulty in traveling on water during this season of the year, and on account of the heavy winds, our original plan of returning to Cook Inlet, by way of lakes Iliamna and Clark, was abandoned, and we decided to cross the Alaska Peninsula to Katmai. The two Kuskokwim natives which we had brought from Kwinhagamut and two Togiak natives which we had picked up on the Togiak River, turned back here, for these people can not be persuaded to travel far beyond the limits of their own country. Our last remaining cedar canoe was by this time about worn out, and being also unsuitable for the rather extended sea trip which we intended, was abandoned here. For our further journey four native skin boats were obtained, made of seal skin and covered, except for three holes or hatches in each, in which men were to sit. Eight Nushagak natives were hired as paddlers for these boats, and a white man who had been employed in one of the canneries also went along as guide. A prospector who had been delayed in Nushagak until the last vessel had left asked to accompany us, and brought his own skin boat or bidarky.

The original plan was to cross the peninsula by way of Becharof Lake, from which there is a short, low portage to the southeastern side of the peninsula, but the natives were afraid, on account of the lateness of the season, of being caught in the ice of the lakes and rivers of this route before they could return, and so proposed to go by way of Naknek River and Lake. On the 5th of October, everything being ready, we started on a very windy day, but could not go far on account of the heavy sea which we encountered on rounding an exposed point. We were unable to start out again, on account of the weather, until the 8th of October, when we paddled about 50 miles along the coast without stopping. Again on the 9th the breakers in front of our camp kept us from launching our bidarkies, but the next day an exceptionally good opportunity was offered and we paddled about 20 miles along the shore and then crossed Bristol Bay to the mouth of the Naknek River, where we found a cannery, now closed for the season. Here we obtained another bidarky for our guide, and half a dozen other native boats joined us by way of doing us honor, so that we formed quite a flotilla. The ascent of the short Naknek River was easy, the only rapid water being in the upper part, just before entering the lake. One hard day's work was sufficient to take us from the cannery to the lake.

On the 12th of October we started paddling across Naknek Lake, which is the largest body of fresh water that we encountered on our trip. The water was very calm, and on account of the danger of heavy gales in these mountain lakes the natives were willing to push ahead as fast as possible. At dark, after having made about 40 miles, a stop was made for supper, after which about 20 miles more was made at night till the head of the lake was reached. The next morning we reached the native village of Savonoski. At Savonoski our Nushagak natives went back, being in continual fear of being frozen in by the increasing cold weather. In order to make as quickly as possible the 60 miles or so of mountains which lay between us and the coast, ten natives from Savonoski were hired to help us carry over, in one trip, our outfit and necessary provisions, everything which was inessential being left behind. The trip from the lake to the seacoast occupied three and one-half days, an average of nearly 20 miles a day, all of which we made on foot, largely through swamps and deep moss. On the 16th of October we crossed the mountain pass and descended to the other side. This pass lies between two extinct volcanoes and is high, snowy, and rocky, and has no definite trail (Pl. XI, B). The wind is often so cold and violent here, even in summer, that the natives do not dare to cross except in calm weather, for the gusts are so powerful that stones of considerable size are carried along by them. On the sea side of the pass we came to a considerable stream of hot water which emerged from the side of one of the volcanoes and flowed down, steaming, to reach the cooler water of the other mountain drainage.

On the 17th of October we arrived at the Aleut village of Katmai, where we found a Russian trader. Having now reached the coast we were disappointed to find that the difficulties in getting farther were even greater than they had been in coming so far, for there were no boats at Katmai except a couple of open dories, belonging to the trader, and one skin bidarky. We knew that in a few days the last steamer would leave St. Paul, on Kadiak Island, 120 miles away, for Seattle; but the Shelikof Strait, which lay between, was so rough and windy that the trader advised us very strongly not to attempt the trip in dories. Finally, the sole bidarky in the village was sent across to St. Paul with three expert native paddlers, with a letter to the agent of the Alaska Commercial Company at that place, asking that a schooner or some other craft should be sent to us in order that we might make connection with the steamer. For several days the winds were so violent that the natives would not cross, and after they had crossed no news was heard of them for a long time, till considerably after we knew that the last steamer must have gone. On the 31st of October, however, we were awakened in our camp on the beach by the whistle of a steamer, which we promptly boarded. We found it to be the Alaska Commercial Company's boat *Dora*, which had been delayed in Cook Inlet considerably past her usual time for returning home on her last trip, and so had got to St. Paul in time to receive our letter and to come to our assistance, a trip which involved a delay of two days for the steamer and its passengers. In the *Dora* we reached Seattle on the 11th of November.

Table of distances taken along route followed by the expedition from Tyonek to Katmai.

	Miles.
Tyonek	0
Mouth of Sushitna River	35
Sushitna Station	53
Junction Yentna and Sushitna	56
Junction Skwentna and Yentna	99
Junction Portage Creek and Skwentna	164
Summit of pass	179
Junction Styx River and Kuskokwim	189
Junction East Fork and Kuskokwim	296
Vinasale	393
Junction Chagavenapuk River	463
Junction Holiknuk River	508
Kolmakof Trading Station	637
Kalchagamut	706
Oknavigamut	716
Bethel	787

	Miles.
Warehouse	865
Kwinhagamut	880
Beginning of portage from Kanektok to Togiak	982
Togiak Lake	1,006
Mouth of Togiak River	1,061
Togiak	1,067
Head of Kululuk Bay	1,108
Mouth of Egoushik River	1,203
Nushagak	1,223
Naknek	1,302
Savonoski	1,376
Katmai	1,425

Magnetic variations,[1] *southwestern Alaska, 1898.*

Lat. (N.)	Long. (W.)	Place.	Date.	Variation. (E.)
° ′	° ′			° ′
61 10	151 10	Tyonek	May 1	27 15
61 58	152 40	On Skwentna River	July 5, 9 a. m	27 20
62 00	152 46	On Portage Creek	July 6, 1 p. m	27 19
61 59	152 57	.....do	July 12, 8 p. m	26 58
61 59	153 01	Near pass	July 14	26 29
61 00	153 04	.....do	July 15, 8 p. m	25 58
61 59	153 05	.....do	July 16, 2 p. m	25 45
61 31.5	160 42	Kuskokwim River	Aug. 7, 2 p. m	23 51
61 26	160 46	.....do	Aug. 7, 7 p. m	23 50
61 17	160 45	.....do	Aug. 8, 2 p. m	25 37
60 53.5	161 18	.....do	Aug. 9, noon	20 22
60 47	161 52	Bethel	Aug. 10, noon Aug. 10, 6 p. m	21 14 21 20
60 35	162 16	Kuskokwim Bay	Aug. 20, noon	20 44
60 09	162 15	Apokagamut	Aug. 22, noon	21 25
59 46	162 01	Kwinhagamut	Aug. 24, 11 a. m	20 38
59 53	160 15	Kagati Lake	Sept. 8, 1 p. m	21 14
59 48	159 59.5	On portage	Sept. 12, noon	22 01
59 07	159 28	Oallek Lake	Sept. 22, 6 p. m	23 13
58 56	158 27	Nushagak	Oct. 2, 10 a. m	25 02
58 48	156 35	Naknek Lake	Oct. 11, 5 p. m	24 53
58 33.5	155 27	Savonoski	Oct. 13, 3 p. m.	23 56
58 04	154 53	Katmai	Oct. 23, 11 a. m	24 33

[1] Observed with a transit reading to 1′. Results ± 5′, about.

GENERAL NATURE OF COUNTRY TRAVERSED.

FROM TYONEK TO THE SUSHITNA-KUSKOKWIM DIVIDE.

CLIMATE.

The climate in the vicinity of Cook Inlet is peculiar to the locality. Heavy storms often hang over the inlet for weeks, while the mountains at the head of the inlet and on Kenai Peninsula are continually bathed in light. Often this is reversed, and the sun shines for weeks on the inlet, while the mountains all around are covered with clouds and rain. The first three weeks of our stay in this country was the transition period between winter and summer, for the spring is so short that it hardly deserves being considered a separate season. During this transition period the deep snow softens and melts during the daytime and is again crusted over during the frosty night, and the ice on the rivers softens and grows rotten. Travel of any sort is very difficult, for the softness of the snow precludes the use of sleds and snowshoes except at night, and the rivers are still blocked by ice too soft to walk on. The Sushitna River generally breaks up between the 10th and 16th of May, according to statements of the traders in the employ of the Alaska Commercial Company in this vicinity. In 1898, however, the ice began to break at the mouth of the river on the 18th of May, while the main break-up did not occur until the 19th and 20th. From this time until the latter part of July, when our party reached the Sushitna-Kuskokwim divide, the weather grew warm with surprising rapidity, and in the course of a very short time the luxuriant, rapidly-growing vegetation, the summer birds, and the abundant insects, with the long, warm days, all gave the aspect of high summer in a temperate climate. The rainfall was very moderate, the weather most of the time being clear and pleasant, although the rapidly-melting snows on the mountains swelled the rivers and caused frequent floods. It was noticed that the rivers rose considerably every night, and it was thought at first that the increase at night represented the snow melted by day, which took several hours to affect the level of the river; but as we gradually approached the source of the floods we found that the periods of rising did not vary, and we therefore came to the conclusion that the nightly rises were due to the fact that evaporation during this time was so much less than during the daytime as to be immediately apparent in the volume of the stream.

On the 10th of May, at the mouth of the Sushitna River, ice still froze solid at night, and there was a slight snowstorm in the evening, but after this there were very few frosts. At this time the snow still lay 4 feet deep in places near our camp, and farther up the river, at our camp of the 24th of May, the snow was melted away only in places;

but a few days after was almost entirely gone from the river bottoms, and day by day the line marking the lower limit of the snows could be seen climbing higher and higher up the mountain sides. After this, on bright sunshiny days, the temperature was often uncomfortably warm for hard work, although the nights, with a very few exceptions, were cool.

VEGETATION.

All along the river bottoms, which on the lower part of the Sushitna are very wide, there is an abundant growth of timber, consisting, in those flats which are near the level of the river, of poplar and willow, while the higher flats a little farther from the river have abundant spruce and birch, both of considerable size. This timbering was found all the way up the river nearly to the pass. Beneath the trees, and also on broad flats where the trees do not grow, are abundant shrubs, grasses, and flowering plants. The alder grows everywhere, even on the sides of steep hills. Various kinds of grasses grow luxuriantly, and in the early part of July, on the upland plateaus on the upper part of the Skwentna, broad open glades were found where the grass grew very thickly and as high as the waist. Berries of various kinds, ferns, and small flowering plants are abundant, the flowers rivaling in variety and beauty those of more southern climates. Moss is everywhere abundant, but is not so thick as in the more humid regions farther south, on the coast, or in the regions of greater rainfall farther north. The abundance of vegetation is most strongly marked in the river bottoms and in the low hills which rise above them. With increasing elevation the vegetation grows more scant. On leaving the main river valley of the Skwentna, at an altitude of 2,500 feet, the spruce and other large timber was immediately left behind, and a belt was passed through where alder brush and grass grew thickly without trees, then a belt where the chief vegetation was low scraggly bushes, and finally a region covered only with moss, of which, however, there was a great variety. The Iceland or reindeer moss and various other edible mosses were especially abundant here.

TOPOGRAPHY.

The shallow region at the head of Cook Inlet, which has been filled with detritus brought down from the interior by the rapid rivers, is covered by broad tidal flats, which are left bare for miles at low tide and are submerged at the flood. The region near the mouth of the Sushitna River has all the aspect of these tidal flats except that it is not covered by the tides, a slight uplift having apparently brought it above their reach; but it is still a barren, dreary moorland, very swampy, and covered only by marsh grasses. The delta of the Sushitna River is broad and low, but the land is nearly everywhere covered by timber. A short distance up the river one encounters the gravel plateau through which the river flows in most of its course. As will be described later in considering more exactly the geology of the country, the river is a very young one, with no well-established valley, but finds its way over this broad, gravelly plateau as best it can to the sea. The surface of the plateau, from Cook Inlet to the Upper Skwentna, is at a nearly uniform height above the bottom of the river, which has cut down through it, although the slope of the plateau as the mountains are approached grows slightly greater than that of the river bottom. On an average the gravel bluffs which generally form the bank of the river rise to a height of 100 feet. The surface of the plateau, generally level, is irregular in detail, with many swamps, ponds, and other unsystematic minor drainage features. Occasionally huge bowlders are found, but generally the surface is smooth and free from obstruction. From this plateau of stratified gravels low mountains rise in the interval between the sea and the main divide. The Sushitna Range and the Shell Hills are apparently ridges of intrusive or old sedimentary rocks, while Yenlo Mountain seems to be an ancient volcano. As the main divide is neared the foothills pass rapidly up into higher peaks until, at the axis of the range, high and serrated mountains are found, with their tops covered with snow and frequent glaciers on their flanks. The rather monotonous scenery of the lower river in the gravelly plateau country here gives way to scenery of the most romantic character.

Where the river flows through the gravels the facility with which these are eroded tends to make the stream spread out broadly, especially at the junction of a tributary, so that it often flows in many channels which change continually in position and volume and split and reunite so intricately that it is hard to find a passage even for a canoe. These channels are often choked with dead trees brought down from the stream above, and such areas are called in the report "snag flats." Sometimes, however, the river in its course has encountered a range of hills like the Shell Hills, and in these places are found canyons carved deep in the solid rock. Three such canyons were found on the Skwentna, all less than a mile in length and separated one from another by much longer stretches of snag flats. In the upper part of the stream the river flows in a deep mountain valley for a short distance below the divide.

GAME AND FISH.

In the early part of June great schools of a small, oily fish known as the candle-fish enter the Sushitna River and ascend the Skwentna at least as far as the first snag flats. This is the same fish which is found in so great abundance all along the southern Alaskan coast, and derives its name from the fact that they are so oily that the natives use them as candles, after running a wick through them. For a short season these candle-fish are so abundant as to almost entirely fill the river in places, so that it is impossible to wade without treading upon them, and they can be dipped up in large quantities with common dip nets, or even with baskets. The candle-fish annually supplies a large part of the food of the natives, who lay up a store for a long season. The salmon and other fish also ascend the Sushitna, although not in so large quantities as in the famous salmon rivers.

Considering the abundance of vegetation, and especially of grass, the whole region from Cook Inlet to the Tordrillo Mountains is singularly poor in game. During the whole of our trip, which occupied nearly two months, our party saw only one bear and one moose as representatives of large game, although tracks were frequently found, and by careful hunting more would probably have been discovered. There is also a lack of small game. It is true that at the mouth of the Sushitna River, at the time of our camp there in the early part of May, there was such an abundance of all kinds of wild waterfowl as I have never seen elsewhere. The entire delta was thickly covered with wild geese, ducks, and swans, and we had no difficulty in shooting all we needed as food with the rifle, and sometimes with the revolver. For a few days the air was continually darkened by flocks flying overhead, and night and day there was a continual babel of shrill cries. Yet this lasted for a few days only, and on the 18th of May the delta was practically deserted by the birds save for stragglers who were hurrying on to overtake the main body. It was evident, therefore, that this was only the halting place of the flocks on their way to their feeding grounds farther north, probably far on toward the Arctic Ocean. On the rest of the river we saw very few geese or large ducks; only the common small divers and fish ducks, which are found everywhere on the rivers and lakes, and which are not very valuable as food. In the spruce groves along the river we found occasional grouse, but never in great numbers. Near the portage we found more of these birds, and also many ptarmigan, so that we were able to obtain enough to form an item in our diet. Of other game we saw almost absolutely nothing. We were told by white people on Cook Inlet that rabbits were numerous in this country, but in all our journey one tiny brown rabbit was all that we saw. Taken altogether, the region was the most destitute of game of any well-watered and fairly timbered and vegetated country that I have ever seen, the outskirts of Boston affording more, except for the occasional large animals that have been mentioned. It is difficult to account for this scarcity, for although this river is hunted over by the natives every year, they are still so few in number that they can hardly reduce the amount of game very rapidly. On the other hand, it seems probable that the small number of natives is directly dependent upon the supply of game, which has never been great enough to support more than a few straggling families.

POPULATION.

The native of the Sushitna is Indian, probably belonging to the class of Athabascans, and resembling in most particulars the Matanuska natives, the Copper River natives, the Upper Kuskowkim natives, and those of the Tanana and Upper Yukon. These Indians, therefore, occupy a continuous belt reaching across Alaska from British America to the Gulf of Alaska, and separating the Eskimo tribes on the north from the Thlinkits and other peculiar and characteristc Alaskan tribes on the south. They speak a language which is very limited in vocabulary and inflection, and on the Copper River Lieutenant Allen has discerned a striking resemblance between the numerals of the natives and those of Indians of the southern United States. The Sushitna native is of medium stature and has generally intelligent, often handsome, features. He is by occupation a fisherman and hunter, but has only very limited hunting grounds, beyond which he will not venture into the hunting grounds of another individual or into the territory of another tribe save for the purpose of visiting some trading post. He is not remarkable in general for his bravery, and his word can not often be depended upon, even if he have apparently no reason for misrepresentation. The general belt occupied by the Athabascan Indians can be easily traced on the map by the names of the rivers, since those which end in "na" or "no" are in regions inhabited by these people, this termination signifying, in all their different dialects, "river" or "water."

On the Sushitna River, in the 30 miles between its mouth and the junction of the Skwentna, there are two small villages of the Sushitna natives, one about 8 miles from the delta and the second and larger one clustered around the trading post a few miles below the mouth of the Skwentna. Together these two villages number only a few hundred people. In the whole length of the Skwentna there is not a single permanent habitation, only temporary camps being found, which are used as stopping places by the natives from the villages mentioned in their fall and spring hunts. In ascending the river at the end of May we met many of these natives returning from the hunt, running down the river with their furs, meat, and families in rude boats made by stretching moose skin over wooden frames; but after this we saw no living being for nearly two months, until we had descended the Kuskokwim over a hundred miles. The uninhabited character of this country is probably due partly to the lack of game, as before mentioned, but also to the character of the Skwentna, which is so rapid and dangerous that it is not a good stream for birch canoes. The Indians do not settle permanently in any place which they can not readily reach in canoes.

KUSKOKWIM RIVER.

CLIMATE.

It was remarked that the side of the Tordrillo Mountains which faced the Sushitna drainage was much more heavily covered with snow than the Kuskokwim side, and was also thickly spotted with glaciers, while on the Kuskokwim side there appeared to be practically no glaciation. Moreover, several high mountain ridges on the Kuskokwim side of the main divide were practically without snow at the time of our passage, although nearly as high as the main ridge. The logical explanation for this seemed to be that the precipitation is heavier on the Sushitna side of the mountains, and that the winds from the Gulf of Alaska are largely deprived of their moisture on striking the cold high mountain range, so that on reaching the Kuskokwim side they are comparatively dry. On the other hand, the whole Kuskokwim River, beginning with a point 100 miles or so away from the mountains and extending 600 miles to Bering Sea, was during the time that we were on it—that is, about five weeks, from the middle of July till the latter part of August—a very rainy country, showers falling nearly every day and continuous rains being frequent. From the Moravian missionaries on the Lower Kuskokwim we learned that this rainy season was not unusual, and that often the rains were so continuous as to delay traveling, for the skin boats ordinarily used on this river must be occasionally dried out in order not to become rotten, and if no opportunity for drying presents itself a stop must be finally made to wait for finer weather.

During this season the days, when clear, were warm and pleasant, and the nights just cool enough to be agreeable. About the middle of August the increasing length of the nights and the more frequent frosts brought about an extremely pleasant change in the conditions, namely, a diminution of the energy of the mosquitoes, which soon ended in their almost complete disappearance; for although after this the insects might be annoying in certain places for a short time, yet they ceased to be the serious burden to life which they had been hitherto. By the 1st of September the general temperature was distinctly cooler than it had been, marking the beginning of the autumn season.

TIMBER AND VEGETATION.

Descending from the high moss-covered mountain passes, the valleys of the Upper Kuskokwim were found to be covered by a good growth of spruce of considerable size, with birch, poplar, etc., entirely similar to the timber on the Sushitna side. Beneath the trees was underbrush, which in the Kuskokwim flats, where the soil is rich, becomes a veritable thicket of tangled vines and shrubs. Here blueberries were found and many so-called high-bush cranberries (Viburnum.) The growth of spruce is continuous along the river till below Kolmakof. Here there is a remarkably sharp division line, where the thick spruce of the hills which line the river suddenly thins out, becomes very straggling, and in the course of a few miles disappears entirely, leaving only barren moss-covered hills, which stretch to the southward away from the river, and run into the low, swampy, treeless plains known as tundra. From here down to its mouth the islands in the river and the flats bordering it have frequent groves of poplar, often of considerable size, but practically no spruce, while the tundra farther away from the river is quite treeless, supporting only low shrubs, but covered with enormously luxuriant growth of moss. It is not easy to discover the reason for the falling away of the spruce as the vicinity of the coast is neared, for the climatic and soil conditions appear to be practically unchanged. Dr. George F. Becker in his report on the gold fields of southern Alaska[1] has suggested as a cause for the general treelessness of Alaska Peninsula the recency of the late general uplift of the land. It is known from independent sources that all this coastal region was entirely submerged beneath the ocean waters in very recent geological time, and it has been suggested that the subsequent uplift has been so rapid that the timber has been unable to migrate coastward at a rate equal to the westward retreat of the shore line. This idea appears to the writer to offer at least an explanation of a phenomena which apparently does not depend upon climatic conditions. The whole Lower Kuskokwim, the Lower Yukon country, and most of the coastal region between the Kuskokwim and Alaska Peninsula are so poor in timber that the natives depend almost entirely upon driftwood for fuel.

TOPOGRAPHY.

West of the main Sushitna-Kuskokwim divide are two considerable mountain ridges parallel to the main range and separated one from another by narrow valleys—the Teocalli and the Terra Cotta mountains. The river flows along each of the valleys for a short distance and then breaks through the two mountain ridges, successively, emerging on a broad, level gravel plateau which reaches to the very foot of the mountains and is entirely similar to the plateau described on the Sushitna side of the divide as reaching from the Tordrillo Mountains to Cook Inlet. For over 100 miles the river runs through this gravel deposit directly away from the mountains. The fall of the stream is very great, for the plateau slopes decidedly to the west. The same

[1] Eighteenth Ann. Rept. U.S. Geol. Survey, Part III, p. 19.

snag flats are formed as on the Sushitna side, being if anything a little worse, so that it is doubtful whether a boat could be gotten upstream by any means. The material composing the banks of the river grows finer as one goes downstream, and some distance above the junction of the two main forks of the Upper Kuskokwim the high gravel bluffs give way entirely to lower banks of silt, and the current becomes comparatively slack. From here on to the vicinity of Vinasale the river flows through a broad, perfectly flat region, sometimes approaching low mountains on the north side. The banks are everywhere of silt, of nearly uniform appearance, and on account of the flatness of the country the current of the river is sluggish and its course exceedingly meandering—a sharp contrast from the straight and rapid upper river. This broad, flat country is in every respect identical in appearance with the Yukon flats at the junction of the Yukon and Porcupine, and, like it, is evidently the bottom of a great, shallow lake which has recently been drained.

Throughout this flat country, as mentioned, the river shows a continued tendency to crowd toward the north and approach the low mountains in that direction, until some distance below Vinasale it enters the mountains and runs through a continuous, well-cut valley for several hundred miles. In some portions of this valley the walls come quite close together, suggesting the ramparts of the Yukon. In other parts the valley broadens out, and there are considerable flats between the river and the mountains. Through these flats the river meanders and often divides into different channels, exactly as is the case farther upstream. In the lower part of this valley the largest tributary of the Kuskokwim, the Holiknuk, joins the main river, coming in from the Nushagak divide to the south, and a little farther up is another large tributary, the Chagavenapuk, which evidently has its source in the Tordrillo Mountains to the east. Below this still, and nearly on the very edge of the mountains, is the old trading post of Kolmakof. This whole range of mountains, cut through by the river from Vinasale to Kolmakof, although often high, never attains in any degree the height, ruggedness, and grandeur of the Tordrillo Mountains. They are generally of somewhat graceful and rounded outlines, are well timbered with spruce well up their sides, and their tops rise to a general level which constitutes an elevated plateau. From this general plateau isolated higher peaks rise, which have at times the appearance of volcanic cones, but which are most probably simply mountains of circumdenudation. On only a few of these higher mountains is there any perpetual snow, and on none of them is there any sign whatever of present or past glaciation.

Shortly below Kolmakof the mountains trend off to the south and thus diverge from the southwesterly flowing river, which here enters upon the level tundra. The junction of the mountains with the tundra is abrupt, like that of mountains jutting into the sea, and from here to the coast the immediate neighborhood of the river is always flat. To the right of the river the tundra stretches away without interruption to the Yukon, while on the left it is bordered by the mountains, which are generally in sight and some spurs of which, such as the Kilbuck Mountains, approach very near the river. The same general belt of mountains runs clear down to the coast, where it is encountered in the region of Cape Newenham, and east of it for a considerable distance.

The mountains through which the main Kuskokwim River flows, therefore, may be divided into three chief groups, the high and rugged Tordrillo Mountains, which have a northeast-and-southwest trend and constitute the Sushitna-Kuskokwim divide; the low mountains, rather a well-dissected divide than a range, which lie to the north of the east-west portion of the upper river, forming the watershed between the Upper Kuskokwim and the Lower Tanana, and which may be called the Tanana Hills; and the broad range of tolerably high mountains which the Middle Kuskokwim cuts through and which run from here to Bering Sea. This last system has a definite northeast-and-southwest trend like the Tordrillo Mountains, and has been called the Kuskokwim Mountains. The general course of the Tanana Hills lies at right angles to the other two systems, being northwest and southeast.

In consequence of the very low gradient of the Lower Kuskokwim, the river broadens out below Bethel, or Memtrelegamut, into a veritable sea, full of islands and often occupying a number of different channels. It begins already at this point to be affected by the heavy tides of this region, and so emerges, with no sharp dividing line, into the broad and shallow Kuskokwim Bay, which, like the river, is lined on both sides by tundra that extends out of sight on the right bank and off to the neighboring mountains on the left.

GAME AND FISH.

The torrential portion of the Upper Kuskokwim, after it emerges from the mountains, flows through a country which apparently has little to support life, for very few signs of Indian camps were seen, and no game. The river is also entirely unfitted for fish. Farther up, in the mountains themselves, however, were all the signs of a good game country, according to Alaskan standards. Many camping places were found which had been made by natives who had once been here on the hunt, and there were horns of moose, caribou, and mountain sheep in a number of places. Wild fowl—ptarmigan, grouse, etc.—were also quite abundant, and some other small game. On the Kuskokwim flats the natives had the meat and skins of moose, bear, wolf, and other animals, but not in large quantity, and it is evident that even where the forest is continuous, the vegetation luxuriant, and the climate comparatively mild, the supply of game is extremely small. Along here, however, the river begins to be abundantly supplied with fish, which forms part of the diet of the few inhabitants. As one goes farther down the river the supply of game grows rather less and that of fish more. Below Kolmakof very little game is found, as the scarcity of skins and furs in the native villages shows. Bears occasionally come down to the river to catch the fish; but the native generally makes a long trip to the nearest mountain range for hunting.

In favorable seasons the salmon ascend the Lower Kuskokwim and its tributaries in enormous numbers, so that the industrious native has little difficulty in gathering sufficient fish for a year's supply of food, even with the crudest appliances. A fish trap, or weir of stakes driven into the stream bed, is used, also smaller traps of rods bound with root fibers, entirely similar in most respects to some fish traps used in Europe. Drift nets of woven root fibers are often employed; and the skillful Eskimo can often fill his kayak with the results of a morning's work with his small bone spear, with which he pierces the salmon as soon as one comes close to the surface in his vicinity. This abundant supply of fish furnishes almost the sole food for the comparatively numerous Eskimos who inhabit the lower river and who many times outnumber the upper-river natives, who subsist partly or chiefly upon game.

PEOPLE.

The Indians.—The natives of the Upper Kuskokwim belong to the general type of North American Indians known to ethnologists as Athabascans. Formerly the word "Tinneh" was employed to designate the Alaskan Athabascans, this word being taken from their own language and signifying simply *men*. The Upper Kuskokwim people have been called the Khuylchan or Kolchane by the Russians, who explored the lower river, according to whom they were treacherous and warlike in character. No account, however, of any visit to these people is extant, and it is probable that many of them had never seen white men until our visit in 1898. We found them a poor and scattered folk, wandering continually from place to place, and possessing no villages of any kind, not even such wretched ones as do the Eskimos of the lower river. In a number of places we found the remains of villages, consisting of a number of houses, but they were all abandoned, while the people we encountered were living, one or two families together, in small temporary camps. In all, we saw not more than a hundred of these people along the main river, and it is doubtful whether the whole population is more than two or three times that number.

In appearance the Kuskokwim Indian (Kolchane) is like the native of the Sushitna or Upper Yukon. He is usually short in stature and of lithe and active build, with a brownish-red complexion, black hair, and very scanty beard. The features vary much in different individuals, but most of them are bright looking and intelligent. Living as they do upon the scanty game and fish of this region, it is probable that their number is diminishing rather than increasing, as the deserted villages before mentioned indicate. There is also some probability that their numbers may have been decreased by war with the neighboring tribes, for the Sushitna natives relate that some time ago the Copper River Indians made an incursion into the Kuskokwim country and nearly exterminated the people. Far from being warlike and treacherous, as the Russians had supposed, we found the Kolchane very gentle and generous, ready to help us in any possible way, and behaving with a certain dignity which would, among civilized people, be called well-bred, and which was strongly in contrast with the behavior of the Eskimos on the lower river. They had all come in contact with the idea of Christianity, and the most remote ones encountered were found in the act of hewing a wooden cross to place over a newly made grave, while the chief, or "tyone," wore a little amulet, evidently obtained from some Russian-Greek missionary. It is likely that they derived this influence from the trading post at Vinasale, where there seems to have been a Greek missionary at one time, although the post at the time of our visit was deserted.

They use long birch canoes in their traveling, of a kind similar to those on the Middle Yukon, but broader and of greater carrying power, as the slacker current of the Kuskokwim permits. Some of them are in possession of guns which they have obtained from trading posts hundreds of miles away, and they fired these in a salute to us as we passed their camps. Many, however, still hunt largely with the spear or bow and arrow, and in other primitive ways. For large and dangerous game, such as bear, it is said that they do not consider a rifle trustworthy, preferring to rely upon the short spear, in the use of which they become so proficient that they attack the largest animal without any fear. It seems hardly possible that the tradition held by the Sushitna natives mentioned by Petroff,[1] as to the Kolchane being cannibals, is anything but a savage fairy tale. These people hold no communication with the lower-river natives, who consider them a wild race occupying an unknown country.

The intermediate people.—According to the Moravian missionaries on the Kuskokwim, the few people inhabiting the Kuskokwim between Vinasale and Kolmakof belong to a tribe differing both from the upper natives and from the Eskimos of the lower river. These people are called Ingeliks. According to Petroff, however, the Ingeliks actually

[1] Tenth Census, Vol. VIII, p. 163.

form part of the Kolchane, and indeed, so far as we saw, there was no evidence of a distinct people, the types between Vinasale and Kolmakof being such as might be expected upon the border land between two great divisions of the human race.

The Eskimos.—From Kolmakof down to the Bering Sea is a comparatively numerous population of Eskimos belonging to a tribe known in their own language as "Kuskokvigamut," signifying *Kuskokwim people*, or simply "Yut," which signifies *the people*. This common ending is shown in the names of other Eskimo tribes, such as the Mahlamut, who are found at the mouth of the Yukon, the Nushagagamut on the Nushagak River, and others. The same termination occurs in the name of each of the numerous Eskimo villages, an *m* being usually prefixed for euphony, so that the termination is usually "myute" or "mut," signifying, as before, *people;* thus, "Memtrelegamut," where the Moravian mission is located, signifies *the smokehouse people*, from the fact that here a peculiar house for smoking fish was first erected. The word "Kuskokwim" is, according to the statement of the Rev. Mr. Kilbuck, who is one of the few persons actually proficient in the Yut language, the genitive case of the word "Kuskokwik," which has for some reason been adopted by the Russians instead of the nominative. The latter part of this word, "kwik," means *a river*, but the first part is of doubtful signification. The Russian word "kuska" (koshka), meaning *a cat*, has been adopted into the Yut language, but it seems quite probable that the name of the river is older and of different signification. According to the Tenth Census report, these people numbered between 3,000 and 4,000, but at the present time they probably do not exceed 2,000. According to Dr. Romig, the physician missionary at Bethel, the death rate steadily exceeds the birth rate, while over half the people suffer from grave chronic diseases. In spite of the abundance of fish on the lower river, there are many seasons when the catch is insufficient for the population, and after such a season there are many deaths from starvation.

The Yuts, like the other Eskimos, lead a somewhat nomadic life, but are yet more settled than the interior Indians and possess numerous considerable villages, which often contain each several hundred inhabitants. Their houses are built mostly underground, with a flat, conical roof of timber covered with moss, earth, and grass, which rises above the surface. The entrance is by a short underground tunnel, and is very low (Pl. XII). In front of this entrance a skin is generally hung as a curtain. The fire for cooking is built in the middle of the habitation, and the smoke ascends through a hole in the roof above. A pile of skins for bedding constitutes almost the sole furniture of these houses, or "barabarras," as they are commonly called by the Russians. In each village of any importance is an exceptionally large and well-built house, which is used as a council house, and also for the celebration of any of their games and festivals. The men of the village generally sleep in this council house, which is called "kashga," or "kashim," and travelers stopping overnight are welcome to sleep here.

The dress of the Kuskokvigamut consists mainly of a large gown-like garment, generally made of squirrel skins, sometimes of mink or reindeer. With the men this garment, or "parka," reaches nearly to the ground, so that it has to be girded up by a belt when walking. The dress of the women differs from that of the men only in their shorter parkas and in the greater length of the seal-skin boots, which are also often worn. Hats are very seldom worn by these people. The dress is uniform over large areas, and in fact varies from one tribe of Eskimos to another only in minor details, such as the custom of retaining the tails of the squirrels in constructing the parka, a peculiar fashion which is often found throughout an entire tribe.

The customs and social conditions of the Kuskokwim Eskimos are exceedingly interesting and demand much closer study than can be given here. In many respects apparently the lowest and most animal-like of the human race, they yet possess many remarkable customs and virtues. Almost perfect socialism and communism is one of their most striking characteristics, while all their ideas and habits are so regulated that it is impossible for one to become more wealthy than another, a fact which possibly explains the lowly condition of the race. Their greatest festivals consist of so-called "igrooskies," which are simply contests in giving away. One village challenges another to a contest of this sort, and the one that succeeds in giving the most to the other is pronounced the victor and is very proud of the honor, even if they have impoverished themselves. In division of the gifts obtained at such a festival, moreover, the very old receive the larger part, while the young, who have given the presents to the opposite side, receive hardly anything. Another similar ceremony is the "potlatch," which is generally held by individuals after the death of a relative, on which occasion the giver distributes his possessions to his visitors. A peculiar custom, considering the other habits of the Eskimos, is their passion for steam baths. Nearly everywhere one finds bath houses built of wood with the chinks tightly cemented; stones are heated and carried into the building and water is thrown upon them till the interior is filled with steam. Here the men like to remain as long as they possibly can, and then dash out into the river, even when they must break the ice to do so. It is very likely that a large part of the sickness among these people comes from this too rigorous habit.

Even a very hasty examination of the dwellings and villages of the Eskimos shows that they are as a race actually in the bone and stone age of development. Most of their implements are made of these materials; knives, skin scrapers, and numerous other articles being made of stone; while spears, arrowheads, knife handles, and so on, are of bone. Stone lamps are also found among them, although they are no longer made, and, curiously enough, they have preserved no tradition of the time of their manufacture, supposing that these lamps have been brought by the spirits or that they represent stones naturally hollowed out by water. Some rude attempts at pottery are found, especially lamps.

For years missionaries have been working nobly and unselfishly among the Eskimos, but their condition still seems for the most part very little improved. It is probable that these people will meet the usual fate of savage tribes who come into contact with civilization. The idea of civilization that they get is that it consists in frame houses, steel ranges, imported clothing, and varied food, such as they see the missionary have. Teaching as to manner of improving their resources might perhaps have some effect in advancing their condition. The tundra could be ditched to prevent excessive water, and potatoes, turnips, cabbages, and similar crops could be raised. There is a profusion of reindeer moss on the tundra, and there are hills near by where the reindeer could be driven in summer to keep them out of the wet and prevent the hoof rot. Fish are abundant, so that on the whole the country might support a hardy and intelligent population. But the Eskimo will never take up any of these things by himself.

When unaffected by ideas received from white men the Kuskokwim Eskimo has no idea whatever of a Supreme Being.[1] There is, however, a general belief in spirits, devils, brownies, and fairies, especially as guardians to animals. It is believed that a special guardian spirit watches over each class of animals; that there is a spirit fish, a spirit bear, a spirit wolf, etc. These spirits are supposed to be very powerful in their ability to help the natives, who do everything to conciliate them according to their ideas. These customs do not always appear at first sight to have any reasonable origin; e. g., the bear's head is never brought home from the chase, but is buried with the nose pointing toward the east, and it would also be considered an offense to the spirit bear to cut any of the bones with a saw, although they may be broken. Usages such as these, which must be observed by the hunter and fisherman, are very numerous, and the failure to fulfill them often brings about, according to their belief, great trouble; for if the spirit fish has been offended in any way he will not permit the fish to be caught by the native who has offended him, or indeed by any other natives of the village. Their beliefs in regard to personal spirits are not so well formed, except that they hold to the very ancient idea that insane persons are possessed by devils and resort to absurd ceremonies to drive the evil spirit out. They also believe that

[1] For much of this information the writer is indebted to Rev. Mr. Kilbuck, Moravian missionary at Bethel.

their shamans, or native medicine men, may be in league with these spirits. It may be noted in this connection that the Eskimos belonging to a different tribe, namely, those inhabiting the south side of the Alaska peninsula and the region of Prince William Sound, believe that after death their spirits pass into the bodies of animals, especially large whales, and it is often a custom of these people, when they see a school of whales, to gather on the shore and shout their word of greeting, "chummai," and to throw food into the waters as a gift to the spirits of their ancestors.

NOTES ON THE ANIMAL AND VEGETABLE LIFE OF THE REGION OF THE SUSHITNA AND KUSKOKWIM RIVERS.

By F. C. Hinckley.

There has been no attempt to make a thorough investigation of the animal and vegetable life of the country, only such notes having been taken as could be conveniently written during the continual and engrossing duties which fall to the lot of a member of an Alaskan exploring party. The writer, while not a member of the scientific corps of the expedition, had had a fair training in natural history, and had taken a deep interest in animals and plants, and it is from his diary that these notes, set down without special intention of publication, have been compiled.

SKWENTNA REGION.

Birds.—The bird life during our whole journey was one of the most interesting features in the natural history. We were surprised to find how early the migratory birds returned to Cook Inlet. The intermediate, Townsend's, and golden-crowned sparrows, the robin, the hermit, and the varied thrush, several species of warblers, and a flock of white-bellied and bank swallows, were among the birds seen during the early part of May. By the middle of the month the birch trees which grew at the top of the gravel bluffs along the inlet were in blossom and full of happy bird voices. The little redpoll, a well-known winter visitor in our Northern States, was present in great numbers, always on the wing, swinging merrily in flocks in and out of the trees, and singing and chirping till the air seemed full of life. By the end of May, when the writer reached the Sushitna delta, the weather had grown warm and pleasant and the river banks were tinged with green. We found that the birds had commenced nesting, and we frequently disturbed them in our passage up the stream. Sometimes a pair of wild geese, rising from the adjacent woods, flew away before us. Often the brilliant arctic tern screamed and chattered as we neared the bar on which her eggs were lying; ducks slid from their nests on the bank and disappeared in overhanging willows; and pairs of gulls, shining in the sunlight, flew high above us, watching silently as we passed their nesting places.

The Sushitna River above the delta, and the Skwentna up to its junction with the Yentna, both flow through generally low and monotonous banks. Above the junction of the Skwentna and the Yentna the mountains which form the Kuskokwim-Sushitna divide become constantly nearer, although these are usually hidden by the high gravel banks, so that the view is generally limited to the snag-covered river bottom. Above the gravel banks we found a rolling plain covered with an open spruce and birch forest, all through which a long grass, similar to our redtop, grew sparingly. Wherever the ground was poorly drained the trees and grass were replaced by moss. In this region the bird life is not varied, although fairly abundant. Along the river bed sandpipers and other shore birds were plenty, and the large glaucous and herring gulls and the small arctic tern were found here and there. In the woods we heard constantly the dwarf hermit thrush, and occasionally the trilling note of the ruby-crowned kinglet. A few harsh-voiced warblers were noted now and then. Redpolls were common everywhere, and several species of grouse were frequently seen. From the alders on the river bank the startling, loud "whoo-pee" of the flycatcher was constantly sounding.

On the portage at the head of the Skwentna bird life was also plentiful. Here a number of warblers, including the common yellow warbler, was seen, and the two species of three-toed woodpeckers which are common in all northern countries. The hawk owl and the goshawk were occasionally seen in the woods, and one day a fierce fight between two goshawks and an owl was witnessed.

On nearing the summit of the pass, which was about 4,800 feet high, we still found considerable bird life. Besides the ubiquitous redpoll we saw the Lapland longspur along the sod-covered slopes, and the pretty arctic finches, called leucosticte, living among the high rocks; we also occasionally came across a brood of ptarmigan and a species of plover. As we approached the summit we heard the scream of a golden eagle, which had its eyry in a neighboring crag.

Plants and flowers.—In the month of June, on the Skwentna River, we found many flowers, not so abundantly as we afterwards found them on the hillsides, but still often making the shrubbery very pretty. We often passed graceful, sharp-cut clumps of rosebushes in full blossom; whenever the bank was moist and snowy the Rocky Mountain bluebell bloomed in profusion; along the shore pink, white, blue, and yellow varieties of the pea family grew abundantly; on the sandbars were several plants characteristic of desert flora; in rich, partly shaded slopes of grass grew the false solomon's seal, and in the spruce woods of the river bottom we found the sweet-scented pyrola and twinflower.

At the head of the Skwentna we noticed that the breezes were filled with balmy odors, and on climbing above the timber line we immediately discovered their origin; the whole country was covered with a thick carpet of flowers, the most conspicuous of which was a Rocky Mountain sunflower and a beautiful white buttercup. Along the bare cliffs a species of fireweed grew, forming a pretty bit of color against the dreary rocks. Among the less conspicuous blossoms the bilberry, the mountain cranberry, and saxifrage were abundant. On the pass itself we found vegetation growing up to the edge of the snow. Here, also, the ground was covered with flowers. Among the most conspicuous blossoms not already mentioned as being among the mountain flora were two species of healall and two of crowberry, a white and yellow. These latter plants grew everywhere, covering the ground like a heavy moss, and in making tea at the summit we used it quite successfully as fuel, since it burns when green, on account of the rich oil which it contains. In the dense grass which grew near our camp, a few miles below the summit, grew a species of dandelion, and blue and yellow violets.

Quadrupeds.—On the whole, animal life, and especially game, is comparatively scarce along the Skwentna. On the lower river there were signs of moose on the sandbars and in the woods, but these animals appeared to be few in number; on the upper river they seemed more plentiful. Beaver gnawings were noted at nearly every camping ground. Once or twice the track of a timber wolf or fox was seen, and occasionally that of a bear, although but one of these latter animals was actually seen by the party. In the tops of the mountains were found great numbers of a little ground rodent, a species of marmot. This animal always lives among broken fragments of rock or in the turf above the tree line, its food supply consisting of the berries, roots, and leaves of the alpine plants. As one walks along he hears marmots barking everywhere around him, but must watch carefully before he catches sight of one; the effect of hearing these sharp cries within a few feet without ever seeing a thing after a while grows quite irritating. It is these little animals whose skin furnishes the common clothing for the Alaskan natives.

Butterflies.—Butterflies are quite common in this region. On Cook Inlet a black butterfly, probably similar to the black yellow-bordered butterfly, was noted early in the month of May. One of the pretty painted butterflies was also seen, and a few small red ones which the writer did not identify. Near the pass the butterflies were more numerous than elsewhere, becoming quite plentiful. A species of black swallowtail, a small argunis, the common white butterfly, and the little blue butterfly were noticed. Here also a few humblebees were seen flying among the alpine flowers.

KUSKOKWIM REGION.

Timber.—Below the spruce-covered Kuskokwim flats, the low, rolling hills which lie between them and the edge of the tundra are covered with a growth of birch and spruce which gradually disappears on approaching the tundra. Of the forest trees growing on the river flats, spruce was the most numerous, although the sandy tracts were covered with balm of Gilead, willow, and alder, while where the land was well drained clumps of birch appeared. Occasionally, on passing a bog, scattering larches were noticed, and on the rocky hills and river bluffs the small-leafed poplar grew. These were the only species of trees noted on the journey.

Quadrupeds.—Animal life on the banks of the Kuskokwim seemed scarce. For hundreds of miles only scattering signs of moose were seen, and very few bear tracks. Fox and wolf signs, which one would expect to notice frequently, were almost entirely absent. This scarcity seems due in part to the lack of food for such animals, and in part to the high price of fur and the introduction of modern firearms. As the wild animals disappear the natives, who are dependent on them for their own life, also dwindle in numbers.

Among the animals not already mentioned as being seen in the Sushitna and Kuskokwim valleys are the muskrat, which lives in great numbers on the tundra streams; the hare, which occurs now and then in patches of willow and alder; the red squirrel, found in the spruce woods, and two species of mice. The first mouse which we noticed was a large, reddish, long-haired animal with a short tail, sparsely covered with spikes of reddish hair. This species was seen both high up on the mountain pass and on the tundra. The second species was a fierce little gray mouse, which lives on the tundra and turns white in winter.

It is interesting to note how important berries are as a food to the animals of this region. As many of the berries do not drop off after ripening, they may be found during the greater part of the year. The principal varieties are the cranberry, bilberry, crowberry, and blueberry. The first two species are found on mountain and tundra alike, while the crowberry is confined to the mountains, and the blueberry to bogs and tundra. Among the kinds which are less important as food are a species of yellow thimbleberry, which grows scattering over the tundra; the bunchberry, growing in boggy ground; an excellent currant, which is found in the rich, grassy openings along the river, and the fruit of a species of viburnum. Among the animals which live more or less largely on berries are the bear, who eats them in fall and spring; the marmot, who lives constantly on them; the ptarmigan, the ducks, and the geese, who descend on them in great flocks in fall and spring.

Tundra vegetation.—The general bird and plant life of the Kuskokwim is similar to that of the Skwentna. The broad tundra, however, which lies between Kolmakof and the coast presents many special features, of which, unfortunately, only a very few can be mentioned.

In the streams of the tundra flourish water plants similar to New England species, but not in so great variety. Small bodies of standing water are often filled up by the large cow lily, and in the grass all along the water's edge the large wild carrot is found growing. An interesting fact noted in the tundra on the Lower Kuskokwim is the abundance of edible mushrooms, whose value does not seem to be known to the natives. Of the mushrooms which grow about Bethel only one genus, the *Boletus*, was identified; this mushroom is supposed to be the *Boletus scaber* common in New England. Two other species were found growing abundantly.

Plants of special interest.—The following notes were taken by Mr. M. E. Fernald, of Harvard University, from a small collection of plants made during the trip:

Among some plants collected during July and August, 1898, on the Sushitna and Kuskokwim rivers, in Alaska, by Frank C. Hinckley, of Bangor, Me., were four species of great geographic interest.

Viola biflora L., a common plant of northern Europe and Asia (Japan, Kamchatka, etc.), has been known on the American continent only from the mountains of Colorado, though it has naturally been expected to grow farther north. Mr. Hinckley found this delicate species, with clear yellow flowers, a common plant on the rich wooded slopes of mountains on the headwaters of the Sushitna and Kuskokwim in July.

Pedicularis hirsuta L., a species well known from arctic Europe and Asia, but more rare on our own Arctic coast, found by Mr. Hinckley on the mountain summits.

Bryanthus taxifolius Gray was also collected on these mountain summits. This, the "Phyllodoce," is common in arctic Europe and Asia, but in America, according to the Synoptical Flora, has been known only on the alpine summits of New Hampshire and Maine, and in Labrador.

Chrysanthemum bipinnatum L., growing from Lapland through northern Asia, has been known from only two American stations—Cape Espenberg and the Yukon Valley. Mr. Hinckley found it along the middle and lower portions of the Kuskokwim, thus extending its known range considerably southward.

LIST OF BIRDS OBSERVED BY MR. HINCKLEY ON THE SUSHITNA AND KUSKOKWIM RIVERS.

Family LARIDÆ (gulls and terns).

Genus PAGOPHILA.

Pagophila alba? (ivory gull). Flock of 7, Middle Kuskokwim, about August 4.

Genus LARUS.

Larus glaucus (western glaucous gull). Nesting in the roots on sand bars. Whole course of Sushitna and Kuskokwim rivers as far as mountains.

Genus STERNA.

Sterna paradisæa (arctic tern). Nesting along Sushitna and Kuskokwim rivers. Found even in high mountain valleys.

Family SCOLOPACIDÆ (snipes and sandpipers).

Genus Gallinago.

Gallinago delicata (Wilson's snipe). Tyonek, Cook Inlet. Shot daily by miners, May 5–15.

Genus Tringa.

Tringa minutilla (least sandpiper). Sushitna and Kuskokwim off and on through summer.

Genus Calidris.

Calidris arenaria? (sanderling). Delta of Sushitna, May 30.

Genus Helodromas.

Helodromas solitarius. Sushitna-Skwentna branch, about June 15.

Genus Actitis.

Actitis macularia (spotted sandpiper). Cook Inlet and Skwentna, May and June.

Genus Numenius.

Numenius longirostris? (long-billed curlew). Wide mountain valley, Upper Kuskokwim, above timber line, July 23.

Numenius ——. Skwentna, June 5.

Family CHARADRIIDÆ (plovers).

Genus Charadrius.

Charadrius dominicus?. Kuskokwim, August.

Genus Ægialitis.

Ægialitis semipalmata (semipalmated plover). Kuskokwim, August.

Ægialitis vocifera (killdeer plover). Kuskokwim, August.

Ægialitis hiaticula (king plover). Kuskokwim, August.

Family APHRIZIDÆ (surfbirds and turnstones).

Genus Arenaria.

Arenaria interpres (or *melanocephalus*) (turnstone). Mountain valleys, Upper Kuskokwim, July 25, and on down Kuskokwim during August.

Family TETRAONIDÆ (grouse, partridges, etc.).

Genus Dendragapus.

Dendragapus obscurus fuliginosus (sooty grouse). Skwentna, about June 15. Also its tail feathers on ground June 5.

Genus Canachites.

Canachites canadensis (Canada grouse). Skwentna, July 3. Mountain valley stream.

Genus Bonasa.

Bonasa umbellus umbelloides? (gray ruffed grouse). Along Skwentna-Kuskokwim.

Genus Lagopus.

Lagopus lagopus? (willow ptarmigan). Bush-covered mountain valleys, Kuskokwim-Skwentna divide.

Lagopus rupestris (rock ptarmigan). Mountain valleys between Kuskokwim and Skwentna.

Lagopus leucurus (white-tailed ptarmigan). Rocks and talus slope of mountains between Kuskokwim and Skwentna. Late July.

Family FALCONIDÆ (falcons, hawks, etc.).

Genus Circus.

Circus hudsonius (marsh hawk). Cook Inlet, May; Lower Kuskokwim in August. Common.

Genus Accipiter.

Accipiter velox? (sharp-shinned hawk). Cook Inlet, May.

Accipiter cooperii? (Cooper's hawk). Kuskokwim, August.

Accipiter atricapillus (American goshawk). Common in Cook Inlet, April 28 and early May.

Genus Buteo.

Buteo borealis calurus? (Western red-tail). Kuskokwim, August.

Genus Aquila.

Aquila chrysaëtos (golden eagle). Skwentna, June 15; Kuskokwim, August.

Genus Haliaetus.

Haliæetus leucocephalus alascanus (Alaskan bald eagle). Common on coast.

Genus Falco.

Falco peregrinus pealei (Peale's falcon). Common all along Koskokwim on rugged bluffs, from which it darts screaming at passerby.

Falco columbarius suckleyi? (black merlin). On rugged bluffs of Kuskokwim. Habits like Peale's falcon.

Genus Pandion.

Pandion haliaëtus carolinensis (American osprey). Middle Kuskokwim.

Family BUBONIDÆ, (horned owls, etc.).

Bubo virginianus saturatus (dusky horned owl). Family on banks of Kuskokwim August 17.

Genus Surnia.

Surnia ulula caparoch (American hawk owl). On portage Skwentna-Kuskokwim. Family in open poplars.

Family ALCEDINIDÆ (kingfishers).

Ceryle alcyon (belted Kingfisher). Common. Sitka, April 13; Cook Inlet, May.

Family PICIDÆ (woodpeckers).

Genus Picoides.

Picoides arcticus (arctic three-toed woodpecker). Skwentna, June 20.

Picoides americanus alascensis? (Alaskan three-toed woodpecker). Skwentna, June 25.

Family TYRANNIDÆ (tyrant flycatchers).

Genus SAYORNIS.

Sayornis. One species. Cook Inlet, Skwentna, Kuskokwim.

Family CORVIDÆ (crows, jays, magpies, etc.)

Genus CYANOCITTA.

Cyanocitta stelleri (Steller's jay). Common. Sitka, April. Also found on Skwentna, June.

Genus PERISOREUS.

Perisoreus canadensis fumifrons (Alaskan jay). Common on Skwentna and Kuskokwim.

Perisoreus ———. Smaller species. Skwentna and Kuskokwim.

Genus CORVUS.

Corvus caurinus (northwest crow). Common in Sitka and Cook Inlet, April and May.

Corvus corax principalis (northern raven). Sitka, April; Cook Inlet, May; Lower Kuskokwim, August.

Genus NUCIFRAGA.

Nucifraga columbiana (Clark's nutcracker (?)).

Genus PICA.

Pica pica hudsonica (American magpie). Mount Sushitna, May 20. Nest of young (?), July 23. Island in river. Mountains of Upper Kuskokwim.

Family STURNIDÆ (Starlings).

Genus SCOLECOPHAGUS.

Scolecophagus carolinus (rusty blackbird). Common in August about Bethel, Lower Kuskokwim.

Scolecophagus cyanocephalus (Brewer's blackbird). Cook Inlet, May 15. Middle Kuskokwim, August.

Family FRINGILLIDÆ (finches, sparrows).

Genus LEUCOSTICTE.

Leucosticte griseonucha? (Aleutian leucosticte). Mountain tops of Upper Koskokwim, 5,000 feet.

Leucosticte tephrocotis littoralis (Hepburn's finch). Mountain tops of Upper Kuskokwim, July.

Genus ACANTHIS.

Acanthis hornemannii exilipes (hoary redpoll). Common everywhere, lowlands and mountains alike.

Acanthis linaria (redpoll). Common everywhere.

Genus CALCARIUS.

Calcarius lapponicus alascensis (Alaskan longspur). Cook Inlet, common, May. Mountains, Upper Kuskokwim, July.

Genus AMMODRAMUS.

Ammodramus sandwichensis (sandwich sparrow). Cook Inlet, early May.

Genus ZONOTRICHIA.

Zonotrichia leucophrys intermedia (intermediate sparrow). Cook Inlet, early May.
Zonotrichia leucophrys nuttalli (Nuttall's sparrow). Cook Inlet, May.
Zonotrichia coronata (golden-crowned sparrow). Upper Skwentna, June, nesting.

Genus SPIZELLA.

Spizella monticola ochracea (Western tree sparrow). Cook Inlet, May.

Genus JUNCO.

Junco hyemalis (slate-colored junco). Cook Inlet and Skwentna, May and June.
Junco hyemalis oregonus. Sitka, Cook Inlet, Skwentna; April, May, June.

Genus MELOSPIZA.

Melospiza melodia rufina (sooty song sparrow). Sitka, April; and Cook Inlet, May.
Melospiza melodia caurina (Yakutat song sparrow). Cook Inlet, May.

Genus PASSERELLA.

Passerella iliaca unalaschcenis (Townsend's sparrow). Cook Inlet, May.

Family HIRUNDINIDÆ (swallows).

Genus HIRUNDO.

Hirundo erythrogaster (barn swallow). Kolmakof, Middle Kuskokwim, August.

Genus CLIVICOLA.

Clivicola riparia (bank swallow). Abundant on Kuskokwim.

Genus TACHYCINETA.

Tachycineta thalassina? (violet-green swallow, or white-bellied swallow). Sitka, April 13; Cook Inlet, May 1.

Family MNIOTILTIDÆ (wood warblers).

Genus DENDROICA.

Dendroica aestiva rubiginosa (Alaskan yellow warbler). Skwentna, June.
Dendroica striata? (black poll warbler). Skwentna.
Dendroica coronata (myrtle warbler). Skwentna, June.

Genus SEIURUS.

Seiurus aurocapillus (oven bird). Abundant Sushitna, Skwentna, May and June.

Family MOTACILLIDÆ.

Genus ANTHUS.

Anthus pensilvanicus (American pipit). Common. Cook Inlet, June; St. Michael, late August.

Family PARIDÆ (nuthatches and tits).

Genus PARUS.

Parus rufescens (chestnut-backed chickadee).. Common. Sitka, Cook Inlet, Skwentna.

Family SYLVIIDÆ (warblers, kinglets, gnatcatchers).

Genus REGULUS.

Regulus calendula (ruby-crowned kinglet). Sitka, April; Cook Inlet, May; Skwentna, June; Kuskokwim, August.

Family TURDIDÆ (thrushes).

Genus HYLOCICHLA.

Hylocichla aonalaschkæ (dwarf hermit thrush). Abundant Sitka, April. Singing early May, Cook Inlet. Singing in June on Skwentna.

Genus MERULA.

Merula migratoria (American robin). Sitka, April; Cook Inlet, May; mountains of Upper Kuskokwim, July.

Genus HESPEROCICHLA.

Hesperocichla nævia (varied thrush). Cook Inlet, early May; Sushitna, May 30. Two nests of eggs along mile of lightly wooded river bottom.

KANEKTOK RIVER.

The lower part of the Kanektok River flows through the same dreary and barren tundra which surrounds the whole of the course of the Lower Kuskokwim. The current is rapid and the stream often splits into several channels, like similar portions of other Alaskan rivers. In the immediate vicinity of the water there is a sparse growth of willow and poplar trees, which do not attain any considerable size, while at a little distance there is only the swampy, moss-covered, treeless tundra. Farther up, the river emerges from a range of low, bare mountains, which grow higher and more rugged as one proceeds toward the head of the stream. The fall of the river also becomes greater, making the stream very difficult to ascend, especially in time of high water. After the mountains are entered wood becomes very scarce, until finally there is only a little willow brush along the rivers and lakes, while the rest of the country has only moss, with abundant berries. Blueberries are especially large and plentiful in their season, while the high[1] and low bush cranberry grows in favorable places, with the salmonberry and others.

The river forks many times into streams of nearly equal size, but the main or trunk stream, which we ascended, heads in a beautiful lake several miles in length, which the natives call Kagati, a word meaning the source. From this lake one must ascend a narrow, shal-

[1] The so-called high-bush cranberry is a species of Viburnum.

low, and extremely crooked creek for 8 or 9 miles, until it gets too shallow for even a kayak or canoe. A portage of half a mile is then made to a little lake, from which a quarter-mile portage is made across an old glacial moraine to another larger and very beautiful sheet of water. Across this lake, a distance of about 5 miles, is the real portage, extending over a bare mountain pass of considerable height. The distance from the lake to a creek emptying into Togiak Lake on the other side of the divide is 15 or 20 miles. The east side of the pass has a gradual ascent and is almost entirely bare and free from brush, while the west side has a sheer fall from the summit, with a rapid descent afterwards to Togiak Lake; and the whole of this side of the pass is densely covered with alder, which makes travel difficult, but furnishes an abundant supply of firewood, for, on account of the oil contained in it, this shrub can be burned green.

Above Lake Kagati rise the highest mountains of the range, and on the sides of some of them are small glaciers, the only ones found in this region. In the valleys, however, are sometimes moraines, and also small lakes which seem to have a glacial origin, showing that some, at least, of the glaciers have been more extensive than they are now.

In the tundra on the lower part of Kanektok River and also in that part of the mountains which lies not far from the tundra were small villages (so called) of Eskimos, consisting sometimes of a single habitation and sometimes of several; but so far as observed, these were all deserted, although perhaps only temporarily. During nearly the entire summer the lower part of the river is teeming with fish, since the different species of salmon follow one another in succession, according to their period of spawning. At the time of our ascent the number of dead salmon in the river was something remarkable, often covering the shore so that it was impossible to find any place to step except upon them, and in places heaped by the current into stacks, so that the stench was at all times very disagreeable. The live fish, too, were so abundant that a native fisherman whom we met had no trouble in filling his boat as fast as he could work with a small drift net, and our own natives were in the habit of spearing them with their small bone harpoons.

Farther up in the mountains there are no permanent habitations, but the whole of this range is the winter and spring hunting ground for the adventurous Eskimos from the various villages on the Lower Kuskokwim. Here they come to hunt the caribou and also the bear, which is very abundant. During our ascent we found the banks of the river everywhere trampled down by bear, and there were many dead fish which had been half eaten and flung aside, for at this time of the year the bear revels in fish and in blueberries. Waterfowl were abundant along the entire river, and, on the whole, the region is a fairly good game country.

We entered the Kanektok River on the 26th of August and crossed the pass on the 14th of September. This season is already fall in this portion of Alaska. During the whole of our ascent we were annoyed and delayed by the tremendous rains, which lasted night and day, so that the river swelled and overflowed its low banks and everything was dripping with moisture. Only when we reached the neighborhood of the pass did a clear day come to us. This rain was accompanied by heavy gales, which, however, owing to our sheltered position, did not delay us very much. On the upper river there were frequent heavy frosts, and on the 8th of September a snowstorm whitened the mountains above us, although it did not extend to the valley.

TOGIAK RIVER.

The Togiak River has its main source in Togiak Lake, which we reached directly after crossing the pass. From the summit a portage of 10 miles took us to a creek, into which we could put our canoes. A short distance down, this stream is joined by another, when the channel becomes quiet and deep, and in a little time a considerable lake is reached. Crossing this, a short stream full of bowlders leads into Togiak Lake. This lake is narrow and long, its chief length being in the direction of the river which drains it; so far as we could see, it seemed to extend for 30 or 40 miles. From the account of natives it appears that it is fed by another stream, which in turn drains smaller lakes; but of this region no one can speak with certainty, for it has never been visited by white men. The lake where we entered it was entirely walled on both sides by high mountains, which grew still higher and more snowy farther up toward the head. From the lower part of the lake flows the Togiak River, which is of considerable size and of moderate current, characteristics which, taken in connection with the fact that it has ordinarily a single well-defined channel and banks comparatively free from underbrush, makes it a very good river for canoe navigation—a quite exceptional thing among Alaskan streams. From its very beginning, at the foot of the lake, the river flows through a belt of tundra, which here begins to separate the mountain ranges and which grows wider as the distance between the mountains increases, toward the lower part of the river. Finally the stream empties, through a number of tidal channels, into Togiak Bay.

On account of the abundance of fish in the Togiak and the fact that the river is so admirably suited to canoe navigation there is a large population. Indeed, this valley, with its pleasant, deep river, its beautiful lakes, and its picturesque mountains, seems an infinitely preferable abode to the rainy and dreary tundra of the Lower Kuskokwim, which is the home of so many Eskimos. The change in the conditions seem reflected in the appearance and character of the people. The Togiak natives are closely allied in race to those of the Kuskokwim, but are cleaner and more intelligent, although they have never come into contact with white men. A party of men who met us as we entered the lake, and who escorted us some distance, were the best-looking Eskimos we had seen, being cleanly and neatly dressed, with ornamented parkas and caps of squirrel skins, and had neatly constructed kayaks. They are a remarkably gentle and mild-mannered people, as if the seclusion of their mountain valley had given them for ages past protection against any violence. On the river large villages are very numerous and in a general way similar to those on the Kuskokwim, consisting of groups of barabarras or dwellings, of caches or storehouses (set up on upright logs away from dogs and other prowling animals), and other usual features of an Eskimo village (Pl. XII). Occasionally the Togiak people were found dressed in parkas made from the breasts of sea fowl, the many-colored feathers making their appearance very picturesque.

FROM TOGIAK RIVER TO NUSHAGAK.

On the northwest side of Togiak Bay, mountains approach comparatively near to the shore, being apparently a continuation of the range which forms the divide between the Kanektok and the Togiak. On the east side of the bay, however, the tundra is very wide, and the mountains which rise at a distance are isolated and comparatively low, often suggesting in shape ancient volcanic cones. The shore line from Togiak to Kululuk Bay is a continuous bluff of coarse bowldery material or solid rock, which varies from 10 to 100 feet in height and is topped by the level tundra. The islands which lie off the shore here are hilly and also have steep bluffs along most of their shore line. Near Kululuk Bay the mountains come down to the shore again, while Cape Constantine is a point of nearly level tundra which runs far out from the mountain front. It is very dangerous to travel around Cape Constantine on account of the shallow water and heavy gales, so it is customary to take a shorter route, which has been used for a long time by natives and traders. This leads from the head of Kululuk Bay to a point on Nushagak Bay, and consists of a string of lakes drained by small streams which are affected enormously by the tides. In traveling on Kululuk Bay the tides must always be taken into account, since they are so strong that one can not make headway against them. After reaching the head of the bay the tide is again made use of to ascend a narrow stream which winds through the tundra. Above the limits of tidal action there is a short distance where the stream is small and contains only fresh water; beyond this is a small lake, which is connected by a short stream with another, and this again with a third. From here a low portage of three-fourths of a mile leads to a lake 2 miles long, and from this a half mile portage to a large lake surrounded by mountains. These two portages represent the slight divide which exists between the drainage of Kululuk Bay and that of Nushagak Bay, for from the last lake a comparatively rapid stream runs down into a second large lake, and from this a larger stream, called Egoushik or Crooked River, runs into Nushagak Bay. The lower part of this last stream is subject to the rise and fall of the tides, and on account of the backing up of the water and the concurrent action of the tides and the fresh-water stream, the periods of the tides are made very irregular, so that it is hard to reckon upon them. Not far from the mouth of this tidal river the fall of the water was upward of 30 feet. In its extreme lowest part the river flows parallel with the shore and only a few hundred yards away for several miles, and at this point a portage is made through the tundra to the coast. The upper part of Nushagak Bay is also subject to tremendous tides, and is shallow, so that the receding water leaves broad stretches of mud, which run out for 5 or 10 miles over the whole upper part of the bay. Through these flats the rivers which enter the bay—namely, the Snake River, the Wood, and the Nushagak—have definite channels with steep mud banks. At high tide the whole bay is filled with water up to the steep bluffs, which rise from 50 to 100 feet and whose tops are on a level with the tundra.

Along this whole route, from Togiak to Nushagak, there is very little wood; on the coast there is nothing whatever but driftwood, while in the inland passage from Kululuk Bay to Nushagak Bay small groves of poplar and birch grow along the shores of the two larger lakes. The upper part of Crooked River has occasional groves of spruce, a tree which has been noted as being remarkably scarce along the coastal belt. Some portions of the tundra are covered with a heavy growth of coarse grasses, especially where it is subject to inundation by very high tides, but most of the tundra has only thick moss.

After leaving the native villages on the shore of Togiak Bay no people were seen until the inland route was reached. There are native villages on Kululuk Bay, but they are apart from the regular line of travel and were not visited. On the inland route two permanent villages were found on the shores of different lakes. These people wore parkas made of feathers to a much larger extent than any other Eskimos we had seen, and they seemed to depend considerably upon wild fowl for their food. It is worthy of note here that the Eskimos of the coast very generally eat moss, such as the Iceland or reindeer moss; they also eat certain fungi, which they find on trees, as well as parts of the common jellyfish, and other things which we do not ordinarily regard as food.

This route is comparatively well traveled, and several parties of natives were encountered journeying forward and backward. No permanent habitations beyond the lakes are met with until Nushagak is reached, where there is a large number of natives on both sides of the river, clustered around the buildings which have been erected by white men. There is a trading post and a Moravian and a Greek mission, and there are several large canneries, erected to utilize, and often to waste, the enormous quantities of salmon which annually enter the mouth of the Nushagak River. In the summer these canneries employ hundreds of men, but in the winter they are deserted. At the time of our arrival in Nushagak, at the end of September, there were about twenty white men in the neighborhood. The Nushagak natives are Eskimo, but have been for some time more in contact with white men than the tribes which have previously been mentioned. They therefore hold in considerable scorn the natives from the Togiak and the Kuskokwim, and indulge in customs brought them by the white men, such as cigarette smoking and card playing, and in wearing clothes bought of the trader.

The weather during our trip from Togiak to Nushagak was very uncertain, with some fine and bright days, but also with a series of tremendous gales, accompanied by rain and snow, which made travel unsafe, even on the small lakes and rivers, and which delayed us several days on the coast of Nushagak Bay.

FROM NUSHAGAK TO KATMAI.

The seacoast from Nushagak around Cape Etolin into Bristol Bay is continuously tundra, which lies at an elevation of from 50 to 200 feet above the sea, and the shore is always a precipitous bluff of sand and gravel, save where this is cut down by small streams entering the sea. Along the coast of this peninsula the mountains are so far inland that they can not be seen. The southeastern shore of Bristol Bay is also tundra, similar to the northwestern shore, but everywhere a continuous line of mountains, which form the backbone of the Alaska Peninsula, can be seen rising out of the treeless plain. The Naknek River, along which we traveled, flows entirely through the tundra portion of the peninsula, for it is very short, and was ascended by us in bidarkies in a single day. In its lower portion it is very sluggish, but for a mile at its extreme upper end, just after leaving the lake which is its source, it is rapid and rocky and its ascent presents considerable difficulties, although it may be worked through in boats without portaging. From the banks of the river rise continuous level-topped bluffs similar to those along the seashore.

The lake in which Naknek River rises lies between mountains whose front is opposite the point where the river begins. This lake is the largest which we met in our journey and is one of the largest in Alaska. The name Naknek Lake, being the same as that of the river which flows from it, has been retained, although the name Lake Walker appears on the map accompanying Petroff's paper in the Tenth Census report.

In shape the lake is irregular, having several long, narrow arms, and, as at so many of the Alaskan lakes, the high mountains rise abruptly from its shores, with no stretch of level land between. The lake is therefore subject to heavy gales, for the narrow mountain valleys act like chimneys, up and down which fierce winds rush. The entire distance of the lake from the head of the river to the native village of Ikkhagamut, or Savonoski, as it is now commonly called, is 50 or 60 miles, the last 20 being in a narrow arm surrounded by especially high and gloomy mountains. From the head of the lake the route goes overland to the village of Katmai, on the shore of Shelikof Strait, a distance of about 60 miles.

During the first part of the land journey the ascent is comparatively gradual, and the traveler passes over extensive swampy areas, with drier knolls, where walking is made difficult by tufts of grass, called "niggerheads" by the prospector or têtes de femme by the Canadian voyageur. The trail leads along the hillside above the bed of the small stream which runs into the lake at Savonoski, and frequently boiling brooks, tributaries to this stream, must be forded. The mountains on both sides of the small valley grow higher, and as one approaches the summit of the range it is seen to be composed of a continuous chain of volcanoes, none of which, however, is at present active, although the natives informed us that one of them occasionally smokes. From the sides of some of these highest volcanoes splendid glaciers wind down into the valley, and in other places great walls of moraine, damming mountain gorges, mark the former positions of glaciers which have now somewhat retreated. So far as observed, these glaciers seem to be more extensive on the northwestern than on the southeastern side of the range.

The Katmai Pass, which leads down to the village of that name, lies between two volcanoes and is extremely wild and rugged, being the most difficult mountain pass we crossed during the journey. For several miles on both sides of the summit there is no trace of vegetation, the surface being composed of huge angular fragments of rock, piled together without even a covering of moss. Through this débris and the underlying lava the mountain streams have cut deep gorges. On all the upper part of the pass the snow lay thick at the time of our crossing, in the middle of October. Many natives have perished here by being caught in gales, for during storms, even in summer, the wind blows with intensity and piercing coldness. At such times stones of considerable size are picked up by the wind and carried through the narrow defiles where the traveler must walk, and we found many of these stones lying upon the snow. Owing to this danger the natives can not be induced to cross except in perfectly calm and clear weather.

Extensive hot springs emerge from the Katmai side of the mountains below the pass, and there are very frequent earthquakes and other evidences of volcanic activity. Our party itself experienced a slight earthquake just after crossing.

The descent from the summit in the direction of Katmai is much more abrupt than on the northwestern side, and in about 10 miles one passes from an altitude of nearly 3,000 feet to a broad, level flat which is at about the level of the sea. In this gravel flat, several miles wide, the Katmai River flows, and on both sides of it are high and rugged mountains, which run quite down to the coast, and, indeed, extend below the sea, as is shown by the fact that the water close to the shore is very deep, as it is nearly everywhere from here southward and eastward along the Alaskan coast. The gravel flat of Katmai Valley forms on the seacoast a sand beach several miles long, which is effectually shut in on both sides by high mountainous promontories.

From Nushagak to the mouth of Naknek River no people are found, but in the passage across the Alaska Peninsula there are encountered three villages of natives—the first at the mouth of the Naknek River; the second, already mentioned, at the head of the lake; and the last on the seacoast at Katmai. These people all belong to the general class of Eskimos, and the Naknek and Savonoski natives resemble in most respects those of Nushagak. The Katmai people, on the other hand, show differences in their stature and physiognomy which indicate an important admixture of other blood, probably Aleutian. The typical Eskimo, as seen from Nushagak to the Yukon, has very scanty beard, while some of these Katmai natives have profuse bushy growths. They are also a stronger and in every way a finer race than most of the natives we had lately seen. This arises probably from their position on the seacoast, which makes them by nature daring boatmen and sea hunters. One of the chief occupations of this village has been for years the hunting of the sea otter during the summer season, and in this pursuit the hunter often remains night and day on the water watching for his game. The natives of Savonoski, on the other hand, are a sickly and undersized race. The food on which the natives live is substantially the same as for other regions farther north. The same abundant supply of salmon enters the Naknek River as has been described for the Nushagak and other streams; at the mouth of the river is a cannery. On the northwestern shore of Bristol Bay our natives killed two caribou, and we saw moose just before crossing Katmai Pass. Bear are also abundant in the mountains around Katmai and grow to enormous size, being in part the brown grizzly bear or Kadiak grizzly, which has already been described by naturalists from the island of Kadiak, and which is one of the largest known species. Many skins of this bear were seen at Nushagak, having been obtained from hunting grounds on the Nushagak and Mulchatna rivers. The natives sometimes hunt the bears with rifles, but prefer to trap them, setting deadfalls, spring guns, and other devices.

From the region of Kolmakof on the Kuskokwim to Katmai the language of all the natives we encountered was the same, although in the various districts different dialects exist, which vary so much sometimes that the traveler who has obtained some knowledge of one dialect is unable to understand another until he has become somewhat used to it. Even between two such closely adjacent settlements as Savonoski and Katmai there is a marked difference in the speech. All of these dialects are variations of the universal Eskimo language, which in one phase or another is spoken all along the Arctic coast of America, in Labrador, and in Greenland. The language is a rich one, highly inflected and capable of a great variety of expression. It has many guttural sounds, especially in certain dialects, such as the Mahlemut, who inhabit the region of the Yukon mouth; but when one has become accustomed to these gutturals the language is far from unmusical.

PREVIOUS EXPLORATIONS.

SUSHITNA RIVER.

The Sushitna River is said to have been explored by the Russian, Malakoff, in 1834, but recent investigations show that the maps of the river which the Russians have handed down to us are extremely inaccurate and make it seem probable that Malakoff did not penetrate very far up the river. Practically nothing of the course of this stream and the geographic surroundings of the country was known until this region was penetrated by prospectors, who brought back accounts of such parts as they had seen, and who made maps, which, though very inaccurate, yet served to show how little had actually been known of the country hitherto. The first accurate explorations were made by the various government parties in the summer of 1898.

The writer has heard a rumor that a party of Russians from Sitka washed placer gold on the Yentna some twenty or thirty years ago, but there are no definite facts thus far known.[1] It is known that the Russian lieutenant, Doroshin, made an investigation in a number of streams in the vicinity of Cook Inlet for the purpose of finding valuable minerals, and in the sands of the Kaknu River on the Kenai Peninsula he is said to have found gold. It seems possible that this is the origin of the rumor concerning gold on the Yentna. Nevertheless, members of our party reported having found pits which had been dug into the earth and marks of cuttings on trees, twenty or thirty years old; this is supposed to have been done by the Russians. It is quite as likely, however, that it was the work of Indians. The only

[1] Mr. George Kostrometinoff, government interpreter at Sitka, in a personal letter to the writer, states his belief that considerable mining was done along the Yentna, but that the amount taken out was never made public.

authentic accounts of any explorations on this branch of the Sushitna are those of American prospectors. In 1887 Mr. P. G. Shell with two partners ascended this river, prospecting. According to the statements of the natives, Shell must have taken the North Fork, or the Yentna, and is said to have explored far up toward the Great Mountain—Mount McKinley. Shell found much fine gold, being an experienced prospector, and on one bar made $2 a day with a rocker; but this did not satisfy him, and, the mosquitoes being troublesome, he returned. In the fall of 1894 J. M. Johnston and Edward Andrews ascended the river as far as the forks and explored several tributaries, traveling backward and forward during the winter several hundred miles with sleds. Like Shell, they found gold in many places, but all fine and in small amounts.

KUSKOKWIM RIVER.

The coast of the Bering Sea as far as the Kuskokwim was explored by Vasilieff in 1829 and again by Kolmakoff in 1830. In 1832 the Russian creole, Lukeen, went with a party of natives from Nushagak up the Nushagak River and down the Holiknuk to the Kuskokwim. This stream is called by Dall[1] the Hulitnak, and is the same as the Chulitna River of the recent maps. It is the largest tributary of the Kuskokwim, and lies in the borderland between the Indians and the Eskimos. The name Chulitna is that given it by the Indians and Holiknuk that by the Eskimos. About 50 miles below the mouth of this river, on the Kuskokwim, Lukeen built a number of log houses, which was called Lukeen's Fort, where he remained several years. In 1835 Glasunoff explored the mouth of the Kuskokwim, and after this supplies were brought up the river to the post from its mouth, and the station took the name of a redoubt. In 1836 Kolmakoff ascended the Lower Kuskokwim in bidarkies. In 1841 the post was partially destroyed by fire at the hands of the natives, and Kolmakoff, then in charge of Fort Alexander at Nushagak, proceeded up the Kuskokwim and rebuilt the post, which has since borne his name. The Russian garrison, then in charge of Dementoff, was withdrawn in 1866, and since that time it has been only an Indian trading post, the supplies for which were formerly carried from the Yukon by means of the water route which connects the two rivers.

Of the Kuskokwim above Kolmakof there exists absolutely no information. None of the writers who have mentioned the Kuskokwim have anything to say of the upper river except to give some vague reports learned from natives. Petroff[2] speaks of the headwaters as untouched by the explorer or trader, and of the native village of Napaimut as being the last-known settlement. Our party,

[1] Alaska and Its Resources, 1870, p. 274.
[2] Alaska: Its Population, Industries, and Resources; Tenth Census, 1884, pp. 13, 90.

however, found a trading station some distance above Napaimut, at Vinasale. These buildings were comparatively new and probably had been built since Petroff's investigations. The post was under the control of the traders at Bethel and Kolmakof, and was occupied only during a part of the year, supplies being brought up by boat in the summer from the lower river and traded for furs, after which the post was abandoned. We also found evidence at Vinasale that the Russian-Greek missionaries had visited the place. I was also told by Mr. Andreanoff, a Russian trader having his chief post at Kolmakof, that he and his sons had been far up the Kuskokwim, and that the river headed in a vast swamp; but I am inclined to believe that this statement came simply from the accounts of the natives concerning the great flats on the Upper Kuskokwim, which have already been described. It is exceedingly improbable that any white men had ever penetrated far above Vinasale. The only existing maps of the river below Vinasale have been derived from Russian sources and have been shown to be, though rough, approximately correct.

From Mr. James Cleghorn, agent of the Alaska Commercial Company at the Sushitna Station, it was learned that about 1889 the famous Alaskan pioneer, Frank Densmore, passed from the Tanana to the Kuskokwim with a party of prospectors, and descended the Kuskokwim to the Yukon portage. About the same time another pioneer prospector, Al King, made the same trip. Afterwards Joe Goldsmith crossed the portage from the Yukon at the Russian mission and ascended the Kuskokwim several hundred miles. James Cleghorn and Harry Mellish also crossed the portage and wintered at Kolmakof.

TOGIAK RIVER.

No mention of the Togiak River was made by the early writers and explorers, and Petroff states that he was the first white man to ascend the river. It is quite certain that since his visit no white man had been there until the passage of our party, and it appears from Petroff's map[1] that he himself did not ascend as far as Togiak Lake, since that body of water is not represented by him. Neither prospectors, white traders, nor missionaries have ever visited the Togiak.

NUSHAGAK RIVER.

The region at the mouth of the Nushagak was early visited by the Russians. In 1829 Father Veniaminoff visited Nushagak and baptized thirteen natives, and in 1832 seventy more were baptized. At this point a fort and garrison were maintained under the name of Fort Alexander. From Nushagak the traders and priests made various journeys in the surrounding country, both with bidarkies and with

[1] Op. cit., 134.

dog sleds. Of these trips, however, there is little recorded. About 1890 three prospectors, Harry Mellish, Percy Walker, and Al King, are said to have ascended the Mulchatna, the chief tributary of the Nushagak, 200 miles, and there to have found gold, which, however, was too fine and flaky to save. In the year 1891 a party sent out by Frank Leslie ascended the Nushagak and Mulchatna and sledded over to Lake Clark, finally reaching the shore of Cook Inlet. Since the establishment of the canneries at the mouth of the river two or three parties of prospectors have ascended it, but have never made any real exploration.

ROUTES THROUGH THE COUNTRY EXPLORED.

ROUTES FROM THE SKWENTNA TO THE KUSKOKWIM.

The route to the head waters of the Kuskokwim by way of the Skwentna was first gone over by our party, and as a water route is not to be recommended, as it can never be safe for traveling. On the other hand, this route offers a way overland into the Upper Kuskokwim country, and thence into the Lower Tanana and the Yukon, which is comparatively free from any obstacle. From the shores of Cook Inlet to the Tordrillo Mountains the way lies over a comparatively level plateau with practically no irregularities, and the Tordrillo Mountains themselves offer convenient passes near the place where they were crossed. A short distance north of this place there appears to be an open passage through the mountains giving connection from one drainage to another without any well-marked divide. On the Kuskokwim side of the mountains the same low, level plateau reaches down to the perfectly flat country through which such a large portion of the Upper Kuskokwim flows. Thus for a wagon road or a railroad there are few engineering difficulties to surmount. From the Upper Kuskokwim communication with neighboring districts is easy. The divide between the Upper Kuskokwim and the Lower Tanana consists of low mountains which offer few obstacles; indeed, a well-known native route to the Kuskokwim is by way of the Toclat River, which enters the Lower Tanana and which communicates with a tributary of the Kuskokwim. It is probable that a wagon road or railroad across this divide would also be a very simple matter.

KUSKOKWIM STEAMBOAT ROUTE.

The Kuskokwim below the torrential portion is wide and comparatively sluggish, and is perhaps the best river for steamboating in Alaska, with the possible exception of the Yukon. Certainly steamboats of considerable size can ascend the river nearly 600 miles and could thus communicate directly with the overland route.

YUKON-KUSKOKWIM WATER ROUTE.

On the Lower Kuskokwim the water route to the Yukon is one which has been of great commercial interest in the past and perhaps may be even more important in the future. The notes of Mr. Hinckley show that the distance between the two great rivers is much shorter than has hitherto been thought, being only about 20 miles at one point. The portages of this route are short and low, and it is very likely that with very slight work a canal route could be established, so that supplies could be brought by steamboat from the mouth of the Kuskokwim, thus saving the long journey around Cape Romanzof and up the Lower Yukon. The chief objection to this plan lies in the fact that the harborage at the mouth of the Kuskokwim River is very poor, the bay being shallow, subject to great tides, and swept by heavy gales. Still it is probable that some place as good as St. Michael, at the mouth of the Yukon, could be found.

The following description of the portage from the Kuskokwim to the Yukon is taken from Mr. Hinckley's notes.

On leaving Bethel we paddled up the Kuskokwim 85 miles to the mouth of a small stream leading northwest into the tundra. After ascending this stream 4 miles we dragged the boats over a well-worn track of mud into a little lake, and crossing this lake we reached another similar rut of mud which led to a 30-foot incline, up which the loaded canoes were dragged. At the head of this incline the mud track was covered with 2 or 3 inches of water, so that the canoes could be hauled more easily. A quarter of a mile beyond we reached another shallow lake, at the farther end of which the party pushed through a field of water grass and emerged on a narrow winding stream leading southwest. This stream was surprisingly deep for so narrow a waterway, having a depth of 10 and a width of less than 30 feet. A peculiar feature along its course was the great number of little lakes similar to those we had crossed. There was nothing to separate the stream from the lake but the thick fields of water grass mentioned above. These lakes seem to have been formed by the sweeping away of the banks in the time of freshets, and they must now act as excellent reservoirs in holding back the spring floods. The view over the tundra was impressive—a great rolling bog stretching far away to dimly outlined mountains. We descended the stream for about 15 miles till we reached a tributary, which we ascended in a northerly direction till we came to a large lake. Shortly before arriving at the lake we passed a large area of tundra which had burned over during the summer—evidently in the rainless season of June and July the surface of the tundra had become quite dry. About a mile before we entered this lake the stream spread out in wide shallows filled with grass, which we traversed with difficulty. A jolly rivalry sprang up here between the canoes, each striving to get ahead of the other by some short passage through the grass. Sometimes a canoe which had forged ahead found itself in a cul-de-sac and was thus obliged to come back and to follow, amid shouts of laughter, in the wake of the others. At last, on pushing out of a growth of willows, we saw before us a wall of muck about 2 feet high, which proved to be the border of a lake. Owing to the low shore across the lake and a slight refraction we were unable to see the other side, so that it almost seemed as if we were looking out on the open sea. In reality the lake was about 3 miles across; it had a uniform depth of 4 to 5 feet, and was completely surrounded by shores of muck. Crossing this lake we ascended a short stream to a still larger lake. Owing to the soft muck bottom the waters of the first were dark and dirty, but those of the second were clearer and of a whitish tinge, as the bottom was of a hard sandy clay. At the end of the second lake our boats were again dragged along a mud track into a brook which led to and through a smaller lake, and this in turn led to a fourth, the separation between the two being again only a field of water grass. Here we met a Russian missionary, who was traveling from his mission on the Yukon to the scene of his winter labors on the Kuskokwim. He was accompanied by a picturesque band of natives—men women and children—with a fleet of native canoes. At the end of the fourth lake our canoes were unloaded and carried for a quarter of a mile over a hill into another rut of mud and water which in a few hundred yards led to a large stream. This stream had a sluggish current and winding course, with monotonously wooded shores and high flood banks. Forty miles of paddling down this stream took the party to the Yukon at a point 6 miles below the Russian mission, the whole trip from Bethel to the Yukon having occupied between five and six days. On the Yukon we encountered a great tide of incoming and outgoing miners, and here we soon boarded a river steamer, which took us to St. Michael, from which point we obtained an ocean steamer for Seattle.

NOTES ON THE MAP (MAP 5) OF THE YUKON-KUSKOKWIM WATER ROUTE.

COMPILED BY W. S. POST FROM NOTES BY F. C. HINCKLEY.

The southern entrance to the route is at the native village of Kalchagamut, where a sluggish stream enters the Kuskokwim. This stream is ascended in a northwestern direction about 3 miles. Its mouth is 70 feet wide and 30 feet deep; 1 mile of it is 100 feet wide and 7 to 12 feet deep, and it gradually narrows to 30 or 40 feet in width in its upper course. The channel is remarkably straight and the depth uniform, with banks 4 to 6 feet high. On August 23, 1898, when the route was traveled, the current was dead, being backed up by high water in the Kuskokwim.

At the point "A" boats are pulled through a swamp and mud rut for an eighth of a mile, and are there portaged 300 feet over a clay bank to a pond whose level is about 6 feet higher. This pond is 150 feet long. From here a second portage 60 feet long is made over a clay bank 15 feet high. Here one passes from tree growth to open tundras. After this portage boats are dragged or poled through a water rut 1,000 feet long to Lake "B," which is 500 feet across. The outlet of the lake is marshy, and the boats are pushed through water grass a short distance to a stream flowing northwest. This is extremely tortuous, 240 bends being noted between "B" and "C," the latter point being its junction with its eastern branch. Its usual width is 30 feet and its depth 6 to 9 feet. The banks are not well defined, but run into swamps and ponds; the current is about 1 mile an hour.

On reaching the junction "C" the main stream is ascended. In the lower portion the banks run into swamps and ponds, while farther up they become better defined and are 6 to 10 feet high, and the stream narrows to 25 feet and even to 10 feet in width. Still farther up it again widens, and the lateral swamps and ponds again replace the banks, affording numerous short cuts for canoes. From "C" to Lake "D" is about 20 miles. Lake "D" is about 3 feet deep, and a winding stream 1 mile in length connects it with Lake Oknakluk, which is 2½ miles long and averages 4 feet in depth, with clay bottom and flat shores.

A water rut one-half mile long extends from Lake Oknakluk into Lake "E," three-fourths mile long, and from here one paddles through water grass to the last lake, "F." At this point the tundras end and the spruce forest begins. A portage is here made over a clay bank 30 feet high to a water rut which runs into the Yukon tributary, the Talbigsak River. This is a large, slow stream with high flood banks. It is at first 100 feet wide and 7 feet deep, but 12 miles farther, at its mouth, is 350 feet wide and 14 feet deep.

The total length of the water route and portages is 66 miles, while the air-line distance between the two rivers, the Yukon and the Kuskokwim, is only 20 miles. The highest clay or gravel bank crossed on the portages is 40 feet.

The relative elevations of the Kuskokwim and Yukon rivers have not been determined, neither has the elevation of the divide between the two been measured, but enough has been seen to warrant the possibility of opening a water route. The current of the Kuskokwim being less than that of the Yukon, the presumption is that if diverted the Yukon would flow toward the Kuskokwim. The Kuskokwim opens probably two weeks earlier than the Yukon, and the lower Bering Sea is comparatively clean of ice in the spring, while St. Michael is still blocked.

The following table gives additional saving in distance from Unimak Pass:

		Miles.
Yukon route:		
Unimak Pass to St. Michael	720	
St. Michael to Talbigsak River	250	
		970
Kuskokwim route:		
Unimak Pass to Goodnews Bay	360	
Goodnews Bay to Kalchagamut	230	
Kalchagamut to Talbigsak River	60	
		650
Difference in favor of Kuskokwim route		320

KANEKTOK-TOGIAK ROUTES.

The route followed by our party from the Kanektok across to Togiak Lake and down to Togiak River was an entirely new one, but does not promise to be very valuable in the near future, since the journey is much easier when made down the Kuskokwim to Goodnews Bay, and then across the peninsula, by a water route with a low portage, to Togiak Bay. On the other hand, the route we followed from Kululuk Bay to Nushagak Bay has long been employed, and is of the very greatest value, inasmuch as it avoids the long and dangerous journey around Cape Constantine.

HOLIKNUK ROUTE.

One of the most important routes in this country is the one from Nushagak down the Holiknuk, which has already been spoken of as that taken by Lukeen when he established the station at Kolmakof. In 1891 Greenfield went over this route from the Kuskokwim up the Holiknuk and down the Nushagak to Nushagak post. This journey, made in behalf of the census, was the first one made over the route by a white man, so far as is known. He reports that the Holiknuk is a sluggish, meandering stream, and that the divide between it and the Nushagak is low.

ROUTES ACROSS ALASKA PENINSULA.

In regard to the routes across the Alaska Peninsula, Petroff[1] states that at a very early date several easy portage routes were discovered across the peninsula from Kadiak. The Russians first made their way to Bristol Bay on Nushagak by these routes, and found abundant evidence to show that they had been the highways for natives for ages past. During the Russian supremacy three important routes across the peninsula converged at Katmai and made that a station of some importance. One of these routes was that taken by our party by way of Naknek River and lake; another, better known and easier in summer, is by way of Becharof Lake; while the third is not definitely known to the writer. These routes have also been taken a number of times by Americans, especially traders and missionaries. In the winter of 1897 Mr. Tilton returned this way from Point Barrow with news of the distressed whalers on the Arctic coast, and the same year two prospectors from the Yukon—Messrs. Hawley and Carr—crossed it and made their way to Kadiak.

GEOLOGY.

OUTLINE OF TREATMENT.

The geologic notes made in the course of so hasty a reconnaissance as an exploring trip through Alaska can be only fragmentary and unsatisfactory. The geologist must take such information as comes to him, instead of being able to seek the special and important points. Under these circumstances it becomes a matter of considerable difficulty to decide, on returning from the field, in what manner his somewhat heterogeneous notes would best be finally presented to the public. It is plainly right to furnish all of his information, if only for the sake of guiding future workers. At the same time this information is often not enough to point unmistakably to general conclusions. In some cases, however, a careful study of his notes may indicate more or

[1] Tenth Census Report, Alaska division, pp. 24, 25.

less clearly certain geological laws concerning the entire country, which yet must await more careful and detailed work to prove them. It is also plainly right to submit such half-proven laws in his report, but he must take care that the facts on which he bases his conclusions are correctly stated, so that subsequent observers may know just where they may expect to deviate from his suggested results.

With the view to making all this clear, the material of the report will be systematized, so that in the first part will be given only a bare description of geological facts observed along the actual route taken by the party. Accompanying these descriptions, geological notes will be found printed on the large scale route maps, and these notes furnish to everyone at a glance the basis for whatever conclusions are made, and may perhaps serve to others as a basis for different conclusions.

Second, the classification of the rocks, both sedimentary and igneous, which have been observed along the route, will be attempted. In this classification rocks within a certain geographical area, whose lithological characteristics and structural relations warrant their grouping under one head, will be classified as a series, and the upper and lower limits as well as the general age will often be left undecided, although, wherever possible, criteria bearing upon these points will be given. It is intended, however, to leave the classification so broad that later on, when more definite divisions may be made in consequence of new information, the old names may be dropped or redefined and the material of this report pass over into a newer classification with as little difficulty as possible.

Third, an attempt will be made to bring out the general geological relations of the entire country traversed. With this end in view the correlation of different rock series in different geographical areas whose lithologic characters, stratigraphic relations, or fossil contents suggest a nearly similar age, will be attempted. It would, perhaps, be safest to classify these groupings of series from the standpoint of time under new noncommital names whose meaning should be indefinite as regards the already established time divisions. On the other hand, data which enable us to a certain extent to classify the groups under the old system of time nomenclature are available, and it is felt that the introduction of new names, though perhaps more exact as regards this special report, would be complicating the general knowledge of the country's geology without sufficient warrant. In the general classification, therefore, the standard time divisions into periods are adopted and the rocks are so classified in the final map. This classification is, however, only approximate.

GEOLOGICAL NOTES ALONG ROUTE.

FROM COOK INLET TO THE TORDRILLO MOUNTAINS (MAP 6).

SOUTHWEST OF TYONEK.

Reconnaissance was made to the southwest of Tyonek for only 5 miles along the shore. For this distance the shore is fringed by bluffs of gravels and bowlder clay, ranging in height from 100 feet down to 50 feet (fig. 1). The bowlders in the clay are often very large, being chiefly of granite, and also of conglomerate, porphyry, sandstone, lava, etc. They are often striated from ice action. The top of the bluffs is level and contains broad, shallow depressions, which are sometimes occupied by ponds, and there are some well-defined terraces.

Unconformably underlying the clays is a series of alternating beds of clay, sand which has hardened to sandstone in huge nodules, and

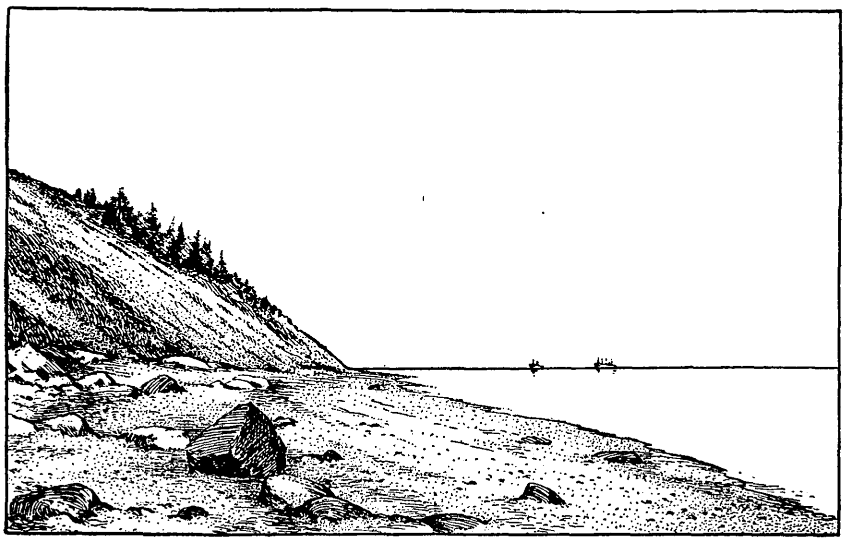

FIG. 1.—Bluffs of bowlder clay near Tyonek.

lignite (fig. 2). The attitude of this series is monoclinal, the strike being, except in the case of local folds, NW., and the dip NE., varying from an average of 35° at the southwestern end of the section to 10° at the outcrop nearest Tyonek, with intermediate steeper phases. The beds of lignite are of varying thickness and the material is generally quite woody and can be split or cut. In places seams have ignited and burned the adjacent clay to a red, orange, or yellow brick. At the contact of these lignitic beds with the overlying glacial deposits the beds are broken and great fragments of them are included in the glacial clay, as if here there had been an actual overriding by a glacier.

FROM TYONEK TO THE BELUGA RIVER.

Proceeding northeast from Tyonek one follows the same bluffs as before mentioned along the shore, except where they are broken down by wide valleys through which very small streams come down to the

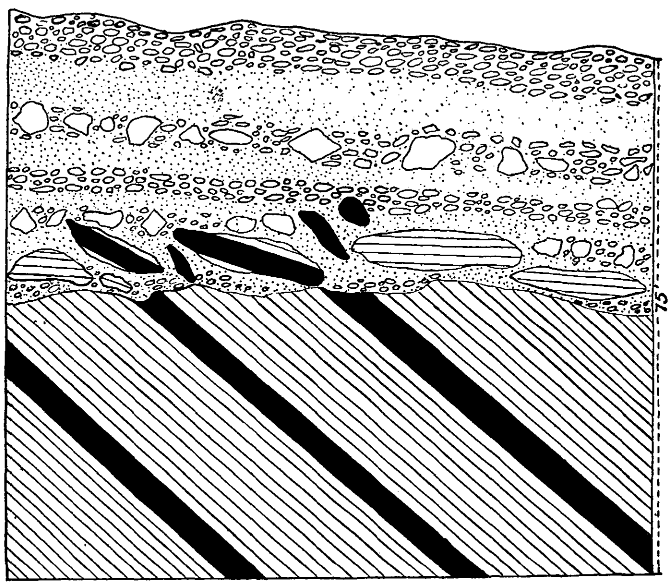

FIG. 2.—Section of shore bluffs near Tyonek, showing unconformity.

inlet. The bluffs consist of clays, sands, and gravels, which are stratified, but often roughly. The pebbles are generally subangular, but sometimes flat or angular. and are of many sizes. The clay is sandy, often with angular pebbles or small bowlders, and there are occasionally embedded bowlders from 1 to 3 feet in diameter (fig. 3). If one follows the clay beds laterally he often finds them better stratified and becoming sandy and pebbly. Sometimes clay with a few pebbles is overlain by more pebbly beds, but speaking generally it may be said that 50 or 75 feet of sandy clay is exposed in the lower part of the bluff, always stratified, although sometimes faintly; above this come frequently the more pebbly beds, yet with no sharp dividing line, and in these the pebbles are often faintly striated; at the extreme top often comes a blue clay, with small, generally angular or subangular pebbles. The

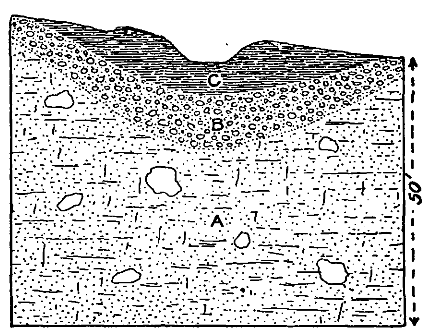

FIG. 3.—Section of shore bluffs near Tyonek. A, sandy clay, with bowlders; B, small pebbles in a sandy clay matrix; C, peat and moss.

material of the pebbles and bowlders is granite, porphyry, rhyolite (possibly a dike rock), quartz, micaceous sandstone, red gypsiferous sandstone, fragments of shiny lignitic coal, gneiss, chert, etc. The deposits are water laid, but are plainly in part of glacial origin. At the very top of the bluff is frequently a bed of peat which becomes as much as 10 feet thick; this is now evidently in the process of formation and is capped by living moss. Sometimes these peat beds coincide with present slight gullies or water courses and sometimes they do not. The stratification of the beds is often considerably inclined (see fig. 4).

Going along the shore, from Ladds Station to Threemile Creek, the bedding of the material becomes better marked and the material itself finer; the pebbles become rounder and some of the beds turn into fine

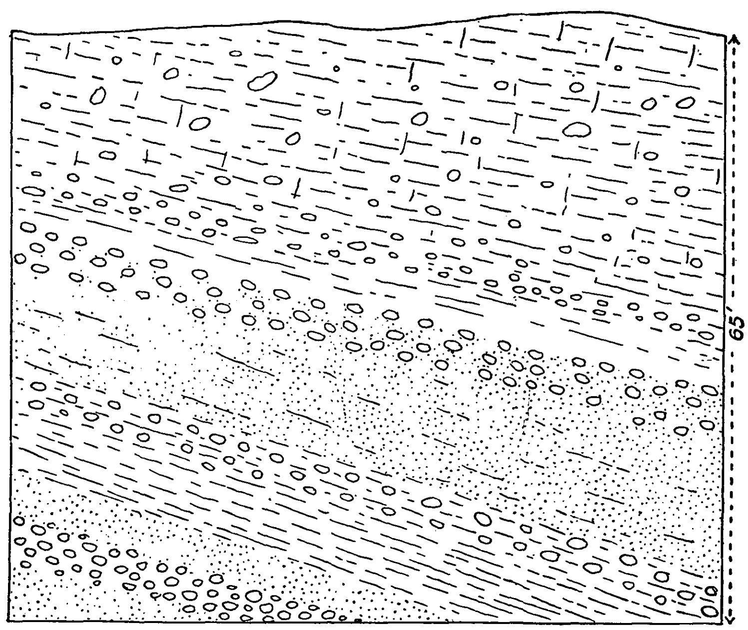

FIG. 4.—Section of shore bluffs near Tyonek, composed of sands, gravels, and clays. Shows inclination of beds.

silts. For 3 miles or so southwest of Threemile Creek there is sometimes at the base of the deposit a compact blue clay, often containing fragments of woody lignite, together with pebbles of quartz and of granite. Along this part of the shore the large bowlders become very scarce and are entirely absent for long distances. At Threemile Creek the bluffs are 85 feet high and the beds are well stratified; the lower half of the bluff has nearly horizontal beds, while the upper half shows a marked cross bedding on a large scale visible from a distance, the layers dipping NE. at a constant angle of from 10° to 18°.

Going from Threemile Creek to the Beluga River the bluffs begin to recede from the actual shore line, and the shore is a broad mud flat, which is the delta of the Beluga River.

FROM BELUGA RIVER TO THE SUSHITNA DELTA.

Great mud flats lie along the shore for the whole distance between the Beluga River and the Sushitna Delta. The shore is of soft mud, almost impossible to land upon from boats, and this mud deposit is cut into by deep ditches or tide-drains, up and down which the tremendous tides of the upper part of the inlet rush. The scene is dreary beyond description, especially in the spring, when the whole is an almost impassable mixture of water, mud, snow, and ice, with stranded logs which must have been left by exceptionally high tides.

At the Sushitna Delta the country is always flat, sandy, and muddy, but there is a light growth of small trees and other vegetation. The islands are cut up by innumerable sloughs, through which the tide runs. The pebbles in the gravel are mostly granitic or dioritic, often of porphyry. There is also compact basalt, red and yellowish jasperoid, and vesicular lava showing feldspar phenocrysts.

FROM THE SUSHITNA DELTA TO THE MOUTH OF THE YENTNA.

From the Sushitna Delta nearly to the Sushitna trading post the banks are very low and are composed of silt and gravel; they evidently form a part of the river delta. The first rock outcrop appears opposite the trading post, where a bluff of coarse, green conglomerate with quartz pebbles is exposed. The rock here appears to have a general strike of N. 60° E., with a dip of 20° SE. On the right side of the river above the station is found a hard glacial gravel or hardpan, which occasionally contains large bowlders and many more or less rounded pebbles of all sizes. It is well stratified and seems to lie horizontally, but is harder than the glacial gravels on the Cook Inlet shore; so that it forms a steep bank. Farther up, at a point where the current sweeps swiftly around some cliffs, forming a dangerous whirlpool, the rocks are of compact basalt, somewhat amygdaloidal. The Yentna enters the Sushitna through low sand flats only a few feet above the water.

FROM THE MOUTH OF THE YENTNA TO THE JUNCTION OF THE YENTNA AND THE SKWENTNA.

A short distance above the mouth of the Yentna are granite outcrops along the river, 40 feet high in places, indicated in the route map. The rock is generally decomposed and green, crumbling like coarse sand under the pick. Some miles farther up the river the same granite is found cutting a dark-blue massive rock, which the microscope shows to be syenite and diorite. The smaller tongues of the granite become quartzose and veinlike, and so change into quartz veins with all possible intermediate transitions. These quartz veins often contain tourmaline and pyrite. In the gravel bars below such outcrops many colors of gold were found in different instances, although in other places the gravels were often barren.

With the exception of these outcrops of igneous rocks, which are found at intervals along the river, the banks are composed of stratified clays, sands, and gravels. Above the first granite outcrop near the mouth of the river are found bluffs 40 or 50 feet high, of blue stratified glacial bowlder clay containing pebbles of all sizes. This is the general type of the higher banks along the river below the junction of the Skwentna, and as one ascends the river he finds these alternating with the very low banks which represent the present flood plain of the stream. The bluffs of bowlder clay sometimes show folding and faulting on a very small scale, the faults noted being only a few inches in displacement but very distinct and clean. The clay often contains pebbly and sandy beds. The top of these glacial bluffs forms a plateau which is very uniform and extends many miles back from the river in both directions. In this plateau the river has cut a very narrow valley, ordinarily not more than a mile wide, although near the junction of the Sushitna it is much wider. As one ascends the river he finds the sand and gravel in the bowlder clay often cross bedded.

At the junction of the Yentna and the Skwentna Yenlo Mountain rises out of the general plateau. From the river it appears as an isolated mountain, although a view from a point farther up shows that it has actually a lower ridge back of it which continues off to the northeast. The upper mountain has a side slope of about 45°, and prominent benches may be seen in the outline all the way up; the top also is remarkably level. The surface is cut, in a very small way, by stream action, but what gullies there are appear to be deep, as if cut in soft material. The top of the mountain is black, while near the bottom of the gulches yellow rock appears. In the stream near the foot of the mountain are found large quantities of light-colored volcanic pumice, so that it is probable that the black upper part of the mountain is ash and the white and yellow is lava or pumice.

THE SKWENTNA FROM THE MOUTH OF THE YENTNA TO HAYES RIVER.

From the junction of the Yentna and the Skwentna one finds the same low silt and gravel banks as before, until the first canyon is reached, some 10 or 15 miles above the junction. For several miles below the canyon the river is divided into many separate channels, which are constantly shifting, and these are obstructed by accumulations of dead trees which have been cut out from the bank farther up the stream and brought down during periods of high water. This splitting of the river into many channels, which is repeated several times farther up and is characteristic of many Alaskan streams, seems to be particularly well marked at the junction of the main stream with some tributary, for here the flats are broader and the river has more opportunity for wandering from side to side.

The first canyon is cut through a low rocky ridge which trends diagonally with the river. The walls of the canyon rise hardly above the general level of the gravel plateau, being 80 or 100 feet high; they are nearly perpendicular and are composed of a dark-blue, apparently flinty rock, sometimes fine-grained and slaty. Prominent division lines, which may represent stratification, trend parallel with the river, N. 87° W., and dip 75° SE. Microscopic examination has shown this rock to be a basaltic glass. The country lying on both sides of the canyon walls is flat, with swamps and little ponds. There is no distinct drainage, but a distinct northeastern seepage, some of the seepage lines heading up close to the river valley.

Above the canyon there are no outcrops along the river for 10 or 15 miles, but on both sides of the stream are level-topped bluffs 80 to 100 feet high, composed of stratified gravels, and on top of the bluffs are small, shallow sink holes sometimes filled with water and often with a shallow groove as an outlet, which on reaching the top of the bluff changes into a slight gully which cuts back into the gravels a short distance. In these glacial gravels the river has worked freely back and forth, cutting and building, with the result that the valley is generally upward of a mile wide, and between the banks shallow water flows among many bars and islands. The down-cutting of these islands and of the main banks goes on very rapidly and so furnishes the great amount of driftwood found all along the river.

To the right of the river the foothills of the Tordrillo Range now become close. They are smooth and rounded in outline, with level tops, and rise probably 1,500 feet above the river. Back of these foothills the main range appears, on which at an elevation about corresponding to the tops of the foothills, can be seen a very smooth level bench or plateau, in places several miles broad. This is a sharp line of demarcation, above which the mountains are jagged and sharp and below which are numerous well-defined benches.

A little farther up the stream the foothills come quite down to the river. At this place there is found on the opposite side of the stream a high bluff composed of typical morainal material, roughly stratified, the stratification dipping 15° to the east on the east-west face of the bluff. In this material are many rounded and subangular bowlders and pebbles; one noted was of granite and was 5 feet in diameter, and many are upward of 1 foot in diameter. The material throughout is almost exclusively granitic, with some fine-grained, dark-colored rocks, probably volcanics and tuffs.

The foothills themselves on the right bank of the river have approximately level tops and slope to the river at a uniform angle of about 15°. They are cut by frequent brook valleys. After the summit of the hills, which has a probable elevation of 1,000 feet above the river, is reached, a series of deep rock-cut valleys is discovered, in which flow small streams, disproportionate to the size of the valleys. The grade in these streams is high and they flow over successive terraces or benches in waterfalls. One of these falls is 60 or 75 feet high, and here the stream has cut back into the bench, forming a slight canyon. There seems to be very little glacial material in these large valleys, although there is so much moss in the bottoms that the underlying material is not often exposed; when it is exposed it appears to be solid rock or large bowlders. The general cross section of the valleys is V-shaped.

Looking across the river it is seen that the chief knob of the Shell Hills, whose continuation forms the rocky ridge cut through by the first canyon, is distinctly and deeply terraced, the chief bench being about three-fifths of the way to the top, although the top itself is distinctly rounded and leveled. One may also perceive that the coarse moraine observed directly across the river trends in a definite line across the country and is traceable by low hills rising considerably above the lower gravel plateau. The line of the moraine appears to cut across the river in a direction about N. 20° W.

The rocks of the foothills here are remarkably alike in appearance, are fine grained in texture, and have a general greenish color, giving the impression of an ancient formation. The microscope is necessary to solve the real nature of these fine-grained, massive rocks, and then it appears that they are in part ancient volcanics, basalt and leucite-phonolite being among the types determined, and in part sediments or tuffs derived from the same volcanic sources. No stratification was observed, although in one place a prominent parting was nearly horizontal.

From this locality nearly to the mouth of the Hayes River no formations older than the gravels were encountered. All along here are bluffs rising generally to a height of 150 feet, although in places they are not more than 80 feet, and composed of horizontal stratified sands and gravels, the morainal material having disappeared. It is noteworthy that at a point on the river immediately above the morainal bluffs the material is entirely of sand, which is often cross bedded at angles up to 25°. There appears to be no constant direction of the cross bedding observable, although the dip is oftenest downstream on the east-west face of the bluff.

We had opportunity to observe a remarkable case of rapid cutting in these gravel deposits. While camping on an island one night the edge of the island was washed away so rapidly that we were obliged to change the location of our camp before morning. At the same time the stream cut away the bank opposite the camp, forming a new bluff 60 feet high and 200 feet long, and cutting away cottonwoods 60 feet high which were growing on the steep wooded bank. The roar of the falling of many tons of earth into the river and the crash of falling trees were heard every few minutes during the night.

Near the mouth of Hayes River the Skwentna again comes close up to the hills, which are timbered and rise to the higher mountains behind. On all of them rock-cut terraces are very beautifully shown. Where the stream cuts the foot of these hills an exposure of a mile or so of gray and yellow partially consolidated sedimentary beds, mainly sandstones and shales, is found. Some of the beds are very soft, while others are harder, distinctly stratified, and even-jointed. At the upper end of the section the dip on the face of the cut is 5° downstream. Half a mile farther back the dip increases to 30°, and a quarter of a mile farther to 60° in the same direction. At several points along the exposure are seams of coal several feet in thickness. This coal is of a lignitic variety, nearly black in color, like the better class of coal on Cook Inlet, and a piece we tried in the camp fire burned fairly well.

The Hayes River, which joins the Skwentna at this point, runs in a wide U-shaped valley, up which one can see a long distance to a great glacier which lies in the head. This glacier fills the whole valley some 20 miles from the mouth of the river, and is in part blackened by the morainal material on its surface. In front of the glacier there runs across the valley a timbered ridge, which is evidently an abandoned frontal moraine. At the head of the glacier are high, jagged mountains of alpine-like scenery.

TORDRILLO MOUNTAINS.

FROM HAYES RIVER TO THE PORTAGE.

Nearly opposite the mouth of Hayes River, just above the partially consolidated beds and coal seams previously described, the bank of the river is a bluff 80 to 120 feet high, composed of slightly consolidated stratified gravels. These are in places horizontal, but sometimes they incline gently as much as 10° both up and down stream. In these gravels are occasionally coal seams, one of which seemed about 4 feet thick; it was arched in the outcrop, and the gravels were conformable above and below. On the very tops of these bluffs is perhaps 10 feet of horizontally stratified sand or silt, which has the appearance of unconformably overlying the lower gravels where these are tilted; where the latter are horizontal the distinction between them and the overlying beds can not be made out from a little distance. On this side of the river gravel bluffs continue, of uniform height, as far as the second canyon (at the camp of June 20).

On the opposite or right-hand side of the river a ridge or spur of the mountain comes down to the river directly above the junction of Hayes River. An examination of this rock shows it to be a fine-grained granitic arkose or sedimentary rock whose materials have been plainly derived from the destruction of granite. Farther up the river, on the same side, other rock outcrops are found till the canyon is reached. These rocks seem to be of the same nature as those of the canyon which we are about to describe.

The canyon is cut out of solid rock and its walls rise perpendicularly to the height of the general gravel plateau, through which the river flows nearly the whole distance from Cook Inlet. The gravel bluffs therefore run laterally into the rock cliffs which make up the canyon, and there is no corresponding ridge in the topography. By this time mountains appear to the left of the river as well as to the right, so that the plateau appears as a broad, smooth, level valley between the two ridges. The course of the canyon is crooked, like that of a meandering stream. The rocks in it are of nearly uniform appearance and have distinct structure lines, which is probably stratification. At the entrance to the canyon the strike is north and south and the dip to the west at angles varying from 30° to vertical. The whole rock is greenish and evidently much decomposed; in places it has the appearance of a conglomerate, which on examination is seen to be due to the process of concentric weathering. This weathering often extends from the top to the bottom of a bluff 200 feet high, although along certain definite zones the alteration has taken place with more uniformity than along certain others; so in some parts the rock has the appearance of a conglomerate, in others is massive, or pulverulent, like sandstone. On examination of the supposed conglomerate both the matrix and the pebbles were found to consist of the same material, and this on microscopic examination proves to be in nearly all cases a basic volcanic rock, chiefly basalt. Some of the apparent slates and sandstones which are associated with the pseudo-conglomerates turned out to be basaltic tuffs which are interstratified with the igneous volcanic rocks. In the slaty and cherty portions of the rocks are rusty quartz veins carrying pyrite.

All along this part of the river, as far back as the mouth of Hayes River, the river gravels, wherever washed, show numerous colors of gold, most of which is fine, although a few grains were found large enough to be classed as coarse gold. The rocks in the gravels outside of those which have just been described are mainly granite, diorite, and alaskite.[1]

This second canyon is longer than the first and opens at its upper end into a comparatively narrow mountain valley. The rocks throughout its whole course are the same as those described, and the series is everywhere highly folded, both on a large and small scale (fig. 5). At the camp of June 23 the strike of the rocks is north and south and the dip 45° to the east. A small interstratified gash vein here showed a matrix of calcite containing peacock copper and copper pyrite, with iron rust. In some places seams of the rock are changed

[1] See p. 189

to black jasperoid and contain small quartz veins which are rusty and cavernous.

On emerging from the canyon into the narrow valley the rocks, which are almost continuously exposed, are found to be of the same formation of ancient volcanics and tuffs. Moreover, the mountains rising above the river to the north and also to the south are evidently

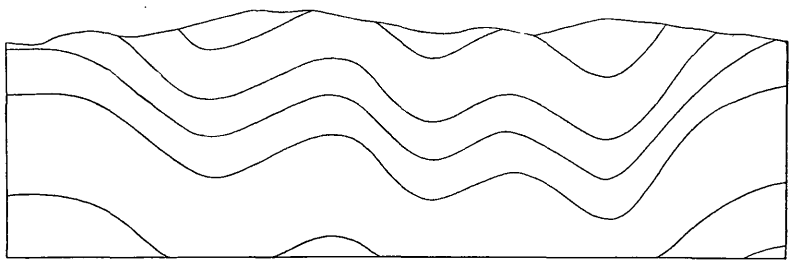

FIG. 5.—Folding of ancient basalts, second canyon, Skwentna River.

of the same rock, and the strike everywhere seems to be uniformly north and south. The dip varies with local folding but is generally to the west at an average angle of about 45°. From the river valley low terraces rise to the mountains above the level plateau in which the canyon valley of the river is cut. Occasionally from the tops of the cliffs yellow gravel comes down, which shows that this formation is still spread over the rock plateau above. Just below the mouth of Happy River the river flows through its third canyon, which is very

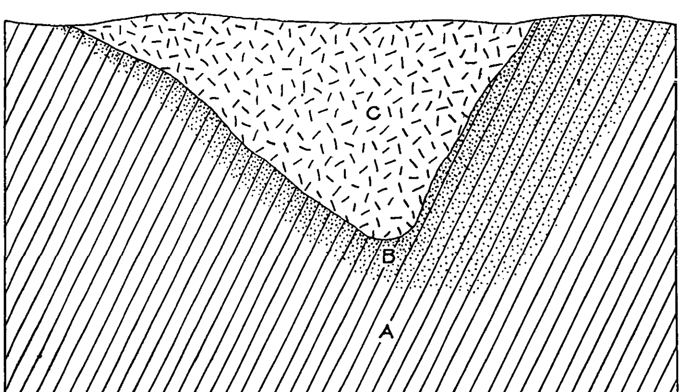

FIG. 6.—Mineralization at contact of intrusive rock, third canyon, Skwentna River. A, Ancient folded basalts; B, same, impregnated by metallic sulphides; C, intrusive granite.

short and is composed of the same ancient volcanics and tuffs, cut by numerous dikes of all sizes; these dikes are granitic, dioritic, and syenitic. In this canyon the strike of the rocks is ENE., and the dip NNW., at angles varying from 50° to vertical. The granite dikes have in general a trend parallel with the strike of the stratified rocks and a nearly vertical dip. The contact of these intrusive bodies is often mineralized, as evidenced by the decomposed condition of the rocks and the presence of disseminated sulphides, which become conspicuous by blossoms of sulphur and sulphates on the cliff walls (fig. 6). Narrow quartz veins up to several inches wide are also very rich in pyrite, chalcopyrite, and galena; they sometimes contain hornblende. Besides the mineralization in these two forms it is also found along certain zones in the rocks which are not at the exact contact of dikes, although in their neighborhood; these zones are generally conformable to the stratification, for there is little shearing. Specimens from these mineralized bodies show the presence of gold and silver, as will be given more in detail later.

The mountains on both sides of the canyon, to the north and to the south, are evidently made up of the same stratified series and are also cut by granitic dikes. A well-marked bench appears on the mountain directly south of the canyon at an altitude of probably 1,000 feet above the river. Farther west, on the same range, another mountain has beautifully marked terraces up to 2,500 feet above the river. From the appearance of these mountains it is evident that granitic rocks begin to form a large portion of their mass, the peak last mentioned being apparently mainly of this material. Near the junction of the Skwentna with Happy River there is a marked change in the stratified series, the rocks becoming all black slate, although having the same general strike and dip as before; the strike, however, has for some time been slowly swinging around to the east from its former north-south direction. Near the mouth of Happy River the slates have an ENE. strike and a dip of 60° NNW. Large dikes of granite are found in these slates, and frequently veins of quartz which carry much pyrite and chalcopyrite and some galena.

The mountains lying to the north of the Lower Happy River Valley all show well-marked stratification and a uniform dark-red or maroon color, and so are probably of the same series as the rocks found in the valley. The attitude of the beds in the canyon changes regularly from an ENE. to an east-west strike in the middle and north end of this minor range, while the dip changes from northwest to north; in these portions of the range, therefore, the beds have from the south the appearance of being horizontal. On these mountains are benches at a maximum height of perhaps 2,000 to 2,500 feet above the river bottom; and above the benches are deep valleys heading in glacial cirques, most of which contain lofty glaciers, some of considerable size. The peaks are generally jagged.

So far as examined, the hills lying between the Lower Happy River Valley and the Skwentna Valley to the south of it are all of dark-green igneous rock. These ridges have nearly level tops, without pinnacles, and the valleys between are deep and V-shaped.

Along the Skwentna, from the mouth of Happy River up to the mouth of Portage Creek, the same series of carbonaceous slates intercalated with layers of sandstone, limestone, and granitic arkose is found. The strike is pretty constantly ENE. and the folding is considerable, the folds being sharp and often merging into faults. The general dip, however, is northwest, at an angle averaging about 45°. As one goes upstream the amount of thicker layers of arkose and limestone seem to increase. The shales and arkoses often contain obscure plant remains, and as a whole the series is identical in appearance with the rocks of the Mission Creek series on the Yukon. Some of the green arkoses contain small angular white patches which seem to be decomposed volcanic material. The slate seams are often very carbonaceous and resemble coal, but do not burn, on account of the great amount of ash. This sedimentary series is cut by frequent dikes of the same general nature as those described below, belonging mostly to the granite or diorite families, although one dike of diabase was found.

The rock along the stream banks generally goes clear up to the surface of the plateau, but in places is overlain by small patches, not often more than a few feet thick, of glacially washed bowlders, subangular and unassorted. The bowlders consist mostly of granite, diorite, and related dike rocks, of the same kind as are found in the river gravels.

PORTAGE ACROSS THE TORDRILLO MOUNTAINS.

Portage Creek, which was followed from its junction with the Skwentna as far as the pass over the mountains, flows in its upper portion through a broad valley evidently of glacial origin and of very moderate grade; in this broad valley the stream meanders between comparatively low banks. The lower part of the creek, however, is very rapid and flows in a canyon which, though slight near the lower end of the broad valley, becomes lower down a magnificent gorge 500 or 600 feet deep, with perpendicular walls; through this the river foams at a very high rate of speed. For a while the canyon is nearly straight, but in its lower part it winds in regular curves, probably meanders inherited from an older and more sluggish drainage. The rock exposed in the gorge is a deeply decomposed diorite, often porphyritic, of the same sort as other rocks in the vicinity, notably between Happy River and the Skwentna. The plateau in which the canyon is cut runs back on both sides a few miles to the surrounding mountains, and has an uneven surface, being full of swamps and small lakes and showing numerous well-marked gravel benches rising to the steeper mountain slopes, which are of solid rock. Above these gravel benches other benches are cut in the rock halfway up to the tops of the mountains, while the upper parts of the mountains are unmarked.

The rocks on both sides of the upper part of Portage Creek, where it flows in a broad mountain valley, are essentially the same younger stratified series as described on the Skwentna above the mouth of Happy River. This series consists of soft carbonaceous shales, gray, impure arkoses or sandstones often carrying obscure plant remains, and thin-bedded limestones. In the more eastern part of this portion of the valley the rocks have a north-south strike and a steep westerly dip, while in the upper part the strike changes to east-west, and the dip is constantly to the north at an average angle of about 30°. Therefore, the mountains to the north of the valley are composed of rocks which, to a certain extent, overlie those to the south, although belonging to the same series. Lithologically the higher rocks to the north are distinguished by a greater abundance of sandstone, which occurs in heavy beds and is of a dense gray color and medium coarse texture; plant remains are also not so common in the upper horizons. On both sides of the valley the rocks are cut by many dikes of intrusive rock, belonging to the diorite and granite families. The general trend of the dikes is north-south and the dip very steep, although some small bodies occur as intercalated sheets in the sedimentary rock. At the contact of the dike with the stratified rock there is apt to be a gulch.

Below the highest rock-cut terrace in the mountains the minor mountain valleys come to an end, and below them the water is led off in a mere gully. Only the more considerable streams have excavated marked valleys below the terraces, and even these have no resemblance to the well-formed valleys in the upper part of their drainage.

Just above the point where the trail from Portage Creek over the pass to the Kuskokwim waters begins the mountains become entirely granitic on both sides. The topography of these peaks is markedly different from the mountains of stratified rock just described, for the former weather into sharp pinnacles and clean-cut vertical columns or spires, so that the scenery is magnificent. This peculiar weathering is largely due to the jointing in the granite, of which there appears to be two or more sets vertically and one set horizontally. The general strike of the contact of the granitic body with the stratified rocks is about N. 20° W. About 3 miles away from the contact a marked change is noticeable in the stratified rocks, in that they become hardened, the shale often passing into a flinty slate, the sandstone becoming quartzite and the limestone bands partly jasperoid. This phenomenon becomes more markéd in measure as the main contact is approached. Dikes of granite and diorite also become much more numerous as this same point is neared, until they merge into the main body, which is also intrusive. Several miles from the largest mass the metamorphosing effect of the dikes on the stratified rocks is not noticeable. Near the main mass, however, the dikes begin to have themselves a marked altering effect, similar to that noted for the main mass, and consisting primarily of hardening and silicification; but soon this alteration is lost sight of in the larger metamorphism proceeding from the central mass. At the contact of dikes and stratified rocks quartz veins frequently occur, and sometimes these are found within the dikes themselves. Near the contact these quartz veins become much more frequent and often contain considerable pyrite, which, however, does not appear to be auriferous, for pans of gravel, derived from the moraine whose sources are near the contact of the granite and slates, when washed showed no colors of gold. The dikes themselves become gradually larger and coarser on approaching the main mass.

The hardening of the stratified rock near the contact shows itself in the topography, inasmuch as here the minor features are less differentiated than in the soft rocks farther east; the gulches are shallower, and on account of the unequal resistance of different layers waterfalls are abundant. Portage Creek heads in many live glaciers, the largest of which has been called Stoney Glacier. This part of the valley of Portage Creek is wide and shows everywhere the signs of glacial scouring. The small creek which leads up toward the pass occupies a broad valley several hundred feet higher than that of Portage Creek, so that at the junction of the two there is an abrupt scarp. Into the face of this scarp the smaller creek has begun to cut back a canyon down to the level of Portage Creek; this canyon is now about a mile in length, and has already reached the level of Portage Creek at its mouth, from which it rises rapidly to the level of the upper valley at its head.

At the junction of Portage Creek with the smaller creeks above mentioned, the drift which fills the valley is for the first time unwashed and unassorted ground moraine, made up of large bowlders, and from here up to the heads of the several minor valleys the material is all morainal. About 2 miles farther up the valley of the main stream is a well-marked abandoned terminal moraine, consisting of a wall of bowlders across the valley, through which the glacial stream finds its way with some difficulty. Back of this there is a succession of abandoned terminal moraines to the foot of Stoney Glacier, where others are now forming. In front of the other glaciers which feed the stream is also a succession of similar moraines. The highest rock-cut terrace on the mountains of Portage Creek is somewhat below the top of the scarp separating the Portage Creek Valley leading to the pass.

The rock of the mountains continues to be entirely igneous from the contact described to the western side of the pass. On the western side of the pass, just below the middle of a small lake, occurs the contact of the intrusive mass and stratified rocks, apparently belonging to the same series as those on the eastern side of the range. The igneous rock here, as elsewhere, is remarkably uniform in appearance, being of moderately coarse grain and containing very few inclusions. There are practically no blebs or eyes, and pegmatite veins are of rather unusual occurrence. The contact is well marked, and the sedimentary beds near it are extremely indurated and jointed.

The beds here have an east-west strike and a dip of 20° to 40° N. Farther away from the contact the strike changes to northwest and the dip to northeast, and still farther, where the trail first reaches the small stream which forms part of the Kuskowim drainage, the strike has become in general north to south and the dip is steeply east, though sometimes vertical or overturned so as to dip steeply west. Looking from this point at the mountains to the north and to the south one may notice a definite zone of close folding, having a north-south trend, in the center of both mountains; within this zone the beds are crumpled intricately (see fig. 7). East of the zone and nearer the contact the beds have the north-south strike and the steep normal or overturned dips above described, while to the west of the zone the highly folded beds show a tendency to assume a simpler structure and a generally flatter dip.

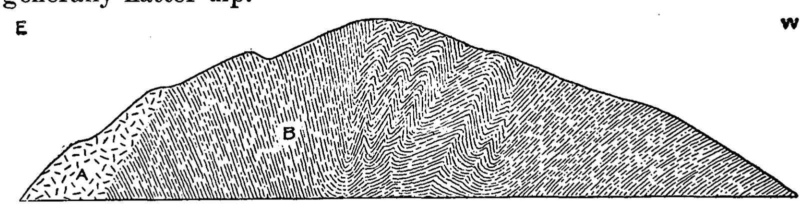

FIG. 7.—Sketch section of mountain on west side of axis of Tordrillo Range, showing zone of close folding parallel to the axis. A, Intrusive igneous rock; B, Shales and sandstones.

The metamorphism of the stratified rocks at the contact with the central mass is perhaps more conspicuous on the west side of the mountains than on the east, since for the whole distance from the contact to the western end of the mountain ridges which run out into Ptarmigan Valley the rocks are all changed from shales and sandstones to hard slates and quartzites, and bright specks of a micaceous mineral have been developed in both. They are intersected by frequent but generally small and noncontinuous veins of milky quartz, sometimes slightly rusty, although no pyrite was observed. At the western end of the mountains referred to, where the metamorphism is less obscure, plant remains were found in the slaty shales.

The various forks of the stream which lies at the western end of the trail over the pass also head for the most part in small glaciers, which lie in well-defined cirques, with benches and abandoned moraines in front of them. Nearly all of these glaciers are dying, however, and some valleys contain none at all, so that on the whole the glaciation appears much less than on the eastern side of the range. On the steep sides of these valleys rock-cut terraces are abundant and well marked, and on the opposite or western side of Ptarmigan Valley they form such regular steps on the mountains as to have suggested the name for this ridge, viz, the Teocalli Mountains, from the suggestion of the terraced Aztec temples.

FROM PORTAGE TRAIL TO THE STYX RIVER.

The small creek which lies at the western end of the Portage trail soon leaves its mountain valley and enters the broad flat of Ptarmigan Valley, in which flows Ptarmigan Creek. Ptarmigan Creek appears to be separated from the headwaters of Happy River by an insignificant divide, flat and full of marshes and small lakes; physiographically, therefore, the two streams, flowing in opposite directions, occupy a single broad valley flanked on both sides by high mountains. Far to the south this same deep, wide valley continues into the mountains, but here it is occupied by a stream which flows to the north, and uniting with the waters of Ptarmigan Creek the combined stream cuts through the Teocalli Mountains to the valley between the Teocalli and the Terra Cotta ranges. From here the course of the river lies in the north-south valley between these two ranges to near the point where the mountains give way to the level plateau which lies to the west. The bottom of Ptarmigan Valley is filled with stratified glacial drift, the materials of which are very little waterworn, but are always assorted, the bowlders being of various sizes up to 6 inches in diameter, but generally not exceeding 1 inch. They are well stratified and ordinarily consist of diorite, slate, or sandstone, the diorite frequently containing fragments of slate and quartzite. It is evident that Ptarmigan Creek has been working for some time over to the western side of its valley, for chains of long, small ponds connected by marshy water courses, which are evidently abandoned channels, are frequent to the east of the present stream. On both sides of the valley shallow but definite terraces descend to the present bed of the stream. The small creek at the western end of Portage trail, after leaving its mountain valley, where its course is northwest, suddenly turns, on entering Ptarmigan Valley, and sprawls through the morainal drift in a western direction, in some places being, with its various channels, half a mile wide, although farther up in its own valley the same stream is contained in a single deep channel so narrow that one can almost jump across.

In the gulch in which this small stream flows, directly after emerging from its narrow valley, sandy slate is found, which has a strike of N. 28° E. and a dip of 65° E. Within a quarter of mile farther down the stream the dip begins to be vertical, and then is steeply overturned to the west. Ptarmigan Valley appears to be in general a strike anticlinal valley, for farther west the Teocalli Mountains are also made up of black carbonaceous shale and impure sandstones, whose general strike is north-south, parallel to the ridge of the mountains, and whose general dip is west. The front (easternmost) range of hills of the

Teocalli Mountains is formed by a comparatively hard bed of sandstone, directly west of which a series of very deep gulches are eroded in the adjacent black shales. The higher parts of the mountains appear to be also of shale.

Looking south and east from the Teocalli Mountains one may see by the color of the rock and by the comparative topography that the igneous rock which forms the ridge of the Tordrillo Range extends farther westward at a point some miles south of the pass than it does in the region of the pass itself. The contact between the igneous rock and the sedimentaries may be clearly traced, and it seems probable that the broad, flat valley which has been described as being a physiographic continuation of Ptarmigan Valley, but in which the stream runs northward to join the waters of Ptarmigan Creek, is almost entirely in granite.

Proceeding southward down Ptarmigan Valley toward the junction of Ptarmigan Creek with the Styx, the flat, level bottom of the valley begins to be cut down by the stream waters, and the walls of the cut grow constantly in height. In proportion as the cutting increases, the stream, formerly much divided, becomes more collected into a definite channel, although the abundance of large glacial bowlders makes boating very difficult. At the junction of the Styx the canyon walls are upward of a hundred feet in height. Above the canyon is a broad upland plateau broadly terraced, the terraces being cut both in drift and in the solid rock.

At the beginning of the canyon are found black slates, striking NW. and dipping NE. 70°. These frequently contain small quartz veins. The same rocks continue down to the junction of the Ptarmigan and the Styx, and have in general a north-south strike, changing to northeast, and a general northwest dip, at a high angle, almost vertical. Above the rock stratified glacial drift, often with very large bowlders, is found, with a thickness of from 30 to 60 feet.

FROM THE STYX RIVER TO HARTMAN RIVER.

Between the Styx and the Hartman, the river (which has now become a considerable stream, since it is formed by the confluence of the Ptarmigan and the Styx and a little farther down, at the camp of July 21, is joined by the stream coming from the north, which has been taken as the main river) turns to the northwest and cuts through the Teocalli Mountains. The valley through which it runs in this portion of its course is narrow. The mountains on the south side of the stream are of sandstone and shale, somewhat metamorphosed and hardened and with a general north-south strike and a dip to the east, at various angles down to 20°, the average being perhaps 30°. On the northern side the mountains appear to be of the same rock. Cutting the stratified rocks are great quantities of quartz veins, nearly all of which contain siderite and ankerite, while small quantities of galena are common, with stains of copper. These veins are cavernous and rusty from the decomposition of the pyrite. In pans of gravel from the bottom of the bluff of stratified drift which in places forms the bank of the stream, colors of gold were constantly found, one grain being larger than a pinhead. This glacial drift caps all of the rocks described, generally to a thickness of 60 feet, and is well stratified. Deep terraces are cut in the sides of the river valley in this drift and in the solid rock. Among the bowlders in the drift and in the river is much light and dark-colored diorite-porphyry or granite-porphyry, which are probably derived from dike rocks intrusive in the main sedimentary mass of the mountains.

Just after emerging into the main valley between the Teocalli and the Terra Cotta mountains and before joining the Hartman River, the main stream describes a curve and runs through a deep canyon, very difficult of passage, where a portage was made. At this canyon are found black slates striking N. 10° W. and dipping 65° NE. These slates contain quartz veins; they are capped by 50 to 300 feet of coarse, stratified, glacial gravel. Directly above the canyon, on the left side of the river, the banks are 400 feet high. In some layers, particularly in the upper ones, many bowlders are several feet in diameter, yet all are arranged layer fashion. The gravels are slightly consolidated, so that the bluffs extend vertically clear to the top.

FROM HARTMAN RIVER TO FAREWELL MOUNTAIN.

A mile below the junction of the Hartman River black slates, on the left-hand side of the stream, strike N. 3° W., and dip 65° E. From here down the river the same rock occurs in frequent outcrops, with a general north-south strike and a dip to the east varying from 65° to vertical; the river flows along the strike of the beds.

From Hartman River to the junction of Rohn River the Teocalli Mountains, on the east side of the valley, present a noticeable contrast with the Terra Cotta Mountains on the west. The former have smooth topography and generally a dark red or nearly black color, and one may nearly always observe plainly the stratification, which strikes in general N. 5° W., and dips east at an average angle of 30°; these stratified rocks are cut by frequent dikes and sheets of igneous rocks. The Terra Cotta Mountains, on the other hand, have a much more rugged and irregular topography, and are, in general, of a light yellow orange or red color, curious and striking. These mountains show sometimes structural lines trending north or northeast with the valley and dipping to the east or southeast about 20°; but the bedding of the rocks is much heavier than in the Teocalli Mountains, and they are apparently more resisting, so that the appearance is quite different. In the Terra Cotta Mountains, moreover, about half the main mass appears to be made up of intrusive rock, which cuts the sedimentaries in immense sheets, dikes, and irregular masses, making in places a most complex mixture. The color of the mountain appears to be due largely to the bright tints which the igneous rocks assume on weathering, and also partly to the weathering of the stratified rock, which is made up of heterogeneous materials and contains much iron. The stratified rocks of the Terra Cotta Mountains are exposed in places along the stream, and are impure limestones, slates, arkoses, and basalts; some of the beds very likely contain some tuffaceous material. The igneous rocks are also found abundantly in the river and are nearly all of a general granitic type, the varieties syenite, granite, and alaskite being common. The stratified rocks are evidently of a series different from those of the Teocalli Mountains, have an older appearance, and recall the rocks on the Skwentna below the junction of Happy River. Near the junction of Rohn River the amount of intrusive material in the Teocalli Mountains becomes also greater, and from this point on numerous dikes and sheets are found in the mountains on both sides of the river, These intrusive bodies cut across the stratified rocks in every conceivable direction.

Below the junction of Hartman River the slates are overlain by glacial bluffs, which are continuous on one side or the other of the river; the bluffs are of yellow stratified gravels and sand, and the material grows finer the farther one goes downstream. The height of these gravel bluffs varies from 60 to 200 feet. On the whole, the river is distinctly cutting its western bank and occupies the western side of the valley, while on the east are broad, river-laid gravel flats of rearranged glacial material, with abandoned channels or sloughs.

On both the Teocalli and the Terra Cotta mountains terraces are strongly marked, the highest being about halfway from the river to the tops of the mountains. Both of these ranges have typical unglaciated topography, with V-shaped valleys, which not only show no glacial accumulations but no signs of ever having had any; there is no suggestion of cirques or other marks of glacial topography.

Below Rohn River the main stream trends to the northwest, and at the same time the general strike of the stratified rocks curves to the northeast, so that from Rohn River to Farewell Mountain the general course of the river is at right angles to the strike, as it had before been parallel to it. This partly explains why the igneous rocks become so much more abundant in the mountains to the right of the river below the junction of Rohn River than above. The predominant rocks from Rohn River to Farewell Mountain are heavy, impure limestones, arkoses, slates, and other heavy-bedded rocks belonging to the same series as those observed in the Terra Cotta Mountains. They are cut through by the same masses of igneous rocks, which are most abundant just below Rohn River, where they are the continuation of the chief zone of intrusives in the Terra Cotta Mountains. Below this they gradually disappear, until the last mountains observed, Egypt and Farewell, appear to be of stratified rocks without any intrusions. The general strike of the rocks continues to be northeast to the front range of hills, where the rocks become buried under the gravel accumulations of the plateau. The changing dip indicates numerous folds ; in general, though, the dip is still toward the southeast, roughly corresponding with that of the rocks of the Terra Cotta Mountains, until the final range of hills is reached, when there is a very evident and persistent dip to the northwest. There is thus evidently an anticlinal fold trending parallel with the face of the mountains and affecting the rocks of this last low range of hills.

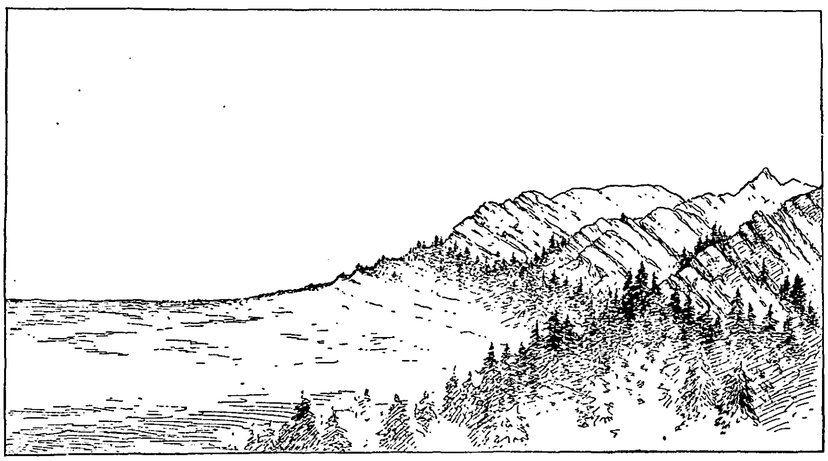

FIG. 8.—Sketch of western front of Tordrillo Range.

Below Rohn River terraces are continually seen along the mountains, and the junction of the mountains with the plateau is marked by a heavily terraced slope (fig. 8). The slope of the plateau itself is away from the mountains, as on the eastern side of the range, and is at first at an angle of about 10°. The rivers coming out of the mountains make deep cuts in the plateau, which are light yellow in color, and are probably through stratified gravels. The outline of Farewell Mountain (see fig. 15) shows a number of distinct benches.

KUSKOKWIM RIVER.

THE KUSKOKWIM FROM THE TORDRILLO MOUNTAINS TO THE JUNCTION OF THE TACHATNA (MAP 7).

Silts and gravels.—After leaving the Tordrillo Mountains the Kuskokwim flows between banks of silt and gravel to its junction with the East Fork. There are no rock outcrops for all of this distance, although at one point two ranges of low east-west trending hills were passed which were probably of rock, but had been worn down very near to the level of the gravel plateau and were themselves probably gravel covered. The river often cuts high banks on the right side, never on the left; these are of horizontally stratified gravel and sand, capped by 10 feet or more of black silt, with peat above all, and the total height of the bluffs is as much as 200 feet. The grade of the stream is at first very high, and the river divides into many channels, which are choked with tangled trees, over which the water rushes, so that boating is very difficult and dangerous. In proportion as the distance from the mountains increases, however, the grade of the river becomes less, and at a little more than half the distance from the mountains to the junction with the East Fork the current rather suddenly becomes gentle and the river meanders between low banks of finely stratified silt and sand, with some fine gravel. These banks are not more than 10 feet high, and at this point there is in every direction, as far as the eye can see, a perfectly flat country. At the junction of the Kuskokwim with the East Fork there is the same low deposit of silt. The river here, however, is approaching the hills or low mountains which lie to the north, between the watershed of the Kuskokwim and that of the Innoko, and before very long the stream cuts the rocks of which these hills are composed on the right side; on the left side the same perfectly level banks of silt, rarely reaching over 10 or 15 feet above the river, are continuous for nearly half of the distance from the junction of the East Fork to the junction of the Tachatna. These silts are in every respect the exact counterpart of the silts of the Yukon Flats and of the similar deposits of the Lower Yukon. Some of the banks contain strata of logs, fairly well preserved, at a depth of 10 or 20 feet below the top, while on top are living spruce trees at least a hundred years old. Driftwood was found on the bank 8 feet above the water, showing that in times of flood these banks are sometimes overflowed.

A short distance below the camp of July 29 (see map 7) the river cuts a bluff of fine yellow silt 100 or 150 feet high. This is blue where unoxidized and is horizontally stratified, with occasional feeble cross bedding. This cross bedding slopes both north and south on the north-south face of the bluff. The top of the bluff is a level plateau, and the face of the bluff runs away from the river nearly at right angles. In one place 70 feet of yellow silts are overlain by 40 feet of more resistant blue clay, which juts out over that below. At the foot of the bluff, where the river strikes it first, is a cut of the lower bank showing a large thickness of peat; but higher up no peat is found. These are the first high bluffs seen since those on the Upper Kuskokwim were passed, many miles away. The height here is about the same as above, but the material is much finer. In the intervening country the silt banks do not reach more than 20 feet above the river.

Course of river.—Along this portion of its course the river almost always cuts the right bank, occasionally the left for a short distance. The current is still sluggish and the river wide and placid, forming broad meanders.

Solid rocks.—The first outcrop of rock seen after leaving the Tordrillo Mountains is 10 miles or more below the junction of the Kuskokwim with the East Fork, and consists of much decomposed clayey limestone and slate, striking N. 55° E., and dipping 15° SE. These rocks contain quartz veins which often carry pyrite in abundance. A panful of the decomposed rock was washed, but showed no colors, although the material was too clayey for the separation of fine gold. Above the decomposed rock is 10 or 20 feet of the fine silts already mentioned. From this point at intervals along the river the same rocks outcrop, showing continual but not close folding, and having in general a northeasterly strike and a comparatively shallow dip to the southeast. Two miles below the high silt bluffs above described the river cuts the hills on its right bank, which are here composed of a heavy-bedded light-gray limestone, striking N. 45° W., and dipping 25° SW. This limestone contains many calcite veins and is highly fossiliferous, the fossils consisting mainly of corals, which indicate a probable Middle Devonian age. The rock resembles strongly the limestone bed in the Tahkandit series of the Yukon, from which Carboniferous fossils were collected in 1896. The same fossiliferous bed was found half a mile farther down the river and is probably at this point on the southwestern limb of a syncline, for between the two lies black, limy shale intercalated with arkose which weathers dark red. The fossiliferous bed is probably 200 or 300 feet thick, being underlain by the same dark-red shales and sandstones which overlie. From this point down to the junction of the Tachatna the river frequently cuts on its right bank rocks of the same nature as those just described, consisting of limy shale or impure fissile limestone containing very small particles of sedimentary mica. The general strike of the rocks along here is northwesterly, while the dip is both northeasterly and southwesterly and varies greatly in angle, indicating considerable folding; in places it becomes vertical.

Between the fossiliferous limestone localities and the Tachatna the left bank of the river is entirely of low silt, and as far as the eye can see there are no hills. On the right bank, in one place, a high silt bluff 60 feet high is cut.

FROM THE TACHATNA TO THE HOLIKNUK.

Topography.—From the Tachatna to the Holiknuk the river generally cuts the right bank—rarely the left. On this side it usually runs quite close to hills or low mountains, and there are sometimes also hills on the left side, although very often there are only wide stretches of a low, flat silt-covered country. At the junction of the Tachatna the hills lie some distance away from the river and have a very smoothed and rounded outline. They are thickly covered to the summits with spruce. Farther down the river the hills appear to gradually approach on both sides until the stream flows most of the time in a broad definite valley between rounded level-topped high hills or low mountains. The scenery then bears a striking resemblance to the Lower Ramparts of the Yukon, just as the flats above are the exact counterpart of the Yukon Flats. This is the first trace of a definite rock valley on the Kuskokwim. The tops of the hills present a nearly uniform level, and the sides are distinctly terraced. Some distance north of the Chagavenapuk River the mountains trend away from the river on the left bank and finally disappear in the dim distance, the space being occupied by low silts and gravels. The Chagavenapuk is a rapid stream, and the pebbles which it brings down are evidently derived from the diorites, granites, and porphyries of the Tordrillo Mountains. Some of this gravel, which was washed just below the mouth of the Chagavenapuk, showed many small colors of gold.

Some few effects of river ice are seen along the river, especially in the striation of small fragments of slate along the beach, but the importance of such effects is small compared with similar phenomena along the Yukon.

Silts and gravels.—Along this portion of the river the silts, as before, are divisible into two distinct classes. In the first class are the low banks, which are only 10 or 20 feet above the river and which consist of fine silt alternating with layers of vegetable matter. Here buried logs and the upright trunks of trees are frequent, while the tops have often a covering of fresh mud, and as vegetation only the brilliant green Equisetum. At several localities in these low banks are found land shells throughout the whole thickness of silt which belong to living species and appear to be the same as those found in similar deposits of the Yukon. One very abundant species has been identified by Dr. Dall as *Succinea chrysis*. The second class of silts referred to consists of the high banks without vegetable material, which are cut more rarely. These vary from 60 to 150 feet in height. Some 10 miles below the Tachatna such a bluff is cut, and this is one of the rare cases where the river has high banks on its left.

Solid rocks.—The first outcrop of rock below the Tachatna is a limy slate or slaty limestone striking N. 65° W., and dipping 45° N. This weathers yellow and red and breaks into small fragments as the result of atmospheric action. The rocks on the whole have almost exactly the same appearance as those above the Tachatna. Farther down the river the same rocks occur in numerous outcrops as far as a point below Vinasale. The strike is nearly constant, being a little north of west, and the dip is usually to the north at an angle of 45° or less; the river cuts directly across the strike. These rocks are rarely cut by porphyritic dike rocks of the granitic family.

At a point some 10 miles below Vinasale there outcrops thin-bedded gray arkoses and conglomerates having a strike N. 10° W. and a dip of 45° W. These rocks contain clay concretions and are quite different in appearance from the shaly limestones on the river above, since they are comparatively fresh and show no metamorphism nor any veins worthy of the name. In general appearance they correspond closely to the Mission Creek series of the Yukon. The pebbles in the conglomerate are sometimes 5 or 6 inches in diameter and appear to be mostly black chert and slate. Rocks of this same appearance outcrop all along the river as far as the Holiknuk. They are everywhere broadly but never closely folded. The general east-west strike which they have where first observed changes gradually to a north-south strike as far as the Chagavenapuk, and this to a northeast strike to the Holiknuk. The river, therefore, where it enters these rocks below Vinasale, cuts across the strike, but soon flows parallel with it, and

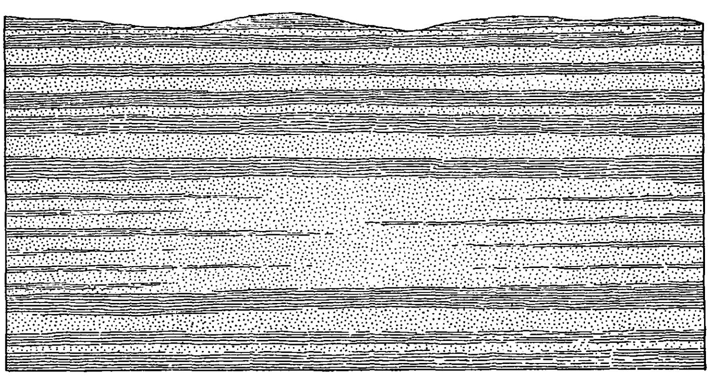

FIG. 9.—Sketch of cliff on Kuskokwim River, showing sandstones and shales passing laterally into one another.

follows it in its curves as far as the Holiknuk. The dip, on the other hand, varies considerably, but the general tendency seems to be toward the west and northwest. In these rocks segregationary pyrite is frequent. The arkose or sandstone which alternates with the shale often passes into shale laterally within a very short distance in a most remarkable way, the arkose spreading into separated beds which become alternate with beds of shale, and these rapidly become smaller as the shale beds increase until the shale forms nearly the entire rock (see fig. 9). In both shale and sandstones are frequent plant remains, generally very obscure; one specimen obtained, however, was evidently that of a dicotyledonous plant, which shows the rocks to be probably later than Jurassic in age. Ripple marks occur abundantly; and a concentric weathering of the arkose is common, when the iron of the rocks separates out into rings of red and gray. The folding of the rocks in general is greatest where they are first encountered, and grows less farther down the river. At the junction of the Kuskokwim with the

Holiknuk the general strike of the rocks changes from northeast to northwest and the river also turns and flows along the strike. The rock here contains heavy, impure argillaceous limestone layers and limy shales, with not quite so much arkose as farther up the river, but has the same plant remains.

FROM THE HOLIKNUK RIVER TO KOLMAKOF TRADING POST (MAP 8).

Cutting of river bank.—Below the junction of the Holiknuk, where the Kuskokwim swings to the northwest and continues in this direction for some distance, the current is continually against the left bank. Several miles farther, above the camp of August 4, near the point where the river turns and runs to the west, the current swings from side to side for awhile, striking now the left bank and now the right. From this point it continues mainly in the middle of the valley until the river takes a sudden shoot to the north, which is the first part of a long loop which it describes before running again to the southwest. Along this shoot the river again cuts the left bank. On the farther or western side of the loop, where the stream bends directly south, the current changes again and cuts the right bank, but from this point on up to the camp of August 5, about midway between the Yukwonilnuk River and Kolmakof, it cuts the left bank continually. From this point to Kolmakof the river keeps, in general, close to the right or north bank.

Topography.—Beginning with the junction of the Holiknuk the Kuskokwim flows in a definite narrow river valley, much more confined and well marked than at any point on its course farther up. The mountains here begin to be higher, and, although of smooth, rounded outline, often show considerable relief. On some of them are patches of snow throughout the summer, and certain peaks, isolated from the rest, rise up above the surrounding country. Above the river the rock bluffs rise to a general height of 500 or 600 feet, which is the level of a broad upland plateau which stretches far away over the country, from which the low, rounded mountains rise. The higher summits are bare of timber, but are generally covered with moss, giving a light green color. After the river has turned from a northwesterly to a southeasterly course, the valley begins to widen just above the junction of the Yukwonilnuk, and the mountains ahead grow lower and farther away from the stream. The mountains still rise out of the same general plateau, which is 500 or 600 feet above the river, and often show definite, deeply cut benches.

Silts.—From the Holiknuk to the camp of August 4, at the northernmost part of an important bend of the Kuskokwim, no silts or any similar deposits are found. In some places there are local banks of sand, alternating with layers of vegetation; these are about 10 feet high and are evidently flood deposited. They often show holes left by melting cakes of ice in the spring freshets. Some 12 or 15 miles below the camp of August 4, just above the sharp, slight turn to the north, is found a local deposit of silt which rises in banks from 20 to 50 feet above the river. About 10 miles farther, directly west of this locality and on the opposite side of the loop, where the river runs toward the south, are found banks of clay and silt 40 to 80 feet high, for a distance of a mile. There is also considerable peat scattered throughout the banks, and a layer of white volcanic ash an inch or so thick is found for some distance at a constant elevation of about 20 feet above the river and 30 feet below the top of the bluff. In places this layer of ash is bent and broken. There are no pebbles associated with the ash, or anywhere else in the bluff. Farther down the river the high bluffs give way to low banks of peat and foul-smelling muck not more than 10 feet above the water. Still farther, where the valley widens, the banks of the stream are usually composed of silt on one side or the other. Below the Yukwonilnuk River are, for several miles on the right bank, continuous bluffs of silt 20 feet high, containing layers of peat; these banks are covered with small timber.

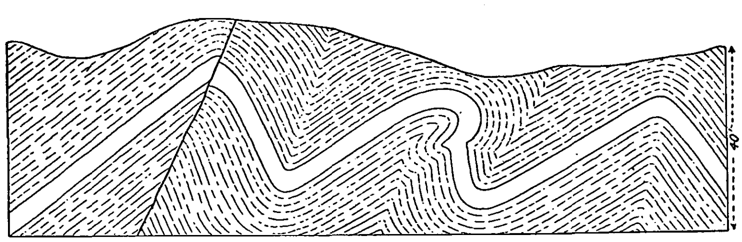

FIG. 10.—Folding in Holiknuk series, below the Holiknuk River.

Solid rocks.—The solid rocks exposed in the outcrops on the left bank just below the Holiknuk are closely folded dark-gray limestones and shales (fig. 10). These are intersected at intervals of several hundred yards by dikes of extremely acid porphyritic rock which cuts across the bedding or runs parallel to it in heavy intercalated sheets. The dikes are usually upward of 100 feet across, while the sheets are only a few feet thick. The igneous rocks weather a brilliant orange color, and the hues are arranged in curves, due to concentric weathering, which gives the outcrops a very striking appearance. The dikes sometimes surround small inclusions of limy shales, which are decomposed and crumbling, but show no mineralization and no very conspicuous metamorphism save iron staining.

The sedimentary rocks themselves contain plant remains. Farther down the river, on the same general course, the same rocks are repeatedly found, but growing continually more sandy and containing frequently beds of coarse arkose. From the increased amount of ferruginous material in the beds they weather a reddish color, while the first-mentioned outcrops weather gray, which at a little distance appears a delicate purple. The entire range of mountains through which the river has cut its narrow valley is composed of these same rocks, which are highly folded; the general strike, however, is usually parallel with the northwest trend of the river as far as the camp of August 4, and the dip, while varying continually, seems to be prevailingly to the southwest. Farther down the river rocks belonging to the same series outcrop, consisting of limy sandstones, arkoses, and shales, cut frequently by acid dikes. The same brilliant hues as above noted result in these rocks from weathering, the pure limestones weathering a purple or wine color, the arkoses reddish, and the porphyries orange. The sandy limestone often contains clay lumps. Where the igneous rocks cut the sedimentaries the contacts are often hardened for a few feet, so that they are more resistant and stand out from the rest of the rock on weathering. Everywhere plant remains are found in the sedimentaries, and sometimes coal fragments, and the shaly layers often become, in general, very carbonaceous. Midway between the Yukwonilnuk River and the camp of August 5 the limestone contains abundant remains of a species of Inoceramus, which shows that the rock is probably of Cretaceous age.

The general strike of the rock from the camp of August 4 to the camp of August 5 is to the northwest, so that the river cuts directly across it. The dip varies considerably where the folding is great. The pebbles brought down by the Yukwonilnuk River are entirely of igneous rock of great variety, among which basalt and granite-porphyry are found. It therefore seems probable that this river heads in mountains which are mainly or wholly made up of igneous rocks. On the right bank of the Kuskokwin, for some distance above Kolmakof, rocks of the same series of shales and sandy limestones outcrop in a number of places, and show frequent ripple marks and all other kinds of shore markings. They also contain plant remains and fossil shells, which also belong to a species of Inoceramus. Dikes are common and of large size. The rocks outcrop in perpendicular bluffs 500 or 600 feet high, and the beds of the black shale alternating with lighter limy seams, made whiter by the sweating out of calcite, gives a striking appearance, comparable to the banding of the black agate.

FROM KOLMAKOF TO THE YUKON PORTAGE AT KALCHAGAMUT.

Cutting of river banks, and topography.—The Kuskokwim below Kolmakof cuts the right bank continuously until it leaves the mountains entirely behind at Kalchagamut and enters the low, flat tundra country which lies between the Lower Yukon and the Lower Kuskokwim. On the left bank there is a broad, level plain stretching back to the mountains, which at Kolmakof have already become distant and which soon diverge so far from the river as to fade entirely from sight, so that there is a horizontal sky line. On the right the mountains still approach the stream quite closely, but break down and give way to low hills in its immediate vicinity. The low hills have smooth, nearly level tops and deeply cut terraces, although these are by no means so sharply defined as were the higher ones on the Tordrillo Mountains. In places the stream in meandering trends away from the hills, which become quite dim in the distance, but a fresh turn again brings it against them, and often it flows for many miles along a high rock bluff on its right bank. The left banks, which are 15 or 20 feet above water, give evidence of being inundated in the spring, for their tops contain fresh driftwood and show recent ice gorges.

In the vicinity of Oknagamut the mountains whose base the river approaches are somewhat higher than those farther upstream, but have the same general type of topography, being rounded, with often level tops and conspicuous horizontal benches, the best marked one being about 1,000 feet above the river. These mountains have no sign of stratification and are probably of solid igneous rock. The river does not actually cut the rock of these mountains, but where it approaches nearest them the bank is a bluff of silts 40 feet high, with augular fragments of gravel, which constitute the main part of the lower beds.

Solid rocks.—About 3 miles below Kolmakof, on the right bank of the river, is a bluff of nearly black color, which appears to be made up mainly of andesite, although some of the beds are probably arkose or shale. In these latter are abundant plant remains and lumps of carbonized wood, which preserve the cellular structure. The arkoses are at times limy and contain tiny calcite veins. These rocks are cut by frequent dikes of yellow-weathering igneous rock, one type of which has been determined to be the siliceous rock bostonite. These dikes are as much as 100 feet wide and in them are straggling pegmatitic veins. In this locality has been found a vein of cinnabar, the ore of mercury, which has been mentioned in numerous reports of Alaskan governors and in other publications. The vein was found by Mr. Lind, a trader along the Kuskokwim River, whose headquarters are at Bethel. According to Mr. Lind, the vein consists in an impregnation of the arkose with red cinnabar, the mineralization taking the form of a vertical zone a foot or two wide, but often irregular and pinching out. Mr. Lind spent about $2,000 in mining some of the ore and getting it to the States, but on account of the small quantity and the low price of mercury he lost much on the venture.

This rock bluff continues for a number of miles along the right bank of the river, and farther down from the locality just described consists mainly of green arkoses and soft shales. The rocks carry plant remains and sometimes show cross bedding; they are cut by frequent dikes, mostly siliceous, although some of them are of basalt. The general strike is almost at right angles to the course of the stream and the general dip is downstream at angles not exceeding 20°, but for long reaches the dip becomes gradually less and less and the rocks are sometimes horizontal. These rocks continue to a point about 14 miles below Kolmakof. Toward the end of the bluff the arkoses are soft and barely consolidated, and in them are found pebbles of shale; the consolidation evidently decreases with the amount of folding. Half a mile below this rock bluff, on the same side of the river, is a steep bank, 40 feet high, of horizontally stratified gravels, made up of small subangular bowlders and pebbles which frequently reach 18 inches in diameter. The material is almost entirely from siliceous igneous rocks of the same kinds as the dikes noted farther up the river, and the deposit is evidently a Pleistocene shore conglomerate. The color of the gravels is, like the color of the weathered porphyry which constitutes the larger part of them, an orange yellow. From this point for

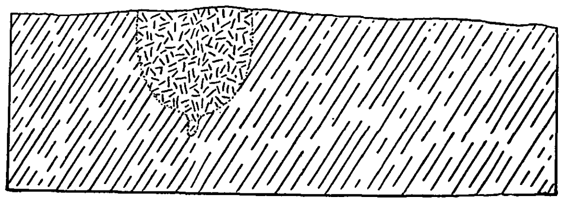

FIG. 11.—Granite rock intrusive into Kolmakof series, Kuskokwim River below Kolmakof.

about 10 miles there are low banks on both sides and then the river cuts, on the right side, a low east-west trending mountain ridge. The first outcrops here are of compact, considerably altered volcanic rocks (partly trachyte and dacite), which are hard and massive and show no traces of bedding. These are cut through by nearly equal amounts of siliceous porphyritic rocks in great masses and dikes of all sizes (fig. 11). Farther along the bluff the rocks vary somewhat, changing from compact volcanic rocks, as first mentioned, to coarse and fine tuffs, which are probably trachytic, at a point some 10 miles farther down, while at an intermediate point a specimen of the sedimentary rock examined was of a curious sort, being a glauconitic calcareous chert containing masses of sponge spicules and evidently of organic origin. Throughout this whole distance the rocks are cut by the same great dikes of siliceous rock, and one of these dikes at the farthest end of the bluff was determined to be of quartz-syenite. A yellow agate was found in the gravels here, which was undoubtedly derived from the volcanic rocks. At the upper end of this series of outcrops are detrital Pleistocene deposits at the base of the first bluff, both at the upstream and at the downstream end. The upstream deposit is of silt and sand, forming gray bluffs 50 feet high, while the downstream deposit, which is about 60 feet high, is of coarse gravel, with many bowlders, and weathers an orange-yellow color.

About 10 miles below the end of this ridge, and at about the same distance below the camp of August 6, the river, after winding for a number of miles with low banks on both sides, again cuts rocks on the right bank, which are at first massive basalt or diabase-porphyry; above this outcrop the river cuts, for a quarter of a mile, horizontally stratified gray silts, which overlap and rest upon the porphyry. The bluff continues down the river for 4 or 5 miles; for about 3 miles it is solid igneous rock, and then begins to have a fine stratified appearance, is often finely banded, and gray or nearly black in color. When examined carefully these beds are found to consist of alternating layers of coarse and fine feldspathic tuff and of shaly beds.

From the point last mentioned nearly to Kalchagamut there are no more outcrops, but the hills on the right show no traces of stratification and are evidently mainly of igneous rock. The banks of the river are of recent silts and gravels.

FROM THE YUKON PORTAGE TO THE KANEKTOK RIVER (MAP 9).

From the beginning of the Yukon portage at Kalchagamut there are no rock outcrops on the Kuskokwim as far as its entrance into Kuskokwim Bay; on both sides is usually, as far as one can see, low, flat country, and the banks are in general not more than 10 feet above the river. The cuts show that the material through which the river flows is generally silt, with upper portions consisting of alternating layers of silt and vegetable matter. Abundant driftwood on the tops of the banks shows that the whole must be inundated every spring. In some places the lower parts of the banks show a deposit of small, cross-bedded gravel, the bedding dipping downstream. At two points between Kalchagamut and Bethel, the low banks are replaced by higher bluffs of sand, silt, clay, and vegetable matter. Such a bluff is found about 10 miles below the camp of August 8, on the right side of the river, and is about 50 feet high. On this bluff the vegetable material is found in layers extending to the very bottom of the bluff. Another bluff of some height is found just above Kameglimut, also on the right bank, but here the silt is clean and contains no vegetable matter. At Bethel the banks are hardly more than 10 feet above high water, and treeless tundra, covered luxuriantly with mosses and dotted with small swampy lakes, stretches as far as the eye can see. In this low country the river is actively cutting away its banks, and is thus constantly shifting its channel. Those banks which are being cut away generally show in the immediate vicinity of the river considerable groves of small willow, cottonwood, and some spruce, while those which are being formed by the river show no timber, but only young vegetation. The river splits up and embraces many large islands, and is probably in places as much as 8 or 9 miles from bank to bank. At Bethel, as I am informed by Mr. Kilbuck, a resident Moravian missionary, the main river was actively cutting the bank in front of the mission fourteen years ago, and threatening to undermine it, while now an island has been built up in front of the bank, and the mission is connected with the main river by a sluggish and shallow channel. The Eskimos at Bethel say that a generation ago one could wade across the channel through which the main river now flows.

All through these silt deposits on the Kuskokwim banks the tusks, teeth, and other remains of mammoth are found. According to Dr. Romig, Moravian missionary at Bethel, these remains are generally found in the bluffs about 10 feet below the top of the moss, in the gravel and sand below the peat. A huge tusk seen at Bethel was stained blue on the outside, evidently from the formation of vivianite (phosphate of lime).

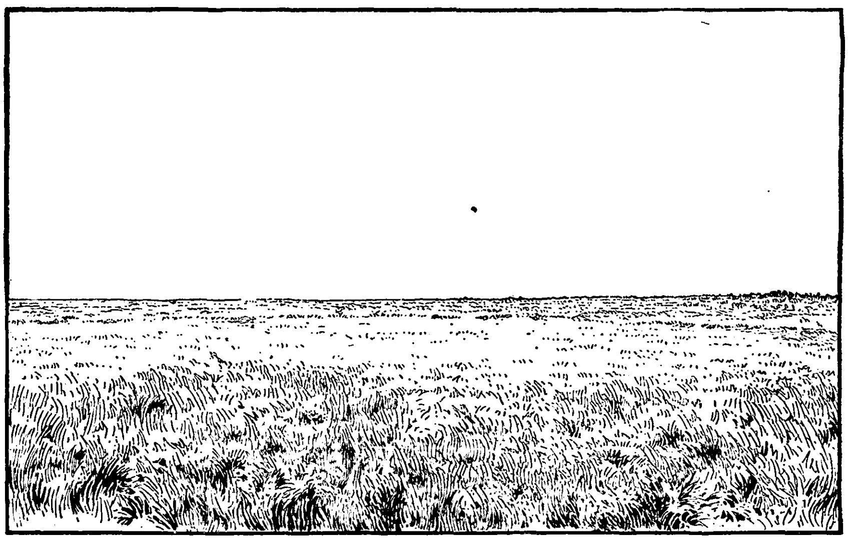

FIG. 12.—Typical tundra, Lower Kuskowim River.

About midway between Kalchagamut and Bethel a low, apparently detached range of mountains is seen in the distance to the east of the river. In a short time the course of the river diverges so much from that of the range that the mountains fade from sight. This low range has been called the Kilbuck Mountains. On the right side of the river there are no more mountains in sight, except that on very clear days the high hills on the farther side of the Yukon may be seen from points on the Kuskokwim not too far below Kalchagamut.

From Bethel to Kwinhagamut, at the mouth of the Kanektok, the country through which the river flows is, as before, treeless tundra (fig. 12). For a long distance above Kwinhagamut there is not even tall brush, but the country is a level swamp covered with several feet of peat, below which is mud or clay. From this clay the natives make some rude earthenware, such as lamps. Occasionally the clay banks are 20 feet high, but mostly are not more than 2 or 3 feet above the river. From Bethel down, the tide begins to affect the river, so that the variation in height at Bethel reaches a maximum of 3 or 4 feet, which increases until at Kwinhagamut it is probably 50 or 60 feet.

THE KANEKTOK AND TOGIAK RIVERS (MAP 10).

FROM KWINHAGAMUT TO LAKE KAGATI.

For four days' journey up the Kanektok River from its mouth, a distance of 30 or 40 miles, the stream runs through the general tundra of the Lower Kuskokwim. All the way, however, abundant brush is found growing on low banks of peat covering soft and sticky mud and generally less than 3 feet above the river; a short distance away from the river banks there is not nearly so much vegetation. The low bars of the stream and the river bottom itself, where the current is not too swift, was at the time of our journey thickly covered with decaying salmon of all sorts, which were at times so abundant that one had difficulty in walking along the margin of the stream without stepping on them. Millions of these salmon ascend the river to spawn, and many become so weak and exhausted from the trip that they do not find their way back to the sea.

The first topographic break in the tundra consists in a definite bluff from which the river emerges upon the plain. This bluff is the front of a level plateau 100 feet or more above the river; the stream valleys are cut in this and low hills rise from it. Its material is invariably a very slightly stratified drift composed of subangular bowlders of diorite-porphyry, sandstone, conglomerate, quartz, and jasperoid, of all sizes up to 3 feet. These bowlders are embedded in a fine soil matrix and are frequently deeply striated by ice action. The drift plateau forms a narrow fringe along the front of the first range of mountains which make up the divide between the Kanektok and the Togiak and which have been named the Oklune Range, a name taken from the Eskimo language. This range was definitely entered just below the camp of August 30, and here were frequent outcrops of arkose, sandstone, conglomerates, and carbonaceous shales, interbedded. The general strike of the rock is NE. and the dip 15° SE. At the camp of August 30 impure gray grit and fine sandstone is intercalated with black carbonaceous shales. The natives of the Lower Kuskokwim come to this locality to secure the grit for use as whetstones, according to our Eskimo guide. The front range of hills has a trend corresponding to the strike of the rock, and frequent outcrops on the crests of the peaks show that the rocks preserve their uniform northeasterly strike; there are also other minor ridges arranged in lines parallel to the first. The forms of all these hills are considerably smoothed, and well-marked terraces are discernible near the bases. In a very large bowlder of sandstone and conglomerate at this locality a species of fossil Aucella was found which, according to Mr. Stanton, of the United States National Museum, refers the rocks to the upper part of the lower Cretaceous. In general appearance the beds are like those on the Kuskokwim above Kolmakof.

A little farther up the river, between the camps of August 30 and August 31, the stream cuts outcrops of hornblende-syenite, which, apparently form part of a large mass having a general trend parallel to the main northeastern trend of the mountains and probably forming the whole of the hills along a narrow zone. Through this igneous rock the river flows in a wide, rock-cut valley, walled by bluffs 100 feet in height; in the bottom of the valley are gravel deposits in which the stream meanders, and these are covered with willow and cottonwood. From the tops of the bluffs above the river there extends a generally level plateau valley, from which rise mountains bare of trees and brush, but covered with moss. Among the bowlders and pebbles in the river gravels were some of yellow ocher, containing stains of copper carbonate. A specimen of this assayed in the laboratory of the United States Geological Survey showed no gold and only 0.15 per cent of silver to the ton. The bluffs contain veins of quartz and of coarse mica.

Above the outcrops of igneous rock on the river come massive fine-grained arkoses or feldspathic sandstones, which often do not show any evidence of stratification. Above the junction of the Klak the rocks are mainly ancient volcanics, trachyte predominating, although arkose comes in again above.

The river along here always flows in a definite mountain valley, which is broad below the junction of the Klak, and contains frequent lone mountains. There is no glacial drift in the valleys nor any signs of glacial topography on the mountains. The latter have generally evenly smoothed and rounded forms and are distinctly terraced. Below the junction of the Klak the river becomes swifter and spreads into many channels, while directly above this junction it narrows again into a single channel. The banks along here are of coarse, stratified gravel 30 feet high, with a uniformly level top, this level extending back with a very gentle slope to the mountains, which rise from it rather abruptly. Above the Klak the plateau valley again becomes narrower and the mountains on each side rise to greater heights, becoming more picturesque. They have a tendency to a southeast slope and a northwest scarp, the ridges of bare rock running parallel with the valley as if the rocks were stratified and had a strike of N. 40° E. and a dip of 15° SE. The outcrops which were found along the river corroborate this idea, for the stream flows constantly along the strike. The mountains have a systematic well-developed drainage, and their entire topography has a direct relation to the structure of the rocks. From their appearance it seems that those to the northwestern side of the valley are chiefly of igneous rock, while those on the southeastern side are mainly stratified.

From the junction of the Klak to the main bend of the river, where the valley turns and runs nearly south, the rocks are mainly sandstones, arkoses, slates, and conglomerates, while at the bend basaltic tuffs come in, interbedded with slates and sandstones. The strike is constantly NE. and the dip is SE. at angles up to 45°. The pebbles in the conglomerate are of slate, chert, granite, and diorite. The slates are sometimes altered to green and brown jasper locally. Between Klak Creek and the main bend above mentioned the river cuts through a definite separate range in the mountain group and emerges from the western front of this range a few miles below the camp of September 5; to the east and northeast a higher range, constituting the central mass of the Oklune Mountains and the main water divide, is now approached as one proceeds upstream.

Although there are frequent outcrops along this northeast stretch of the river, the banks are usually of roughly stratified drift containing subangular and often striated bowlders of various sizes. At the camp of September 5 the banks have increased in height to 100 feet, which is much higher than any noted farther down the stream. It is to be remarked that the drift deposits are found almost exclusively along those portions of the river valley which front the mountain ranges. In these higher mountains, which lie below the camp of September 5, the upper peaks have ragged outlines and are frequently sharp, while the gulches are V-shaped and the larger valleys are filled with the accumulation of drift.

From the great bend in the river to Lake Kagati are occasional outcrops of sandstone, conglomerate, and shale, and the general strike seems to change and to turn to a northwesterly direction, so that the river still flows parallel with it; the dip appears to be mainly southwest. This stratified series is cut by occasional siliceous dikes. In the silicified and altered slate near the contact of one of these dikes veins of spathic iron were noted. The sedimentary rocks are similar to those in the Kuskokwim Ramparts, since they consist of predominant slate with occasional sandstone beds which often become conglomeratic.

The covering of drift in the valley becomes more important as one goes up the river, and in the stratified gravels which are cut by the stream are found many bowlders, some of which are as much as 10 feet in diameter. These bowlders are largely diorite and diorite-porphyry, and are generally striated. All of the cuts show a stratified arrangement and the effect of water action throughout. This drift covers the broad valley, and is evenly terraced up to the slopes of the mountains; higher rock-cut terraces run from one-half to two-thirds of the way to the tops of the peaks. In the level valley are small lakes occupying depressions which appear to be due to irregularities in the distribution of the drift. As one ascends the river the size of the bowlders increases markedly. This portion of the stream has a current which is not so rapid as that farther down, where the river cuts through the mountain range.

In one place a pan of gravel derived from the morainal material which had been rewashed by the river was found to contain no gold, and only a very small amount of black sand.

FROM LAKE KAGATI TO TOGIAK LAKE.

Lake Kagati outlets through banks 40 feet high, which are of roughly stratified drift containing little worn or entirely unworn rock fragments of all sizes. On the left side of the lake, going up, the drift bluffs change in the course of half a mile to rock bluffs of the same height. The rocks are of thin-bedded gray or greenish tuff, striking N. and dipping 70° W.

Lake Kagati lies in a definite mountain valley, with high mountains on both sides and with another considerable mountain dividing it in the middle, while the lower end of the lake is entirely in low country and at the upper end is also a wide flat which is the continuation of the general valley. The highest mountain in the vicinity—Mount Oratia—rises from the northern side of the lake, and is sharp and pinnacled. Valleys coming down from Mount Oratia to the lake are U-shaped in cross section, with jagged or almost perpendicular walls. In the bottoms of these broad steep valleys the streams have eroded deep gullies. At the heads of the valleys are glacial cirques and large masses of snow and ice, while farther down are often glacial lakes, one of which is walled in by precipitous cliffs several thousand feet high and is dammed by morainal accumulations. This moraine is evenly terraced, and clean-cut terraces also mark the rocky sides of the mountain far up and extend off down the valley, while the mountain which divides Lake Kagati in the middle is terraced clear to the top. Along the bank of the lake fragments of talus rock show striation and polishing from the movement of lake ice.

From the camp of September 8, above Lake Kagati, it was possible to discern in a general way the structure of most of the surrounding mountains. The mountain directly southwest of the camp (see map) is composed of stratified rocks striking N. 55° W. and dipping 30° S. The high mountain bounding the lake on the southwestern side—Nuklunek Mountain—has a level top parallel with the longest direction of the lake and following the strike of the strata, so that the steep scarp which faces the lake affords a longitudinal section of the beds. North of the camp is the valley of Atmugiak Creek, lying between Mount Oratia and Atayak Mountain. This valley is broad, with steep sides, and on both sides the strata dip away from it, so that it evidently occupies the crest of an anticlinal fold (see fig. 13). Atayak Mountain seems to be composed of igneous rock, since the topography indicates no stratification, nor are there any outcrops of plainly sedimentary rock. Looking up the valley toward the pass, the mountains on the left side show no structure lines, while those to the right have a steep scarp on the valley side and an even slope on the other, so suggesting stratified rocks.

The valley of the creek above Lake Kagati is a broad level expanse of small pebbles and mud, confined by rock bluffs generally half a mile apart. In this valley the creek meanders intricately. There are no large pebbles or bowlders in the valley, and therefore no glacial drift. The mountains to the south of the valley are cut by deep terraces all the way to the top. The deepest cut bench is about 800 feet above the bed of the stream, while another almost as deep is about 400 feet above it; these are cut back nearly a quarter of a mile.

At the upper end of this Crooked Creek, at the camp of September 11, is a little lake, which is narrow and extends along the general

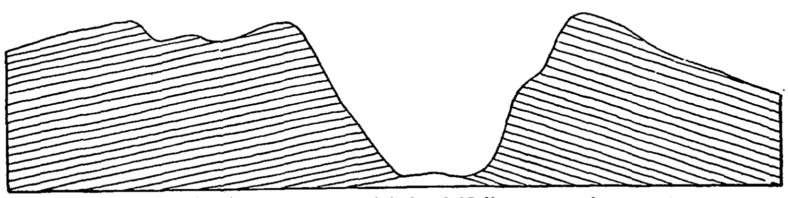

FIG. 13.—Section across Atmugiak Creek Valley, near Lake Kagati.

length of the mountain valley. This is dammed by a slight ridge in the drift accumulation. At the upper end of this little lake a moraine extends across the valley and separates it from a larger lake above. This ridge of huge bowlders is composed of mounds and irregular hollows, where great cakes of ice have melted. The upper lake is also narrow and long, in the general direction of the normal valley. In the mountain side, above the lake, on the right side going toward the pass, are huge bowlders. Perfect terraces, cut both in drift and in the solid rock, rise far above the moraine on the mountains.

Along that portion of the valley occupied by these two lakes outcrops of a light-colored aphanitic, apparently massive rock, are common. In places this rock is of a fine granular texture and seems to be igneous, and specimens examined microscopically show it to be mainly basalt or andesite-basalt (aleutite). This rock is cut by occasional dikes of coarser igneous rock, some of which were determined to be diorite.

The mountain valley which leads up to the pass is broad and of gradual ascent. Its bottom is covered thinly with morainal drift and the bowlders which strew the surface are heavily coated with moss. The valley shows no signs of glaciation in the immediate vicinity of the pass, either on the east or on the west side. In the mountains on both sides are no glacial moraines, except one or two tiny ones, such as may be formed from snows. In the bottom of the upper part of the valley the stream has cut a canyon 40 feet deep for some distance. The only evident glacial features in the vicinity are the small glacial valleys and cirques on the side of Piskuk Mountain and in those mountains to the south of the larger of the small lakes just described.

The rocks along the broad valley which rises to the pass are substantially the same as those described. They are in general massive, but often show stratification. Some of these rocks are very full of pyrite, so as to weather red on exposed surfaces. They are mainly basalts and andesites, with derived tuffs interstratified with them. As is the case farther down the valley, these old volcanic rocks are cut by frequent dikes of diorite, which is often porphyritic. The pass itself is occupied by a great, coarse mass of granite, which also forms the mountains rising above it. The mountains on the Togiak side of the pass are also formed largely of the dike rock, but where this is not found they have the characteristic dark-reddish color of the volcanic and tufaceous rocks on the east side. The contact of the great granite dike with the country rock on the west side of the pass is silicified and ferrated for several feet.

While the ascent of the pass on the western side is gradual, on the eastern there is a steep fall from the summit of 800 feet. On the eastern side also the cross section of the valley is different, being more V-shaped and sharp cut.

The bottom of the valley on the eastern side is partially filled with talus bowlders, which have come down from the steep walls. Generally, however, the stream flows over a bed of solid rock. The stream is confined within this mountain valley until it reaches the valley of Togiak Lake, where level flats, composed of stratified small bowlders, are cut in banks 40 feet high by the stream. About midway in this flat, between the mountain valley and Togiak Lake, the stream is dammed into a small shallow lake by a transverse ridge of gravel and bowlders. Breaking through this a rocky stream connects with Togiak Lake, the banks being about 15 feet high and composed chiefly of sand and gravel, with a few bowlders, and being horizontally stratified.

The rocks of the valley to the east of the pass are largely of coarse intrusive diorite, cutting through the greenish ancient volcanic rocks and tuffs. The mountain at the eastern end of the valley, on its left side, shows gray stratified rocks heavily bedded, striking N. 70° E., and dipping 25° SE.

Togiak Lake occupies the eastern side of a wide mountain valley, the western side of which is occupied by the horizontally stratified drift just described, which is cut by creeks and contains small lakes in its hollows. The lake is long and narrow and is evidently a dammed-up portion of the mountain valley; besides its main body, it occupies little inlets which are the flooded valleys of small tributaries. The scenery is somewhat similar to the fiords on the coast of southern Alaska, or to the lakes of the Upper Yukon. The lower end of the lake has no definite dam, the formation cut by the river, which is the outlet, being of stratified silts and gravels like those along the lake. The banks are 10 to 40 feet high, with a slightly irregular top, though on the whole there is a generally uniform level stretching back to the mountains. On these mountains there are no marks of glaciation except a small high cirque on one peak. Well-marked terraces are cut up to a height of 1,000 feet or more on the mountain on the western side of the lower end of the lake; the mountain on the eastern side is chiefly of tilted stratified rocks, probably in part slate. These rocks strike with the valley (that is, about N. 10° W.), and dip 65° E. On the west shore of the lake a large subangular bowlder of basaltic tuff was found.

TOGIAK RIVER.

Togiak River has a moderate current, and for the whole distance from the lake to the bay flows through a low valley without high rock bluffs. The banks of the river are, in general, of rather fine horizontally stratified gravels, with well-worn pebbles, and show a cross bedding which generally dips downstream, but is often reversed; this cross bedding is irregular and uncertain, not like that of a river, but rather that of varying currents. As one goes downstream from the lake the valley broadens out continually, the mountains on both sides diverging from the stream. The river keeps on the right side of this broad mountain valley from Kashaiagamut down, the ridges on the east fading far into the distance. Above this village the stream is about in the middle of the valley, while the lake, as noted above, is on the eastern side. From the camp of September 18 to Togiak Bay the bluffs are about 30 feet high, and often the lower strata are of finer gravel while the upper 10 feet is much coarser and is bowldery. All along the river are very large bowlders lining the shore, which seem to be brought down by the river ice, since many of the rock varieties were not found in the bluffs.

The mountains which lie near the upper part of the river are high, picturesque, often rugged, and of uncertain structure. Those which lie to the east of the lower river are of different appearance, being low, often with flat tops, and many are isolated conical hills of medium size, suggesting ancient volcanoes.

The first outcrop in the river is situated a short distance above Kashaiagamut, and consists of a fine-grained, nearly aphanitic dark-gray rock, which the microscope shows to be mainly a volcanic tuff. The rock shows nearly vertical jointing and slight shearing, with slickensides, but the stratification is uncertain. The same rock outcrops for 4 or 5 miles below Kashaiagamut. About 6 miles below Kashaiagamut tuffs again outcrop, striking N. 23° W. and dipping generally 45° NE., but locally reversed; there is less shearing here and the bedding is thinner. A mile below this, on both sides of the river, there are outcrops of massive greenish andesite full of amygdules and impregnation veins rich in pyrite; below this the tuffaceous stratified rock comes in again with the same strike and dip as noted above. Above Gechiagamut are numerous large bowlders of vesicular basalt, which appear to have been brought down into the river by the ice of one of the tributaries which head in the mountains bordering the main valley.

About 5 or 6 miles above Togiagamut low tundra banks come in and extend as far as that village. The shore of the bay below Togiagamut is a bluff 40 feet high, with a level top composed of brown clay full of large bowlders, the whole having a certain rude horizontal stratification and being apparently a coarse shore deposit. About 2 or 3 miles before reaching the trading post of Togiak these gravel bluffs are replaced by cliffs of the same height, which are made up of basalt identical with that seen farther up the river. This rock is dark gray in color, but when oxidized is red throughout; it has a conspicuous vertical columnar jointing; is generally compact, though porous, and contains numerous round or irregular vesicular blotches, apparently portions of a vesicular crust which has been broken up and mingled with the lava, which subsequently cooled. There are also seams and shrinkage cracks in the denser rock which are filled with lava of the same vesicular variety. The bluffs of basalt and gravel extend back as a uniform level tundra to the mountains, which appear to be, in part at least, volcanic.

FROM TOGIAK TO KATMAI (MAP 11).

FROM TOGIAK TO NUSHAGAK.

From Togiak southeastward along the shore there are bluffs of basalt 30 feet high. On the opposite side of the bay also the rocks seem to have a vertical columnar jointing, and may be basalt. In places the rock bluffs near Togiak give way to yellow stratified gravel containing many very large bowlders. The top of the bluffs is a level plain running back to the rounded subconical hills, which are probably of volcanic origin. These hills have the same appearance as those in the vicinity of St. Michael, being bare and brown, and often have terraces distinctly visible. Walrus Island and the other islands near by have at their base the same appearance of columnar jointing; they are mountainous islands, and may be of volcanic origin. Southeast of the strait between Walrus Island and the mainland is still basalt and stratified drift for some distance, and then comes in a great deal of a light yellow rock in a shallow bay. The surfaces of this rock are often curved, as if from folding, and it has the appearance of being coarsely stratified. In the hollows caused by the undulations is a darker colored stratified horizontal drift which extends up to the tops of the bluffs, which are here 50 or 60 feet high. Huge blocks of the yellow rock below are often included in the drift, and study of a specimen shows it to be rhyolite.

On the west side of the point which lies at the western entrance of Kululuk Bay the cliffs consist of shaly, impure limestones and arkoses, which are folded and often strike vertically; the general strike is east-west, and the general dip south, but this is often reversed. The stratified rocks are cut through by great masses of basalt, so abundant that for a considerable distance the stratified rock and the basalt are about equal in amount, and then the intrusive rock becomes more abundant. When the basalt forms most of the rock the shales become hardened into slates, and they are often noticeably contorted at the contact with the intrusive masses. Basalt of about the same variety constitutes almost the whole of the rock along the western side of Kululuk Bay, and here the massive sheets are interbedded in places with coarse basaltic tuffs.

The upper part of Kululuk Bay has a low shore of sand and silt, and the depression which forms the bay is continued northward in a broad, flat valley bounded by hills on the east and west. At the shore of the bay is a broad, flat gravel bar, bearing the marks of ancient beaches above the reach of the highest tides at present; behind this is a marsh through which the river meanders. With the flood tide the current flows up the stream, being reversed only just below a small lakelet. Here the banks are of stratified gravel, a few feet high. From here a succession of ponds, connected by marshy and diverging streams, takes one to the low divide, which is, at its lowest point, about 50 feet above the lakes on both sides. A short portage across this divide takes one to a large lake, which is the source of the Egoushik River. During all this distance there are no rock outcrops, the whole course being through a continuous mountain valley filled with stratified sand and gravel. The north shore of the lake in which the Egoushik heads has banks of horizontally stratified gravel and silt, while large angular bowlders of tuff or impure slate line the shores, and are probably derived from the mountains which rise directly above it on the northwest side. From the lake a small, rapid stream runs down to another lake of equal size, and at the beginning of this stream are outcrops of the same fine tuff or slate seen on the lake, the rest of the river banks being of horizontally stratified silt and gravel and about 40 feet high. The second lake is also walled in by mountains, and at its lower end are outcrops of sedimentary rocks like those described above, which stand at high angles and often contain sheets and large crosscutting bodies of dark-colored igneous rock. The only outcrop really examined was of this intrusive rock, which proves to be a basalt. From the second lake a stream runs, at first with considerable current, then, after flowing through a small, shallow lake, becomes broad and slowly winding, perceptibly backed up by the tide. There is thus a continuous mountain valley from Nushagak Bay to Kululuk Bay, occupied by a series of shallow lakes and connecting streams, with tidal rivers running into the two bays. The bottom of the valley is entirely filled, save for a few projecting ridges of rock, with stratified gravels.

About 10 miles below the second lake the river cuts on its left bank close to the mountains again, for the last time before reaching the bay. The rock of these mountains is mostly basalt. The ridge near the camp of September 23 consists of basaltic tuff, with a conglomerate which in reality is of igneous origin, having basalt as the cement, which includes rounded pebbles of all sizes up to several inches in diameter. Some of them are of slate, while others are of alaskite, or granite porphyry verging on alaskite, but most are of compact, sometimes vesicular, basalt. All of these pebbles bear evidence of having been rolled in water before being embedded in the cement, which must have been a volcanic flow. Interstratified with the volcanic conglomerate and with the tuff are beds of granitic arkose. The general nature of the rocks, therefore, appears to be volcanic, and those on the second lake (above mentioned) may be considered as lava flows interbedded with sedimentaries which are more or less tuffaceous in origin, and the whole series must have been folded, for, as noted, the rocks on the lake stand steep. In this connection it is noteworthy that certain mountains standing west of the first lake, at the head of the Egoushik, have peculiar topographic features at their summits which contrast strongly with the general conventional forms. They have on their tops peculiar sharp spikes, with nearly perpendicular sides, which suggest volcanic necks, which have come up through the sedimentary rocks and have since been laid bare by erosion.

As a rule the mountains have smooth and rounded tops, with terraces distinctly visible in places. About 60 feet above the first large lake, at the head of the river, a very deep, rock-cut terrace stretches back to the hills. This must be of marine origin, for if the sea stood at this level it would flow over all the low land on the various slight divides and connect the two bays. There is no trace of even trivial glaciation in all the region from Togiak Lake to Nushagak.

Proceeding south and west along the Egoushik River, from the camp of September 23, the last mountains passed are at a considerable distance from the river. These end in a gentle slope down to the tundra. Beyond this is only swamp and moss, with occasional hummocks, the whole, in general, absolutely flat. The cuts along the river show blue mud and silt. At the camp of September 25, near the bay, the tide, falling probably 30 feet, exposes hard, blue clay, so much consolidated that it is rolled by the currents into round pebbles or bowlders. About 10 feet from the top of the bluff is a layer, a foot or two thick, of large pebbles and bowlders.

The western shore of Nushagak Bay is low swamp land, nearly at the level of high tide. This extends clear to Cape Constantine, which is itself composed of tundra. From the shore of the bay long mud flats run out, especially between the Snake and the Wood rivers, at the head of the bay. These flats are covered at high tide, but at low tide they extend 10 miles or more from the shore. On the northern shore of the bay, beyond the Snake River, bluffs from 60 to 80 feet high come in, which are composed of pebbles and round or subangular bowlders in a matrix of stratified clay. These bluffs are continuous as far as Nushagak, where they are upward of 100 feet high, and from their tops the tundra can be seen extending off to the east as far as the horizon. The tops of these bluffs are, in general, level, but have slight irregularities like those of the present flats. All the bowlders on the beach between Nushagak and the Moravian Mission at Carmel are scratched, on their upper surfaces only, by ice, evidently the tidal ice in the spring.

FROM NUSHAGAK TO NAKNEK RIVER.

On the east shore of Nushagak Bay, south from the trading post, is at first a low tundra swamp, which forms a belt between the shore and the line of level-topped bluffs. This swamp has a maximum width of about a mile, and the bluffs behind it appear to be of gravel, but somewhat consolidated, and the bedding shows slight folding, the dip varying from horizontal to 20° north. At the cannery south of Nushagak the bluffs come down to the shore line, and they are here about 150 feet high, with still level tops. They are composed of stratified gravels, coarse sands, arkoses, and clays. Some of the gravels and sands are so cemented by iron that they form solid masses and projecting ledges, and often a ledge of conglomerate thus solidified overlies many feet of soft sand; in places, also, the sand is consolidated. The iron which forms the cement appears to be derived from the coarse, impure sand and arkose. The strata are often cross-bedded, showing varying currents. The pebbles in these beds are subangular or rounded, and some of the bowlders show ice scratches. The material is chiefly diorite of many varieties, most of it coarse and granular, with dark porphyritic inclusions, while some specimens are finer grained, light gray to nearly white, and with large phenocrysts. There is also considerable fine-grained basaltic or andesitic rock; and dark slate occurs, often silicified and penetrated by chalcedonic or quartz veinlets. Chalcedony, red and gray quartz, and red jasper are sometimes found. The strata below the cannery are distinctly, though not greatly, flexed, sometimes dipping as much as 20°.

From the cannery around Cape Etolin to the camp of October 8, on Bristol Bay, the shore line is always the same high bluff, continuous except in gaps where little streams have cut through. Beginning with 150 feet at the cannery, as before mentioned, the bluffs dwindle in height to 40 feet at the camp of October 8. Just after passing Ekuk the bluffs are folded and contorted, while at the very top a bed of clay appears, which is 10 or 15 feet thick, is horizontally bedded, and unconformable upon the underlying strata. At the camp of October 8 the bluffs are composed almost entirely of horizontally stratified clay containing occasional pebbles and bowlders, which are frequently ice scratched. This clay is from 20 to 40 feet thick, and below it is from 3 to 5 feet of fine horizontally stratified gravels, which in turn rest, with a slight unconformity, on interbedded gravels and clays that have in places been slightly folded and faulted, in one place the layers dipping 45° or 50° for a short distance. The folded gravels are as soft and unconsolidated as the upper ones. The clays which are interbedded with them have locally undergone intense crumpling on a very small scale, while the gravels with which

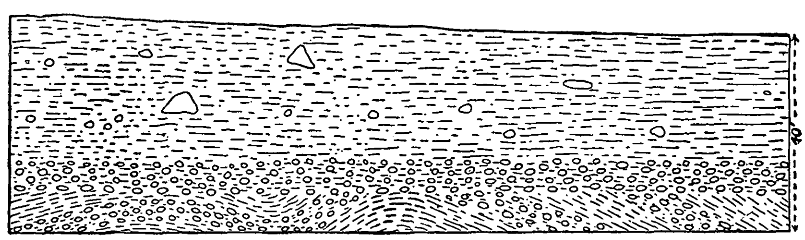

FIG. 14.—Unconformity in gravel bluffs on Nushagak Bay.

they are interbedded show little or none. The lower unconformable gravels and clays are exposed at this point only in occasional swells above the beach line (see fig. 14). They are heavily cross bedded, the layers almost invariably dipping southwest, down the bay, although occasionally reversed.

Summing up, it may be said that on the peninsula between Nushagak Bay and Bristol Bay there is exposed a thick series of gravels and clays, which are slightly folded and resemble the Pliocene beds (Palisades conglomerates) of the Yukon. The greatest thickness is exposed at the cannery and is nearly 150 feet, and nowhere has any solid rock been seen below. Above this lower series is horizontal undisturbed clay, with scattered ice-scratched bowlders and pebbles. Of this clay there is from 10 to 40 feet, making up the top of the bluffs, with generally 3 or 4 feet of stratified gravel as a base. The bottom of this clay and upper gravel and the top of the bluff grows lower going east from Ekuk.

From the camp of October 8 to a point on the northwestern shore of Bristol Bay opposite the mouth of the Naknek River the bluffs of horizontally stratified blue clay with striated bowlders continue, the general height being from 20 to 40 feet. Beneath them are occasional swells of the folded clays and gravels above described. Along the shore are large bowlders, some of which are 4 or 5 feet in diameter and are striated and polished by ice. At several points raised beaches, which have a very fresh appearance, were observed.

NAKNEK RIVER AND LAKE.

There are no rock outcrops on the Naknek River, the shores being always stratified clays and sands, undisturbed and horizontal, and containing many bowlders, which reach large size. These bowlders are often striated and are chiefly mica-diorite, generally very coarse, although some are porphyritic, and there is a dense andesitic or basaltic lava, containing feldspar phenocrysts. At the coast the bluffs are from 40 to 60 feet high, but farther up the river they shrink to 20 feet, and then increase again to the same height as those of the coast. In places there are well-marked terraces about half way up to the tops of the bluffs, which are level.

At the upper end of the river, where it leaves the lake, there is no rock ridge, but only the same stratified drift as farther down. Just above, however, on both sides of the lake, the first hills appear out of the general flat, and these soon increase in height farther inland, until at the upper end of the lake the mountains rise steeply from a long narrow arm of water. These mountains are distinctly terraced to a height of at least 1,000 feet; and the lowest terraces, which are not more than 100 feet above the lake, are almost perfectly fresh, with quite unmodified sea cliffs, and talus at the bottom.

The rocks on the lower lake are evidently mainly igneous, as only such are found in the drift bowlders which line the shores. Some 10 miles from the outlet of the lake, on the left side going up, the immediate country rock is an andesite, although a coarse syenite occurs near by. On the opposite side of the lake, some 10 miles farther up, is a large body of pyritiferous hornblende-granite. A few miles east of this, on the same side, at the first great bend, the mountain is composed of fine-grained dark-green columnar-jointed andesite. From here up to the head of the lake, at Savonoski, the mountains on the left side seem igneous, while those on the right are of nearly horizontally stratified rock which has the appearance of sandstone. These last mountains are high, jagged, and snow covered. They are deeply eroded, with V-shaped valleys, and no signs of glaciation. On the beach below Savonoski, at the camp of October 12, the rock is green sandstone or arkose, containing Jurassic fossils.

FROM NAKNEK LAKE TO KATMAI.

The first 15 miles of the trail from Savonoski to Katmai lies through swampy flats in the broad valley which forms a continuation of the lake. Afterwards a series of rises over slight benches bring one to a larger plateau valley, which, however, is level and generally swampy. The trail lies along this until near the pass, where the plateau valley and the deeper valley of the stream come together. The mountains on both sides have well-marked horizontal benches, up to 1,000 feet at least.

At the first rock bluff above Savonoski, where the trail leaves the flats, is an outcrop of dark-green granitic arkose, with nearly horizontal stratification. The rock of the sharply eroded mountains on both sides nearly as far as the pass is of the same horizontal bare green strata, which, by fragments included in the drift of the valley, are shown to be green arkoses and limestones. Jurassic fossils are found abundantly in these. Near the summit of the range is a continuous chain of volcanic peaks, some with the sides more or less furrowed by drainage, others smooth and perfect. Against one of these volcanoes the horizontal rocks are turned up, this being the only folding observed anywhere. Along the axis of the mountains are large and well-developed glaciers, especially on the sides of a tall volcano which stands directly at the head of the valley up which the trail runs. Here the glaciers are many and distinct and have splendid moraines. The main valley is filled with horizontally stratified sand, in which are great angular bowlders, which are also beautifully arranged in layers. This deposit has a generally level top, but there are many sharp hillocks formed of bunches of huge bowlders. The streams have cut deep channels through this.

On each side of the chain of volcanoes which form the axis of the range the stratified rocks dip away very gently and are slightly undulating. On the Katmai side of the divide the green fossiliferous rock has perfect crystals of mica in it, giving it an igneous appearance. These have probably developed as a consequence of metamorphism.

The pass lies between two volcanoes, the one on the right having a cone scarcely modified by erosion, while that on the left is somewhat furrowed, but carries no glaciers. Below the pass, on the Katmai side, streams of very hot water burst out of the ground in many places and, joining together, form a considerable rapid stream. This water contains much sulphureted hydrogen and makes copious precipitates of iron and sulphur, so that the earth through which it oozes is colored a brilliant yellowish red.

The valleys of the streams which drain both sides of the pass are deeply excavated, especially that on the northwestern side, which has cut down at least 100 feet through lava bowlders. Owing to the excessive frost action the whole surface of the volcanoes is covered thickly with these large bowlders. On the northwestern side, near the summit, a lake half a mile long is dammed in by the débris from three volcanoes which rise above it. On the sea side of the pass no glaciers or glacial phenomena on a large scale were observed. On this side are broad benches of great height, the material of which is rolled bowlders from the mountains above; on the surface the frost has cleaved these bowlders into jagged fragments.

From the mountain sides below the pass one looks down upon a broad valley with a flat several miles wide, mostly covered with bare gravel, giving the appearance from a distance of an arm of the sea, and through this flat the Katmai River runs in many channels.

At the coast in the vicinity of Katmai and for some miles inland are green arkoses, fine grained and granitic; there are also beds of conglomerate containing granite pebbles. The rocks in general are horizontal, although at the point which bounds Katmai Bay to the east they are uptilted on the sea side so as to dip very slightly to the northwest. There is also a system of nearly vertical fractures, and some slight faulting, but no folding. Along some of the seams are calcite veins. The rocks at this point are at the bottom hard and massive, dark gray, granitic arkose; above this comes massive andesite, probably a flow; while higher up are arkoses and conglomerates. About 200 feet above the base of the cliffs the arkose becomes nearly white and is found to be made up of coarse granitic fragments. Jurassic fossils are found in these rocks at various points, in gray, compact limestone, which evidently comes from the upper part of the dark-gray grits that underlie the white arkoses, and also from the white arkose itself; indistinct plant remains are also frequent. The entire thickness of the horizontally stratified rocks exposed in the mountains near here is at least 1,500 feet. At Katmai Point a large dike of volcanic rock has burst through the grits.

CLASSIFICATION OF SEDIMENTARY ROCKS.

METHODS OF CLASSIFICATION.

Considering the various rocks which have been observed in the field, and which have previously been described without attempt at classification, merely according to the desultory method of observation, certain natural divisions suggest themselves. For a considerable distance, for example, rocks may be gone over which, however diverse in character, yet are so complex that they can not be separated into different parts, while farther on a similar complex series may have certain constant characteristics which distinguish it from the first series, although, like the first, it may consist within itself of totally different rocks. These primary distinctions between two complex rock series constitute the first natural step in classification. In the absence of full and definite information every isolated fact must be utilized as a help in reasoning out the true order of things. Broad and general divisions are all that are possible. In some cases, where a considerable thickness of rocks is distinguished by constant lithologic peculiarities from an adjoining series, this peculiarity is used as a basis of distinction, although it may be that in both series many rocks could be found which are identical in structure and composition. The relative age of rocks is of the highest importance as a means of dividing them, and where no fossil evidence exists other criteria are welcome. The criterion of superposition is important, resting upon the accepted fact that when a series of rocks rests stratigraphically upon another series it is the younger of the two. The criterion of comparative amount of movement in the earth's crust is also used, by which those rocks which show in a marked degree more folding, faulting, and crushing than others which lie in the same area are deemed to be the older. Allied with this are the criteria of internal metamorphism and general alteration, by which those rocks which have been internally altered and decomposed to a marked degree throughout, or have recrystallized, are deemed to be older than rocks in the same area which have suffered less from these processes. In such work as a geologic reconnaissance of Alaska, divisions must sometimes be made on a very small amount of evidence, which must be very nicely weighed.

Such divisions will now be attempted in the rocks of the Kuskokwim and adjacent districts, along the line of travel followed by the expedition. So far as possible the limits of each rock series will be defined and its general characteristics stated; its relative age and therefore its proper position in the geologic column will also be stated or suggested. After these divisions have been made an attempt to correlate them, so that the different series found in different areas will fall into general systems, will be made, and so far as possible these systems will be directly correlated with the established major divisions of geologic time.

A word as to the nomenclature is in place here: The different terms used to designate large and small divisions of stratified rocks, such as group, system, series, formation, beds, stage, assize, etc., have been very loosely established and scarcely any two authorities can be found who agree even in the main points. To take a single example, the word formation is used by Geikie[1] as synonomous with the word series. Dana[2] considers that "any group in the series of stratified rocks, whether large or small, may be called a formation if the parts are related in period or time of origin." Le Conte[3] describes a for-

[1] Text Book of Geology, London, 1893, p. 678.
[2] Text Book of Geology, 1895, p. 90.
[3] Elements of Geology, 1891, p. 181.

mation as "a group of strata conformable throughout and containing a continuous record and separated from other conformable groups by a line of unconformity." Finally, Van Hise[1] defines a formation as a "lithological subdivision of a series."

Such being the uncertainty in nomenclature, it is proper to define terms before using them. In the following descriptions, therefore, the word group will be excluded, since its use as recommended by the International Geological Congress at Bologna, and its commonly accepted English use as defined by Geikie[2] differ so widely. The words stratum, formation, series, and system will then be used, as a set of terms each one of which is made up of two or more of the one preceding it in the order named. Concerning the word stratum there is very little uncertainty. The word formation is used to refer to a definite and persistent set of strata, which are characterized by the same lithologic peculiarities throughout. The term beds is in a general way used as synonymous with formation, and in this case the formation is made up of different rocks interstratified, such as, for example, a series of interstratified clays, sands, and gravels, or limestones, sandstones, and shales. Where the formation is of one uniform rock throughout, the name of this rock may be substituted in place of the word formation; thus, the term sandstone, conglomerate, shale, etc., preceded by a proper name has the same value as the word formation. The next most important division is indicated by the word series, which may consist of many formations. although it is often not possible to differentiate them. Finally, the word system includes in a general classification many series which may or may not be lithologically similar and may or may not be exact chronological equivalents, but which at least have a very close correspondence in point of relative age. In the classification of the systems, therefore, the first definite attempt is made to correlate these Alaskan sedimentary rocks with those of the rest of the world.

PRE-TERTIARY SEDIMENTARY ROCKS.

SKWENTNA SERIES.

Distribution.—The rocks which will be grouped under the name of the Skwentna series are first encountered on the Skwentna some 10 or 15 miles above the junction with the Yentna, at the first canyon where the river cuts through the extension of a rocky ridge which in general stands above the plateau, and has been named the Shell Hills. In this canyon there is a continuous cut of rock, but above and below are only sand and gravel deposits. The next point where these rocks are actually met with in outcrop is in the foothills of the Tordrillo Mountains, on the right side of the Skwentna, some miles below the mouth

[1] Correlation papers, Archean and Algonkian, Bull. U.S. Geol. Survey No. 86, p. 175. [2] Ibid.

of Hayes River. For an area which extends several miles back from the river and a number of miles parallel to it these rocks were found continuously. Farther up the river, just above the entrance of Hayes River, is another outcrop, at the point where the spur of the mountain which lies on the left side of Hayes River juts out into the Skwentna; and from this point, at intervals along the right bank as far as the entrance to the second canyon, rocks of the same general character occur. From the entrance of the second canyon, just below the camp of June 21, there is an almost unbroken series of outcrops through the second canyon, along the narrow mountain valley which lies between the second canyon and the third canyon, and through the third canyon as far as the camp of June 26, or near the mouth of Happy River. Along this portion of the Skwentna, from the entrance to the second canyon to Happy River, the mountains on both sides are evidently made up of the same rocks that outcrop on the stream. At about the mouth of Happy River the rocks of this series are succeeded by others which will be classified under the name of the Tordrillo series.

Lithology.—At the first canyon, where the river cuts through the Shell Hills, the nearly perpendicular walls are composed of a dark blue, apparently flinty rock, which is sometimes fine grained and slaty. No idea of the actual nature of the rock was obtained in the field, but under the microscope it proves to be a somewhat devitrified basaltic glass. At the locality below the mouth of Hayes River the rocks are all remarkably alike in appearance, being fine grained in texture and with a general greenish color, giving the impression of considerable age. In this case also the microscope is necessary to determine the real nature of the rocks, and they are then found to be a series of volcanic rocks, apparently interbedded with tuffs which have been derived from them. Among the types which have been distinguished are hornblende basalt, basaltic tuff, probable andesitic tuff, trachyte, and chloritic and feldspathic slate, which is probably also an extremely fine-grained tuff. At the locality above Hayes River the rock is fine grained, massive, and dark green in color, and at first suggests a fine-grained igneous rock; however, microscopic observation shows that the rock is a fine-grained granitic arkose.

In this place it may be well to define the term "arkose" as here used. It designates sedimentary rocks which are plainly derived from the destruction of igneous rocks which can not be shown to be volcanic flows. Sedimentary rocks whose composition shows that they are derived from the destruction of granites, diorites, etc., are therefore arkoses, while rocks derived from the destruction of basalts or trachytes are classified as tuffs. It follows from this definition that arkoses always contain a considerable proportion of feldspar, and in addition generally quartz and the darker colored rock-making ferruginous minerals or secondary minerals derived from the alteration of these. The word "arkose" has been defined by Kemp as "a sandstone rich in feldspar fragments," which conforms to the present definition so far as composition goes, while the present definition includes besides an idea of the origin. Sedimentary rocks of this sort are extremely common and important, but the words used to designate them have been of loose and vague significance. The word "graywacke" has been sometimes used, but Kemp defines this term as "chiefly applied to metamorphosed shaly sandstones that yield a tough, irregularly breaking rock, different from slate on the one hand and from quartzite on the other."[1] The word "grit" has also been often used, and indeed has chiefly been employed by the writer hitherto, with this significance. This is actually nearer the proper term than "graywacke," but as defined by Kemp,[2] and as often used, it implies simply a coarse sandstone.

Returning to our description of the lithology of the rocks of the Skwentna series, the outcrops in the second canyon above Hayes River come to notice next. Here the rocks are of nearly uniform appearance, of greenish color, and much decomposed. In many places the rock appears like a conglomerate and in others is like sandstone, but on examination both of these appearances are seen to be due to processes of weathering, and it is found that the rock in its fresher condition is really massive or heavily bedded. Rocks of the same appearance occur all the way to Happy River, being generally dense and aphanitic in texture and dark green or gray in color. In some specimens evident phenocrysts may be seen, showing the rock to be volcanic, while in others there is a definite bedding or slaty structure. All of these rocks, however, are only to be properly differentiated by the aid of the microscope. It is then found that they are, as before stated, a series of ancient and somewhat altered volcanics interstratified with tuffs. Besides these volcanic rocks there is sometimes carbonaceous chert and beds of arkose whose minerals show an evident derivation from granite and sometimes plainly from hornblende-granite. Among the volcanic rocks basalt and trachyte have been identified, and possible rhyolite; the tuffs are andesitic or basaltic and grade into slates.

Folding and faulting.—At the first canyon there is no evident bedding, although prominent division lines, which may be stratification, trend N. 33° W., and dip 15° SE. In the massive rocks below Hayes River also there is no evident attitude, although in one place a prominent parting was noticed which was nearly horizontal. From the beginning of the second canyon to the mouth of Happy River the attitude of the rocks is continually observable, however, and for a long distance the strike is true north to south, while the dip varies from east to west, but is west generally at high angles, showing a con-

[1] Handbook of Rocks, New York, 1896, p. 140. [2] Ibid.

siderable amount of folding. On the mountains on both sides of the stream the same attitude of rocks may be observed. Near the mouth of Happy River the strike swings around to northeast and the dip changes to northwest, and the rocks of the Skwentna series thus dip under the rocks farther up the river, which belong to the Tordrillo series.

Dikes and quartz veins.—The only intrusive rocks observed in the Skwentna rocks are in the third canyon just below the mouth of Happy River, where the ancient volcanics and tuffs are cut by numerous dikes of all sizes. These dikes will be described more in detail later, but are essentially dioritic, with some syenite and granite. Intimately associated with the dikes are narrow quartz veins, which sometimes become several inches wide, and which contain pyrite, chalcopyrite, galena, and sometimes hornblende. Near these dikes and veins is a small amount of gold and silver in the rock. Farther down the stream, at the camp of June 23, small gash veins were also found, which were composed sometimes of calcite and sometimes of quartz, the quartz being rusty and the calcite containing copper pyrite.

Definition of Skwentna series.—The Skwentna series may then be defined as a series of volcanic rocks interstratified with tuffs and derived slates and with some arkoses. The degree of alteration in the volcanic rocks indicates of itself a considerable age for the series. All of these rocks have been highly folded, and in localities near the axis of the Tordrillo Mountains they have been cut by dikes and have undergone some mineralization.

Conditions of formation.—The Skwentna series was thus evidently formed at a period of volcanic activity, probably along the shore line, which was marked by a chain of volcanoes, for the interstratified tuffs were probably water-laid and the lavas themselves may have been poured out under the water, or if poured out on land must have been periodically depressed to receive the coverings of sediment. At the same time a part of the adjacent land mass must have consisted of granite (in part hornblende-granite), as is indicated by the coarse and fine arkoses.

Relative age of Skwentna series.—The rocks of the Skwentna series near the mouth of Happy River dip under rocks which will be described as the Tordrillo series, and lie in apparent conformity to these. They are therefore the older of the two series. The Skwentna rocks are cut by dikes, which are evidently branches of the main igneous intrusion which furnished the rock forming the backbone of the Tordrillo Mountains.

TORDRILLO SERIES.

Distribution.—Near the junction of the Skwentna with Happy River the rocks classified under the head of the Tordrillo series were first noted. These rocks also lie in the Lower Happy River Valley so far as explored, and apparently in the mountains lying to the north of this valley. The same series is found along the Skwentna from the mouth of Happy River to the mouth of Portage Creek in numerous outcrops. On both sides of the upper part of Portage Creek the mountains are nearly bare and consist of rocks of the same series. The sequence of outcrops is interrupted at the beginning of the trail from upper Portage Creek over the pass by the central igneous mass which constitutes the actual ridge. On the west side of the pass the same series again appears, however, and was continuously followed down Ptarmigan Valley and through the gap where the Kuskokwim waters cut through the Teocalli Range. The Teocalli Mountains themselves are all composed of rocks of this series. The boundary between these rocks and others to the west, which will be classified under a separate name, that of the Terra Cotta series, appears to lie in the Kuskokwim Valley, between the Teocalli and the Terra Cotta Mountains. The last outcrops of the Tordrillo series, therefore, are seen where the river turns a little to the northwest and proceeds to cut across the Terra Cotta Mountains preliminary to debouching upon the plain.

Lithology.—The rocks of the Tordrillo series are purely sedimentary, without admixture of volcanic material. The boundary between the Skwentna series and the Tordrillo series at the mouth of Happy River is strongly marked, for here the greenish massive lavas and tuffs of the Skwentna series change suddenly to a thick series of black shales. From here to the mouth of Portage Creek the black shales are continually found, intercalated with layers of sandstone, impure limestone, and granitic arkose. As one goes upstream the amount of arkose and limestone seems to increase. Both shales and arkoses often contain obscure plant remains, and some of the shale is so carbonaceous that it resembles coal, although it does not burn well.

On the upper part of Portage Creek Valley the dip is constantly north, so that the mountains north of the valley are composed of rocks which in general overlie those on the mountains to the south. The higher rocks on the north side have a greater amount of sandstone, which occurs in heavy beds, while those to the south are more shaly. In the upper horizons on the north side also plant remains are not so common.

Near the contact of the central body of igneous rock the rocks of the Tordrillo series become noticeably altered, the chief effect being silicification and hardening, so that shales, sandstones, and limestones become slates, quartzites, and jasperoids. On the western side of the pass the same effects of metamorphism are noticed near the contact, and in some of the stratified rocks a micaceous mineral has been developed. A microscopic examination of some of the arkoses in this series show, that they, too, are evidently derived from the destruction of granite.

Folding.—At the mouth of Happy River and at the contact with the Skwentna series the general strike of the beds is northeast or east-northeast and the dip is northwest. The attitude of the rocks over the area between here and the summit of the Tordrillo Mountains, and laterally to the mountains on the north and on the south, shows many broad folds, one set of folds apparently striking east and west, with a general dip north, while the other set strikes north to south, with a general dip west. As a rule, however, the whole series seems to have a general northeast strike, which results as a compromise between the two sets of folding, and a general northwest dip. There is no close folding, so far as observed, on the eastern side of the mountains, the stratified rocks near the contact with the intrusive mass being broadly folded but not contorted, and the folding having no evident relation to the intrusion.

On the western side of the mountains the stratified rocks show at first no close folding, having an east-west strike and a northerly dip not exceeding 40°. Farther away from the contact the strike changes gradually until it becomes north to south, and at this point there is a definite zone of close folding, following the general trend of the axis of the mountains. Within this zone the beds have been crumpled and locally overturned (see fig. 7). Farther west this zone of close folding soon fades out into the more general folds characteristic of the region. Ptarmigan Valley seems to be a strike valley, running along an anticlinal fold, while the Teocalli Mountains are evidently synclinal. On the western side of the Teocalli Mountains the strike is constantly true north-south, and the dip always east at angles varying from 25° to 65°. This general north-south strike prevails in the Tordrillo series west of the axis of the Tordrillo Mountains. West of the Teocalli Mountains the rocks of the Tordrillo series overlie the rocks of the Terra Cotta series, which will be described later.

Dikes and veins.—All the way from the mouth of Happy River to the mouth of Portage Creek, along the Skwentna, large dikes are frequently found cutting the rocks of the Tordrillo series, and associated with them are veins of quartz which carry much pyrite and chalcopyrite and some galena. Most of the country lying between the valleys of Happy River and the Skwentna, below Portage Creek, is made up of a dark-green igneous rock, which is basaltic, and may be a dike or an ancient flow. Along the upper part of Portage Creek Valley dikes are very common and are of all sizes. The general trend of the intrusive bodies is north and south, with a very steep dip, although small bodies occur as intercalated sheets in the stratified rock. The axis of the range is composed of a heavy dike of coarse igneous rock, which forms Cathedral Mountain (the peak guarding the pass on the south side) and the other very high mountains along the crest of the ridge. As this main mass of intrusive rock is approached the smaller dikes become progressively more numerous, and the quartz veins, which are frequently found at the contact of dikes and stratified rocks and sometimes within the dikes themselves, are more frequently met. Near the contact these quartz veins often contain considerable pyrite. Substantially the same phenomena were observed in the stratified rocks near the contact on the western side of the pass. West of the pass dikes in general are comparatively rare as far as the Terra Cotta Mountains. In the slates which compose the Teocalli Mountains, however, especially as exposed where the river cuts through these mountains just above Hartman River, are great numbers of quartz veins, nearly all of which contain siderite and ankerite, small quantities of galena, and copper stains. Below Hartman River, on the right side of the Kuskokwim Valley, the Teocalli Mountains contain frequent dikes and sheets of igneous rock, which apparently are the offshoots of the larger and more numerous masses of the Terra Cotta Mountains on the left side of the valley.

The dikes of the Tordrillo series will be considered a little more in detail, petrographically, later on. They show a considerable variation in composition and structure, ranging from acid aplites (or, as they will be termed later, alaskites) to gabbros or diabases. Within the range from alaskite to gabbro are found biotite, granite, augite-soda-syenite, mica-syenite, hornblende-biotite-syenite, biotite-dacite, diorite, diabase, and olivene-diabase or gabbro. Structurally, also, the rocks vary from porphyritic, with finely crystalline or at times aphanitic groundmass, through the coarse granular forms, to idiomorphic or aplitic structures.

Definition and relative age of Tordrillo series.—The Tordrillo series consists of a considerable thickness of black shales, which are often carbonaceous. Intercalated with these shales are numerous beds of sandstone, arkose, and impure limestones. In the upper part of the series the sandstone seems to become predominant. Throughout the rocks are imperfect plant remains. All of the rocks have been highly folded or cut through by great masses of intrusive material. The appearance of the rocks suggests a younger age than those of the Skwentna series, which, moreover, they are seen to overlie on the east side. On the western side of the Tordrillo Mountains they overlie the rocks of the Terra Cotta series.

TERRA COTTA SERIES.

Distribution.—All of those sedimentary rocks which lie to the west of the rocks of the Tordrillo series, as above defined, beginning at a point midway between the camps of July 24 and July 25, where the Kuskokwim turns and runs to the northwest, as far as the camp of July 26, where the rocks are covered by a thick mantle of gravel which constitutes the plateau fronting the mountains, are classified under the name Terra Cotta series. In this comparatively short distance outcrops are frequent.

Lithology.—The stratified rocks of the Terra Cotta Mountains, as exposed in places along the stream, are composed of impure limestones, slates, arkoses, and dark-green fine-grained igneous rocks. They are distinguished in appearance from the rocks of the Teocalli series by a distinctly heavier bedding and by a certain altered and greenish appearance which seems to indicate a greater age. In general appearance they strongly suggest the rocks of the Skwentna series, and, indeed, it is believed that the two series may be of the same age, although they are here, for purposes of caution, classified separately. In the weathering outcrops of the Terra Cotta Mountains the stratified rocks, as well as the igneous, assume bright red and yellow colors, which seems to be due, in the former case, to the heterogeneous materials of which the rocks are made up. The rocks of the Tordrillo series in the Teocalli Mountains, on the other side of the valley, have a generally plain dark red or nearly black color, forming a decided contrast.

As is the case in the Skwentna series, the use of the microscope is needed to determine accurately many of these rocks. They are then found to be mainly sedimentary, consisting of fine-grained, often carbonaceous limestone, siliceous limestone, carrying grains of detrital quartz, shale which is often carbonaceous and often contains coarser detrital material, granitic or dioritic arkose, fine-grained conglomerate with chert pebbles, and a fine-grained basaltic diabase which is probably an interbedded rock contemporaneous in origin with the sedimentaries mentioned, although it may possibly be a later intrusion.

Folding.—The rocks of the Terra Cotta series are considerably and often confusedly folded, the folds being broken and complicated by the intrusive rocks. In general, however, the north-south strike of the Teocalli Mountains swings around to the northeast and locally is nearly east; the general strike, however, is northeast. The general dip from the contact with the Tordrillo series to below the camp of July 25 is southeast, while in the outcrops which are found above the camp of July 26, along the front range of foothills, the dip is constantly northwest. These characteristics of strike and dip seem to be continuous for some distance in the mountains on both sides of the river, so that a definite anticlinal fold in the Terra Cotta rocks is observed, the axis of this fold trending parallel with the front range of foothills and the southeastern limb of the fold dipping down under the Tordrillo rocks.

Dikes and veins.—The Terra Cotta Mountains, immediately to the west of the chief north-and-south shoot of the river, are cut through by a complex of dikes and sheets of igneous rock. The weathering of these dikes tends much to give to the mountains the general curious red, orange, or yellow color. Along the main ridge about half of the entire mass seems to be made up of intrusive rock. These intrusions evidently follow a definite zone, however, for when the river turns to the northwest and cuts through the mountains toward the foothills the dikes become rapidly less, and disappear almost entirely before the last range of foothills is reached. Associated with the dikes are occasional quartz and calcite veins.

So far as collected and studied the dikes of the Terra Cotta series all belong to siliceous varieties, which accounts for the bright colors on weathering. Typical alaskite is extremely common, which grades through rhyolite-porphyry and granite-porphyry to biotite and hornblende-granite, often with aplitic structure; finally much syenite is found, generally porphyritic.

Definition and relative age of Terra Cotta series.—The Terra Cotta series may be defined as a series of heavy-bedded, impure limestones, slates, and arkoses, with probably some volcanic rocks, which have been heavily folded, and which have been cut through by masses of intrusive rock. The rocks of this series underlie with apparent conformability the rocks of the Tordrillo series (see map No. 12).

TACHATNA SERIES.

Distribution.—The first rock outcrop on the Kuskokwim, below the point where it emerges from the Tordrillo Mountains, is some distance below the junction of the Kuskokwim with the East Fork. This locality is the farthest east of those which have been classified as the Tachatna series. From this point down to the junction of the Tachatna the river frequently cuts rock outcrops, generally on its right bank, and also from the Tachatna to a point immediately below Vinasale, which is the limit of the Tachatna series, rocks classified under the head of the Holiknuk series succeeding.

Lithology.—The first outcrop of the Tachatna series, above mentioned, is of much decomposed clayey limestone and slate carrying quartz veins. Two miles farther down is a heavy-bedded light-gray limestone, which contains many calcite veins and is highly fossiliferous; still farther down is found black limy shale intercalated with arkose, which weathers dark red. The same general characters persist as far as the line of division between the Tachatna series and the Holiknuk series, the rocks usually consisting of a limy shale or an impure limestone, which often contains sedimentary material.

Examined microscopically, no new features are developed in regard to the lithology. The limestone is very often pure, but in some cases contains particles of chemically precipitated quartz which are disseminated through it; again, small areas are taken up by chert or cryptocrystalline silica. Some of the slates are carbonaceous, others chloritic. The arkose layers are sometimes fine, sometimes coarse, and in the latter case often evidently granitic, being made up of quartz, orthoclase, plagioclase, and various ferruginous minerals evidently derived from the alteration of others.

Folding.—At the first outcrop below the junction of the two branches of the Kuskokwim the rock strikes northeast and dips southeast at a slight angle. This northeast strike and southeast dip persists for a number of miles, and then changes to a general northwesterly strike and a southwesterly dip as far as the point where the Kuskokwim turns and begins to flow toward the south. From this point as far as the boundary line between the Tachatna series and the Holiknuk series the strike continues northwest (nearly west), and the dip varies, being generally, however, north at angles not exceeding 45°. In addition to the usual attitudes of the rocks, as just stated, there is continual folding, so that the dips are often locally reversed, and in some cases the rocks stand vertical. The folding, however, is rarely close.

Dikes and veins.—Below Vinasale the rocks of the Tachatna series are cut by occasional porphyritic dike rocks, all being apparently of nearly the same variety. A specimen from one proves to be a granite-porphyry. Except in this neighborhood no dikes were observed in the series. Throughout the series, however, there are continual small quartz veins, although never in great abundance; these veins contain pyrite, but could not be shown to be auriferous.

Definition of Tachatna series.—The Tachatna series may be defined as a series of gray limestones (generally thin bedded and fissile), limy, carbonaceous, and chloritic slates, and occasional generally fine-grained arkoses. These rocks have been considerably folded, contain frequent quartz veins, and in general give the impression of considerable age. In one district they are cut by granitic dikes.

Relative age of Tachatna series.—At a point on the Kuskokwim some 5 miles below the camp of July 29, just above the point where the river turns and begins its southward journey, abundant fossils were found in a light-gray limestone, which strongly resembles the limestone bed in the Tahkandit series of the Yukon, from which Carboniferous fossils were collected in 1896. Mr. C. H. Schuchert, of the United States National Museum, has examined these fossils and has found that they indicate a probable Middle Devonian age. The following is from Mr. Schuchert's letter:

The material submitted consists of a blackish weather-worn limestone, containing corals. Of these there are the following:

Favosites, much like *F. billingsi* of the Hamilton formation.

Favosites, with smaller corallites. It may, however, be but a variation of the one mentioned above.

Alveolites, with very small corallites.

Striatopora, sp. undet.

Crepidophyllum?

Stromatoporoids, two species, one having a globular and the other a ramose mode of growth.

There are no corals in this fauna pointing unmistakably to the Silurian (Upper), and since there is nothing present to disprove a Middle Devonian aspect I assume that to be the age.

The only other Devonian locality known to me in Alaska is Kuiu Island, Saginaw Bay, in southern Alaska, south of Sitka (see Seventeenth Ann. Rept. U. S. Geol. Survey, pp. 900 and 902). The fossils from Cape Lisburn in North Alaska are also all corals and appear to indicate the Upper Silurian, but there is also a possibility of their being Devonian. The few fossils gathered last summer by Mr. Brooks may also be Devonian.

Between the Tachatna series and the succeeding Holiknuk series there is evidently an unconformity, indicated by the discordance in the attitude of the beds. The Holiknuk series is evidently the younger, and its lowest member is a conglomerate which rests directly upon the Tachatna rocks. The Holiknuk series will presently be shown to be probably Cretaceous.

HOLIKNUK SERIES.

Distribution.—At a point some 10 miles below Vinasale conglomerates and arkoses, which are taken as the base of the Holiknuk series, outcrop. From this point there are frequent outcrops along the river as far as Kolmakof, at which point the boundary between the Holiknuk series and the Kolmakof series has been chosen. The river here flews for the most part in a definite rock-cut valley, so that the only interruptions in the section are occasional local silt deposits.

Lithology.—As before mentioned, the basal bed of the Holiknuk series consists of conglomerates and arkoses which are quite different from the shaly limestones of the Tachatna series farther up the river, having a comparatively fresh appearance. The pebbles in the conglomerate are sometimes 5 or 6 inches in diameter, and are mostly of black or dark-gray siliceous limestone or limy shale, evidently derived from the Tachatna series. From this point all of the way to the Holiknuk the rocks are generally uniform in appearance, being composed of granitic arkose and sandstone alternating with carbonaceous shale, the arkose or sandstone often passing into the shale laterally within the limit of a single cliff. Plant remains are common in both shales and arkoses. At the junction of the Kuskokwim with the Holiknuk the rock becomes more limy, with not quite so much arkose, but contain similar plant remains. Below the Holiknuk rocks of the same character are found, but they grow continually more sandy and contain frequent beds of coarse granitic arkose. On the right bank of the river, for some distance above Kolmakof, the same series of shales, sandy limestones, and arkoses show frequent plant remains, also ripple marks and all other kinds of shore markings.

Folding.—The basal bed of conglomerate has a northwest strike and a dip of about 45° SW. From here about halfway to the Chagavenapuk the general strike is northwest, while the dip varies constantly from northeast to southwest with the folding in the rocks, which is constant, but never close. The folding in general is greatest at the first point where the series is encountered, and grows less farther down the river, the folds becoming more and more gentle. At a point about halfway between Vinasale and the Chagavenapuk River the strike changes to true north to south in general, so that the river flows along the strike, while the dip, as before, varies. From the Chagavenapuk to the Holiknuk, where the course of the river changes, the strike of the rocks is also found to change, becoming constantly northeast and parallel with the trend of the river. Along here the general dip is northwest at slight angles. From the Holiknuk to the Yukwonilnuk River the strike of the rocks again changes, in general conforming with the northwest shoot of the Kuskokwim. The series is here, however, more highly folded than higher up the river, so that deviations are numerous; the dip, as before, varies greatly. Where the northwest shoot of the river gives place to a southwest shoot above the Yukwonilnuk the strike of the rocks remains the same, so that the river cuts directly across it, and this seems to be true in general as far as Kolmakof.

Dikes and veins.—The rocks between Vinasale and the Holiknuk are practically free from dikes. Just below the Holiknuk are heavy intrusive bodies of siliceous porphyritic rock, which cut across the bedding of the sedimentaries or run parallel to it in heavy sheets. Like the intrusive rocks of the Terra Cotta Mountains, these dikes weather a brilliant orange color, and owing to concentric weathering the colors are often arranged in curves. From here all the way to Kolmakof the sedimentary rocks are cut frequently by similar siliceous dikes. The Yukwonilnuk River brings down a great variety of igneous rocks, which makes it seem probable that its course lies in mountains which are largely made up of these.

Examined microscopically, it is found that the dike rocks are all members of a decidedly siliceous series. Beginning with a peculiar quartz-scapolite-porphyry, which will be described later on, the series runs through many varieties of granitic rocks, which make up most of the specimens, the varieties being always porphyritic and generally having a granular groundmass. Finally isolated specimens of garnetiferous biotite-syenite and aleutite[1] were observed. In the vicinity of the dikes the sedimentary rocks are hardened for a few feet, so that they are more resistant, and near these contacts are occasionally small

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[1] See p. 190.

veins of quartz or calcite; as a whole, however, the whole series is free from veins.

Definition of Holiknuk series.—The Holiknuk series is a series of alternating beds of sandstone, argillaceous or siliceous limestone, shale, and arkose, which are everywhere bent into open folds. The basal bed of the series is a conglomerate containing pebbles apparently derived from the Tachatna series. Throughout all of the rocks are frequent obscure plant remains, and in many places, especially above Kolmakof, are indisputable evidences of a shore formation in the presence of ripple marks and other shore marks. The series is well separated from the Tachatna series by unconformity, lithology, and generally younger appearance, while the division between it and the succeeding Kolmakof series is based on the presence of volcanic materials in the rocks of the later series.

Relative age of Holiknuk series.—It has been mentioned that the Holiknuk series overlies uncomformably the Tachatna series, in which have been found fossils indicating a Middle Devonian age. In the Holiknuk series itself fossil remains, though frequent, are generally too imperfect to admit of identification. At a locality about half way between the Chagavenapuk and Vinasale a small specimen containing imperfect plant remains was collected, which Dr. F. H. Knowlton, of the National Museum, pronounces to contain a fragment of a dicotyledonous leaf, indicating an age presumably later than the Jurassic. Midway between the Yukwonilnuk River and the camp of August 5, the limestone contains abundant remains of Inoceramus, and the same fossils occur a short distance above Kolmakof associated with the ripple-marked shales and shaly limestones. These fossils were submitted to Dr. T. W. Stanton, of the United States National Museum, who made the following comment:

> Localities 11 and 13 yielded only fragments of Inoceramus too imperfect to determine whether more than one species is represented. The genus Inoceramus begins in the Trias and continues to the end of the Cretaceous, being most abundant in the latter. So far as can be judged from the very imperfect material the fragments in this collection probably belong to a Cretaceous species.

KOLMAKOF SERIES.

Distribution.—The Kolmakof series outcrops frequently all along the right bank of the Kuskokwim, between Kolmakof and the beginning of the low silt plain just above the entrance to the Yukon portage route above Kalchagamut. For all this distance there are no outcrops on the left side of the river.

Lithology.—The first outcrop below Kolmakof on the right side of the river is nearly black in color and proves to be made up mainly of andesite, although apparently interstratified with some beds of arkose or shale; these latter beds contain abundant plant remains and lumps of carbonized wood. The same general exposure, a few miles farther down the river, changes to green arkoses and soft shales, which sometimes show cross bedding and carry plant remains. About 15 miles below the end of this exposure, which is terminated by an expansion of the superficial silts and gravels that form the left bank continuously, the next exposure is composed of various volcanic rocks having an altered and ancient appearance; these vary to coarse and fine tuffs, evidently directly derived from the volcanics. A few miles farther down one of the beds of the same general series proved to be a glauconitic calcareous chert, full of sponge spicules. A number of miles still farther, about 10 miles below the camp of August 6, the river again cuts massive basalt on its right bank. This bluff is continuous along the river for a number of miles. After a few miles it begins to have a fine stratified appearance, and when examined was found to have changed into alternating layers of tuff with shaly beds. From this point nearly to Kalchagamut there are no outcrops, although the hills not far from the river on the right seem to be made up mainly of igneous rocks.

The rocks of the Kolmakof series are sometimes evidently volcanic, but again are so dense and fine grained that they can hardly be distinguished in the field from massive sedimentaries. They have all a general greenish color, such as naturally belongs to ancient and somewhat altered lavas. The microscope is needed to determine their exact nature, and then they are found to comprise dacite, trachyte, andesite, and basalt. The associated tuffs appear to be mainly trachytic, so far as examined. The arkoses are all fine grained.

Folding.—The general strike of the bed rocks below Kolmakof seems to be north to south, while the strata are bent into broad folds having this trend, so that the dip varies from horizontal to vertical and from east to west; the strike also changes considerably, becoming in places as much as east to west.

Dikes and veins.—Both volcanic and sedimentary rocks of the Kolmakof series are cut by many dikes, mostly of a siliceous nature, and in many cases the intrusive rock is nearly equal in amount to the rocks through which it cuts. As a whole, therefore, it may be said that the intrusive rocks, which were very rare in the Tachatna series and in the Holiknuk series above the Holiknuk, become progressively more abundant farther down the river and culminate in the Kolmakof series between Kolmakof and Kalchagamut, which series is also distinguished from the rest by containing within itself such great quantities of bedded volcanic rocks.

When examined microscopically the dike rocks are found to be ordinarily of siliceous varieties, although some are more basic. It is possible that these more basic ones may belong to an earlier period of intrusion and be more connected with the volcanic flows. The most siliceous rock examined was a biotite-granite-porphyry, and other varieties are bostonite, quartz-syenite, hornblende-diorite-porphyry, diabase-porphyry, and basalt.

The rocks of the Kolmakof series do not, in general, contain veins, but in the vicinity of numerous dikes are many small veins and other evidences of alteration. The material of these is generally calcite. About 3 miles below Kolmakof a vein of cinnabar, which is evidently one of the features of mineralization connected with the intrusive rocks, has been discovered and worked on a small scale by a trader, but at a loss.

Definition of Kolmakof series.—The Kolmakof series consists of a series of volcanic rocks of various types, which change laterally into or are interbedded with volcanic tuffs, shales, impure limestones, and fine-grained arkoses. The rocks contain frequent plant remains and are characterized by ripple marks and other evidences of shore formation. They are considerably folded and are cut through by great masses of intrusive rock.

Relative age of Kolmakof series.—The rocks of the Kolmakof series, except those of volcanic origin, are essentially like those of the Holiknuk series, being of the same lithologic variety, containing frequent plant remains, and showing the same ripple marks and other evidences of a shore formation. Just above Kolmakof rocks which have been included in the Holiknuk series carry plant remains and an Inoceramus, which has been determined to be probable Cretaceous. Not far below Kolmakof rocks of similar appearance, which have been referred to the Kolmakof series, also carry many imperfect plant remains, but no fossil shells. The stratigraphic relation of the Kolmakof series to the Holiknuk series could not be determined, but as far as the evidence goes the two may be provisionally considered as essentially contemporaneous in origin, the lithologic difference arising from variations in local conditions.

OKLUNE SERIES.

Distribution.—The first rocks which are classified under the head of the Oklune series are encountered several days' journey up the Kanektok River, at the point where the river merges from the Oklune Mountains upon the plain of gravel and silt which divides these mountains from Kuskokwim Bay. From this point as one goes up the river there are frequent outcrops all of the way to the extreme head. Across the pass which separates the Kanektok waters from the Togiak waters, rocks which have been referred to the same series are found on Togiak Lake and along the Togiak River, although on the Lower Togiak basalts have been found which will be referred to a younger period. These later basalts form a considerable interruption, but on the point just west of Kululuk Bay rocks which are classified with the Oklune series are again encountered, and on the route which was followed from Kululuk Bay to Nushagak Bay, by way of little crooked rivers and lakes, occasional outcrops of rocks were seen, which are also included in the same classification. The easternmost limit of this series as thus discovered lies on the Egoushik River, which drains into Nushagak Bay on the west side. From this point as far as Naknek Lake no solidified rocks were encountered, but only Tertiary and Pleistocene silts, sands, and gravels, which will be described later.

Lithology.—When first encountered on the west side of the Oklune Mountains along the Kanektok River the rocks are sandstones, arkoses, conglomerates, and carbonaceous shales. The conglomerates contain pebbles of quartz and of quartz-feldspar-epidote-schist. A little farther up, at the camp of August 30, gray grit and fine sandstones are found intercalated with black carbonaceous shales. Farther up still, the rocks are predominatingly massive fine-grained arkoses or feldspathic sandstones, with often very slight evidences of stratification. Above the junction of the Klak the rocks are mainly volcanic, with predominating trachyte, although arkoses frequently occur. From the great bend in the river as far as Lake Kagati the rocks are mainly basaltic or other volcanic tuffs, with sandstone, conglomerates, and shales. From Lake Kagati to the pass are mainly volcanic tuffs, alternating with the volcanic rocks themselves, which all have an ancient appearance and are folded in with the tuffs. These ancient lavas are thoroughly altered and are of a general greenish color, so that they are hardly recognizable to the naked eye as volcanic rocks, and, indeed, they resemble closely the ancient volcanics of the other series which have been described, namely, the Kolmakof and the Skwentna series. On the east side of the pass, above Togiak Lake, the mountains consist of volcanic, probably for the most part basaltic, tuffs, which are well folded.

Summing up the bedded rocks of the Oklune series as far east as Togiak Lake, the following may be said: Limestone occurs in thin beds and is sometimes siliceous. In one case it was seen to be made up entirely of sponge spicules and to contain considerable pyrite. Slates of various kinds are common, some calcareous, some chloritic, many siliceous. Arkoses frequently occur, many of which are plainly derived from granite. Others, which are highly feldspathic, do not point unmistakably to any one variety of igneous rock as their source, but some seem to be derived from syenite and diorite. In one arkose, which was a transitional sediment, being made up mainly of calcite, with many grains of quartz and feldspar, there were also found considerable fragments which seemed to be devitrified volcanic glass. Conglomerates are frequent, which carry slaty and cherty pebbles, pebbles of schist, and apparently of granite. One specimen examined was of calcareous flint, which probably has a directly organic origin.

Among the ancient volcanic rocks which are interbedded with these purely sedimentary rocks an augite-trachyte has been distinguished, and in a number of cases basalt, while one specimen seems to be pyroclastic rhyolite. There are also many sediments which are directly derived from these volcanic rocks, and so are classified as tuffs. In many cases the origin of these tuffs is clear, and frequently they can be shown to be basaltic; in other cases the origin can not be determined. Near the pass some of the fine-grained massive rocks which are interbedded in the series were determined to be ancient basalts, while one specimen is petrographically a diabase of very fine grain, although it is undoubtedly part of the same flows.

The mountains on the eastern side of Togiak Lake are composed of tilted, stratified rocks, which appear to be in part slaty; on the opposite side of the lake a large ice-rafted bowlder was found to be composed of basaltic tuff. Proceeding down Togiak River the first outcrop is just above Kashaiagamut, and is a fine-grained dark-gray rock, which the microscope shows to be a volcanic tuff. The stratification here is uncertain, but the rock is broken by vertical jointing and slight shearing, with accompanying slickensides. The same rocks occur several miles farther down, and are here thinner bedded and evidently folded; the shearing is also less. Below this again are a number of outcrops of massive greenish andesite and of stratified tuff, having the same highly folded attitude as the outcrops just mentioned. Above Gechiagamut is a vesicular basalt in the drift, which is not classified with the rocks of the series under consideration, being evidently of later age. The same younger basalt outcrops frequently all of the way along the shore nearly to the entrance of Kululuk Bay, while in the cliffs, just before entering the bay, shaly and impure limestones and arkoses are found, which are highly folded. These rocks are cut through by great masses of basalt, which probably belong to the younger period just referred to. Along the west shore of Kululuk Bay are massive basalts, interbedded at times with coarse basaltic tuffs, and it is uncertain to which of the volcanic series, the older or the younger, these are to be attributed, although they have been provisionally regarded as belonging to the younger rocks. Proceeding along the inland route northeast from Kululuk Bay, the large lake in which the Egoushik River heads has a mountain rising steeply from the northwestern side, which is composed, as shown by many bowlders which come down to the shore of the lake, of a highly feldspathic and ferruginous sediment which may be regarded as a slate or an impure tuff, whose materials are probably volcanic. The same rock outcrops near the outlet of the lake and again at the lower end of the second lake. Here the sedimentary rocks stand at high angles, and are cut by sheets and dikes of basalt, which belong to the younger period of intrusion. About 10 miles below the second lake the river cuts close to some mountains in which the last outcrops of the rocks classified as the Oklune series were seen. The rocks of these mountains are mostly basalt; on the ridge near the camp of September 23 they are mainly basaltic tuff, with sheets of basalt. One bed of this basalt contains many rounded waterworn pebbles of basalt like the matrix, and also of granite-porphyry and other siliceous dike rocks, as well as slate. Beds of granitic arkose are interstratified with the volcanic conglomerate and with the tuff.

Summarizing: The rocks between Togiak Lake and Nushagak Bay are considerably folded and show evidence of belonging to a comparatively ancient period; the following varieties may be enumerated: Shales are very common, being carbonaceous or feldspathic, the feldspathic shales verging on fine-grained tuffs. Chert of probably volcanic origin, often containing detrital grains, is sometimes found. Tuffs are common, being generally basaltic. Among the volcanic rocks themselves, andesite and basalt are found, the latter more commonly. The frequent beds of arkose are sometimes evidently granitic, being made up in one case of grains of quartz and orthoclase, which often occur in micrographic intergrowths, together with striated feldspar, biotite, augite, and chlorite. In another case the arkose seems probably to be from syenite, since it contains no quartz, only orthoclase and plagioclase, with abundant secondary minerals, of which chlorite and muscovite are very important. Finally come the occasional conglomerates, which are both sedimentary and volcanic.

Folding.—All of the rocks classified as the Oklune series are characteristically folded, often highly, although the folds are in general large and open. Where the first outcrops on the Kanektok River, above described, are encountered the strike is persistently northeast and corresponds with the general front of the mountain range. There are along here a number of ridges which are all parallel with the strike of the beds. The river itself flows in a strike valley between two of these northeast and southwest ridges, along its long northeasterly shoot from the front of the mountain range as far as the great bend. At the great bend there is a marked change in the general strike of the rocks from northeast to southeast and in places to due south. The mountain ridges again conform to this change, and the river valley turns abruptly to the south and southeast along the strike. From here as far as the pass between the Kanektok and the Togiak, the main branch of the Kanektok, which was followed, lies in a typical strike valley. In the mountains on the western side of Togiak Lake the strike is still northeast, but on the eastern side it appears to be north to south. It is probable that the valley of Togiak River and Lake, so far as it is a mountain valley, is also conformable to the strike of the rocks, as the attitude just mentioned on the eastern side of the lake indicates. In the chief outcrops on Togiak River the general strike is northwest and the dip northeast, but the outcrops are so few that the general folding can not be made out. The same is the case in the isolated group of outcrops on the western side of the entrance to Kululuk Bay, where the strike is east to west and the dip varies much on account of the folding, although it is generally south at high angles. Neither can anything definite be said of the structure of the rocks which have been classified under this series between Kululuk Bay and Nushagak Bay, for although they are seen in places to be steeply dipping and therefore considerably folded, no general system of folding can be made out with the few data that were obtained.

Coming back to the Kanektok River, it will be noted that the change in the strike of the beds at the great bend is also accompanied by a uniform change of dip, since the beds on the western side of the great bend dip southeast and those on the eastern side southwest. It is evident, therefore, that the river in following the strike is flowing around the margin of a broad synclinal fold which has a northeast and southwest axis and a decided pitch to the southwest. This is the largest fold discerned in these mountains, although an interesting minor fold is found in the mountains directly northeast of Lake Kagati, where, in the valley of Atmugiak Creek, between Mount Oratia and Atayak Mountain, a decided anticlinal fold is observable (see fig. 13), and this anticlinal fold is probably persistent for some distance through the mountains to the north of the Upper Kanektok, above Lake Kagati, although it was not actually traced. In the mountains to the south of this part of the Kanektok, between Lake Kagati and the pass, the uniform strike is accompanied by a uniform dip south or southwest. at various angles, but not generally exceeding 50°.

Dikes and veins.—On the western side of the Oklune Mountains, where the Oklune series has first been described, these rocks alternate with outcrops of hornblende-syenite, which form part of a large mass that seems to be intrusive. Farther up the river, between the great bend and Lake Kagati, occasional siliceous dikes cutting the stratified series were found. In the vicinity of these dikes the slates are silicified and altered, and in one locality veins of spathic iron were found near the contact. Along the broad valley at the very head of the Kanektok and in the region of the pass the ancient volcanics and tuffs are cut by frequent siliceous dikes, and the pass itself is occupied by a great coarse mass of intrusive rock, which also forms the mountains rising above. At the contact of the great dike the country rock on the western side of the pass is altered, chiefly by silification, for several feet.

On the western side of the point which lies at the western entrance of Kululuk Bay the highly folded shaly limestones and arkoses are cut by great masses of basalt, so abundant that for a time the stratified rock and the basalt are about equal in amount, and then the intrusive rock becomes more abundant. Near the contact of the basalt the shales become hardened into slates and are often noticeably contorted. Some few miles west from this locality there is a great deal of a light yellow rock, which was only slightly examined, so that its exact nature can not be told; but study of a specimen shows it to be rhyolite, and it is very likely a dike rock. On the Egoushik River, as above noted, the sedimentary rocks are cut through by many sheets and dikes of basalt. This younger basalt is somewhat different petrographically from the basalt which occurs among the ancient volcanics of the Oklune series, since it is more basic and contains olivine.

Definition of Oklune series.—The term Oklune series is applied to a series of rocks which form the larger part of the consolidated sedimentary formations exposed between Kwinhagamut and Nushagak Bay, along the route of travel of the expedition. Lithologically the series consists of beds which are in a general way similar throughout, being shales, impure limestones, and cherts, often organic, with beds of arkose, derived from granites or other coarse-grained igneous rocks. In nearly every district are abundant volcanic rocks, of ancient appearance, having a greenish color due to alteration, and associated with these are sedimentary tuffs, which are evidently directly derived from the same volcanic sources. Volcanic material is more abundant in certain districts than in others, but is throughout characteristic of the series. From the Lower Kanektok to Nushagak all of the rocks of this series are folded into broad, well-marked folds, which have determined the topography of the mountains and the courses of the rivers. The series is cut through by occasional, sometimes abundant, dikes, which may be referred to two divisions—the siliceous dikes of the Oklune Mountains, mainly granite, diorite, and syenite, and the basalt dikes of the region between Togiak and Nushagak.

Relative age of Oklune series.—Near the point where this series is first described on the Kanektok River, near the camp of August 30, many fossil shells were found in a large bowlder of sandstone and conglomerate which undoubtedly came from the rocks in the immediate vicinity. These fossils were examined by Mr. T. W. Stanton, of the National Museum, who refers them to the species *Aucella crassicollis* Keyserling (?). Mr. Stanton observes that these specimens belong to a broad robust form of Aucella, like some of the varieties of the Lower Cretaceous of California which are referred to *Aucella crassicollis*, and states that if it had come from California he would not hesitate to assign it to a position well up in the Lower Cretaceous, the Knoxville beds.

The basalt masses which cut the Oklune series between Togiak and Nushagak are apparently contemporaneous with the associated surface flows of basalt, and these will be spoken of later as presenting a close analogy with the basalts of St. Michael and vicinity and other basalts of that general class, which are probably of Neocene age.[1] In general, therefore, the Oklune series may be said to contain rocks which lie between the Lower Cretaceous and the Neocene, and, from the similarity of the beds throughout, the writer is inclined to classify the whole series as Cretaceous.

NAKNEK SERIES.

Distribution.—About halfway from the mouth of Naknek Lake to the head at Savonoski there outcrops at the chief bend an ancient greenish volcanic rock, which is included under the general classification of the Naknek series. From this point to Savonoski the mountains on the south side of the lake are all of horizontal sedimentary rocks. From Savonoski nearly to the pass which separates the waters draining into Naknek Lake from those of the Katmai River, the same sedimentary series occurs. At the pass the series is broken by a chain of volcanoes, but on the southeastern side it reappears, and outcrops almost continuously as far as Katmai Point, which was the last place where it was observed. It will thus be seen that the rocks of the Naknek series, as here classified, occupy most of this section across the peninsula of Alaska.

Lithology.—As above noted, the westernmost rock of the Naknek series, as above understood, is an augite-andesite which outcrops on Naknek Lake. It is not absolutely certain that this rock represents a flow contemporaneous with the sedimentary rocks of the series, but in the absence of evidence this has been assumed, especially as the ancient and decomposed appearance of the rock suggests a different age from that of the later volcanic material, portions of which occupy the axis of the mountain range. The most of the rocks of the Naknek series, however, are arkoses, sometimes fine, sometimes coarse, and merging into conglomerates. These arkoses are either green, from the decomposition of ferruginous minerals and the production of chlorite, or light colored from the predominance of feldspathic constituents. In nearly every case it is possible to tell under the microscope that the arkose has been derived from granite, and in some cases it is plain that the granite was a hornblende-biotite-granite, all of the component minerals being found in very little altered and reassorted condition in the sedimentary rock. In the vicinity of Katmai and at Katmai Point the basal rock exposed just above tide water is a hard, massive granitic arkose; above this comes a dense andesitic rock which is perhaps a flow contemporaneous with the deposition of the sedimentary rocks, and higher up come arkoses, made up of very coarse granitic fragments, and coarse conglomerates, having pebbles of biotite-granite.

[1] Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 246, 249.

Through all the rocks of this series indistinct plant remains are common.

On the west side of the pass the sedimentary rocks are somewhat altered near the contact of the volcanic rock, and have developed some mica.

Folding.—The mountains which form the southern side of the upper part of Naknek Lake are of strata which are nearly horizontal, and this general horizontal structure continues southeastward as far as the pass. On each side of the chain of volcanoes which forms the axis of the range the stratified rocks dip away very gently and are slightly undulating. On the Katmai side of the divide the rocks are in general horizontal, although at Katmai Point the beds are tilted up so as to dip very slightly to the northwest. There is, however, no folding accompanying this tilting. A series of nearly vertical fractures, accompanied by slight faulting, indicates that the tilting occurred when the rocks were not covered by any great load.

Dikes.—As before noted, the axis of the mountain range which constitutes the greater part of the Alaska Peninsula consists of a chain of volcanoes, the volcanic rock evidently having burst up through the sedimentaries of the Naknek series. Except for this central mass of intrusive rock there are very few dikes in the Naknek series. At Katmai Point a large dike of basalt, probably intimately connected with the igneous mass which forms the divide, has burst up through the central arkoses; and, as before noted, it is possible that the considerable mass of andesite at the chief bend on Naknek Lake may also be intrusive and of the same general age and origin as the main volcanic belt, as well as the interbedded sheet of andesitic rock at Katmai Point, although it has been considered that these two masses belong to flows contemporaneous with the arkoses.

Definition of Naknek series.—The Naknek series consists of a great thickness series of granitic arkoses and of conglomerates which generally contain pebbles of granite. All of these sedimentary rocks are evidently derived from the destruction of a land mass which consisted largely of hornblende-biotite-granite. There are probably some volcanic flows interstratified with the arkoses and conglomerates, although it is not absolutely proved that those examined may not be intrusive. The series is cut through by andesitic-basaltic (aleutitic) lava of later age, especially along the axis of the range, where the amount of volcanic rock is very great.

Relative age of Naknek series.—Throughout the whole series the arkoses carry abundant fossil remains, both of plants and of marine organisms. At a number of places fossil shells were hastily collected and submitted to Mr. T. W. Stanton, of the National Museum, from whose report the following notes are made:

Naknek Lake, upper end: *Aucella*, probably *Aucella pallasi* Keyserling.

Katmai Pass: *Aucella pallasi* Keyserling. *Aucella* sp. Small individuals, possibly distinct from last. *Natica* sp., small cast. *Belemnites* sp., indeterminate fragment.

Bluff back of Katmai: *Aucella pallasi* Keyserling.

Five miles southeast of Katmai Pass: *Terebratula* sp., *Avicula* sp., *Aucella* sp., probably *Aucella pallasi* Keyserling.

Katmai Point: *Astarte* (?) sp.

Mr. Stanton observes that the fossils from all of the localities except the last "apparently all come from beds of about the same age, most probably the Upper Jurassic. It should be noted, however, that the determination is based entirely on the Aucellæ, of which closely similar forms occur also in the Lower Cretaceous, so that in the absence of other determinative fossils the discrimination between Lower Cretaceous and Upper Jurassic can not be made with very great confidence." Concerning the last locality (at Katmai Point), he adds: "The single species of Astarte is not sufficient to determine the horizon, which may be the same as that of the Aucella-bearing beds, or more recent."

Conditions of deposition.—As before noted, the coarse conglomerate and grit of the Naknek series indicate that these sedimentary rocks were largely derived from an adjacent granitic land mass. In the lower part of Naknek Lake there appears to be a belt of granitic rocks from which specimens from both sides of the lake have been examined, one being a syenite and the other a hornblende-granite-aplite; these granitic rocks being similar to those which make up so large a proportion of the arkoses, it may be suspected that they formed the land mass at the time that the Naknek series was formed. At any rate, it is certain that the Alaska Peninsula was a land mass in Jurassic times. The plant remains which are found throughout the series also indicate shore conditions.

POST-CRETACEOUS SEDIMENTARY FORMATIONS.

PROBABLE TERTIARY FORMATIONS.

THE TYONEK BEDS.

Description.—Along the shore of Cook Inlet, southwest of Tyonek, is exposed a series of beds of clay alternating with sand which locally is indurated, forming sandstone in nodular masses. This series of beds contains abundant brown peaty lignite so little metamorphosed that the original grain and structure of the wood is preserved and often a specimen may be split, following the grain of the wood. This lignite has been used for fuel on a small steamer plying on Cook Inlet. The attitude of the series where examined is monoclinal, being steeply uptilted so as to dip at an average angle of 35° NE., which, however, becomes flatter near Tyonek, where it is only 10°. Besides this general tilting there are local folds.

Relative age.—These folded clays, sands, and lignites are overlain unconformably by horizontally stratified gravels and bowlder clay, which will be described later as belonging to the probable Pleistocene series of Cook Inlet gravels. It has heretofore been thought sufficient to classify rocks of this region which contain lignite or lignitic coal as belonging to the Kenai series, which is Eocene or Oligocene; but, as has been shown by the work of the writer in the Yukon district, beds which are later than the Kenai series may also contain plant remains and lignite—such, for example, is the Palisades conglomerate of the Yukon, which is Pliocene or possibly Upper Miocene.[1] Therefore, while these beds are evidently Tertiary, being younger than the highly folded and indurated probably Cretaceous[2] series of the Tordrillo Mountains, and older than the unconformable overlying Pleistocene, the presence of lignite is not sufficient to classify them with the Kenai series; and in view of the fact that the rocks, in their degree of consolidation and in the character of the lignite, resemble more the occasional Neocene beds which are found in Alaska, the writer is inclined to provisionally regard them also as Neocene.

YENTNA BEDS.

Description.—The name Yentna beds is here given to rocks of which only a single outcrop was examined. This is opposite the Sushitna trading post, on the Sushitna River below the mouth of the Yentna, and consists of coarse-grained conglomerate containing quartz pebbles, with a general northeast strike and a dip of 20° SE.

Relative age.—From the general appearance of this rock and its lithologic characters it is provisionally referred to the Kenai series.

HAYES RIVER BEDS.

Description.—Just below the mouth of Hayes River, on the Skwentna, there is an exposure of a mile or so of gray and yellow, partially consolidated, sedimentary beds, some of which are very soft while others are harder and distinctly stratified and jointed. The rocks are gently folded, the dip changing gradually from 5° at one end of the section to nearly 60° at the other end. Farther up the Skwentna, nearly opposite the mouth of Hayes River, a bluff of 100 to 120 feet high is composed of slightly consolidated stratified gravels, which are sometimes horizontal and sometimes inclined as much as 10° both up and down stream. In both these exposures, viz, that below the mouth of Hayes River and that opposite it, are seams of lignitic coal, some being several feet in thickness. The coal is dark brown and nearly black in color, and occurs in seams conformable with the partially consolidated gravels.

[1] Geology of the Yukon gold district, Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 199.

[2] See p. 183.

Relative age.—While the Hayes River beds, as stated, are folded, these folds as a rule are very gentle and the rocks have a tendency to lie horizontal. There is thus an evident unconformity between them and the more highly folded, hard, and altered rocks of the Skwentna series, which they overlie. Inasmuch as the Skwentna series is apparently folded to about the same extent as the overlying Tordrillo series and is apparently conformable to this series, it seems that the comparatively slight folding of the Hayes River beds indicates that they are also younger than the Tordrillo series. There is, moreover, an entire lack of dike material in the Hayes River beds, such as cuts the Tordrillo series so abundantly. The Tordrillo series will presently be shown to be probable Cretaceous, and therefore the Hayes River beds must be Post-Cretaceous. At the locality opposite the mouth of Hayes River the gently folded gravels which contain the lignite seams are topped by about 10 feet of horizontally stratified sands or silts, which overlie the lower gravels unconformably where these are tilted, although where the latter are horizontal the distinction between them and the overlying beds can not be made out from a little distance. These upper gravels, forming the surface of the plateau in which the bluff, over 100 feet high, is cut, are evidently Pleistocene, so that the lignite-bearing beds must be referred to the Tertiary. The same reasons that have been given in describing the Tyonek beds—namely, the slight degree of induration which the beds have suffered as compared with the hardened and more highly folded Kenai series—suggest that these beds should be referred to the Neocene rather than the Kenai.

NUSHAGAK BEDS.

Description.—The high bluffs which form the east shore of Nushagak Bay are composed of stratified gravels, coarse sands, arkoses, and clays, which in places are slightly consolidated, apparently being cemented by iron which has leached out of the arkoses. These beds, in general horizontal, are frequently distinctly flexed, sometimes dipping as much as 20°, and in places there is even considerable folding and distortion. The strata are often heavily crossbedded and contain pebbles derived from a great variety of rock, some of which are striated, apparently from ice. This formation is exposed for a number of miles along the shore of Nushagak Bay and around Cape Etolin to Bristol Bay.

Relative age.—Overlying the folded clays and gravels which have been called the Nushagak beds are uncomformable horizontally stratified clays and gravels which contain many pebbles and frequently large bowlders, both pebbles and bowlders often being striated by ice. Near Nushagak these upper beds occupy the tops of the bluffs, which are in places as much as 150 feet high, but where the bluffs become lower and the beds themselves become thicker they often come down to the beach line, so that the underlying uncomformable series is not exposed. These upper beds must be referred to the Pleistocene, so that those which underlie are probably Tertiary. In this connection a note made by Dr. Dall concerning fossils collected at Nushagak by C. W. McKay is of interest.[1] According to this, fossils were collected in an "indurated clayey matrix," which evidently refers to the Nushagak beds just described. They include *Modiola multiradiata* Gabb, *Pectunculus patulus* Conrad, *Nucula tenuis* Lamarck, and *Serripes gronlandicus* Beck, and determine the age of the clays and gravels in which they occur as Miocene.

PLEISTOCENE FORMATIONS.

Like the beds which have just been described, the Pleistocene formations will be summarized only briefly, a more detailed account of them being found in the preliminary general notes on the geology of the region traversed. The salient points of the Pleistocene formations will be brought out to establish them in their place in classification.

COOK INLET GRAVELS.

The Cook Inlet gravels, as this name is employed, extend all the way from Cook Inlet along the drainage basin of the Skwentna River as far as the Tordrillo Mountains. These gravels are exposed continuously along the shore between Tyonek and the mouth of the Beluga River, in bluffs from 50 to 100 feet in height. The exact nature of the materials in the gravels differs somewhat. To the southwest of Tyonek the bluffs consist of gravel and bowlder clay containing bowlders which are often very large. Going from Tyonek toward the Beluga River the deposits in the bluffs become finer grained, changing from bowlder clay and coarse gravels to finer gravels interstratified with silts and fine clays; at the same time the large bowlders become very scarce and are finally entirely absent. From the Beluga River to the Sushitna delta the shores are low and are composed entirely of mud, but while they are of Pleistocene formation they are decidedly later than the gravel bluffs above described and are not included under the general name of Cook Inlet gravels. The same low banks, composed almost entirely of silt and gravels and evidently forming part of the river delta, are found from the Sushitna mouth nearly to the Sushitna trading post.

On the Yentna River, a short distance up, bluffs of blue stratified bowlder clay, containing pebbles of all sizes, which are often striated, reach the height of 40 to 50 feet. From here to the junction of the Skwentna this bowlder clay typically forms the higher banks, the lower ones being those which represent the present flood plain of the river. The tops of the higher banks rise to a uniform plateau

[1] Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, p. 847.

which extends many miles away from the river in both directions. As the river is ascended the bluffs become in general somewhat higher, although they are composed of the same stratified gravels. At a point several miles below the junction of Hayes River the bluff is composed for a short distance of typical morainal material, roughly stratified. This material contains many subangular bowlders, one of which was noted as being 5 feet in diameter, and many are upward of 1 foot; these bowlders are chiefly granitic. From an elevated point of view the moraine may be traced across the gravel plateau by a series of low ridges, and the general trend is about N. 20° W. A little farther up the river the bluffs change laterally to sands and gravels; immediately above the morainal bluffs they are entirely of sand. From here as far as the second canyon the horizontally stratified sands, clays, and gravels continue to form at least the top of the general bluff which marks the level of the plateau, and in the canyon itself yellow gravel occasionally comes down from the tops of the rock cliffs, showing that this formation still forms a thin sheet spread over the plateau valley above. Stratified drift is found at intervals as high up as the upper valley of Portage Creek, the material becoming gradually coarser and changing into a stratified moraine. In the upper part of Portage Creek there is a definite line separating the stratified drift from unstratified morainal material, which fills the extreme head of the valley.

KUSKOKWIM GRAVELS AND SILTS.

On the west side of the divide between the Skwentna and the Kuskokwim the bottom of Ptarmigan Valley is found to be filled with stratified glacial drift, the materials of which are very little waterworn and comprise bowlders up to 6 inches in diameter. This glacial drift is found continually along the valley of the stream, capping the solid rocks where these form the banks. Just above the junction of Hartman River there is a deposit, on the left bank, of coarse stratified glacial gravel which reaches 400 feet in height; some of the layers contain bowlders several feet in diameter. Below the junction of Hartman River are continuous bluffs of yellow gravel and sand, which grow finer the farther one goes downstream, the height varying from 60 to 200 feet.

Where the river leaves the Tordrillo Mountains it enters a plateau similar to that through which the Skwentna flows on the eastern side of the mountains, and, like all of the other rivers coming out of the mountains, makes deep cuts in the gravels which make up this plateau. The total height of the bluffs is at first as much as 200 feet, the lower part being stratified gravel and sand, while the top consists of 10 feet or more of black silt overlain by peat. The height of the bluffs gradually decreases downstream, and at about half the distance from the mountains to the junction with the East Fork the river enters a low, flat region where the higher banks are of finely stratified silt and sand, and rarely over 20 feet high, while the ordinary banks are hardly over 10 feet and evidently constitute the present flood plain. This low silt deposit is continuous to the junction of the Kuskokwim with the East Fork, and with the exception of a few low rock outcrops is the only formation encountered in the banks for nearly half the distance from the junction of the East Fork to that of the Tachatna. The first high bluff is encountered a short distance below the camp of July 29 and consists of fine yellow silt and blue clay. From here to the junction of the Tachatna the left bank of the river is generally composed of about 10 feet of silt, although in one place a high bluff 60 feet high is cut. Between the Tachatna and the Holiknuk the banks are generally of rock, but occasionally silts are cut which, as before, are divisible into two classes. The first class is the low banks, which are only 10 to 20 feet above the river, and which consist of fine silt alternating with layers of vegetable matter. These are evidently river-laid deposits, as land shells which belong to living species have been found in them. The other class of silts consists of high banks with no vegetable material; these vary from 60 to 150 feet in height. From the Holiknuk River to the camp of August 4, at a great bend of the Kuskokwim, no silts are found except the low river-laid banks, which are occasionally cut. Some 12 or 15 miles below the camp of August 4 the river flows through a local deposit of silt which rises 20 to 50 feet above the river, and a similar small area is cut through 10 miles farther down. In this latter place there was considerable peat and a layer of volcanic ash at a distance of about 20 feet above the river and 30 feet below the top of the bluff.

About 14 miles below Kolmakof a high rock bluff is terminated at its downstream end by a deposit of horizontally stratified gravels, made up of pebbles and subangular bowlders which frequently reach 18 inches in diameter. The bluff made of this material is 40 feet high, and the deposit is evidently a shore conglomerate. Where a similar rock ledge cuts into the stream about 10 miles below the above-mentioned locality there are unconsolidated detrital deposits, both at its upstream and at its downstream end, the deposit above being of silt and sand, while at the latter it is of coarse gravel, with many bowlders; and in both cases the bluffs rise 50 or 60 feet.

From a point on the river some distance above the beginning of the Yukon portage, at Kalchagamut, the banks are composed entirely of silts, which are generally low and must be very little above the level of the river at high water. Occasionally, however, higher bluffs, reaching 50 feet above the river, are cut, which are always composed of clean silt, with occasional pebbles. These observations are true of the Kuskokwim as far as its mouth.

KANEKTOK SILTS AND GRAVELS.

The same deposit of silt not far above the level of the sea extends along the lower course of the Kanektok River until one reaches the neighborhood of the Oklune Mountains. At this point there is a definite bluff about 100 feet high, whose material is a very slightly stratified drift composed of gravel, with many bowlders which are often deeply striated by ice action. From here to the junction of the Kanektok with the Klak there is very little drift, but above this point the banks are of coarse stratified gravel 30 feet high, and the tops merge into a level plateau, which extends back, with a very gentle rise, to the mountains. From this point up to Lake Kagati the banks, with the exception of frequent rock outcrops, are always of roughly stratified drift, containing subangular and often striated bowlders. As one goes up the stream the covering of drift becomes more important and the bowlders larger, some near the lake being as much as 10 feet in diameter. In the drift plateau below Lake Kagati are depressions which are occupied by smaller lakes. The lake itself outlets through banks of roughly stratified drift 40 feet high, the fragments in which are little worn.

The upper part of the crooked creek which drains into Lake Kagati is dammed into little lakes by ridges in the general drift accumulation which fills the valley, and also by lines of glacial moraine, consisting of huge bowlders.

TOGIAK GRAVELS.

The west side of Togiak Lake is composed of level flats of sand and gravel, with some stratified small bowlders. These are all horizontally stratified. The eastern side of the lake has a mountain wall, but the lower end has no definite dam, the outlet being through banks of stratified silts and gravels from 10 to 40 feet high. These banks rise to a nearly uniformly level plateau, which stretches back to the mountains. Farther down the Togiak River the banks continue to be of the same material and often show cross bedding, generally dipping downstream.

BRISTOL BAY SILTS AND GRAVELS.

On Togiak Bay the bluffs are partly made up of brownish clay, with huge bowlders, the whole having a certain rude horizontal stratification and being apparently a coarse shore deposit. The tops of these bluffs are usually about 40 feet high. From Togiak along the shore toward Kululuk Bay the basalt which forms the usual country rock alternates with yellow stratified gravels containing very many large bowlders. Kululuk Bay itself has mountains on the eastern and on the western side, but the upper end has a low shore of sand and silt. From this point to the large lake which is the source of the

Egoushik River there are no rock outcrops, the whole valley being filled with stratified sand and gravel. On the northern shore of the lake are banks of horizontally stratified gravel and silt, and the same deposits are cut by the river which drains the lake. This river, after flowing through a second large lake, emerges upon the tundra again, which is formed of blue clay and silt, as cuts along the river show.

Along Nushagak Bay the Tertiary Nushagak beds are overlain by clays and gravels similar to those described, likewise nearly always containing pebbles and bowlders which are deeply scratched and polished by ice action. These horizontal clays sometimes constitute only the upper 10 feet of a bluff as much as 200 feet high, but as one goes along the shore toward Bristol Bay the bluffs become lower and begin to be composed almost exclusively of these deposits. The southeastern shore of Bristol Bay, at the mouth of the Naknek River, is also made up of stratified clays and sands containing many bowlders, often of large size. These bowlders are chiefly of mica-diorite, although sometimes of andesitic or basaltic lava, and they are frequently heavily striated. At the coast the bluffs are from 40 to 60 feet high, and the river flows through a similar deposit all of the way from the lake to the bay, the bluffs in places shrinking to 20 feet as one goes up the river and then increasing to the same height as at the coast. Naknek Lake outlets through this drift, there being no distinct dam. In the valley which lies between the upper end of Naknek Lake and the pass above Katmai there is a mantle of very coarse stratified drift, and at the upper end of the valley is a heavy deposit of horizontally stratified sand, containing great angular bowlders, which, however, are also arranged in layers. On the surface are many little hills formed of bunches of bowlders.

CONDITIONS OF DEPOSITION OF THE PLEISTOCENE.

The Pleistocene deposits in the vicinity of mountain ranges consist of gravels made up of glacial material, and often merge into coarse conglomerates and stratified water-laid moraine material. In proportion as the distance from the mountain ranges increases these coarse stratified deposits become finer and change into sands and fine silts. From evidence which will be given in detail later, in considering the chief movements which the land has undergone since the Tertiary period, it is certain that the coarse gravels and conglomerates were deposited at a period when the sea stood at least 3,000 feet higher than at present, so that the only land masses were the higher mountains, which stood out as peninsulas and islands; the lower mountains were entirely submerged. The shores where the sea stood at this period are represented by the deep rock-cut terraces which are found on the Tordrillo, Oklune, and Aleutian mountains. The successive terraces on the mountains below the highest ones indicate that the land emerged slowly from the sea, so that the latter stood at successively lower levels. In proportion as the land rose rivers began to run down over the newly made land, and in favorable places large shallow lakes were formed. The rivers brought down large amounts of detritus, which were deposited at their mouths in the sea or in the bottoms of shallow lakes. With later elevation the delta deposits were transformed into dry land and the lakes were gradually drained. Many of the finer silts and gravels which cover the country and which have been referred to the Pleistocene, along with the evidently marine shore deposits, have undoubtedly been formed in lakes. As an example of the deposits formed by these different processes, the Cook Inlet gravels and the high gravel plateau at the head of the Kuskokwim are true marine deposits formed along the shore line which now stands marked upon the mountains; but the broad flats of the upper Kuskokwim represent a lake deposit formed at a later period, while the vast stretch of tundra in the region of the Lower Kuskokwim and the Lower Yukon represents sediment brought down by these great rivers, which accumulated in the bottom of the shallow Bering Sea and was transformed into dry land toward the close of the uplift.

CORRELATION OF SEDIMENTARY SERIES.

DEVONIAN-CARBONIFEROUS SYSTEM.

Tachatna series.—The Tachatna series consists of a series of gray, generally thin-bedded limestones, with limy, carbonaceous and chloritic shales, and some fine-grained arkoses. The rocks have been considerably folded, and contain frequent quartz veins. They are cut by granitic dikes in rare cases. From the light-gray limestone in this series fossils have been obtained which indicate a probable Middle Devonian age for this horizon. The Tachatna series is separated from the overlying Holiknuk series, in which probable Cretaceous fossils occur, by an unconformity, while the series underlying the Tachatna was not exposed.

The Tachatna series is taken in this report to be a rough equivalent to the Tahkandit series described in thè Yukon report.[1] The latter series was defined as a series of white or gray limestones alternating with carbonaceous shales and sometimes with conglomerates; this series underlies the Mission Creek series of the Yukon, which was determined to be, in part at least, Cretaceous. In the Tahkandit series at one locality Upper Carboniferous fossils were found in white crystalline limestones.

JURASSIC SYSTEM.

Naknek series.—The Naknek series is composed of granitic arkose and conglomerates, all of which are derived largely from hornblende-

[1] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 169.

biotite-granite; there are probably also some volcanic flows interstratified with the granitic detritus. The series is cut by basic intrusive rocks, which also form the line of volcanoes along the Alaskan Peninsula. Throughout the whole series are abundant plant remains, which, so far as examined, were not determinate, and marine faunal remains that indicate a probable Upper Jurassic age.

Skwentna series.—The Skwentna series consists of ancient volcanic rocks interstratified with tuffs and slates, and with some granitic arkose. Concerning the correlation of the Skwentna series with known divisions of geologic time, we have very few data. It is to be noted, however, that from the rocks of the Naknek series northeast along the coast, at least as far as Tuxedni Harbor, in the vicinity of Mount Iliamna, Jurassic fossils have been found in a continuous zone.[1] Other localities where Jurassic fossils are found occur also to the southwest of the Naknek series, so that the Jurassic forms a nearly continuous zone for several hundred miles from the vicinity of Unimak Pass to Mount Iliamna.[2] The prolongation of this belt a hundred miles or so farther to the northeast would make the Skwentna series fall within it.

Concerning the horizons which lie below the Skwentna series nothing is known, but the less-altered shales of the Tordrillo series overlie the Skwentna series, and these Tordrillo rocks will presently be correlated with the Cretaceous, although on no grounds which furnish an absolute proof.

Considering the problem of correlation from the standpoint of lithology, we find the rocks of the Skwentna series appearing at first entirely different from those of the Naknek series, the former consisting chiefly of volcanic material and the latter of granitic arkose. When we come to analyze the conditions of formation of the Skwentna series, however, we remember that its rocks were laid down in the vicinity of a shore, a part of which must have consisted of hornblende-granite, as is indicated by the arkoses; this shore must have been marked by a line of volcanoes which furnished the lavas and the interstratified tuffs. Similarly, the Naknek series has been shown to have been laid down in the vicinity of a land mass composed largely of hornblende-biotite-granite, and here also there are indications pointing to the existence of volcanic activity. The occurrence of these two series in the definite Jurassic zone, bearing evidence of having been derived from the destruction of the same partly granitic land mass, warrants a provisional correlation and justifies the assignment of the Skwentna series to the Jurassic, in part at least.

Terra Cotta series.—The Terra Cotta series consists of heavy-bedded

[1] See p. 235.

[2] Dr. W. H. Dall, Report on the coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, p. 865.

impure limestones, slates, and arkoses, with probably some volcanic rocks, which represents flows contemporaneous with the sedimentaries.

Between the Terra Cotta and the Skwentna series lies the Tordrillo series, whose outcrops show that the general structure of the mountain range is a pitching synclinorium, although there are many minor folds. On the eastern side of this synclinorium the beds of the Skwentna series underlie the Tordrillo rocks with apparent conformity, and on the western side of the fold the Terra Cotta beds underlie the same Tordrillo rocks, also with apparent conformity.

It is natural, then, to assume that the Terra Cotta series may be of the same age as the Skwentna series, although this conclusion by no means follows absolutely, but has only the value of a probable hypothesis. From a paleontologic standpoint there is no evidence to assist us in this problem, and when we come to lithologic evidence we find that the rocks of the Terra Cotta series are, on the whole, different from those of the Skwentna, as will be evidenced by referring to the descriptions just given. There are, however, among the Terra Cotta rocks beds of granitic arkose like those which occur in the Skwentna series, and, morever, there is some volcanic material in the Terra Cotta beds, although not nearly so much as in those of the Skwentna. In both series the volcanic material is highly altered and gives evidence of considerable age, and the rest of the rocks of the two series, although unlike, is yet such as might naturally be formed simultaneously at different points in the same sea. The Terra Cotta series may be conceived as being formed at a point more remote from the shore line than the Skwentna series. Therefore the provisional classification of the Terra Cotta series with the Jurassic, which is here provisionally adopted, rests, first, upon its correlation with the rocks of the Skwentna series, and, second, upon the proof, which is not yet absolute, that the Skwentna series is the equivalent of the Naknek series, which is certainly Jurassic.

CRETACEOUS SYSTEM.

Oklune series.—The Oklune series is the only one of the series provisionally assigned to the Cretaceous in which perfectly reliable fossils have been found, and is therefore here first presented. In general, it consists of shales, impure limestones, granitic arkoses, and abundant volcanic rocks of ancient appearance, which are interstratified with sedimentary beds, and associated with abundant tuffs. The series is cut through by occasional dikes referable to two chief divisions—the siliceous granitic dikes of the Oklune Mountains and the basaltic dikes of the region between Togiak and Nushagak. Near the western boundary of the area occupied by the Oklune series fossils have been found which identify the horizon as Lower Cretaceous. For the correlation of this locality with the rest of the area whose rocks are included under the head of the Oklune series the general folding and the lithology furnish the only grounds. The folding is such that all the rocks included under the head of the Oklune series nearly as far as Nushagak might well be included in horizons not far removed from that in which the fossils were found, although the nature of evidence is not sufficient to make any positive statement. The lithology, especially the abundance of ancient volcanic material, is characteristic through all the rocks of this series as far east as Nushagak Bay, and therefore the whole is provisionally classified as Cretaceous. The upper and lower limits of the series were not determined, since the area is bounded both on the east and on the west by Pleistocene silts and gravels. On the east, after passing across Nushagak Bay and Bristol Bay, the next solid rocks encountered are the Jurassic Naknek series.

Holiknuk series.—The Holiknuk series, which was encountered on the Kuskokwim River, from a point about 10 miles below Vinasale as far as Kolmakof, consists of alternating beds of sandstone, impure limestone, shale, and arkose. The basal bed of the series, exposed at its farthest upstream boundary, is a conglomerate containing pebbles apparently derived from the Tachatna series, which has already been referred to the Devonian-Carboniferous system and which occupies the area immediately adjoining the Kolmakof series, farther up the Kuskokwim. There is an apparent unconformity between the Holiknuk series and the Tachatna series, so that on this end of the Holiknuk area the rocks are younger than the Devonian-Carboniferous system. Throughout all the Holiknuk rocks as far as Kolmakof are frequent obscure plant remains, and in many places are undisputable evidences of shore formation, such as the presence of ripple marks and other shore marks. At a locality about halfway between the Chagavenapuk and Vinasale imperfect plant remains indicate an age presumably later than the Jurassic. Farther down the river at intervals are localities, of which the last occurs only a short distance above Kolmakof, where ripple-marked shales and shaly limestones contain fossils which are probably Cretaceous. Taking the paleontologic evidence together with the stratigraphic, and these with the lithologic (for the rocks are essentially similar throughout and show evidences of similar conditions of deposition), it seems quite safe to refer the whole series to the Cretaceous.

Kolmakof series.—The Kolmakof series outcrops along the right bank of the Kuskokwim from Kolmakof as far as a point some distance above the entrance to the Yukon portage route at Kalchagamut, where it is succeeded by the level Pleistocene silts. The series consists of volcanic rocks of various types, which change laterally into or are interbedded with volcanic tuffs, shales, impure limestones, and fine-grained arkoses. The rocks are considerably folded and are cut by great dikes. They contain frequent plant remains and are characterized by ripple marks and frequent evidences of shore formation. No fossil shells were found in the Kolmakof series, but only plant remains, which, although not identified, seem to be similar to those of the Holiknuk series. So far as stratigraphy goes, the attitude of the rocks of the Kolmakof series, as compared with that of the Holiknuk series, does not oppose the hypothesis that the rocks of one series may run into those of the other laterally and belong to the same horizons. The plant remains, the ripple marks, and the evidences of shore formation, as well as the similar appearance of the sedimentary beds, considered apart from the volcanic material of the Kolmakof series, strengthens the same hypothesis. The Kolmakof series is therefore provisionally correlated with the Holiknuk series and referred to the Cretaceous system.

Tordrillo series.—The Tordrillo series occupies the central part of the Tordrillo Mountains and consists of heavy black shales, often carbonaceous, intercalated with beds of sandstone, arkose, and impure limestones. The beds are considerably folded and are cut by great masses of intrusive, generally siliceous, rocks. No good fossils were found, but only imperfect plant remains, which, although abundant, were not identifiable. From the standpoint of lithology the Tordrillo series recalls immediately the Mission Creek series of the Yukon, which has been defined in the Yukon report as being in part at least Cretaceous.[1] It also has a general resemblance to the Cretaceous Holiknuk series of the Kuskokwim and also to the Cretaceous Matanuska series, described by Mr. W. C. Mendenhall, on the Matanuska River.[2] The presence of plant remains in the Tordrillo series, as in all the other series mentioned, is also a point in evidence. Considering the correlation in the light of dynamic disturbances, the Tordrillo series would seem to have undergone about the same amount of folding and alteration as the before-mentioned Cretaceous series, but in general to have undergone decidedly less alteration than the rocks of the Tachatna series, which belong to the Devonian-Carboniferous system, or the rocks of the Skwentna series, which have been provisionally assigned to the Jurassic. Stratigraphically, the Tordrillo series overlies, in apparent conformity, the rocks of the Skwentna series and of the Terra Cotta series, both of which have been provisionally referred to the Jurassic. What evidence there is, therefore, all favors the assignment of the Tordrillo series to the Cretaceous system.

EOCENE OR OLIGOCENE.

Yentna beds.—The single outcrop of Yentna beds has been provisionally referred to the Kenai on purely lithologic grounds. The

[1] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 175.
[2] See Mendenhall's paper in this volume, p. 307 et seq.

Kenai, formerly considered to be Miocene, has later been referred to the upper Eocene,[1] and Dr. Dall even inclines to place the group as high as the Oligocene.[2]

NEOCENE.

Hayes River beds.—The Hayes River beds consist of slightly consolidated gravels and sands, which are gently folded and contain beds of lignite. The beds are unconformably overlain by silts, which have been referred to the Pleistocene, so that the beds themselves are pre-Pleistocene. On the other hand, the comparatively slight folding which they have undergone indicates that they are of later age than the main folding, which resulted in the formation of the Tordrillo Mountains, and which is exhibited in the Tordrillo and the Skwentna series, the former of which has been correlated with the Cretaceous. The Hayes River beds are therefore probably Tertiary; and since it may be assumed, by inference from other districts, that the main folding took place not only later than the Cretaceous, but also after the Kenai period, the Hayes River beds must be referred to the Neocene. This conclusion is corroborated by the slight consolidation which the beds have undergone.

Nushagak beds.—The Nushagak beds consist of a series of sands, gravels, and clays which are practically unconsolidated, and which have been slightly folded. From a dynamic standpoint alone one would classify them with the Neocene, for the same reasons as have been stated for the Hayes River beds. The report of the discovery of fossils in these beds, however, definitely places them within the Neocene.

Tyonek beds.—The Tyonek beds are a series of clays and sandstones, with many interstratified beds of brown lignite. The whole series has been considerably folded. Taken from a standpoint of alteration and induration, the Tyonek series is evidently post-Cretaceous, showing much less alteration than do the Cretaceous series. From its proximity to established localities of the Kenai group, and from the presence of lignite, as well as from the considerable folding, it might be referred to the Kenai; but from the slight degree of consolidation, and from the fact that the lignite is very woody and resembles more strongly the lignitic beds of the Hayes River Neocene than the coal of the Kenai, it is also quite possible that these beds may be Neocene in age, and to this period they are provisionally assigned until definite proof.

PLEISTOCENE.

The term Pleistocene as used by the writer is conceived as defined in terms of earth movement rather than in terms of the organic record.

[1] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 192.

[2] Report on the coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, p. 842.

The latest Neocene deposits, wherever examined in Alaska, are found to be constantly folded, to a great or small degree, and there is an unconformity between them and the overlying sediments, which are horizontal or at most only disturbed in the very slightest manner. All the deposits above this line of unconformity are referred to the Pleistocene. The writer has shown in a previous report[1] that Alaska, as a whole, experienced a disturbance in late Miocene or early Pliocene times, and this disturbance was followed by a period when the rivers cut deep gorges in the old shallow valleys. Subsequent to this there was a period of submergence, when the sea reached a height of several thousand feet greater than at present. Those deposits which we have actually classed with the Pleistocene appear to have mostly begun with the period when the sea stood at its greatest height, and to have been continually deposited from that time until quite recently, in proportion as the land rose and new shore lines were established. At the time that the sea stood at its maximum height it received large contributions of detritus from glaciers, which in many cases still exist, and it has been shown in the Yukon report that the lobes of the Cordilleran Glacier, as described by Dr. Dawson, also probably ended in the sea at this period. The period of maximum submergence was, therefore, contemporaneous with a period of glaciation more extensive than at present; but it is by no means certain that a correlation can be made in point of time with the maximum extension of the continental glacier of eastern North America. Moreover, in our scheme we are somewhat at a loss to recognize those deposits which were formed as the land sank, before reaching the period of maximum submergence. Very little Pliocene has been recognized in Alaska, and it still remains to be determined whether the period occupied by the subsidence of the land is to be classified with the Pliocene or with the Pleistocene.

Toward the end of the period of elevation which brought the land to its present position abundant, now extinct, mammals flourished, belonging to species of the elephant, the horse, and the buffalo. The position in which these are found in the Pleistocene deposits—nearly always near the tops of the silts and near the surface, and, moreover, in those regions which are still very near the coast and so must have been the last to emerge from the sea—indicates that the period at which these lived must have reached to a time which was much nearer the present day than it was to the time of maximum submergence. In the gravels which were formed around the mountains in the broad plateau at the time of maximum submergence no fossils of any sort have yet been found.

Description of Pleistocene deposits.—Under the general term of Pleistocene are here correlated the Cook Inlet gravels, the Kuskokwim silts and gravels, those of the Kanektok, the Togiak, and those border-

[1] Geology of the Yukon gold district: Eighteenth Annual Report U. S. Geol. Survey, Part III, p. 218.

ing on Bristol Bay. These are all characterized throughout by pebbles and bowlders scratched by ice, showing that glaciers contributed much of the material toward their upbuilding, by not being in the slightest degree consolidated, and by lying horizontal, and thus being unconformable to even the slightly folded Neocene below. Most of the deposits, moreover, have evident relation to shore lines, still freshly preserved on the mountains, to the present river systems, or to the present coast line, which can hardly be said of any of the older formations.

CORRELATION OF THE SEDIMENTARY ROCKS OF THIS REPORT WITH THOSE DESCRIBED ELSEWHERE.

The accompanying table shows provisional correlations which have been made by the different geologists who have lately examined portions of Alaska adjacent to the Kuskokwim district:

Table of provisional correlations.

	Spurr; Yukon district, 1896.	Brooks; White River and Tanana district, 1898.	Mendenhall; Resurrection Bay to the Tanana River, 1898.	Spurr; Southwestern Alaska, 1898.	Eldridge; Sushitna Valley, Alaskan Range, and Cantwell River, 1898.	Schrader; Copper River district, 1898.
Pleistocene	Silts and gravels.	Silts and gravels.	Sands and gravels.	Silts, sands, and gravels.	Sands, gravels, and bowlder clays.	Silts and gravels.
Neocene	Twelvemile beds, Porcupine beds, Nulato sandstone, Palisade conglomerate.	Tok sandstone.		Tyonek beds, Hayes River beds, Nushagak beds.		
Eocene or Oligocene	Kenai series.			Yentna beds.	Kenai series.	Valdes series. (?) Orca series.
Cretaceous	Mission Creek series.		Matanuska series.	Tordrillo series, Holiknuk series, Kolmakof series, Oklune series.	Cantwell conglomerate. (?)	Valdes series. (?)
Jurassic				Naknek series, Skwentna series, Terra Cotta series.		
Devonian and Carboniferous.	Tahkandit series.	Wellesley series, Nilkoka beds.	Sunrise series. (?)	Tachatna series.	Cantwell conglomerate. (?)	Valdes series. (?)
Silurian	Rampart series.	Greenstone-schists.	Greenstones. (?)			
Pre-Silurian sediments.	Birch Creek series, Fortymile series.	Tanana schists, Nasina series.	Tanana schists.		Sushitna schists.	Klutena series.
Archean	Basal granite.	Gneissic series.			Basal granite and gneissic series.	

CLASSIFICATION OF THE IGNEOUS ROCKS ACCORDING TO COMPOSITION.

PRINCIPLES OF CLASSIFICATION.

Those igneous rocks which were collected in Alaska during the season of 1898 have first been classified in such a manner as to permit of their identification and to permit the selection of definite designations. In the following pages the different rocks will be found described separately and in detail. They will also be found to be grouped together in an orderly fashion under separate families, groups, etc.

In order to understand the reason for these groupings and for some of the peculiarities of the rock nomenclature found in the descriptions, a classification table has been drawn up and prefixed to the descriptions.[1] The table elucidates a scheme of classification which was forced upon the writer as being the only natural expression of the relations and characteristics of the rocks as understood by him. The idea of the classification is simply to express the nature and relations of these Alaskan rocks, and no idea was originally entertained of proposing a classification which should find general favor. At the same time the writer realized that a classification which should express faithfully the relations of so great a variety of rocks as those described in this report must also, if it be a true one, be capable of being extended or modified so as to embrace other rocks. Accordingly some justifying statements were prepared, explaining briefly where methods which are here used have been used before, with what authorities the writer agrees and where he deviates from them, together with the reasons for the chief principles adopted in the classification. This discussion, at first incorporated in this report, was afterwards withdrawn and published separately.[2] To this separate publication the reader is referred.

It may be stated here briefly, however, that the classification employed by the writer is based on (1) mineral composition, (2) structure, and (3) chemical composition, which are given precedence in the order named. The four other principles which have been variously employed in the classification of rocks by different authors, namely, mode of occurrence, origin, geologic age, and locality, are altogether discarded.

Starting with the main principle of mineralogic composition, it is suggested that rocks are divided into great classes, each class being characterized by the prevailing presence of an all-important mineral, such as feldspar. Of these different rock classes the feldspar class is the only one included in the present scheme. The feldspar class is divided into three families on the basis of the feldspar species and

[1] See page 192.

[2] The classification of igneous rocks according to composition: Am. Geologist, March, 1900.

between these three families are two transitional families. Within the families are subdivisions depending at first upon separate mineralogic combinations and finally on structure, the ultimate division determining the exact name of each separate rock. Thus the class, family, group, species, variety, and type are subordinated one to the other, so that a rock may be variously defined, with a greater or less degree of accuracy, as belonging to any one of these divisions. Thus augite-syenite-aplite is a type name finally defining a rock. Less definitely the rock belongs to the mineralogic variety augite-syenite and the mineralogic species pyroxene-syenite. Further, it belongs to the syenite group and the granitic family and, in the widest sense, to the class of feldspar rocks.

NEW TERMS PROPOSED.

In the descriptions of rocks that follow, certain names appear that are here used for the first time and certain others that are used with a special significance. The detailed justification for these particular applications is to be found in the discussion above referred to,[1] and therefore only a bare definition of the terms will be here inserted.

Alaskite group.—This group name covers many rocks which have been described as granite, rhyolite, aplite, elvan, granulite, eurite, granitel, semi-granite, etc. On the other hand, all of the rocks described under these names do not belong to the alaskite group, but many would belong to other mineralogic groups. The alaskites form a distinct mineral group consisting of quartz and alkali feldspar only, and in this sense it is quite new and so a new name is given. The most common name for certain rocks of this kind is aplite, but this word has come to have a structural use which overshadows and obscures the mineralogic meaning. Of course the word must be used in one or the other sense, and not in both. It is the structural use, therefore, that is retained in the classification, while for the whole group of essentially quartz-alkali-feldspar rocks the name alaskite[2] is proposed, and for the corresponding lava or rock of any other habit which has a porphyritic structure, with a fine-grained or aphanitic groundmass, the name tordrillite [3] is used. Chemically the group of alaskites is characterized by being exceptionally high in silica and low in iron and lime.

Belugite group.[4]—The belugite family comprises rocks transitional between the diabasic family and the dioritic family, rocks whose feldspars belong partly to the andesine-oligoclase group, and partly to the labradorite-anorthite group, or whose feldspars are of a species

[1] The classification of igneous rocks according to composition: Am. Geologist, March, 1900.

[2] Derived from Alaska.

[3] Derived from the Tordrillo Mountains, where it occurs as a dike rock.

[4] The word belugite is taken from the Beluga River in Alaska, in the neighborhood of which rocks belonging to the family were found.

intermediate between andesine and labradorite. Since rocks form a connected series and classifications are arbitrary, and since the same is true of the feldspars, it follows that between two such arbitrary divisions as the dioritic and diabasic families there are actually intermediate rocks. For example, between the granitic family and the dioritic family comes the monzonitic family, already elaborated by Brögger. The belugitic family occupies a corresponding position between the dioritic and diabasic families. Under the belugitic family the only group given in the table is the belugite group, which is characterized by feldspars intermediate between those of the dioritic family and those of the diabasic family, and also contains mica, amphibole, or pyroxene. The best excuses for the creation of this group will be found in the special descriptions which come later in this report. For the type of the belugite group characterized by a porphyritic structure with aphanitic or fine-grained groundmass the name aleutite is proposed. So far as yet studied the aleutites comprise many of the late Tertiary and Pleistocene lavas along the belt of the Aleutian islands and peninsula, hence the name.

Tonalite group.—Tonalite is adopted as a group name instead of quartz-diorite, as being shorter and more characterizing. In the same way single characteristic names would be better for compound group names such as quartz-syenite, olivine-diabase, etc. In general, however, the system tends toward a great simplifying of rock names.

Igneous feldspar rocks.

[Collected in Alaska by J. E. Spurr in 1898.]

Classification according to mineralogic composition.	Types (structural variations).				
	Granular; hypidiomorphic or allotriomorphic.	Panidiomorphic, generally fine-grained.	Porphyritic; groundmass coarse.	Porphyritic; groundmass fine or glassy.	Glassy.
GRANITIC FAMILY (alkali feldspars—orthoclase, microcline, anorthoclase, and albite):					
ALASKITE GROUP (feldspar and quartz)	Alaskite	Alaskite-aplite	Alaskite-porphyry	Tordrillite	
GRANITE GROUP (feldspar, quartz, and mica, amphibole, or pyroxene).	...	...	Granite-porphry	Rhyolite	
MICA-GRANITE (feldspar, quartz, and mica)—					
Biotite-granite	Biotite-granite	Biotite-granite-aplite.	Biotite-granite-porphyry	Biotite-rhyolite	
		Biotite-hornblende-granite-aplite.	Biotite-soda-granite-porphyry	Biotite-soda-rhyolite	
Muscovite-granite	...	...	Muscovite-granite-porphyry.	...	
AMPHIBOLE-GRANITE (feldspar, quartz, and amphibole)—					
Hornblende-granite	Hornblende-biotite-granite.	Hornblende-granite-aplite.	...	...	
PYROXENE-GRANITE (feldspar, quartz, and pyroxene)—					
Augite-granite	...	Augite-biotite-granite-aplite.	...	Augite-rhyolite	
QUARTZ-SYENITE GROUP (intermediate between granite and syenite; consisting of feldspar and mica, amphibole, or pyroxene, with accessory or subordinate quartz).	Quartz-syenite	...	...	...	
MICA-QUARTZ-SYENITE (characteristic ferromagnesian mineral mica)—					
Biotite-quartz-syenite	Biotite-hornblende-quartz-syenite.	...	...	...	
AMPHIBOLE-QUARTZ-SYENITE (characteristic ferromagnesian mineral amphibole)—					
Hornblende-quartz-syenite	Hornblende-biotite-soda-quartz-syenite.	...	...	...	

Igneous feldspar rocks—Continued.

Classification according to mineralogic composition.	Types (structural variations).				
	Granular; hypidiomorphic or allotriomorphic.	Panidiomorphic; generally fine-grained.	Porphyritic; groundmass coarse.	Porphyritic; groundmass fine or glassy.	Glassy.
GRANITIC FAMILY—Continued.					
SYENITE GROUP (feldspar and mica, amphibole, or pyroxene).	Syenite		Syenite-porphyry	Trachyte	
MICA-SYENITE (feldspar and mica)—					
Biotite-syenite			Biotite-syenite-porphyry.	Biotite-apotrachyte	
AMPHIBOLE-SYENITE (feldspar and amphibole)—					
Hornblende-syenite	Hornblende-syenite			Hornblende-apotrachyte.	
PYROXENE-SYENITE (feldspar and pyroxene)—					
Augite-syenite		Augite-syenite-aplite		Augite-trachyte Augite-soda-trachyte.	
DIORITIC FAMILY (more siliceous soda-lime feldspars—oligoclase and andesine):					
TONALITE GROUP (feldspar with mica, amphibole, or pyroxene, and quartz)—					
MICA-TONALITE (feldspar, quartz, and mica)—					
Biotite-tonalite				Biotite-dacite	
AMPHIBOLE-TONALITE (feldspar, quartz, and amphibole)—					
Hornblende-tonalite				Hornblende-dacite	
PYROXENE-TONALITE (feldspar, quartz, and pyroxene)—					
Augite-tonalite				Augite-dacite	
DIORITE GROUP (feldspar with mica, amphibole, or pyroxene).			Diorite-porphyry	Andesite	
MICA-DIORITE (feldspar and mica)—					
Biotite-diorite					
AMPHIBOLE-DIORITE (feldspar and amphibole)—					
Hornblende-diorite	Hornblende-diorite		Hornblende-diorite-porphyry.	Hornblende-mica-andesite.	
PYROXENE-DIORITE (feldspar and pyroxene)—					
Augite-diorite	Augite-diorite			Augite-andesite	
Hypersthene-diorite		Hypersthene-diorite-aplite.			

Igneous feldspar rocks—Continued.

Classification according to mineralogic composition.	Types (structural variations).				
	Granular; hypidiomorphic or allotriomorphic.	Panidiomorphic; generally fine-grained.	Porphyritic; groundmass coarse.	Porphyritic; groundmass fine or glassy.	Glassy.
BELUGITIC FAMILY (intermediate between the dioritic and diabasic families and comprising rocks whose feldspars belong partly to the oligoclase-andesine group and partly to the labradorite-anorthite group, or whose feldspar is of a composition intermediate between andesine and labradorite):					
BELUGITE GROUP (feldspar and mica, amphibole, or pyroxene).				Aleutite	
MICA-BELUGITE (feldspar and mica)—					
Biotite-belugite					
AMPHIBOLE-BELUGITE (feldspar and amphibole)—					
Hornblende-belugite			Hornblende-belugite-porphyry.		
PYROXENE-BELUGITE (feldspar and pyroxene)—					
Augite-belugite	Augite-biotite-hornblende-belugite.			Augite-aleutite	
DIABASIC FAMILY (less siliceous soda-lime feldspars—labradorite, bytownite, and anorthite):					
DIABASE GROUP (feldspar and mica, amphibole, or pyroxene):			Diabase-porphyry	Basalt	Basalt glass.
AMPHIBOLE-DIABASE (feldspar and amphibole)—					
Hornblende-diabase				Hornblende-basalt	
PYROXENE-DIABASE (feldspar and pyroxene)—					
Augite-diabase	Augite-diabase		Augite-diabase-porphyry.	Augite-basalt	
Bronzite-diabase				Bronzite-basalt	
OLIVINE-DIABASE GROUP (feldspar and olivine, with mica, amphibole, or pyroxene).				Olivine-basalt	
AMPHIBOLE-OLIVINE-DIABASE (feldspar and olivine, with amphibole)—					
Hornblende-olivine-diabase	Hornblende-diallage-biotite-olivine-diabase.				

Igneous feldspar rocks—Continued.

Classification according to mineralogic composition.	Types (structural variations).				
	Granular; hypidiomorphic or allotriomorphic.	Panidiomorphic; generally fine-grained.	Porphyritic; groundmass coarse.	Porphyritic; groundmass fine or glassy.	Glassy.
DIABASIC FAMILY—Continued.					
OLIVINE-DIABASE GROUP—Continued.					
PYROXENE-OLIVINE-DIABASE (feldspar and olivine, with pyroxene)—					
Augite-olivine-diabase				Augite-olivine-basalt.	
Bronzite-olivine-diabase				Bronzite-olivine-basalt.	
Diallage-olivine-diabase				Diallage-olivine-basalt.	

DESCRIPTION OF IGNEOUS ROCKS.

GRANITIC FAMILY.

(*Characterized by alkali feldspars.*)

ALASKITE GROUP.

(Characterized by essential alkali, feldspar, and quartz.)

Structure granular; hypidiomorphic or allotriomorphic (*alaskite*).—For the typical alaskite see analyses and descriptions given in the special paper above referred to.[1] In addition, a specimen obtained on the Skwentna River may be described, which is of a coarse texture and granular structure and in places contains enough ferromagnesian constituents to represent a transition to the granite group. In the section examined, however, the rock is a typical alaskite, being essentially quartz and feldspar, with a coarse, often micrographic, structure. The feldspar is partly kaolinized orthoclase, partly unkaolinized and striated. The latter tested by the Fouqué method is proved to be anorthoclase. There is a little pyrite and biotite in the section.

Structure panidiomorphic, generally fine grained (*alaskite-aplite*).—The only rock which has been classified under this head comes from the Terra Cotta Mountains, most of the rocks which have the mineralogic combination quartz and feldspar, and which would therefore be classed under the old head aplite, being actually characterized by a granular hypidiomorphic or allotriomorphic structure. Even this case is not a typical aplite, except in portions where the structure, which is often hypidiomorphic granular, becomes idiomorphic. The rock is coarse in texture, like a medium fine-grained granite, and easily shows the individual minerals to the naked eye. It is essentially composed of quartz and feldspar in about equal proportions, the feldspar being mostly orthoclase, but some striped. The striped feldspars were determined in three cases, once by the Michel Lévy method and twice by the Fouqué method, all determinations showing the mineral to be an albite verging toward anorthoclase. One tiny area of iron oxide and chlorite represents a probably decomposed flake of mica.

Structure porphyritic, groundmass coarse (*alaskite-porphyry*).—A case of alaskite-porphyry is given as No. 4 of the analyses in the above-mentioned paper, to which the reader is referred. A somewhat more typical rock, mineralogically, although it has not been analyzed, comes

[1] The classification of igneous rocks according to composition: Am. Geologist, March, 1900.

from the Terra Cotta Mountains on the Upper Kuskokwim. The rock in the hand specimen is moderately fine grained and light gray, with occasional dark specks. Under the microscope it is seen to be essentially a micrographic intergrowth of quartz and kaolinized orthoclase; green biotite is a sparing accessory. There are occasionally small phenocrysts of feldspar, chiefly unstriated.

Structure porphyritic, groundmass fine grained (*tordrillite*).—The reader is referred to No. 5 of the examples cited under the head of the alaskite group in the special paper above mentioned.

GRANITE GROUP.

(Characterized by having, as essential constituents, alkali feldspars, quartz, and mica, amphibole, or pyroxene.)

Porphyritic, with coarse groundmass (*granite-porphyry*).—Granite-porphyry was collected at Sitka and at various points on the Upper Kuskokwim. The rocks which have been classified under this head are porphyritic rocks, evidently belonging to the granite family, but with the ferromagnesian minerals indeterminable, so that the rocks can not be referred to a special species of granite-porphyry.

Porphyritic, groundmass fine (*rhyolite*).—The rocks classified as rhyolite in the foregoing classification are all dike rocks, and they all occur in the Terra Cotta Mountains, near the source of the Kuskokwim. They are usually characterized by abundant phenocrysts of quartz, which is generally in the form of dihexahedra, sometimes with prisms, and by phenocrysts of orthoclase, with some striped feldspar. Occasionally there are phenocrysts of biotite, or secondary minerals forming apparent pseudomorphs after biotite or other ferromagnesian minerals. The quartz and feldspar phenocrysts often show embayments or resorption borders, indicating invasion by the groundmass. The striped feldspars are ordinarily anorthoclase or albite, although in one case there was a little andesine-oligoclase determined by the Fouqué method. The groundmass is variable. In some cases it is semiopaque, grayish, and isotropic, evidently a glass. In other cases it is partly brown and isotropic and partly faintly polarizing; again it has the structure known as pilotaxitic, with feldspar microliths; again it is cryptocrystalline or microfelsitic, or finely spherulitic and micrographic. In some cases all the minerals show a certain pyroclastic structure, both the groundmass and the phenocrysts being broken as if by movements of the igneous rock after it had somewhat stiffened.

MICA-GRANITE.

(Characterized by the combination of the essential constituents alkali feldspar, quartz, and mica.)

VARIETY, BIOTITE-GRANITE.

(Alkali feldspar, quartz, and biotite.)

Granular, hypidiomorphic or allotriomorphic (biotite-granite).—Biotite-granite is found widely distributed, especially in the Tordrillo Mountains. It also occurs at Katmai, forming the essential part of granitic conglomerates and arkoses which are probably Jurassic in age; the granite of the Tordrillo Range, on the other hand, is post-Cretaceous. That of the Tordrillo Range is in the form of dikes, while the Katmai granite is supposed to be derived from a pre-Jurassic land mass which may possibly be Archean. Ordinarily the biotite-granites are coarse and well crystallized, and are of varying degrees of basicity, some of them approaching alaskite very nearly, while others contain large quantities of the ferromagnesian minerals. The structure is generally granular hypidiomorphic, sometimes poikilitic, as is beautifully shown in a specimen of typical coarse biotite-granite from the summit of the Tordrillo Range. The chief constitutents are, of course, quartz, feldspar, and biotite, the feldspar being usually orthoclase, with some striated kinds. The striated feldspar in a specimen from the Upper Skwentna River was shown by optical tests to be anorthoclase.

Panidiomorphic structure, generally fine grained (biotite-granite-aplite).—Biotite-granite-aplite is a phase of the granite dikes which occupy the axis of the Tordrillo range. In appearance it differs little from the ordinary granites, being generally finer grained and of more uniform texture. Under the microscope it appears to have a generally idiomorphic habit of the minerals. Besides the biotite there is often considerable pale-green hornblende, which is almost entirely idiomorphic. The tendency toward intergrowths of quartz and feldspar is frequently shown. The feldspar is mostly orthoclase, and in one case the striated feldspar which was present was determined by the Fouqué method to be anorthoclase. In the same specimen there were found as accessory minerals zircon, apatite, and abundant chlorite.

Porphyritic, with coarse groundmass (biotite-granite-porphyry).—Biotite-granite-porphyry is the name given to a dike which was found on the Upper Kuskokwim, near Vinasale. It has a groundmass made up mainly of quartz and orthoclase, with micrographic structure. The phenocrysts are of quartz, showing zones of resorption and surrounding aureoles, together with orthoclase, striped feldspars, and dark-brown biotite.

Biotite-soda-granite-porphyry.—This rock occurs as a dike in the vicinity of Kolmakof. It is very coarse in texture, being made up of many large phenocrysts, although the groundmass between is moderately fine. Under the microscope the groundmass is seen to be fine granular and to be made up of quartz and feldspar in about equal amounts. There are many phenocrysts of feldspar, some unstriated and appearing like orthoclase, others finely striated. Four optical tests showed in three cases albite, in one anorthoclase, for both the striated and the unstriated feldspars. The characteristic feldspars of the rock are, therefore, those which have soda predominating over potash in their chemical composition, and so the rock is called a soda granite, as distinguished from those granites whose feldspars have predominating potash in the alkalies. Among the other phenocrysts in the rock are biotite and a little hornblende.

Porphyritic structure, fine-grained groundmass (biotite-rhyolite).—Biotite-rhyolite occurs as a dike on the Kuskokwim River in the vicinity of the Yukwonilnuk River. In appearance it is light gray, with some small phenocrysts of quartz and feldspar in a dense aphanitic grayish-green groundmass. Under the microscope the groundmass is finely cryptocrystalline or microfelsitic, the component minerals being indistinguishable, although the fibers seem to represent at times quartz, feldspar, and muscovite. The phenocrysts are of quartz, which show resorption, of orthoclase, and occasionally of little biotite.

VARIETY, MUSCOVITE-GRANITE.

(Alkali feldspar, quartz, and muscovite.)

Porphyritic, groundmass coarse (muscovite-granite-porphyry).—At Sitka and in dikes on the Upper Kuskokwim muscovite-granite-porphyry was found. These rocks are generally fine grained, with small phenocrysts, and are very light in color, so that they are hardly distinguishable from the alaskite porphyries in the hand specimen. Under the microscope the phenocrysts are of quartz and feldspar, the latter being partly orthoclase and partly striated feldspar. One of these striated feldspars, in a specimen from a dike on the Upper Kuskokwim, tested by the Fouqué method, showed itself to be an oligoclase-albite. The groundmass of the rocks is generally fine grained and granular and is composed of quartz, feldspar, and muscovite, with some calcite.

AMPHIBOLE-GRANITE.

(Essential constituents, alkali feldspar, quartz, and amphibole.)

VARIETY, HORNBLENDE-GRANITE.

(Alkali feldspar, quartz, and hornblende.)

Granular, hypidiomorphic or allotriomorphic structure (hornblende-granite).—The rock that has been selected as a type of hornblende-granite is really a hornblende-biotite-granite, which forms the summit of the divide between the head of the Kanektok and Togiak Lake. The rock is a typical one in every respect, being medium grained and composed of quartz, feldspar (among which orthoclase predominates), hornblende, and somewhat less-abundant biotite.

Panidiomorphic structure (*hornblende-granite-aplite*).—Under the head of hornblende-granite-aplite have been classified rocks which are entirely different in their outward appearance. One from the Terra Cotta Mountains is fine grained and greenish, and has the appearance of an arkose. The other, from Naknek Lake, is coarse grained and has the appearance of a granite except that such of the minerals whose outline is clearly defined are seen to be idiomorphic. Under the microscope, however, the rocks are seen to be essentially alike, differing only in texture. The rock from the Terra Cotta Mountains is composed of the usual minerals of hornblende-granite, but the idiomorphic structure governs throughout, especially in the hornblende, which is in long idiomorphic prisms. The same is true of the rock from Naknek Lake, where the hornblende is dark green; in this rock there is also some fresh biotite. Among the feldspars orthoclase predominates, but many crystals are striated.

PYROXENE-GRANITE.

(Composed of alkali feldspar, quartz, and pyroxene as essential constituents.)

VARIETY, AUGITE-GRANITE.

(Composed of alkali feldspar, quartz, and augite as essential constituents.)

Panidiomorphic structure (*augite-granite-aplite*).—The only rock classified under this head is really an augite-biotite-granite-aplite. It occurs on the fourth canyon of the Skwentna River as a dike cutting the carbonaceous shales, and probably is an offshoot from the main granitic mass of the Tordrillo Mountains. The structure of the rock is in general intersertal or ophitic, depending upon the arrangement of the feldspar crystals; the grain of the rock is moderately fine. The essential constituents are striped feldspar in stout lath-shaped crystals, augite, and biotite, with abundant orthoclase, magnetite, and quartz. Chlorite, probably formed from biotite (monoclinic—clinochlore or ripidolite), is more abundant than any other of the dark minerals. Considerable calcite and some muscovite results from the alteration of the feldspars. The biotite is brown, the augite colorless to pinkish. The feldspars by optical test proved to be chiefly orthoclase.

Porphyritic structure, fine groundmass (*augite-rhyolite*).—A dike rock occurring in the Tordrillo Mountains near the highest point where the Kuskokwim waters were encountered has been classified as augite-rhyolite. It is a dark-colored rock containing phenocrysts and including round or subangular masses of fine-grained granite. Under the microscope the groundmass is found to be glassy, grading into faintly microcrystalline. It is often opaque. The phenocrysts are of quartz and orthoclase, and have their outlines generally broken and rounded, and there are a few crystals of augite.

QUARTZ-SYENITE GROUP.

(Intermediate between granite and syenite, and consisting chiefly of alkali feldspar and mica, amphibole, or pyroxene, with accessory or subordinate quartz.)

Granular, hypidiomorphic or allotriomorphic structure (quartz-syenite).—Where the characteristic ferromagnesian mineral is not determinable, the rock having the foregoing structure is classified simply as a quartz-syenite. The rock taken as a type occurs as a dike in the probable Cretaceous series in the vicinity of Kolmakof and is of granular structure and dark colored. Under the microscope the structure appears to be hypidiomorphic. The chief constituent is feldspar, which was determined by the Fouqué method to be orthoclase; the feldspar crystals are often surrounded by micrographic fringes. Besides the feldspar there is very subordinate quartz, considerable magnetite, and less chlorite and bleached mica.

MICA QUARTZ-SYENITE.

(Characteristic ferromagnesian mineral mica.)

VARIETY, BIOTITE-QUARTZ-SYENITE.

Granular, hypidiomorphic or allotriomorphic structure (biotite-quartz-syenite).—The rock which falls into this class is more strictly a biotite-hornblende-quartz-syenite and is one of the phases of the intrusive mass which forms the backbone of the Tordrillo Mountains. In appearance the rock is striking, being composed of white feldspar and nearly black mica, which contrasts strongly. The texture is medium. Under the microscope feldspar and fresh brown biotite are seen to make up the bulk of the rock. The feldspar is partly striated, partly not; and determinations by the Fouqué method of two unstriated feldspars show orthoclase and anorthoclase, while in one striated individual the determinations showed oligoclase-albite. The feldspar is altered in part to muscovite. There is considerable very pale-brown hornblende and a little quartz, and there are inclusions of apatite in the biotite.

AMPHIBOLE QUARTZ-SYENITE.

(Characteristic ferromagnesian mineral amphibole.)

VARIETY, HORNBLENDE-QUARTZ-SYENITE.

Granular, hypidiomorphic or allotriomorphic structure (hornblende-quartz-syenite).—The rock which will be described under this head is more accurately a hornblende-biotite-soda-quartz-syenite, and comes from the pass over the Tordrillo Mountains, being a phase of the same eruptive mass as has been before spoken of. The rock is moderately coarse grained and contains a great deal of the ferromagnesian minerals. Under the microscope it is seen to be made up of striated and unstriated feldspar, the former predominating, with pale-green hornblende and biotite and a little quartz. Opical tests of both feldspars show them to be chiefly anorthoclase.

SYENITE GROUP.

(Containing as essential constituents alkali feldspar and mica, amphibole, or pyroxene, and without quartz.)

Granular, hypidiomorphic or allotriomorphic (*syenite*).—Syenitic rocks which have not their characteristic ferromagnesian mineral sufciently well determined are classified simply as syenites when they have the foregoing structure. Rocks which have been given this name were found on the Upper Skwentna, in the Terra Cotta (Tordrillo) Mountains, and on Naknek Lake. They differ considerably in appearance, that from the Upper Skwentna being fine grained and somewhat decomposed, and resembling to the naked eye a sandstone, while that from the Terra Cotta Mountains resembles in general that from Naknek Lake, both being gray and uniform in texture, and both characterized by the segregation of iron into pyrite or iron oxide. The rock from the Upper Skwentna is composed chiefly of orthoclase, bleached biotite, and derived chlorite; that from the Terra Cotta Mountains is made up of interlocking grains of orthoclase with muscovite, while that from Naknek Lake seems to be essentially of coarse-grained orthoclase, mostly altered to sericite and other minerals, and areas of calcite, actinolite, pyroxene, etc., are found, seeming to represent the decomposition of some original ferromagnesian mineral.

Porphyritic structure, groundmass coarse (*syenite-porphyry*).—Under the head syenite-prophyry are included rocks of that type which do not show any determinable or well-determined ferromagnesian mineral. The two rocks to which this name are given both occur in the vicinity of the Terra Cotta Mountains, but differ in appearance, one being light gray and the other dark gray in color. In the lighter colored one sparing phenocrysts of feldspar show themselves to be of the orthoclase-albite series. One shows a kernel of albite with a zonal growth of orthoclase. Both orthoclase and albite show bisectrices; the outer a positive obtuse, which has an angle of 3° with the good basal cleavage; the other has a negative bisectrix which has an angle of 72⅛°, with the albite twinning, indicating albite. The albite shows both albite and pericline twinning; the orthoclase has zonal structure, and the intergrowth between the two varieties of feldspar is gradual. The groundmass is fine granular, and is formed almost wholly of two distinct kinds of feldspar, one distinguished by kaolinization, the other clear. There are small areas of hornblende (uralitic?), chlorite, and epidote.

In the darker colored specimen of syenite-porphyry are phenocrysts of feldspar, chiefly orthoclase, with some probable microline and albite. The groundmass is of secondary quartz and of chlorite, but chiefly chlorite, which seems to represent the alteration of small mica crystals. There are nodules of metallic oxide and subordinate secondary minerals.

Porphyritic structure, groundmass fine (*trachyte*).—The two rocks defined simply as trachytes are both dike rocks occurring at different places in the lower Terra Cotta Mountains, where these are cut by the Kuskokwim. They are essentially similar in appearance, being both rocks such as are commonly styled trap by the old-school field geologists, and consisting of a dense, nearly black groundmass speckled with small crystals of feldspar. Under the microscope the feldspar phenocrysts are found to be partly twinned, partly not. In one of the sections feldspars which have albite twinning, and which show equal extinction on both sides of the twinning line, and are therefore in the zone of symmetry, have the angle of equal illumination greater than that of extinction, and are therefore more acid than oligoclase—probably albite. In the other sections the feldspars are chiefly orthoclase, while some of the twinned crystals were determined by the Fouqué method as oligoclase-albite. In one of the specimens the groundmass is finely cryptocrystalline, and in the other finely spherulitic, in both cases the component minerals being quite indistinguishable. In one of the specimens there appeared to be pseudomorphs of serpentine after small phenocrysts of hornblende.

MICA-SYENITE.

(Characteristic ferromagnesian mineral mica.)

VARIETY, BIOTITE-SYENITE.

Porphyritic structure, groundmass coarse (*biotite-syenite-porphyry*).—Biotite-syenite-porphyry is found as a dike rock on the Kuskokwim near the mouth of the Yukwonilnuk River. It is a moderately coarse-grained dark-gray rock, with phenocrysts of feldspar and smaller ones of biotite. Under the microscope the feldspar is seen to be mainly orthoclase, with some twinned individuals. There is also biotite and considerable of an isotropic mineral which is probably colorless garnet, together with several undetermined minerals. The groundmass is granular and light colored and seems to be mostly orthoclase.

Porphyritic structure, groundmass fine (*biotite-trachyte*).—This rock is found on the third canyon of the Skwentna as part of the bedded series which has been called the Skwentna series and provisionally referred to the Jurassic; it undoubtedly occurs as a flow. In appearance the rock resembles much a compact slate, being entirely aphanitic and of a nearly black color. Under the microscope there is so much alteration that the rock might properly be called an apotrachyte, the prefix apo signifying its alteration from its original structure and composition. It is distinctly banded, both in the hand specimen and the thin section. Under the microscope it has a peculiar appearance, on account of the numberless phenocrysts of orthoclase, which are very small in size and are often massed together in bands with very little space between, while in other bands is more groundmass. Besides orthoclase there is frequently light-brown biotite and sparing plagioclase. The groundmass is in places glassy or faintly microfelsitic. It has in general, however, been devitrified to a thick felty mass of sericitic fibers, indicating that the composition of the glassy groundmass corresponds somewhat to that of orthoclase.

AMPHIBOLE-SYENITE.

(Characteristic ferromagnesian mineral amphibole.)

VARIETY, HORNBLENDE-SYENITE.

Granular, hypidiomorphic or allotriomorphic structure (*hornblende-syenite*).—Hornblende-syenite occurs in two localities, the first being on the Yentna, not far above its junction with the Sushitna, the second being on the Kanektok, not far above the point where it emerges from the mountains. Both the rocks are dark colored and greenish, the former being somewhat finer grained than the latter, although both are moderately fine grained. In the former locality the rock is cut by granitic dikes and quartz veins, so that it is older than these, but its real age is unknown. The age of the occurrence on the Kanektok is also unknown. The rock from the Yentna shows in thin section as chief constituents pale-green hornblende and orthoclase, with a little twinned feldspar; the orthoclase was determined optically to be such. The structure is often poikilitic, the feldspar including the hornblende crystals. In the occurrence on the Kanektok the structure is allotriomorphic-granular and the rock is made up of green hornblende and orthoclase in nearly equal amounts, with much epidote in large grains.

Porphyritic structure, groundmass fine (*hornblende-trachyte*).—This rock is found in the Kolmakof series, below Kolmakof, on the Kuskokwim, and seems to occur as dikes, sheets, and ancient surface flows. In appearance the rock corresponds to the popular designation trap, being essentially like the trachytes which have just been described, and having a fine-grained nearly black aphanitic groundmass speckled with feldspar phenocrysts. Under the microscope the rock is shown to be a hornblende trachyte or apotrachyte. The groundmass is felty and greenish, composed of a mixture of actinolite needles, which are probably secondary, and granular feldspathic materials. The phenocrysts are of low doubly refracting feldspar, in stout crystals, generally unstriated. One unstriated crystal was shown by the Fouqué method to be probably oligoclase or anorthoclase, while others were shown to be orthoclase. Pseudomorphs of chlorite and calcite appear to be after hornblende.

PYROXENE-SYENITE.

(Characteristic ferromagnesian mineral pyroxene.)

VARIETY, AUGITE-SYENITE.

Panidiomorphic structure (*augite-syenite-aplite*).—This rock occurs on the Skwentna River below the second canyon, probably as dikes. It is granitic and medium-grained in appearance. Under the microscope the structure is idiomorphic, sometimes poikilitic. The feldspar, tested by the Fouqué method, proves to be orthoclase. Pyrite is common in large grains.

Porphyritic structure, groundmass fine (*augite-trachyte*).—This rock occurs on the Kanektok River, above the junction of the Klak, and here probably forms part of the country rock of the Kanektok series, which has been provisionally referred to the Cretaceous, in which case it is an ancient volcanic flow. The rock is fine grained, and greenish in color. The thin section shows a groundmass which is nearly opaque and is composed of fine secondary grains. It shows indistinct groupings, or incomplete spherulitic and arborescent forms. There is no dark material in the groundmass. The phenocrysts are elongated feldspars, much decomposed to muscovite and chlorite, the latter often spherulitic. Smaller imperfect crystals are of colorless pyroxene.

Augite-soda-trachyte.—This rock occurs as a dike in the black carbonaceous shales of the probably Cretaceous Tordrillo series, in the Tordrillo Mountains, on the east side of the pass. It is greenish in color and marked by many phenocrysts of feldspar. Under the microscope the feldspar phenocrysts were determined several times by the Fouqué method and seemed to be all albite; there are also sparing phenocrysts of greenish augite. The groundmass is cryptocrystalline and indeterminable.

DIORITIC FAMILY.

(*Characterized by the more siliceous soda-lime feldspars—oligoclase and andesine.*)

TONALITE GROUP.

(Composed essentially of oligoclase-andesine feldspars with mica, amphibole, or pyroxene, and quartz.)

The word tonalite is used as a general term to include all the rocks of the above mineralogic composition, the term quartz-diorite having been abandoned in favor of this more convenient designation. Among the structural variations of the tonalite group the dacites represent the lavas, or those forms which are porphyritic with a fine-grained or aphanitic groundmass.

MICA-TONALITE.

(Consisting essentially of oligoclase-andesine feldspars, quartz, and mica.)

VARIETY, BIOTITE-TONALITE.

Structure porphyritic, groundmass fine (biotite-dacite).—The only specimen of biotite-dacite obtained was from the western side of the pass from the Skwentna over the Tordrillo Mountains. The specimen was found in the morainal drift, and is probably a representative of numerous dikes which cut the stratified rocks in this vicinity. The phenocrysts of the rock are somewhat rounded in shape, and consist of feldspar, biotite, and quartz, the last being rather sparing; there is also a little magnetite. Secondary minerals are chlorite, calcite, and hydrated iron oxides. Of three optical determinations of the feldspar, two show andesine-oligoclase and one andesine. The groundmass is fine-grained granular, composed of feldspar, biotite, and chlorite.

AMPHIBOLE-TONALITE.

(Consisting of oligoclase-andesine feldspars, quartz, and amphibole.)

VARIETY, HORNBLENDE-TONALITE.

Structure porphyritic, groundmass fine (hornblende-dacite).—Hornblende-dacite occurs among the ancient effusive rocks of the Skwentna series on the river of that name. In the single specimen examined the phenocrysts consisted of green hornblende, feldspar, and quartz. Two determinations of the feldspars in different crystals showed the species to be andesine, a section perpendicular to the negative acute bisectrix giving an angle of 67°, while one perpendicular to the positive obtuse bisectrix gave an angle of 12°. The groundmass is porous and pilotaxitic, showing many small feldspar prisms.

PYROXENE-TONALITE.

(Consisting of oligoclase-andesine feldspars, quartz, and pyroxene.)

VARIETY, AUGITE-TONALITE.

Structure porphyritic, groundmass fine (augite-dacite).—Augite-dacite occurs in the collections made in two widely separated localities, one on the Kuskokwim between Kolmakof and the entrance to the Yukon portage at Kalchagamut, the other on the west side of Katmai Pass, on the Alaska Peninsula. The occurrence below Kolmakof seems to be an interstratified flow in the sedimentary beds of the Kolmakof series, which have been provisionally referred to the Cretaceous. The occurrence at Katmai Pass is a variation of the central mass of intrusive and extrusive lava which forms the backbone of the Aleutian Mountains, and which ordinarily consists of andesite, aleutite, and basalt.

The specimen from below Kolmakof is very fine grained, showing only one small phenocryst of augite, altering to chlorite. The groundmass has a holocrystalline pilotaxitic structure, consisting largely of feldspar laths, with irregular grains of orthoclase and quartz. There is also abundant chlorite, calcite, pale-colored hornblende, epidote, and pyrite, all secondary. The feldspars are generally more or less altered to muscovite. Nearly all long sections of microliths extinguish parallel, so they must be oligoclase, according to Michel Lévy's method of determination. Occasionally others have extinctions up to 15° or 16°. These may be albite or labradorite. There is probably a little augite in the groundmass.

The specimen from near Katmai Pass has a groundmass composed of feldspar and augite, with probably a little quartz. The structure is holocrystalline intersertal. The phenocrysts are feldspar, which a good test shows to be typical andesine (angle of 8° on a section perpendicular to the positive bisectrix), pale-green augite, and a large crystal of quartz surrounded by a rim of augite crystals.

DIORITE GROUP.

(Consisting essentially of oligoclase-andesine feldspar, with mica, amphibole, or pyroxene.)

Structure porphyritic, groundmass coarse (*diorite-porphyry*).—When the ferromagnesian constituents are not determined or are indeterminable, the rock is classified simply as a diorite-porphyry. The specimen which is put under this head comes from a dike cutting the dark, probably Cretaceous shales, on the east side of the pass over the Tordrillo Mountains. The rock shows large phenocrysts of striated feldspar. Two determinations of the feldspar, according to the Fouqué method, shows it to be intermediate between andesine and oligoclase, and nearly oligoclase. Much of the feldspar is decomposed, chiefly to calcite. Pseudomorphs of calcite, iron oxides, chlorite, and actinolite are after phenocrysts whose form suggests original augite. Pyrite altering to hematite and large clumps of calcite, both secondary, are common, and secondary quartz appears in small amount. The groundmass is microfelsitic, apparently mainly feldspar grains with a little quartz.

Structure porphyritic, groundmass fine (*andesite*).—The rocks classified simply as andesite in this description are those whose ferromagnesian minerals are not determined or are indeterminable. Of this rock three localities have been found, the first in the third canyon of the Skwentna River, where it appears as a dike cutting the ancient volcanics and tuffs of the Skwentna series; second, on the Togiak River, about midway between the lake and Togiak Bay, where it occurs as a lava flow, probably of Tertiary age; and third, on the island of Unalaska, 3½ miles south of the village, where it occurs as a dike in diorite, 20 or 30 feet thick.

The specimen from the first locality is on the border line between diorite-porphyry and andesite, but is more properly the latter, since the groundmass, which is feldspathic, has a finely microfelsitic structure. The phenocrysts are of feldspar, iron-stained, and on being optically tested prove to be andesine.

On the Togiak River the specimen examined shows as groundmass a finely microcrystalline aggregate of kaolin, sericite, a little secondary quartz, and much secondary chlorite. There is abundant feldspar in phenocrysts, altered to calcite and sericite.

In the specimen from Unalaska there is shown much decomposition. The groundmass is pilotaxitic, consisting of lath-shaped plagioclase feldspars, and contains much serpentine. There are phenocrysts of feldspar, and amygdules which are filled with zeolites.

AMPHIBOLE-DIORITE.

(Consisting essentially of oligoclase-andesine feldspars and amphibole.)

VARIETY, HORNBLENDE-DIORITE.

Structure granular, hypidiomorphic or allotriomorphic (*hornblende-diorite*).—Hornblende-diorite occurs on the Skwentna River 10 or 12 miles above its junction with the Yentna, forming the country rock and being cut by dikes of mica-granite, alaskite, various scapolite rocks, and veins containing quartz, tourmaline, and other minerals. It also occurs on the island of Unalaska, forming the greater part of the mountains which rise above the village.

The specimen from the Skwentna River is moderately fine-grained in texture, and has an ancient appearance. The structure is hypidiomorphic granular, and it is made up almost entirely of pale-green hornblende and striated feldspars.

On the island of Unalaska the rock collected is moderately fine grained and fresh in appearance. Its structure is coarse granular, sometimes intersertal. The essential minerals are feldspar and subordinate hornblende, with a very little quartz and some pyrite. The feldspars were tested seven times and shown to be andesine.

Structure porphyritic, groundmass coarse (*hornblende-diorite-porphyry.*)—Hornblende-diorite-porphyry occurs as a dike cutting the carbonaceous shales of the Skwentna series on the eastern side of the Tordrillo Mountains above Portage Creek. It is dark green and fine-grained in appearance, and under the microscope shows many phenocrysts of dark-green hornblende and of striated feldspars in a microcrystalline feldspathic groundmass which contains much chloritic material.

Structure porphyritic, groundmass fine (*hornblende-andesite.*)—Hornblende-andesite is found on the Kuskokwim River, about 3 miles below Kolmakof, where it seems to be part of an ancient volcanic flow occurring in the supposedly Cretaceous Kolmakof series. In the hand specimen the rock is dark-green and dense, but with occasional phenocrysts of hornblende. Under the microscope the phenocrysts are found to consist, besides brown hornblende, of brown biotite, without feldspars. The groundmass is fine-grained microlitic, composed of feldspar, biotite, chlorite, magnetite, etc. The feldspar microlites show a maximum extinction of about 8°, indicating andesine. There are some quite large grains of calcite, apparently secondary.

PYROXENE-DIORITE.

(Composed essentially of oligoclase-andesine feldspars and pyroxene.)

VARIETY, AUGITE-DIORITE.

Granular structure, hypidiomorphic or allotriomorphic (*augite-diorite*).—Augite-diorite is found on the island of Unalaska in an outcrop on the shore near the village. It has a dark grayish-green color, and when examined under the microscope shows a holocrystalline intersertal structure. The feldspars, which are very abundant, were determined mainly as albite-oligoclase, with probably some andesine. There is much pale-green augite, with scattered metallic oxides.

Structure porphyritic, groundmass fine grained (*augite-andesite*).—The only specimen of typical augite-andesite which has been studied comes from the Alaska Peninsula; it has a greenish and ancient appearance, and forms the country rock of the mountains rising above Naknek Lake at its chief bend.

The rock shows itself under the microscope to be considerably altered. The phenocrysts consist partly of an aggregate of uralitic hornblende, with residual areas of augite from which the hornblende has probably been derived. The typical cleavage of the pyroxene is preserved in cross sections of this uralitic aggregate. The groundmass surrounding these large phenocrysts is thickly filled with very small perfect feldspar crystals set in a finely microcrystalline to nearly glassy groundmass. These feldspars have a common orientation, showing perfect flow structure which curls around the phenocrysts. Sections of this apparently parallel to M(010) gave extinction angles of +6° and 14°, indicating an oligoclase-albite. Grains of augite and considerable uralitic hornblende are also disseminated throughout the groundmass. Iron oxides are comparatively scanty.

VARIETY, HYPERSTHENE-DIORITE.

Structure panidiomorphic (*hypersthene-diorite-aplite.*)—Hypersthene-diorite-aplite occurs in the harbor of Sitka as an interbedded sheet in a folded rock series—probably a flow contemporaneous with the rest of the rock. It is very fine grained, and dark greenish in color. It shows no phenocrysts, and under the microscope the structure is panidiomorphic intersertal. On a section perpendicular to the positive bisectrix the feldspars show an angle of 3°, and on a section perpendicular to the negative bisectrix an angle of 65½°, showing in the first case andesine-oligoclase and in the second andesine. Hypersthene is abundant and there is much green felty chlorite.

BELUGITIC FAMILY.

The name belugite is proposed for the rocks which are intermediate between the diorite and the diabase families—for rocks whose feldspars belong partly to the oligoclase-andesine group and partly to the labradorite-anorthite group, or whose feldspar is of a species intermediate between andesine and labradorite. For the fine-grained porphyritic form or the corresponding lava the name aleutite is proposed. Since the belugitic family as defined depends upon the character of the feldspars, it is necessary to give it the same weight in classification as is given to the three chief families, which also depend upon the feldspars for their definition. Only one group is given under the family, although others certainly exist. This is the belugite group.

BELUGITE GROUP.

(Composed essentially of the characteristic feldspars of the belugitic family, with mica, amphibole, or pyroxene.)

Structure porphyritic, groundmass fine grained (*aleutite*).—When the characteristic ferromagnesian minerals are not determinable, the rock having the characteristic feldspars of the belugitic family and the structure above indicated is classified simply as an aleutite. The specimen taken as a type comes from the Kuskokwim River at the mouth of the Yukwonilnuk, where it occurs as a probable dike. The groundmass of this rock is microcrystalline, appearing to be mainly feldspar, with chloritic material. The phenocrysts are feldspar, striated and unstriated, in about equal amounts. A determination of one of the striated crystals showed it to be an andesine-oligoclase, while one of the unstriated feldspars was found to be probably an andesine-labradorite. A monoclinal mineral, perhaps pyroxene, is represented by pseudomorphs of fibrous actinolite. Only occasionally are tiny grains of quartz found, and this is apparently secondary. Apatite is common.

AMPHIBOLE-BELUGITE.

(Consisting essentially of the characteristic feldspars of the belugitic family, with amphibole.)

VARIETY HORNBLENDE-BELUGITE.

Structure porphyritic, groundmass coarse (*hornblende-belugite-porphyry*).—Hornblende-belugite-porphyry occurs in the Tordrillo Mountains, in the vicinity of the camp of June 13, on the Skwentna River (see map 6). The rock is granular, medium grained, and gray in appearance, and under the microscope shows a granular feldspathic groundmass with phenocrysts of feldspar and dark-green hornblende. The feldspar, on being tested, shows the optical properties of andesine-labradorite. There is much pyrite.

PYROXENE-BELUGITE.

(Consisting essentially of the characteristic feldspars of the belugitic family, with pyroxene.)

VARIETY, AUGITE-BELUGITE.

Structure granular, hypidiomorphic, or allotriomorphic (augite-belugite).—The augite-belugite comes from the same locality on the Skwentna River as the hornblende-belugite-porphyry above described, and is closely related to it in structure and composition. It is a coarse granular rock, consisting of striated feldspars, abundant pale-green augite, some biotite and hornblende, and considerable pyrite. The feldspars, when tested, gave angles of 61° and 68° on sections perpendicular to the negative bisectrix, showing a variation between labradorite and andesine.

Structure porphyritic, groundmass fine grained (augite-aleutite).—Augite-aleutite was collected from two localities. One was from a large bowlder 10 feet in diameter on the shore at Tyonek in Cook Inlet, and is evidently derived from the lavas of the Chigmit Range close by. The other locality was at Katmai Pass, between Naknek Lake and Katmai, where the rock represents in part the lava of the volcanoes which constitute the axis of the Aleutian Mountains here. The two occurrences are along the same general line of active or recently extinct volcanoes, which traverse the Alaskan Peninsula for many hundred miles.

The specimen from the vicinity of Tyonek has phenocrysts of feldspar and augite in a vitreous green translucent groundmass. Optical tests of the feldspar show in some cases the presence of andesine-oligoclase, in others labradorite-bytownite, the latter probably representing more nearly the prevailing feldspars. The augite is pale green, nearly colorless.

The two specimens from the vicinity of Katmai Pass both show phenocrysts of feldspar and pale-green augite in a fine-grained groundmass. In one specimen the groundmass is brown and opaque, with well-marked flow structure, while in the other it is pilotaxitic, but shows also flow structure. In both specimens optical determinations of the feldspar by the Fouqué method were made. In one case a determination showed andesine-oligoclase, and another andesine-labradorite, while in the other specimen two good determinations on sections perpendicular to the negative bisectrix showed labradorite tending to andesine.

DIABASIC FAMILY.

(*Characterized by the less siliceous soda-lime feldspars—labradorite, bytownite, or anorthite.*)

Under the diabase family only two groups founded on mineral combinations are given—diabase and olivine-diabase.

DIABASE GROUP.

(Consisting essentially of the characteristic feldspars of the diabasic family, with mica, amphibole, or pyroxene.)

Structure porphyritic, groundmass coarse grained (*diabase-porphyry*).—When a rock has the essential features of the diabase group and a porphyritic structure, but with its ferromagnesian constituents not determinable, though evidently present, it is classified simply as a diabase-porphyry. Both of the specimens which will be described come from the Middle Kuskokwim River, one from a rock outcrop above Oknagamut, the other from coarse gravels just below Oknagamut. Both rocks are comparatively coarse grained in the hand specimen, but differ in color, the first being dark gray and the second light gray.

The first specimen shows phenocrysts of feldspar altering to calcite, in a holocrystalline groundmass which is mostly feldspar, with a great abundance of secondary chlorite and calcite, and some muscovite. One of the feldspar phenocrysts was determined as being bytownite.

The second specimen is much decomposed. Feldspar phenocrysts are many, but of small size, and are included in a felty feldspathic groundmass. Two optical tests of the feldspar showed it to be labradorite. Phenocrysts of original ferromagnesian minerals have been decomposed and are now represented only by areas of felty or fibrous muscovite.

Structure glassy (*basalt glass*).—The walls of the first canyon, or Shell Canyon, of the Skwentna River consist of a dark-blue or dark-green aphanitic rock, whose nature is quite problematical in the field, but which under the microscope appears to be an ancient volcanic glass. What appears in the hand specimen to be stratification is seen under the microscope to be a flow structure, indicated by lighter and darker streaks, the coloring being given by minute irregular clumps of dark-brown opaque material, perhaps iron oxide, which is thickly and uniformly disseminated throughout the rock, but especially in these streaks. A high power shows abundant long needles and sheaf-like bunches of actinolite. The main part of the rock is a faintly microcrystalline, often nearly isotropic mass, in which only occasional grains reach sufficient size to be recognized as individuals. Some of these have the appearance of feldspar. From the evident basicity of this volcanic glass, it is placed among the basalts. There are veins of granular or chalcedonic silica or chert in the rock, which are parallel to the direction of flow.

AMPHIBOLE-DIABASE.

(Consisting essentially of the characteristic feldspars of the diabasic family, and amphibole.)

VARIETY, HORNBLENDE-DIABASE.

Structure porphyritic, groundmass fine (hornblende-basalt).—The specimen of hornblende-basalt comes from the Skwentna River, where it was found as a pebble at a locality just below the mouth of Hayes River. In appearance it suggests the typical lava of the Aleutian Range, and is much like the aleutites in the region of Katmai. Under the microscope fresh phenocrysts of feldspar and hornblende are found in a groundmass which is hyalopilitic, consisting of feldspar laths scattered through a light-brown isotropic substance. Optical tests of the feldspar by the Fouqué method showed it to be a labradorite. The hornblende is brilliantly pleochroic, varying from a rich brown to yellowish green.

PYROXENE-DIABASE.

(Consisting essentially of the characteristic feldspars of the diabasic family, with pyroxene.)

VARIETY, AUGITE-DIABASE.

Structure granular, allotriomorphic or hypidiomorphic (augite-diabase).—Two specimens of augite-diabase have been examined, both of which come from the Terra Cotta Range in the Tordrillo Mountains. They are medium grained to coarse grained, and are composed of soda-lime feldspar and augite. The rocks are much decomposed, and among the secondary products are muscovite, chlorite, and quartz. There is considerable ilmenite in one specimen, largely altered to leucoxene.

Structure porphyritic, groundmass coarse grained (augite-diabase-porphyry).—Augite-diabase-porphyry forms the main country rock at the lower end of Lake Nenevokuk, which is on the northwest side of the pass between the Kanektok River and Togiak Lake. The rock in appearance is greenish and fine grained, resembling somewhat a metamorphosed quartzite. Under the microscope very large phenocrysts of feldspar are discerned, and smaller ones of augite, these being set in a fine-grained holocrystalline groundmass consisting of feldspar and augite, the former preponderating; the intersertal structure is sometimes present. One feldspar phenocryst was determined as labradorite-bytownite.

Structure porphyritic, groundmass fine grained (augite-basalt).—Augite-basalt occurs in a number of places in southwestern Alaska. First, on the Lower Kuskokwim River at the mouth of the Yukwonilnuk, where it is probably a dike rock, and again as a dike rock cutting the sedimentaries at a point 14 miles below Kolmakof. Second, at the head of the Kanektok River. Third, in the region between Togiak Bay and Nushagak Bay, where it occurs in several places, especially in a mountain on the left bank of the Egoushik River, near the camp of September 23. The lava of this mountain occurs not only as sheets but in a form of a pseudoconglomerate, of which the matrix is basalt and the pebbles are partly basalt of the same variety and partly granite, slate, or other rocks. Fourth, augite-basalt is a phase of the characteristic lava of Katmai Pass.

The basalt from the mouth of Yukwonilnuk River shows phenocrysts of feldspar and augite in a nearly isotropic glassy groundmass, which is semiopaque and brown in color. Magnetite or ilmenite are common. Optical determinations show the feldspar to be anorthite, bytownite, and labradorite.

The dike basalt 14 miles below Kolmakof is dense and fine grained, nearly black in the hand specimen. Under the microscope it shows sparing phenocrysts of feldspar and augite in a very fine-grained holocrystalline groundmass, composed chiefly of feldspar with much dark ferruginous material and magnetite.

At the head of the Kanektok River, near the camp of September 9, the country rock is an altered augite-basalt, which probably forms an integral part of the ancient series which makes up the mountains here. Under the microscope the rock is essentially like some phases of the lava in the vicinity of Katmai Pass, but with a little more augite in the groundmass. The phenocrysts are stout and chiefly of intergrown broadly-striped feldspar, which was determined by the Fouqué method to be labradorite and bytownite. There are some small light-colored augite phenocrysts, and areas of serpentine which seem to be derived from the augite. The groundmass is fine grained and holocrystalline, consisting of feldspar laths with abundant augite and serpentine, and the structure is intersertal. Large clumps of pyrite are occasionally found.

The augite-basalt from the Egoushik River is typical in every way, except that some specimens are much decomposed, the augite being almost entirely altered to a uralitic hornblende.

The two specimens of augite-basalt from Katmai Pass, one being from the northwestern side and the other from the top of the pass, differ considerably in appearance, the former being black and comparatively fine grained while the latter is light grayish pink, and resembles in every way the typical aleutite which has been described from the same locality. Under the microscope, however, the two specimens are very similar, and the specimen from the top of the pass, being more typical, may be described. There are phenocrysts of feldspar and augite, the former predominating, in a microfelsitic groundmass consisting chiefly of feldspar with some ferruginous material. The augites are dark brown and are partly altered to iron oxides, and the feldspars are stout crystals showing zonal structure and twinned according to the albite and pericline laws. Many optical determinations of the feldspar showed sometimes bytownite, nearly approaching in some cases anorthite, and again labradorite-bytownite.

VARIETY, BRONZITE-DIABASE.

Structure porphyritic, groundmass fine grained (bronzite-basalt).—The only specimen of bronzite-basalt examined comes from the glacial drift in the vicinity of Tyonek, where it occurs in pebbles and bowlders. The microscope shows phenocrysts of feldspar and bronzite in an opaque ferruginous groundmass. The feldspar has a double refraction equal to that of bronzite, or yellowish red of the first order; tested by the Fouqué method it gives an angle of 46° on the intersection perpendicular to the positive bisectrix, proving it to be a bytownite-anorthite.

OLIVINE-DIABASE GROUP.

(Consisting essentially of the characteristic feldspars of the diabasic family and olivine, with mica, amphibole, or pyroxene.)

Structure porphyritic, groundmass fine grained (olivine-basalt).—Olivine-basalt occurs in many places on the Yukon River, where it has been described by the writer in a previous report.[1] It also occurs on the island of St. Michael and on the Skwentna River. These rocks require very little special description, all containing phenocrysts of olivine and feldspar in a ferruginous, often opaque groundmass.

AMPHIBOLE-OLIVINE-DIABASE.

(Consisting essentially of the characteristic feldspars of the diabasic family, with olivine and amphibole.)

VARIETY, HORNBLENDE-OLIVINE-DIABASE.

Structure granular, allotriomorphic or hypidiomorphic (hornblende-olivine-diabase).—Hornblende-olivine-diabase is found on the west side of the pass over the Tordrillo Mountains, on the shores of a small lake. From its occurrence and appearance it seems to be a very basic facies of the granite which forms a great dikelike mass in this region. The structure of the rock is coarse granular, and the essential minerals are feldspar, olivine, diallage, hornblende, and biotite; there is accessory apatite. All the minerals are very fresh. The feldspar was determined by the Michel Lévy method to be labradorite.

[1] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 242.

PYROXENE-OLIVINE-DIABASE.

(Consisting essentially of the characteristic feldspars of the diabasic family, with olivine and pyroxene.)

VARIETY, AUGITE-OLIVINE-DIABASE.

Structure porphyritic, groundmass fine grained (*augite-olivine-basalt*).—Augite-olivine-basalt occurs on the island of St. Michael, also on the Skwentna River at intervals between the second and the third canyons, or between the mouth of Hayes River and the mouth of Happy River, and on the Togiak River. The occurrences from St. Michael and the Togiak are similar, being of very vesicular pinkish lava, and in probably both cases the rock is of late Tertiary age. The specimens which came from the Skwentna River, however, belong to an ancient series, which is interbedded with stratified rocks, and has been grouped with them under the name of the Skwentna series and provisionally referred to the Jurassic. The rocks from this river are dense in grain and of a greenish color.

The rocks from St. Michael and the Togiak River show phenocrysts of feldspar, olivine, and pale-green or light-brown augite in a microlitic groundmass in which feldspar, iron oxides, olivine, and augite grains are discernible.

Of the two specimens from the Skwentna River the first, which is from the Second Canyon, above the Hayes River, is considerably decomposed and has a fine-grained intersertal groundmass. In some parts of this groundmass the feldspar microliths inclose areas which are green and mostly isotropic, evidently glass. The phenocrysts are large and consist of feldspar, augite, and pseudomorphs of serpentine and anthophyllite, which seem to be after olivine. The feldspar itself is muscovitized, and the augite is much decomposed to kaolin and anthophyllite. There is considerable serpentine throughout the rock. In the second specimen fragments of augite phenocrysts, with rarer ones of olivine, and similar phenocrysts of augite surrounded by a groundmass of opaque isotropic glass, the whole constituting broken fragments, are embedded in a fresher glass matrix. Devitrification of the groundmass has given rise to some chlorite and muscovite, and to faintly polarizing, microfelsitic or spherulitic areas. Together with the augite there is a little pale-green hornblende among the phenocrysts. As secondary products pyrite and calcite are abundant.

VARIETY, BRONZITE-OLIVINE-DIABASE.

Structure porphyritic, groundmass fine grained (*bronzite-olivine-basalt*).—Bronzite-olivine-basalt is found on Togiak Bay at the Togiak trading post, where it forms columnar cliffs on the shore. In the hand specimen the lava is porous and granular; under the microscope it is holocrystalline and consists of striated lath-shaped feldspars intergrown with yellowish bronzite and abundant olivine. There is a little pyrite.

VARIETY, DIALLAGE-OLIVINE-DIABASE.

Structure porphyritic, groundmass fine grained (diallage-olivine-basalt).—Diallage-olivine-basalt occurs in cliffs on the Sushitna, about a half mile below the mouth of the Yentna. The chief constituents are feldspar, olivine, and diallage, all very abundant; there is a little colorless augite and some iron oxide. Occasional amygdules are filled with natrolite.

ROCKS NOT INCLUDED IN THE FOREGOING CLASSIFICATION.

A few rocks which have been examined have not been included in the classification, for the reason that they form the only representative of special groups, and the writer did not feel like proposing at present a new group for the sake of classifying a single occurrence. One of the rocks which thus remains to be described belongs to the type bostonite, being essentially a feldspar rock with panidiomorphic or aplitic structure. The writer believes that an additional group of rocks is needed in the granite family, which should consist essentially of alkali feldspars with other essential constituents, and which should have the ordinary variations, dependent upon changes of structure. As yet, however, this has not been done, bostonite standing practically alone among those granitic rocks which consist essentially of alkali feldspars.[1] Other rocks which are not included in the classification are those which contain scapolite as an essential constituent. The position of the scapolite rocks is as yet somewhat problematical, and so the description of these occurrences has been delayed until now.

Finally a rock which has been classified (following Rosenbusch) as a leucite-phonolite will be briefly described.

BOSTONITE.

Bostonite occurs as a dike rock about 3 miles below Kolmakof on the Kuskokwim River. In the hand specimen it is of light-gray color and uniform, fine-grained texture. Under the microscope the structure varies from intersertal to trachytic. The rock is chiefly of feldspar, with some accessory quartz; among the feldspars the lath-shaped striated individuals, which were believed to be mainly anorthoclase or albite, are most common, while the unstriated grains, which probably represent orthoclase, are subordinate in amount. Frequent large areas of calcite have probably separated out from the rock by the alteration of some of the feldspars. There are no dark minerals.

[1] Excepting the rare "trachytes" without ferromagnesian constituents, and similar "syenites."

SCAPOLITE ROCKS.

ANDESINE-OLIGOCLASE-SCAPOLITE-BIOTITE ROCK.

This rock was found on the Yentna River some 12 or 15 miles above the junction with the Sushitna, where it forms large masses of uniform appearance, which are probably great dikes cutting on older rock, specimens of which were shown to be hornblende-syenite and hornblende-diorite. The scapolite rock is coarse grained and granitoid in appearance, the bluish gray of the scapolites suggesting quartz at first glance. Under the microscope the structure is hypidiomorphic granular, grading to panidiomorphic. The essential minerals are feldspar, scapolite, and biotite, abundant in the order of naming. The feldspars are mostly twinned according to the albite law, and one section examined by the Fouqué method showed on a section perpendicular to the negative bisectrix an angle of 70° between the plane of the optic axes and the albite twinning, proving it to be an andesine-oligoclase. The scapolite is both idiomorphic and hypidiomorphic, like the feldspar. Some sections are always dark, and give the dark cross of uniaxial minerals in convergent light. The cleavages, which are often broken, intersect at right angles and belong to the faces 100 and 010; another less perfect cleavage evidently belongs to the prism 110. The relief of the mineral is small, like quartz, while the double refraction is higher, giving a light-yellow color; it is optically negative. The biotite is fresh, and like the other minerals is idiomorphic or hypidiomorphic in habit; it contains grains of apatite. Small crystals of zircon, showing the prism and pyramid faces, are occasionally found.

Analysis of andesine-oligoclase-scapolite-biotite rock.

[Analyst, Dr. H. N. Stokes.]

	Per cent.		Per cent.
SiO_2	62.78	SrO	Trace.
TiO_2	.56	CaO	4.84
CO_2	....	MgO	2.32
P_2O_5	.15	K_2O	2.15
S	.02	Na_2O	4.11
Cl	Trace.	Li_2O	Trace.
Al_2O_3	17.16	H_2O at 100°	.24
Fe_2O_3	1.96	H_2O at 110°	.88
FeO	2.31		
MnO	.06	Total	99.58
BaO	.04		

The above analysis bears out the results of the optical investigations and throws some additional light on the probable variety of scapolite. The high percentage of silica in the rock and the low percentage of lime indicate that the scapolite is probably of the variety dipyre. The rock, therefore, presents some analogy to the so-called dipyre-diorite of the Norwegian geologists.

MICROCLINE-SCAPOLITE ROCK.

In the outcrop this rock had the appearance of a vein, forming a distinct tongue of light-colored material between walls of mottled rock, which appear to be essentially the same as the scapolite rock previously described, but of finer grain. This finer-grained biotite-scapolite rock grades off distinctly into the coarser-grained lighter-colored vein, which is about 2 inches thick. Under the microscope the structure is very coarse and the constituent grains are intergrown. Among the minerals microcline prevails, with considerable scapolite, which is largely altered to calcite. The scapolite gives in the basal section uniform darkness and the interference cross; it has abundant irregular cleavages and cracking, and shows yellow of the first order as an interference color.

QUARTZ-SCAPOLITE-PORPHYRY.

A rock called quartz-scapolite-porphyry, for want of a better name, comes from a point far distant from the rocks just described, being found on the Kuskokwim River at the mouth of the Holiknuk, where it occurs among the light-colored dikes which cut the Cretaceous shales and shaly limestones. Under the microscope the rock shows phenocrysts of quartz, which are of small size and are bounded chiefly by the dihexahedral planes, but sometimes with the prism sparingly developed and sometimes showing the faces of pyramids of two orders; the edges are often frayed by magmatic resorption. There are frequent large idiomorphic phenocrysts of scapolite, more or less broken down by decomposition. These phenocrysts give a uniaxial figure in convergent light. The outlines of the crystals show that they are of the tetragonal system, and they are characterized by low single and double refraction; they are optically negative. There is good cleavage parallel to the two lateral pinacoids, while that parallel to the prism is present but not so well developed. Irregular fractures are common. The mineral has decomposed along the margins and cleavages, partly to calcite, but mainly to an opaque kaolinic substance which is colored brown with iron oxide. There are abundant microscopic inclusions arranged in zones within the crystal. Judging from the paucity of calcite among the decomposition products and also from the apparent small single and double refraction of these scapolites, the mineral is probably a soda scapolite (marialite end of the series). By exception, some almost entirely altered phenocrysts now consist almost entirely of calcite, but what remains seems to be scapolite, and the outlines of the phenocrysts corroborate this inference. These entirely decomposed scapolites are probably lime scapolites, or meionites. A few small phenocrysts, almost entirely altered to calcite, muscovite, etc., seem to have been originally soda-lime feldspar. The groundmass is a fine-grained aggregate, consisting chiefly of quartz, orthoclase, and muscovite. In the fresher scapolite phenocrysts the cross sections are sometimes rectangles, but the favorite occurrence is in the form of a penetration twin of two such crystals along the composition plane 110; and the corners of the pinacoids whose faces constitute the rectangles are truncated by the prism. There are no true longitudinal sections in the slide, all being of small double refraction and having approximately the same orientation.

OCCURRENCE OF SCAPOLITE ROCKS ELSEWHERE.

The scapolite rock from Norway in the vicinity of Oedegården has been described by Brögger and Reusch. This rock is essentially a mixture of scapolite and amphibole with accessory titanite, and was regarded by the describers as a facies of the gabbro (hyperite) in the neighborhood of veins of apatite which traverse the gabbro. The observers concluded, moreover, that the scapolite rock was formed by the alteration of the normal hyperite or gabbro, since they found remnants of diallage in the hornblende, as if the former were the original mineral, and of plagioclase in the aggregates of scapolite as if the scapolite had formed from the plagioclase. The alteration, according to Brögger's view, was due to gaseous or pneumatolitic action.[1]

In Canada, also, granular rocks containing scapolite have been described from a number of localities.[2] In one of these rocks the principal constituents are pyroxene, hornblende, and scapolite, with accessory epidote, enstatite, pyrrhotite, and rutile, and the rock is classified as a scapolite-diorite, it having a granular structure. Another rock is made up of an aggregate of plagioclase, scapolite, and green hornblende, with accessory pyroxene, quartz, epidote, and pyrite, and this rock is termed a plagioclase-scapolite-diorite. It is stated in the pamphlet referred to that "although the derivation of at least a part of the hornblende of these rocks from pyroxene is well-nigh certain, the derivation of the scapolite from plagioclase, which, as already stated, has been pretty clearly proved in the case of the Norwegian rocks, is not so evident in these similar rocks from Canada." Also, Dr. P. A. Coleman reports from Ontario a scapolite rock consisting of hornblende, plagioclase, and scapolite, in which the scapolite was evidently primary.[3]

Finally, scapolite rock occurs in the white limestone of New Jersey

[1] See Rosenbush's Mikroscopische Physiographie der Massigen Gesteine, Vol. I, p. 331.

[2] On some Canadian rocks containing scapolite, etc., by Frank D. Adams and Andrew C. Lawson; Canadian Rec. Sci.

[3] See Zirkel's Lehrbuch der Petrographie, Vol. II, p. 783.

at many localities and in large amounts, the rock consisting in one locality of scapolite, hornblende, pyroxene, and sphene, and in another locality of the same minerals with the addition of a little plagioclase. These dikes are evidently igneous, and fumarolic or gaseous action has been suggested as taking part in their formation.[1]

In addition to these granular scapolite rocks, scapolite gneisses and amphibolites have been described from various places.[2]

In the locality on the Yentna River which has been described the main intrusive rock of the country was noted in the field to be a biotite-granite, but of this, unfortunately, no specimen was retained. Dikes of quartz-feldspar rock or alaskite, which were found cutting the granite, have been carefully examined microscopically, and connected with this alaskite were rocks transitional into the granite, and quartz veins sometimes containing tourmaline. The specimen of scapolite rock was from a large mass forming bluffs 40 feet high, and seemed typical; it is certain that this rock occurs in notable quantity, but just in what proportion to the other dikes is not certain. All these dikes cut an ancient igneous rock, which was shown in one case to be a hornblende-syenite and again a hornblende-diorite. In the second case which has been described, namely, the quartz-scapolite rock from the Kuskokwim River, the scapolite dikes were associated with a number of other siliceous dikes. Those which were examined microscopically, besides the scapolite-porphyry, are an alaskite-porphyry and a granite-porphyry.

In both these cases the scapolite is regarded as original. There is no evidence of its derivation from feldspar, but rather, in every case, of contemporaneous formation. Certainly the mineral is not the product of weathering, for it is itself nearly always in a process of decomposition, showing itself as unstable under atmospheric conditions as are the feldspars. It is exceedingly probable, however, that in the formation of this, as in other occurrences of scapolite rock, gases have played an important part. The scapolites contain chlorine, otherwise they have essentially the composition of the soda-lime feldspars. The marialite scapolite corresponds to oligoclase, and the meionite scapolite to anorthite, with a series between like that of the feldspars, so that when scapolite is found instead of feldspar we may suppose chlorine gas to have been present at the time of the formation of the rock. This is, however, no good reason for considering the rock as of secondary origin, for in most igneous rocks the gases play some part in the formation and in many a very weighty part, the rocks nevertheless belonging to the class of original igneous rocks. The writer is inclined, therefore, to give the scapolite rocks a place among the primary igneous rocks wherever the scapolite shows evidence of having formed contemporaneously with the other rock minerals. In cases where it evidently

[1] F. L. Nason, Annual Report of the Geological Survey of New Jersey, 1890, p. 33.
[2] Zirkel, op. cit., Vol. III, p. 339.

is an alteration product from some other rock, the classification will of course be different.

In case classification is attempted, the scapolites should be considered for the purposes of classification as equivalent to the feldspars, when they occur in rocks where feldspar is present in an equal or greater amount. Thus the biotite-scapolite rock from the Yentna River might be called a biotite-scapolite-belugite, since the feldspar belongs to the andesine-oligoclase series and the equally important scapolite seems to be of a variety containing much lime and corresponding to anorthite in the feldspar series. The scapolite-belugites might then be considered a group of the belugite family.

The coarse-grained microcline-scapolite rock does not fall into any of the divisions made in the foregoing classification, although it could easily be fitted in by an elaboration of the scheme.

The porphyritic scapolite rock from the mouth of the Holiknuk on the Kuskokwim might be called a scapolite-adamellite-porphyry, adamellite being the name adopted by Brögger for the quartz-bearing monzonites. In this case the scapolite appears to belong mainly to the soda end of the soda-lime series, and thus is the equivalent of oligoclase-andesine. The groundmass appearing to be mainly orthoclase, the feldspathic constituents (considering scapolite as such) would be on the whole intermediate between the granite and diorite families, or in the monzonite family. In this case the rock might be considered to belong to what might be called the scapolite-adamellites, which would be a group under the monzonite family where the scapolite partly takes the place of the feldspar.

It would probably be best, however, to separate the scapolite-feldspar rocks into a distinct class, and to give the groups characteristic names, the analogy with the feldspar rocks being expressed by writing in the tabulation each group laterally opposite the corresponding group of feldspar rocks. Thus the rock first described may be called yentnite, from the Yentna River, instead of a scapolite-belugite, but it may be written opposite the belugite group; the type would then be a biotite-yentnite. Similarly the quartz-scapolite-porphyry from the Kuskokwim[1] river might be called a kuskite, instead of scapolite-adamellite; the kuskite group of the scapolite-feldspar of rocks could be written opposite the adamellite group of feldspar rocks, and the type might be called a kuskite-porphyry.

AUGITE-LEUCITE-PHONOLITE.

Augite-leucite-phonolite occurs on the Skwentna River below the junction of Hayes River, as an ancient volcanic flow interbedded with derived tuffs, and forms part of the Skwentna series, which has been

[1] Eskimo *Kuska*, derivation uncertain, *kwik*, genitive *kwim*, river.

referred to the Jurassic. The rock has a definite flow or "trachytic" structure. It contains small clumps of minerals which are usually allotriomorphic granular in their form and which are surrounded by a finer-grained groundmass, which is isotropic, semiopaque, or sometimes microfelsitic. The larger crystals are of orthoclase, augite, and hornblende, the latter pale and very likely uralitic. The augite is also very pale in color. There is a little plagioclase, one crystal determined by the Fouqué method being andesine-oligoclase. In the groundmass many tiny colorless isotropic hexagonally-outlined crystals are probably of leucite. The orthoclase is of the variety sanidine, but somewhat decomposed. Tests for the presence of nepheline by gelatinizing and staining in the groundmass were unsatisfactory, on account of the kaolinic decomposition products. The rock is classified as above, according to Rosenbusch's definition.

CLASSIFICATION OF IGNEOUS ROCKS ACCORDING TO GEOGRAPHICAL PROVINCES.

In the following division of the report the igneous rocks which have been described under the "Classification according to composition" will be brought together as they occur, and their relations to one another briefly pointed out. Inasmuch as all the important types have been described the details of composition and structure will not be referred to again.

IGNEOUS ROCKS OF THE TORDRILLO MOUNTAIN REGION.

GRANITIC ARKOSES.

(Derived from probably pre-Jurassic granite.)

The oldest igneous rocks of the Tordrillo Mountain region of which we have any record are not found in place, but only in detrital fragments, which make up sedimentary arkoses—which are often coarse enough to permit of the original character of the igneous rocks from which they are derived to be ascertained. These arkoses are found in the series of interstratified volcanic and sedimentary rocks which occurs on the Skwentna River between Shell Canyon and the mouth of Happy River. They also occur in the sedimentary rocks which make up the main mass of the Terra Cotta Range on the west side of the Tordrillo Mountains, which rocks are also made up of various sediments besides the arkoses, together with probable volcanics. The series which occurs on the Skwentna River has been called the Skwentna series, and those which make up the Terra Cotta Mountains have been called the Terra Cotta series, and both series have been provisionally assigned to the Jurassic system, on grounds which have been discussed in a previous part of the report. Finally, arkoses which are plainly derived from the destruction of granite are found in the Tordrillo series, which comprises most of the sedimentary rocks in the heart of the Tordrillo Mountains, at the point where this range was crossed, and which has been provisionally referred to the Cretaceous system.

In all these sedimentary rocks the material making up the arkoses is often plainly determinable as granite, and frequently it can be shown to be a hornblende-granite. This points to the existence of a granitic or partly granitic land mass in the general neighborhood of what is now the Tordrillo Mountains as early as a period preceding Jurassic times. From the similarity of the material in the arkoses of the probably Jurassic rocks and in the probably Cretaceous rocks, and from the apparent lack of any granitic material intruded into the Jurassic rocks previous to the deposition of the Cretaceous, it seems probable that all these arkoses were derived from the same land mass.

ANCIENT (JURASSIC?) VOLCANICS.

Yentna River below the junction with the Skwentna.—On the Yentna River, at intervals of 10 to 20 miles above its mouth, are found dense, dark-green, ancient-appearing, fine-grained, igneous rocks outcropping at intervals. Two specimens of these rocks were examined microscopically and proved to be, in one case, a hornblende-syenite, and in another a hornblende-diorite. The exact origin of these rocks could not be determined, but from their general resemblance to some of the plainly volcanic rocks of the Skwentna series farther up the river the writer is inclined to include them in that series and to regard them also as volcanics. These rocks are cut by abundant dikes of granite, alaskite, and scapolite rocks.

Skwentna River from Shell Canyon to the mouth of Happy River.—At Shell Canyon the cliffs are composed of partly devitrified volcanic glass, probably basaltic. At a point some distance below Hayes River was found ancient augite-leucite-phonolite interstratified with volcanic tuffs. In the second canyon of the Skwentna, above the mouth of Hayes River, the rocks are largely augite-basalt and augite-olivine-basalt, interstratified with basaltic tuffs. In the third canyon of the Skwentna, and in the mountains above, augite-olivine-basalt and biotite-apotrachyte were found, also alternating with tuffs and slates.

All these rocks, from Shell Canyon to the mouth of Happy River, evidently represent ancient volcanic flows. All are interbedded with tuffs and other sedimentaries and form a rock series which has been assumed to be Jurassic in age.[1] These igneous rocks are evidently older than the dike rocks which cut through them in great abundance, and which will next be described, and are evidently younger than the granite which has furnished the material for the arkoses with which they are associated.

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[1] See page 180.

Summing up the varieties of ancient lava in the Skwentna series, we find, beginning with the most siliceous, biotite-apotrachyte, augite-trachyte, augite-leucite-phonolite, basalt glass, augite-basalt, and abundant olivine-basalt.

Terra Cotta Mountains.—The rocks of the Terra Cotta Mountains were not carefully examined, but they appear to consist, as before stated, of sedimentary rocks interstratified with some ancient volcanics. Inasmuch, however, as they are cut by a great number and variety of dikes, and since the rocks from the mountains were collected mainly in the form of pebbles from their bases, it is not always easy to tell whether a certain rock appears as a dike or flow. Certain specimens suggest by their structure a lava and are also in their stage of decomposition further advanced than the ordinary dike rocks. The writer believes, therefore, that they actually form an integral part of the Terra Cotta series. Of these rocks only one variety will be mentioned, that of augite-diabase, which in two specimens is fine-grained, greenish, and resembles the basalts of the Skwentna series.

POST-TORDRILLO DIKE ROCKS.

(Period of intrusion probably Eocene.)

Tyonek.—In the drift at Tyonek were noticed some rocks which evidently belong in this classification, although they were not in place; they were, however, derived from the Tordrillo region. These rocks were biotite-granite and rhyolite, both probably dike rocks.

Yentna River below the junction of the Skwentna.—Remark has already been made concerning the dike rocks which cut the hornblende-syenite and diorite on the Yentna River not far from its mouth. These rocks in some places form considerable bodies and consist of granite, alaskite, and scapolite rocks. The typical scapolite rock, which seems to occur in large masses, is an andesine-oligoclase-scapolite-biotite rock. The other scapolite rock examined, which appeared in the form of a small dike or vein traversing the more ordinary variety, was composed of microcline and scapolite.

Skwentna River from the mouth of Hayes River to Portage Creek.—Below Hayes River bowlders of morainal material and pebbles in the river bed, evidently derived from the heart of the Tordrillo Mountains, show the rock varieties—augite-biotite, hornblende-belugite, hornblende-belugite-porphyry, augite-syenite-aplite, biotite-granite, and alaskite. At the third canyon of the Skwentna, below the mouth of Happy River, the rocks of the canyon and the mountains above are cut by many dikes of syenite, diorite-porphyry, andesite, and augite-biotite-granite-aplite. On the ridge between the upper Skwentna and Happy River is a decomposed basalt, which may be a dike rock or a flow.

From Portage Creek to the Styx River.—On the mountain above

Portage Creek, the shales of the Tordrillo series are cut by frequent dikes which grow larger and more numerous as the central intrusive mass of the mountains is approached. These dikes, as examined, consist of diorite-porphyry and augite-soda-trachyte. Near the summit of the range the main intrusive mass is several miles wide, and while apparently nearly homogeneous in appearance, yet varies considerably in structure. A specimen from Crucifix Mountain, on the east side of the pass, is biotite-hornblende-quartz-syenite. One mile east of the pass the rock was found to be a biotite-granite-aplite; while on the summit of the pass it was a hornblende-biotite-soda-quartz-syenite. Just below the pass, on the western side, on the shores of the little lake which is there situated, the rock becomes locally a hornblende-olivine-diabase. Farther down there are found in the drift numerous specimens of dike rocks, which all belong to the same series. Among the species identified were biotite-granite-aplite, biotite-dacite, augite-rhyolite, and alaskite.

From Styx River to emergence of the Kuskokwim from Tordrillo Mountains.—The dike rocks which are so abundant near the summit of the Tordrillo Range become less important and sometimes nearly absent in the Teocalli Mountains, a minor range which lies to the west of the main divide; but in the Terra Cotta Mountains, the range next west, they become extraordinarily abundant, often forming half of the whole mass of the mountains, and being usually of siliceous varieties, as a consequence of which the rock, on weathering, assumes brilliant yellow and reddish colors, which have given the name to the range. Among these dike rocks, which have been chiefly identified from specimens picked up in the river valley at the base of the mountains, are alaskite, alaskite-aplite, alaskite-porphyry, tordrillite, biotite-granite, hornblende-granite-aplite, abundant rhyolite, syenite, syenite-porphyry, and trachyte.

Summary.—Summarizing the intrusive rocks of the Tordrillo Mountains, it may be said that the central mass of the mountains is made up of a great dike several miles wide, which has cut through the shales of the Tordrillo series. The general type of this central mass, so far as examined, seems to be a quartz-syenite, or a rock intermediate between a granite and a syenite; but there are many other phases, an exceptional one being hornblende-olivine-diabase. On the eastern side of the main mass, dikes are numerous in the neighborhood of the central body and seem to be in general of the same type as the central mass, although varying considerably from alaskite through various varieties of granite (including augite-granite) to syenite and trachyte (including typical syenite, augite-syenite-aplite, and augite-soda-trachyte), and finally to frequent diorite-porphyry and andesite, while occasionally less siliceous dikes are met with which form exceptions to the rule, such as belugite and diabase or basalt. On the west side of the Tordrillo Mountains, in the immediate vicinity of the main mass, are similar dikes, also of a siliceous nature, among which alaskite, augite-rhyolite, biotite-granite-aplite, and biotite-dacite were identified. Farther west, in the Terra Cotta Mountains, is a distinct zone characterized by a great amount of intrusive material, and the dikes in this locality are in general more siliceous than in the districts previously noted. Alaskite and rhyolite occur in greater abundance, and there is a complete series, as regards composition and structure, of the siliceous igneous rocks as far down as the trachytes.

TERTIARY OR PLEISTOCENE LAVAS.

Volcanic rocks belonging to the Tertiary or Pleistocene period were not found in place in the Tordrillo Mountain region, but occasional fragments found in the drift show that these rocks do exist. From their fresh appearance they separate themselves sharply from the ancient volcanics of the Skwentna series, and in their mineralogic composition they show a consanguinity with the typical Tertiary or Pleistocene lavas of the Aleutian Mountains.

Tyonek.—In the drift at Tyonek were found two specimens of fresh lava evidently belonging to the Tertiary or Pleistocene lavas of the Aleutian Range. One of these was an augite-aleutite and the other a bronzite-basalt.

Sushitna River near the station.—A short distance above the station on the Sushitna River the right bank shows a cliff of dark fresh-appearing lava, which does not resemble the ancient lavas of the Skwentna series. This rock is a diallage-olivine-basalt.

Yenlo Mountain.—Yenlo Mountain was not actually visited, but from a distance of half a mile it appeared to be undoubtedly of volcanic origin, and not long extinct. In the neighborhood of this mountain there are numerous fragments of pumice along the river, which were identified as being of volcanic origin, although not referred to any particular rock species.

On the Skwentna below Hayes River.—At this locality there was found in the river a large pebble of perfectly fresh hornblende-basalt, which evidently belonged to the Tertiary or Pleistocene lava, and must have been derived from the Tordrillo Mountains near this point.

RÉSUMÉ OF IGNEOUS ACTIVITY IN THE TORDRILLO MOUNTAIN REGION.

The earliest igneous rock of which we have any record in the Tordrillo Mountain region formed at least a part of the land mass from which the rocks of the Skwentna series were derived and which was therefore probaby pre-Jurassic. The type of this rock seems to have been a hornblende-granite. The next occurrence of igneous rock, in point of age, is the lavas which are associated with the sediments of the Skwentna and the Terra Cotta series, and which were probably poured out in Jurassic times. These lavas are mainly basaltic, and olivine-basalt may be taken as the type, but there were some trachytic rocks. The third division of igneous rocks in point of age is represented by the numerous dikes of the Tordrillo Mountains, which were all intruded subsequent to the deposition of the probably Cretaceous Tordrillo series, and which are not found in the probably Neocene Hayes River beds; it is likely, therefore, that they were intruded during the Eocene period. These rocks are mainly siliceous, and a siliceous granite may be taken as the type, although there are many variations in both directions.

Finally, in late Tertiary or Pleistocene time the volcanic activity which made itself felt all along the Alaskan Peninsula and Aleutian Islands reached with diminished energy into this region, where it is represented by scattered flows. The type of these lavas seems to be aleutite.

THE IGNEOUS ROCKS OF THE KUSKOKWIM MOUNTAIN REGION.

GRANITIC ARKOSES.

(Derived from Pre-Devonian granite.)

The most ancient igneous rock of the Kuskokwim Mountain region (which, so far as has been studied, includes the region of low mountains traversed by the middle Kuskokwim, between the Tachatna and the Yukon water portage at Kalchagamut) appears to have been granite. This rock has not actually been found in place, and the only record of it is in the sedimentary arkoses of the detrital rock series which are found in this region. In the Tachatna series, which has been described, occasional arkoses are encountered, some of which are evidently derived from granite. In the Holiknuk and Kolmakof rock series, which lie farther down the Kuskokwim, the arkoses become much more abundant, forming a large part of the rocks, and also become coarser. The Tachatna series is, in part at least, Middle Devonian, while the other two rock series mentioned probably belong to the Cretaceous system, so that the granite from which these arkoses are derived must have formed part of a land mass as early as Devonian times and must have continued to furnish sediments throughout the Cretaceous period.

ANCIENT (CRETACEOUS?) VOLCANICS.

The rocks which lie between Kolmakof and the Yukon portage at Kalchagamut frequently contain interbedded and evidently contemporaneous lavas and are also often cut by dike rocks of the same varieties. These volcanic rocks are generally ancient in appearance and are interstratified with arkoses, shales, and other sedimentary rocks which show ripple marks and other shore markings, with plant remains, giving evidence of littoral formation.

At the mouth of the Yukwonilnuk, out of the many large pebbles brought down by the stream from the mountains in which it heads was an augite-basalt which is regarded as probably belonging to this series of ancient volcanics. Three miles below Kolmakof the country rock consists of an ancient hornblende-mica-andesite. About 11 miles farther down the river the sedimentary rock contains interbedded, apparently contemporaneous, sheets of lava and is also cut by dikes of the same material; one of these dikes on examination proved to be an augite-basalt. Six miles farther down, the country rock, forming a constituent part of the Kolmakof series, was identified in two cases as being hornblende-apotrachyte and augite-dacite. At the camp of August 6 the country rock is a syenite or diorite-porphyry of fine grain, which is apparently, as in the other cases, an effusive rock of considerable age. Finally, 12 miles farther down, the country rock is a fine-grained diabase-porphyry, which undoubtedly represents a flow contemporaneous with the associated sediments.

The ancient lavas of the Kolmakof series so far as examined, therefore, are essentially intermediate and basic, the most siliceous rock being a syenite or diorite-porphyry, and the series grading from this through hornblende-apotrachyte, augite-dacite, hornblende-mica-andesite, augite-basalt, and diabase-porphyry.

POST-CRETACEOUS DIKE ROCKS.

The Tachatna series of the Upper Kuskokwim is almost entirely free from dike rocks, only a single dike having been cut in it. This was just above the trading post at Vinasale, where the dike was a biotite-granite-porphyry. Farther down the river, in the Holiknuk series, there were no dikes observed between Vinasale and the Holiknuk River. At the mouth of the Chagavenapuk River, between Vinasale and the Holiknuk, pebbles of rhyolite and biotite-granite, both evidently dike rocks, are found in the gravels, but these have probably been brought down from the Terra Cotta Mountains, in which the Chagavenapuk heads. At the mouth of the Holiknuk a number of siliceous dikes are found cutting the stratified rocks. These dikes, so far as examined, were alaskite-porphyry, muscovite-granite-porphyry, and quartz-scapolite-porphyry. A number of miles farther down the river, at the camp of August 4, dikes of granite porphyry were found. At the mouth of the Yukwonilnuk River large pebbles of garnetiferous biotite-syenite-porphyry, granite-porphyry, and aleutite were found. All probably represent dike rocks. Three miles below Kolmakof a dike of bostonite was found, and at the camp of August 6 there were dikes of quartz-syenite. In the gravels between these two localities a dike rock of the variety biotite-soda-granite-porphyry was found. Below Oknagamut diabase-porphyry and hornblende-diorite-porphyry were found in the drift.

It will thus be seen that the banks of the Kuskokwim from the Tordrillo Mountains as far as the Holiknuk are almost entirely free from intrusive rock. Below the Holiknuk dikes are frequent, and are most numerous in the region between Kolmakof and Oknagamut, a region which is also characterized by the appearance of abundant ancient volcanic material, as has just been described. In general the dikes belong to siliceous varieties, beginning with alaskite-porphyry and running through granite-porphyry, quartz-scapolite-porphyry, bostonite, biotite-soda-granite-porphyry, garnetiferous biotite-syenite-porphyry, quartz-syenite, hornblende-diorite-porphyry, aleutite, and diabase-porphyry. Of these varieties the siliceous ones are by far the most common.

SUMMARY OF IGNEOUS ACTIVITY.

Summarizing the igneous activity in the region of the Kuskokwim Mountains where they are cut by the Kuskokwim River, we see that there was an early granitic land mass which existed previous to Devonian times. During the Cretaceous period (Kolmakof series) lavas of varying composition appear to have been poured out over restricted areas. The general type of these lavas was basic, but trachyte is found among them. Finally, in post-Cretaceous times dike rocks were intruded along the zone of the Kuskokwim Mountains, especially the zone of Cretaceous igneous activity, but practically not at all in the gently folded and undisturbed region between the Kuskokwim Mountains and the Tordrillo Mountains. The composition of these latest intrusive rocks was essentially siliceous, and granite may be fairly taken as the type.

IGNEOUS ROCKS OF THE OKLUNE MOUNTAIN REGION.

CRETACEOUS ARKOSES.

(Derived from pre-Cretaceous igneous rocks.)

In the igneous rocks of the Oklune series, as exposed on the Upper Kanektok, are frequent arkoses interstratified with slates, tuffs, and ancient volcanic flows. Some of these arkoses are plainly granitic, while others seem to be derived from syenite and diorite. On the Egoushik River the volcanic conglomerate which has already been described (page 166) as part of the Oklune series contains among its pebbles, besides basalt (which is of the same nature as the matrix of the conglomerate and probably nearly contemporaneous with it), pebbles of granite-porphyry, slate, and alaskite.

Therefore, in the region of the Oklune Mountains there existed, previous to the deposition of the Oklune series (which is, in part at least, Cretaceous), granular and porphyritic rocks, such as granite, syenite, diorite, granite-porphyry, and alaskite.

ANCIENT (CRETACEOUS?) VOLCANICS.

On the Kanektok River, just above the junction of the Klok, augite-trachyte occurs as an integral part of the Oklune series, interbedded with tuffs and other sedimentaries. At the camp of September 9, above Lake Kagati, the country rock is an ancient augite-basalt; and a little farther up, at the small lake called by the natives Nenevokuk, it is a diabase-porphyry. On the Togiak River, 7 or 8 miles below Kashaiagamut, the country rock is a decomposed andesite. On the Egoushik River, as already noted, the country rock is in places an augite-basalt, which is interbedded with sediments and has been folded into the mountains, and so is considered a part of the same ancient series.

All through the Oklune series, even where the solid lavas do not occur, abundant tuffs show that volcanic activity was great during the deposition of the rocks. The general nature of the lavas which were poured out during this period was basic, an augite-basalt being the type. Besides this rock we have the nearly related diabase-porphyry, then andesite, and finally augite-trachyte.

POST-CRETACEOUS DIKE ROCKS OF THE OKLUNE MOUNTAINS.

(Period of intrusion probably Eocene.)

In the Oklune Mountains are occasional siliceous dikes, some of them of large size, which cut the rocks of the Oklune series, both igneous and sedimentary. On the western front of the Oklune Mountains a large bowlder in the drift, evidently a dike rock, was determined to be rhyolite. A little farther up the Kanektok River, at the first great bend, there is a broad belt of hornblende-syenite, evidently intrusive and trending northeast with the general trend of the mountains. In the neighborhood of the pass between the Kanektok and Togiak rivers are occasional dikes of hornblende-biotite-granite, of which a broad dike, several miles across, forms the summit of the pass.

On the coast, between Togiak Bay and Kululuk Bay, a mass of yellow rock, a specimen of which proved to be rhyolite, was observed, but no close examination was made.

Therefore, after the deposition of the Oklune series, it was cut through by siliceous dikes which, so far as hastily examined, were syenite, rhyolite, or granite. Owing to the discovery of Cretaceous fossils on the Middle Kanektok (see p. 134), we may say that this intrusion was post-Cretaceous, and since we know that the deep erosion of land forms which has operated upon the dikes as well as upon the inclosing rocks probably took place in Miocene time,[1] we may believe the period of intrusion to have been early Tertiary or Eocene.

[1] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p 260.

TERTIARY VOLCANICS.

In the region between Togiak Lake and Nushagak much of the country, especially in the vicinity of the coast, is covered by volcanic rocks which are fresh in appearance and evidently of younger age than those which have been described. Lava of this sort is found along most of the coast between Togiak Bay and Kululuk Bay, and many low, rounded hills appear a short distance from the shore, which resemble defaced volcanic cones, such as are well shown on the island of St. Michael and vicinity. Rock specimens were examined from two localities, one from the Middle Togiak River, below Gechiagamut, and one from the trading post at Togiak; the first specimen was augite-olivine-basalt and the second bronzite-olivine-basalt. The fact that these rocks are olivine-basalts unites them closely with the olivine basalts of St. Michael and the Yukon River, which are probably mainly Pliocene, and separates them from the ancient basalts of the Oklune series, which do not, so far as examined, contain olivine. In the volcanic region between Togiak Bay and Kululuk Bay, moreover, the comparative freshness of the volcanic topography, indicating that no very long period has elapsed since the outpourings of lava, and the close resemblance of the topography to that in the neighborhood of St. Michael, all go to show that these lavas belong to the same period as those on the Yukon.

Associated with these Tertiary flows are dikes of the same age and composition, which cut the rocks of the Oklune series in great profusion, where these are exposed between Togiak Bay and Kululuk Bay.

SUMMARY OF IGNEOUS ACTIVITY.

Summarizing the igneous activity in the region of the Oklune Mountains, we find that previous to Cretaceous times there existed granitic and dioritic igneous rocks, forming part, at least, of a land mass; these rocks are represented, so far as known, only by the derived sediments. During the deposition of the Oklune series in Cretaceous times there was considerable volcanic activity, and much lava was poured out, probably from many scattered volcanoes. During the period immediately succeeding the Cretaceous, siliceous dike rocks were thrust up into the Cretaceous beds. During late Tertiary time there was a renewal of volcanic activity, mainly in a slightly different part of the region from the Cretaceous vulcanism; and from many scattered vents, which were probably, in part at least, submarine, lavas were poured out, of a general character like those of the Cretaceous period, but more basic.

IGNEOUS ROCKS OF THE ALEUTIAN MOUNTAIN REGION.

FROM THE NAKNEK RIVER TO KATMAI.

Naknek Lake granite, probably pre-Jurassic.—On Naknek Lake coarse-grained granitic rocks seem to occupy a considerable belt, trending parallel with the main trend of the Alaska Peninsula. On the north side of Naknek Lake a bowlder of this rock examined was of syenite, while on the other side a specimen from an extensive outcrop was hornblende-granite-aplite.

The rocks of the Naknek series, which outcrop between Naknek Lake and Katmai, contain an abundance of arkoses, and often of conglomerate. In many cases these sedimentary rocks are plainly derived from hornblende-biotite-granite or from biotite-granite, and the coarseness and abundance of the conglomerates and the lack of water wear evidenced in the arkoses shows the close proximity to a granitic shore line.

The resemblance of the granites in the conglomerates and arkoses at Katmai to the extensive outcrops on Naknek Lake suggests that the former may have been derived from the latter, and that the Naknek Lake granite is pre-Jurassic, since the sedimentaries of the Naknek series contain abundant Juratrias fossils.

Jurassic volcanics.—At the great bend of Naknek Lake the mountains are composed of augite-andesite, which is of greenish color and shows by its alteration evidence of greater age than the more recent volcanics which occupy the summit of the Aleutian Mountains in this vicinity. The extent to which the Naknek Lake lava has been cut by erosion also shows that it is not very recent.

At Katmai Point a bed of decomposed green lava occurs, interbedded with the arkoses and conglomerates, and appears to have been a flow contemporaneous with them—a supposition to which in this case also the ancient and altered appearance of the lava gives weight.

In both these cases the ancient volcanics seem to have been contemporaneous with the deposition of the Jurassic rocks of the Naknek series, although there is a possibility that they may be intrusive. In both cases the lava is an augite-andesite.

Late Tertiary and Pleistocene lavas.—The summit of the Aleutian Mountains in this vicinity is formed by a continuous chain of volcanoes. One of these volcanoes is said by the natives to smoke occasionally. Earthquakes and hot springs are among the volcanic phenomena actually experienced in the region, and the continuation of the chain of volcanoes extends to those which have been active in historical time, such as St. Augustine and the volcano in the vicinity of the Ugashik lakes, as well as many others along the same range farther southwest.

The volcanoes in the vicinity of Katmai Pass bear on their surfaces evidence of some difference in their periods of eruption, some showing smooth surfaces, while others are furrowed by streams, and still others carry fine glaciers upon their sides. It is evident that the latter have not had any eruptions during late Pleistocene time, while those which have smooth surfaces must have been active comparatively recently. The line of volcanoes is along a belt where the lava has broken up through the sedimentary Jurassic rocks, tilting these very gently on both sides away from the central mass. A basaltic dike at Katmai Point, which cuts through the Jurassic sediments, is probably an offshoot of the same igneous mass. We may conclude that these volcanoes originated in late Tertiary times, since there is evidence that some of the glaciers on their sides were already formed and discharged into the sea at a time when the latter stood several thousand feet higher than at the present and the highest Pleistocene stratified gravels were being deposited;[1] and we know that there is still a general volcanic activity along this zone.

ISLAND OF UNALASKA.

The central part of the island of Unalaska, or at least those mountains examined by the writer in the immediate vicinity of Iliuliuk in 1896, are composed of diorite, of which several specimens were examined microscopically. In one specimen from the mountain above Iliuliuk the rock is a hornblende-diorite, the feldspars proving to be, by seven tests, andesine, and the other specimen, from near the settlement of Iliuliuk, is augite-diorite, the feldspars being mainly albite-oligoclase. A dike of andesite, probably an offshoot from the same igneous mass which has burst out as Tertiary-Pleistocene volcanics on portions of the island and on the adjoining islands, was found cutting the diorite upon the mountain.[2]

OTHER PARTS OF ALASKA PENINSULA AND ALEUTIAN ISLANDS.

Becker[3] has noted that at Karluk, on Kadiak Island, there are magnificent cliffs of diorite. Dr. Dall[4] refers to the Shumagin Islands, off the coast of the Alaska Peninsula, as consisting in part of fundamental granite. Mr. Chester W. Purington, formerly of the United States Geological Survey, kindly presented to the writer, several years ago, a map upon which all available information as to the rock geology of Alaska had been compiled by himself.

Upon this map a belt of granite and other siliceous igneous rocks is represented as running along the Alaska Peninsula from the Ugashik River to the neighborhood of Port Möller, forming the northwestern

[1] See p. 251.
[2] See also Becker, Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 42.
[3] Gold fields of southern Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 41.
[4] Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, p. 835.

front of the Aleutian Mountains; granite is also represented as occupying a considerable area between Naknek Lake and Becharof Lake, forming Johnston's Hill, which is a conspicuous landmark on Bristol Bay, and being a continuation of the same general northeast and southwest trending belt. The writer is unable to find, in Mr. Purington's absence, from what authority this belt of siliceous igneous rocks is represented, but since it accords with his own observations on Naknek Lake, he is inclined to accept the notes as correct.

SUMMARY.

It appears probable from the foregoing that a belt of fundamental granite and diorite extends the whole length of the Alaska Peninsula and probably of the Aleutian Islands, and forms the true foundation of this remarkable ridge in the crust of the earth; the belt is exposed at a number of places, but is often covered by later sediments or by later volcanics. This fundamental igneous rock constituted, as early as Jurassic times, a land mass which supplied the detrital material toward building up the Jurassic sediments.

During the Jurassic period, following evidence in the vicinity of Katmai and Naknek Lake, there appears to have been some volcanic activity, the type of lavas being andesitic. The eruptive rock of this period, therefore, is generally more basic than the fundamental rock, although at Unalaska the composition appears to be about the same.

Finally, in late Tertiary and early Pleistocene time, there was a renewal of volcanic activity all along the Alaska Peninsula and the Aleutian Islands, reaching from the Skwentna River at least as far as Little Sitkin Island, a distance of about 1,500 miles (see map 13). The type of this latest lava seems to be intermediate between andesite and basalt, or aleutite.

GENERAL DESCRIPTIVE GEOLOGY OF SOUTHWESTERN ALASKA.

Assembling upon a map (map 14) the results which have already been arrived at, we may briefly consider the geology.

DISTRIBUTION OF ROCKS.

Fundamental granite.—According to Dr. Dall,[1] the mountains of the region between the Yukon and the Kuskokwim rivers are said to be "essentially granitic, while bearing metamorphic quartzites and argillites upon their flanks."

Along the Alaska Peninsula, as has already been described (see p. 234), there runs a belt of fundamental granite and diorite, which is at least

[1] Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, pp. 862-863.

pre-Juratrias, and possibly may go back as far in age as the probably Archean granite of the Kaiyuh Mountains.

Pre-Silurian schists.—According to Dr. Dall,[1] the Kaiyuh Mountains are composed of rocks which are apparently metamorphic and have a general dip NW. and SE. The same writer[2] describes metamorphic quartzites at various points on the Lower Yukon alternating with areas of Tertiary sedimentaries, and notes that Point Romanof and Cape Romanzof are metamorphic, as well as some low ranges of hills to the southward.

Devonian-Carboniferous sediments.—The Tachatna series outcrops for a considerable distance along the Upper Kuskokwim above the trading post of Vinasale, and has been assigned to the Devonian-Carboniferous periods.

On the Swan River, a tributary of the Mulchatna, which is itself tributary to the Nushagak, the specimen of rock given to the writer by a prospector, as well as a description of its occurrence, recalled very forcibly the rocks of the Tachatna series of the Kuskokwim.

On the Lower Tanana, near Baker Creek, Mr. Brooks, of the United States Geological Survey, found strata which are regarded as Paleozoic and which have a general resemblance to the Paleozoic of the Kuskokwim.

Jurassic sediments.—Jurassic sediments from the Alaska Peninsula in the vicinity of Katmai have been described in the previous pages, and also rocks provisionally regarded as Jurassic from the Tordrillo Mountains (the Skwentna series and the Terra Cotta series). Other localities which bear probable Jurassic fossils have been found at many places along the general trend of the Alaska Peninsula from Port Möller to Tuxedni Harbor, in the neighborhood of Mount Iliamma. At Port Möller fossils were collected by Dr. Dall[3] which seem to be regarded by Dr. White, who examined them, as belonging to a fauna transitional between the Jurassic and the Cretaceous. From Kialagvit Bay Dr. Dall[4] collected fossils which Prof. Alpheus Hyatt referred to the Jurassic (inferior Oolite).

From Coal Harbor, not far from Katmai Bay, fossils have been collected[5] which are also, in Professor Hyatt's opinion, Jurassic.

From Kamishak Bay fossils collected by Dr. Dall have been referred by Professor Hyatt to the Jurassic (Upper Liassic).

On the shores of Tuxedni Harbor characteristic fossils were found,[6] referred by Professor Hyatt to the Jurassic (Inferior Oolite).

At Anchor Point, on the southeastern shore of Cook Inlet,[7] many pebbles containing *Inoceramus porrectus* are found at low water, and

[1] Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, pp. 862-863.

[2] Op. cit., p. 817.

[3] Op. cit., p. 867.

[4] Op. cit., pp. 871 and 907.

[5] Op. cit., p. 908.

[6] Op. cit., p. 907.

[7] Op. cit., p. 866.

as this fossil is one of those which is so abundant in the Juratrias limestone at Tuxedni Harbor it may be supposed that these pebbles come from the same horizons, and that the Jurassic rocks underlie this part of Cook Inlet, close to the shore of Kenai Peninsula.

As further evidence on this point the occurrence of fossils at Kachemak Bay, not far from Anchor Point, may be mentioned.[1] Here, near Port Graham, a heavy bed of limestone contains fossils, referred by Eichwald to the Neocomian (lowest Cretaceous). There appears, however, to be some doubt[2] whether these beds may not be similar to the Port Möller beds and represent a commingling of the Cretaceous and Jurassic faunas.

Cretaceous rocks.—The rocks occupying the central part of the Tordrillo Mountains, where these were crossed by the writer, were referred to the Cretaceous, although without fossil evidence (see p. 183). On the Kuskokwim all the rocks between Vinasale and Kalchagamut were also referred to the Cretaceous, and in the Oklune Mountains most of the sedimentary rocks between the Kuskokwim and Nushagak Bay were included in the same system. In the passage up the Kanektok River a characteristic fossil was found in the Cretaceous sediments. Farther southwest, on the summit of the winter route between Goodnews Bay and Togiak Bay, the rock, as shown by a specimen given to the writer by the Rev. Mr. Kilbuck, Moravian missionary on the Kuskokwim, is in part a fetid limestone, which, on microscopic examination, proved to be identical with a peculiar type of the Cretaceous on the Kanektok, in that it was made up largely of sponge spicules.

Kenai sediments.—The Kenai rocks occupy a considerable area of the Kenai Peninsula, on Cook Inlet.[3]

On the mainland, not far from Katmai, coal-bearing rocks, regarded by Dr. Dall as probably Kenai, were reported by the Russians.

On Nunivak Island Dr. Dall[4] reported sandstones which he believed to belong to the Kenai group.

At Point Vancouver, at a point opposite Nunivak Island, Dr. G. M. Dawson[5] found sandstones carrying plant remains, which identified them with the Kenai.

On Norton Sound, Dall[6] describes beds of the Kenai group carrying plant remains, and also notes the same rocks from a branch of the Unalaklik, which flows into Norton Sound. This area of the Kenai extends inland between Norton Sound and the Yukon River, where the beds appear again.

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[1] Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, p. 866.
[2] Op. cit., p. 868.
[3] Dr. W. H. Dall, Correlation papers, Neocene, Bull. U. S. Geol. Survey No. 84, map, p. 268.
[4] Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, p. 814.
[5] Op. cit., p. 815.
[6] Dr. W. H. Dall, Correlation papers, Neocene, Bull. U. S. Geol. Survey No. 84, p. 246.

On the Lower Yukon Dr. Dall[1] notes outcrops of sandstone at various points between Andreafski and the vicinity of Nulato, and includes these partly in the Kenai group and partly in the overlying Nulato marine sandstones. The writer has also briefly mentioned the occurrence of the Kenai in this region in a previous report.[2]

Neocene sediments.—Within the limits included by the general map Neocene rocks have been described at various places. On the Lower Yukon the Nulato sandstones, which carry marine fossils, indicating a Miocene age, have been described by Dall.[3] New localities have been added by the writer.[4] Within the previous pages of the present report Neocene beds have also been described from Nushagak and from the Skwentna River.

Pleistocene sediments.—The upper part of Cook Inlet is filled with stratified gravels and clays, and these stretch far into the Sushitna Valley and along the valley of the Skwentna to the base of the Tordrillo Mountains.

On the west side of the Tordrillo Mountains the Upper Kuskokwim flows through a broad stretch of stratified gravels, sandstones, and clays as far as the beginning of the Kuskokwim Mountains below the junction of the Holiknuk. The Holiknuk heads far to the south and flows in a northeasterly direction, and it is said that its course lies through low, flat country, and that a divide, not exceeding 500 or 600 feet high, separates it from the waters of the Nushagak.[5] On the other side of the divide the valley of the Nushagak lies mainly in a region made up of stratified gravel deposits, and at Nushagak Bay this flat country extends from the low mountains to the west and northwest of the bay as far as the Aleutian Mountains on the Alaska Peninsula. The whole of the peninsula between Nushagak Bay and Bristol Bay is essentially gravel.

On the northwest shore of the Alaska Peninsula a broad belt of level stratified drift deposits, without hard rock outcrops, fringes the coast and divides it from the Aleutian Mountains, which, on the southeastern side, come quite down to the sea.

The whole Lower Kuskokwim, below the entrance to the Yukon portage route, flows through a vast area of stratified Pleistocene deposits, which stretches away to the north and west to the Yukon and reaches east as far as the Oklune Mountains.

Besides the great belts of Pleistocene mentioned, the valleys of many of the streams occasionally contain considerable areas of stratified drift, and along the coast, between Bristol Bay and Kuskokwim

[1] Dr. W. H. Dall, Correlation papers, Neocene, Bull. U. S. Geol. Survey, No. 84, p. 246.
[2] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Surv., Part III, p. 191.
[3] Bull. U. S. Geol. Surv., No. 84, p. 247.
[4] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Surv., Part III, p. 196.
[5] Alaskan volume of 11th Census Report, p. 97.

Bay, there are several such areas, alternating with places where the mountains come down to the sea.[1]

Tertiary volcanics.—On the Lower Yukon olivine-basalt of late Tertiary age occupies a considerable area.[2]

Olivine-basalt, like that on the Lower Yukon and evidently of the same general age, occurs on Nunivak Island and Cape Vancouver.[3]

Between Togiak River and Nushagak, in the vicinity of the coast, are considerable areas of olivine-basalt, which are evidently closely allied in composition and age to the Lower Yukon basalts (see p. 231).

Tertiary-Pleistocene volcanics.—Volcanic rocks, part of which were probably extruded in late Tertiary, but which are nevertheless of somewhat later date in general than the Lower Yukon olivine-basalts, are found in a continuous chain along the Aleutian Islands and the Alaska Peninsula, from Little Sitkin Island northeast as far as the Yentna River, a distance of 1,500 miles or 1,600 miles.[4]

Tertiary siliceous intrusions.—Siliceous intrusions of the Tertiary period are conspicuous in the Tordrillo Mountains, where they play an important part in places and have evidently determined the existence of some of the chief features of the topography. In the Kuskokwim Mountains siliceous intrusions are frequent, though not so abundant as in the Tordrillo Mountains. In the valley region between the Tordrillo and the Kuskokwim Mountains, on the other hand, siliceous intrusions are almost absent. In the Oklune Mountains intrusive siliceous rocks of Tertiary age are found at intervals, sometimes in large bodies which have an important effect on the topography. So far as observed, therefore, the Tertiary siliceous intrusions appear to have occurred along the two principal zones of mountain folding.

PRINCIPAL MOUNTAIN SYSTEMS OF SOUTHWESTERN ALASKA.

Aleutian system.—It is plain from an inspection of the map that the mountain ranges of southwestern Alaska trend northeast-southwest. The most prominent system is that which includes the mountains of the Alaska Peninsula and of the Aleutian Islands, and so, partly submerged, runs across nearly to the coast of Asia. The mountains of the Alaska Peninsula the writer proposes to call also the Aleutian Mountains. They are an integral part of the mountain system which appears in the Aleutian Islands and extends nearly unbroken northeast to the Chigmit Mountains, between Lakes Clark and Iliamna and the coast. Farther northeast, offset a little to the northwest and very likely separated by a slight gap from the Chigmit Mountains, are the

[1] See pp. 177 of the present report. Also geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 209.

[2] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 244. Dall, Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, pp. 817 and 862.

[3] Dall, Seventeenth Ann. Rept. U. S Geol. Survey, Part I, pp. 814, 815.

[4] See pp. 226, 232 of this report; also map 13.

Tordrillo Mountains. Still farther to the northeast, and separated from the Tordrillo Mountains by a distinct gap, are the Alaskan Mountains, which contain the highest peak in North America.

All these mountains, from the Gulf of Kamchatka to Mount McKinley, constitute a single system, which may be called the Aleutian Mountain system. From a point near the western extremity of the Aleutian Islands eastward the general trend of the system is northeast. The system does not, however, extend farther northeast than the Alaskan Mountains, for these mountains turn without breaking down and run at right angles to the general trend of the Aleutian Mountains, to the southeast, forming the general divide between the Tanana River and the Sushitna and Copper rivers, and having as a continuation the Nutzotin Mountains, which lie at the headwaters of some of the branches of the Copper River, near the head of the Tanana.

St. Elias system.—Southwest of the peninsula of Alaska are mountains belonging to a system which will be only briefly mentioned, since it lies mostly outside of the scope of this report. This mountain system is represented by the mountainous Kadiak Island and smaller island peaks to the southwest of it, and is traceable from here in a northeastern direction by a continuous line of mountainous islands, which are evidently parts of a submerged range, to the Kenai Peninsula. The mountains of the Kenai Peninsula are continued farther north by the Talkeetna Mountains, which lie around the headwaters of the Matanuska. From Kadiak Island to the Talkeetna Mountains the mountain system has a northeast trend, parallel with the Alaska Peninsula, but at the Talkeetna Mountains it turns at right angles and runs southeast, forming a continuous chain, consisting of the Chugatch Mountains, in the vicinity of Prince William Sound, and, farther southeast, of the St. Elias Mountains.

Kuskokwim system.—The mountains of the Oklune Range have a definite northeast trend, and reach on their southwestern extremity quite down to the sea, between Togiak Bay and Kuskokwim Bay. The Oklune Mountains are continued farther northeast by detached northeast-trending minor ranges, such as the Kilbuck Mountains, and these minor ranges lead to the Kuskokwim Mountains, which, although not high, occupy a definite zone which cuts the central part of the Kuskokwim. The trend of the mountains of the Kuskokwim system north of the Kuskokwim is not certain, but from the position of the rivers it seems probable that this system also suffers a deflection and continues at right angles to its former course, constituting at first the divide between the Innoko and the Kuskokwim, and, after making its turn, between the Kuskokwim and the Lower Tanana and Yukon.

Yukon system.—The Kaiyuh Mountains, which lie between the Innoko and the Yukon, have a northeast trend. Farther northeast this mountain system crosses the Yukon and appears as the Yukon

Hills on the other side. The Yukon Hills run directly into the Rampart Mountains, which turn at right angles to the former course of the system and cross the Yukon at the Lower Ramparts, and, running off to the southeast, become the Tanana Hills, and, still farther, the Ketchumstock Hills.

VALLEY SYSTEMS BETWEEN THE MOUNTAIN SYSTEMS.

The four mountain systems which have been described are separated from one another by equally distinct valley systems. Between the St. Elias Mountain system and the Aleutian Mountain system there lies, first, the submerged valley beginning with Shelikof Strait and extending to the head of Cook Inlet. Along the Sushitna the valley system probably changes its trend, corresponding with the change of the mountain systems, and is represented to the southeast by the level Copper River Plateau, which lies between the mountains of the St. Elias system to the southwest and those of the Aleutian system to the northeast.

Between the Kuskokwim system and the Aleutian system there lies a broad valley system, occupied chiefly by the uppermost Kuskokwim, the Holiknuk, and the Nushagak. The last two head close together at a low divide and flow parallel, but in opposite directions.

Between the Kaiyuh Mountains and the Kuskokwim Mountains (that is, between the Yukon system and the Kuskokwim system) lies the valley of the Innoko. It appears probable that the Tanana River lies in the valley between the mountains of the Yukon system and those of the Aleutian system, for in the region south of the Tanana it seems that the Kuskokwim system merges into and becomes confused with the Aleutian system; at least it is not yet possible to distinguish the two.

GENERAL STRUCTURE OF THE CHIEF MOUNTAIN AND VALLEY SYSTEMS.

Aleutian system.—Where the Tordrillo Mountains were crossed the rocks, as already described, are folded in the form of a general synclinorium. The only other point in which a cross section was made was in the region above Katmai, where the rocks are essentially horizontal. In the first-named mountains the sedimentary rocks were regarded as Cretaceous and Jurassic, and in the second region as Jurassic. As already noted, a line of intervening localities shows that the sedimentary rocks of the Aleutian system, as exposed between the Tordrillo Mountains and the southernmost end of the Alaska Peninsula, are chiefly Mesozoic. It also seems probable that the general folding is synclinal, and we know that the general strike of the rocks is parallel with the mountains; yet the synclinorium of the Tordrillo Mountains has a northeast pitch, suggesting the existence, between the

Tordrillo Mountains and Katmai, of a slight anticlinal arch along an axis at right angles to the trend of the mountains.

Kuskokwim system.—The strata of the Kuskokwim Mountains, although affected by much petty folding, seem to be bent in general in the form of a broad synclinorium which has a northeast pitch (see map 14). The strata of the Oklune Mountains, between the Kuskokwim River and Togiak Lake, are bent into the form of a very perfect syncline, which is affected very little by minor folding, and pitches to the southwest. The main structure of the Kuskokwim Range, therefore, appears to be synclinal, but from the pitch of the folds there is suggested an anticlinal arch between the Kuskokwim Mountains and the Oklune Mountains, the axis of which is at right angles with the trend of the mountains and the chief axis of folding. The Kuskokwim Mountain system, so far as noted, is composed of Cretaceous rocks.

Yukon system.—The Kaiyuh Mountains, according to Dr. Dall's brief note, and, as represented on map 14, seem to be essentially anticlinal. This is to be expected, since, as already noted, these mountains form a direct continuation of the Yukon system between the Tanana and the Yukon, where the mountains have been shown to depend upon the existence of a great geanticline, which was described in a previous report and called the Yukon geanticline.[1]

The rocks of the Kaiyuh Mountains appear to be fundamental or Archean granite and metamorphic, probably pre-Silurian schists. Farther northeast the schists of the Yukon Mountains have already been slightly described by the writer,[2] and still farther northeast the metamorphic rocks of the Rampart Mountains, together with those between the Tanana and the Yukon, have been treated at length in the Yukon report. The whole mountain system, therefore, consists mainly of the most ancient rocks, in sharp contrast to the other two principal systems just described, which consist of the younger rocks.

Structure of the intervening valley systems.—On the Upper Kuskokwim the valley between the Tordrillo and the Kuskokwim mountains is occupied by the Tachatna series, which has been provisionally called Devonian-Carboniferous. There are some reasons to suspect that the Paleozoic rocks run southeast along this valley system to the Nushagak waters and northeast to the Tanana River. The general structure of this Paleozoic valley must, therefore, be anticlinal (see map 14).

The narrow valley of the Innoko, lying between the Kuskokwim and the Kaiyuh mountains, must be monoclinal, since it lies between a geanticlinal fold and an adjacent geosynclinal fold.

[1] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S, Geol. Survey, Part III, p. 259. See also map, Pl. XXXVIII, same report.

[2] Op. cit., p. 143.

NOTES ON THE GENERAL MAP AND SECTIONS.

From the various sources which have been mentioned the accompanying map of southwestern Alaska (map 14), covering the areas explored and adjacent territory, has been prepared. Most of the tinted areas are colored on fairly good grounds, while other areas are left blank with the probable structure indicated by dotted lines and notes. The probable continuance of the Tachatna series with the Paleozoic beds near Baker Creek, on the Lower Tanana, which Brooks reports, will readily be seen, as will also the connection between the Kaiyuh Mountains and the others of the Yukon system.

A general cross section has been made from Cook Inlet to St. Michael, intended to show roughly the structure. On this section the synclinal Tordrillo Mountains and Kuskokwim Mountains are seen, and the anticlinal Kaiyuh Mountains. Two other short cross sections are given—one across the Oklune Mountains and the other across the Aleutian Mountains near Katmai. The first shows the synclinal structure of the Oklune Mountains between the Kuskokwim River and Togiak Lake and the probable anticlinal structure of the Togiak Valley. The second shows horizontal Jurassic sediments lying upon fundamental granite and cut through by the Tertiary-Pleistocene volcanic rocks, while on the northwestern end of the section the Pleistocene gravels rest upon the granite and explain at a glance the origin of Naknek Lake.

GEOLOGICAL HISTORY AS INTERPRETED FROM PHENOMENA.

History up to the Pleistocene.

PRE-DEVONIAN TIME.

Throughout the portion of southwestern Alaska which is described in this report the sedimentary rocks contain granitic arkoses, which bear evidence to the existence of ancient granite, constituting part of the land mass as far back as Devonian times at least; for in the Devonian rocks of the Tachatna series we find these arkoses, as well as in formations of later date. Older sedimentary rocks than those of the Tachatna series are not exposed in this region, but in the Yukon district they are represented by the Rampart series, the Fortymile series, and the Birch Creek series, the latter two being metamorphic and schistose and lying directly upon a fundamental granite which has certainly contributed very largely from its material toward their upbuilding. Since this granite in the Yukon country is evidently the true foundation of the geologic column we may assume that it is from the same ancient granite that the arkoses of the Tachatna series were derived.

The ancient schistose sediments of the Yukon district which have been mentioned were traced by the writer in a previous report[1] from

[1] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III.

the Rampart Mountains in the Lower Ramparts of the Yukon southwest along the Yukon to the vicinity of the Nowikakat River. According to the note afforded us by Dr. Dall,[1] the Kaiyuh Mountains, which form a direct continuation of the belt of metamorphosed sediments on the Yukon northwest of the Nowikakat, are themselves made up of metamorphic rocks, and Dr. Dall notes that Point Romanof and Cape Romanzof, on the Bering Sea, which lie in the same general northeast-southwest trending zone, are also of metamorphic rocks.

DEVONIAN-CARBONIFEROUS TIME.

Within the region actually visited by the writer in 1898, however, the rocks of the Tachatna series are the oldest. They are conceived to correspond in a general way to the Tahkandit series of the Yukon, in which Carboniferous and Devonian fossils have been found.[2] The rocks of the Tachatna series contain a comparatively small amount of granitic material, being made up mostly of thin-bedded limestones and limy shales.

Subsequent to the deposition of the Tachatna series there was an uplifting and folding of these rocks previous to the deposition of the Cretaceous of the Holiknuk series, for this latter series rests upon the Tachatna series unconformably and has as its lowest member a basal conglomerate. In the region of the Alaska Peninsula the Cretaceous and the Jurassic appear to lie conformably; moreover, this region appears to be exceptional among American districts as containing the possible equivalent of the European Neocomian, or the lowest division of the Cretaceous, and there is an indication of continuous sediments and unbroken faunas between the Jurassic and the Cretaceous. We may therefore conclude that the unconformity shown on the Kuskokwim between the Tachatna series and the Cretaceous actually belongs between the Tachatna series and the Jurassic. In the Yukon region no Jurassic rocks were found, but an unconformity corresponding to that on the Kuskokwim River was found between the Tahkandit series and the Mission Creek series, which is probably Cretaceous.[3]

JURATRIAS PERIOD.

Triassic fossils have been reported from one place on the Alaska Peninsula,[4] but as this is entirely exceptional it may for the present be passed over. The Jurassic sediments, so far as yet known in this region, are confined to the neighborhood of the Alaska Peninsula. This peninsula, as already stated, probably formed a land mass, and the Jurassic beds are essentially littoral, being composed largely of the granite which must have formed a large part of the land, and also

[1] Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, pp. 862, 863.
[2] Geology of the Yukon gold district, pp. 169, 174.
[3] Op. cit., p. 258.
[4] W. H. Dall, Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, p. 865.

containing frequent plant remains. This period must have been one of volcanic activity, for ancient lavas and interstratified water-laid tuffs are abundant.

CRETACEOUS PERIOD.

Cretaceous beds were deposited over a broad area, apparently nearly the whole of southwestern Alaska. Between the Cretaceous and the Jurassic there is no observable unconformity, and the transition is not marked by any conglomerate. There was, so far as we know, therefore, no break in the sedimentation, but the Cretaceous sediments are on the whole rather finer and more shaly than the Jurassic, as if the land had become more worn down. Everywhere are evidences of shallow water and shore formation, such as ripple marks, plant remains, etc., while fossils occasionally found show that the rocks were laid down mainly in salt water. These conditions were practically the same as prevailed during the Cretaceous period in much of western North America.

The material of the occasional Cretaceous shore conglomerates and of the arkoses shows that the land was partly granitic and partly made up of the uplifted rocks of the Tachatna series. During this period also there was considerable volcanic activity, especially in the region where now are the Kuskokwim ranges, and also in the region of the Oklune Mountains, for in these districts much basaltic and trachytic lava and derived tuffs are mingled with the usual littoral sediments. In the same regions certain peculiar types of sediments, such as the glauconitic calcareous chert found in the Kuskokwim Mountains and the limestones made up of sponge spicules, which occur in the Oklune Mountains, tell of deposition some little distance from shore.

TERTIARY REVOLUTION.

After the deposition of the Cretaceous there was an epoch of folding in the earth's crust. The sediments were elevated above the sea, and systems of folds on a large scale were originated, giving rise subsequently, when erosion had attacked the uplifting rocks, to great mountain and valley systems. The axis of the main folding in southwestern Alaska was NE.-SW., but in the eastern part of Alaska the series of great folds, originated probably at the same period, have a trend at right angles to that just mentioned, or NW.-SE. In some cases it seems probable that one of the great folds having an axis belonging to one of the systems, on approaching the region where the other system dominates, turns at a right angle and runs conformable with this system without losing its identity. Thus the Yukon geanticline,[1] which was traced from the region of the White River northwest to the Lower Ramparts of the Yukon, appears to turn, and still

[1] Geology of the Yukon gold district, p. 259.

maintaining its geanticlinal nature runs through the Yukon Hills and Kaiyuh Mountains and probably still farther on clear to the coast, although in the vicinity of the Lower Yukon it is largely covered up by Tertiary volcanoes and sediments. Parallel with the southwestern arm of the Yukon geanticline (as that portion southwest of the Rampart Mountains may be called), and to the southeast of it, lies the broad geosynclinal folding of the Kuskokwim Mountain system; farther southeast the probable geanticlinal valley system of the Upper Kuskokwim, the Holiknuk, and the Nushagak; and next the zone of folding of the Aleutian Mountains, which at one point at least (the Tordrillo Mountains) consists of a general synclinorium. All these folds are great flexures in the earth's crust parallel with each other, and accompanied by a great complexity of minor folding in the strata.

We know that the epoch of this folding was post-Cretaceous, since the Cretaceous beds are involved in it as much as any that underlie. The Neocene beds, such as those at Nushagak and at the mouth of Hayes River on the Skwentna, are folded, but not nearly so much as the Cretaceous rocks, so that an unconformity must exist between the Cretaceous and the Neocene. In the region examined, the Kenai (Eocene or Oligocene) beds are not present in those places where they could throw much light upon the age of the folding, but it seems very likely that they took an important part in the folding and were uplifted with the rest, so that the period of the main revolution was post-Kenai, as on the Yukon.[1]

Probably contemporaneously with the beginning of folding came intrusions of siliceous granitic rocks along the zones of weakness, these zones being parallel with the system of great folds and naturally becoming, as the folding progressed farther, also zones of close folding.

With the post-Kenai folding and elevation, erosion attacked the land vigorously. The geanticlinal arches, which, as it happened, were also the zones of least folding, were attacked more rapidly than the geosynclinal zones, especially as the latter contained seams and ribs of hard igneous rock which had been intruded as dikes, and which soon came to the surface as the overlying rocks were stripped off, standing out as mountain ranges and protecting the softer strata. The intervening belts, therefore, even though anticlinal, soon became valley systems, while the synclinal belts, especially where ribbed by hard igneous dikes, remained as mountains. Between the mountains of the Kuskokwim system and those of the Aleutian system, a river probably ran parallel with them, occupying the present valleys of the Upper Kuskokwim, the Holiknuk, and the Nushagak.

During the Miocene period, while this erosion was progressing, deposits were laid down in the sea, in lakes, and in rivers; these, so far as we know, consist of gravels and clays, containing pebbles which

[1] Geology of the Yukon gold district, p. 259.

sometimes appear to be scratched by ice, and so suggest that the higher mountains carried some glaciers, as at the present day, or at least that the rivers and lakes were occasionally frozen. Silts and beds of lignite are also found. Contemporaneous with this erosion and deposition there appear to have been uneasy movements in the crust, and the rocks went on slowly folding even while the land was being worn down and the rivers were making for themselves broad valleys. We therefore find that the Miocene beds are themselves folded, often to a marked degree, but nearly always less than the pre-Miocene sediments.

The post-Cretaceous mountain building, which was most active before the deposition of the recognized Neocene beds, did not reach its close till probably the end of the Miocene, as is shown by the folded Miocene marine sediments at Nushagak on the Lower Yukon and along the flanks of the St. Elias range, between Cape Yaktag and Lituya Bay. The deposition of these Miocene sediments, the mountain building, and the erosion must all have gone on simultaneously, but it was not until the folding of the crust was practically completed that the foundations of the present topography could have been reached. This situation probably occurred in late Miocene or early Pliocene times.

In considering the present topography of southwestern Alaska we find that much of that which was developed previous to Pleistocene times has been completely covered with the Pleistocene deposits. It is only in the mountainous regions that we find systematic valleys and deep-cut surface features marking a long period of erosion. Considering the topography in these mountainous regions, we find the general type of valley deep with high mountains rising above it, but with a broad level floor, indicating that the streams at this period did much lateral cutting. One feature, however, stands strongly at variance with this well-developed systematic topography, namely, the gorges and canyons in which the present streams flow and which are cut in the bottoms of the broad plateau valleys. Although these canyons have steep and perpendicular walls, indicating rapid cutting, yet they often curve after the fashion of sluggish streams, showing that the course must have been inherited from the streams which flowed in the bottom of the old broad valley. These canyons cut in the old valleys are found all over Alaska and are probably of early Pliocene age.[1]

Overlooking these Pliocene canyons, as well as the Pleistocene features, we may turn to the general topography, which is older than these and belongs to the period at the close of the Miocene or in the early Pliocene, as just described. We find that rock structure has an important influence over topographic forms. Hard igneous rocks have given rise to ridges, while easily eroded sedimentaries have induced the formation of valleys or lowlands. The summit of the Tordrillo Mountains, the Oklune Mountains, and of the Aleutian Mountains,

[1] Geology of the Yukon gold district. Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 263.

near Katmai, are all marked by a ridge of hard igneous rock, and many minor ranges have the same governing influence. The breaking down of the Tordrillo Mountains to the northwest of the pass which was crossed is plainly due to the incoming of the soft Cretaceous shales, which here form a northwesterly pitching syncline, and the heights of the mountains apparently decrease in proportion to the pitch of the beds. Since both the folding of the rocks and the intrusion of igneous bodies has been along a general northeast and southwest axis, this is also the general trend of the ridges and main deep-cut valleys.

In those mountain regions which show comparatively slight relief, such as the Kuskokwim Mountains, we find fewer igneous rocks and less folding. The valleys here are broader and the hills lower and more rounded.

This, then, was the general condition of the topography of southwestern Alaska in late Miocene or early Pliocene times, a period contemporaneous with the best development of the Yukon Plateau.[1] There were mountains of considerable relief and height, probably as high or higher than at present, cut by deep valleys; while in other portions of the country were lower and more rounded mountains traversed by shallower and broader valleys. The drainage was regular and the current of the rivers not rapid. At the same time, the extent of the land surface was probably greater than at present. The fiords, which are found all along the coast of the Gulf of Alaska, form a direct continuation of the river valleys and without doubt represent submerged portions of them, and since these valleys were excavated during Miocene time it follows that all this belt which is now sea was at that time land. Along the shores of the Bering Sea there may possibly exist the same submerged valleys, but if there were any here they have been buried by the later (chiefly Pleistocene) sediments which have choked this inclosed sea, while on the shores of the Gulf of Alaska the depth of the Pacific keeps the sea near the shores from being so rapidly filled up.

From what has been said concerning the late Miocene topography it will be seen that it is entirely improper to speak of the Miocene land surface as a peneplain, although certain portions of it show a nearly level surface, or many points which fall into a general plane. At present there is a general tendency for students to see in nearly every such possible plane an old peneplain, without considering how far the operation of uniform erosive agents may have given a uniform height to hilltops or mountain tops, or what may have been the possible leveling action of the sea in one of its great transgressions. Alaska, in Tertiary and Pleistocene times, seems to have moved up and down, and to have been warped so often that the erosion of rivers could not possibly

[1] Op. cit., p. 260.

reduce the land to a plain, the development of which demands long stability.

The cutting of the sharp canyons in the old valleys during Pliocene time was evidently due to one of these earth movements, and, since the cutting is universal, it is probable that it resulted from general tilting or warping of the crust. A simple uplift does not necessarily accelerate the motion of streams and generally not to any marked degree, and any acceleration may accompany a depression as well as an uplift, being chiefly dependent upon the accompanying warping, which is, of course, of far greater importance. That there was tilting is shown by the fact that while the currents of the rivers were in general accelerated and have remained so up to the present day, the outer portions of the Miocene-Pliocene river valleys have been submerged, the coast line having moved landward instead of seaward, as it would have done in case of a general uplift. This can only be explained by differential movement. In the case of the region around the Sushitna and Copper rivers, for example, we may suppose that the movement occurred along an east and west axis at the head of Cook Inlet and Prince William Sound, the movement being relatively down on the south side and up on the north side. Lakes Clark and Iliamna are also very probably due to differential movement.

HISTORY OF THE PLEISTOCENE PERIOD.

PLEISTOCENE SUBMERGENCE.

The Pliocene tilting was followed by a general depression, so that most of the land was sunk beneath the sea, leaving only the higher mountains as islands and peninsulas. This condition is plainly indicated by terraces which are cut deep upon the mountains, often at such heights and in such positions that they can not possibly have been cut by inclosed waters, but must be marine. Quite as convincing evidence of the submergence is afforded by the great areas of water-laid silts, sands, and gravels, which reach continuously from the shores of the sea far up on the mountains, over hill and dale, without break.

The terraces are sometimes cut in the sides of the deeply eroded late Miocene or early Pliocene valleys, and the associated gravel deposits, which are also generally fashioned into constructional terraces parallel with the rock-cut terraces and so contemporaneous with them, often fill the late Pliocene canyons.

The general problem of the Pleistocene submergence and the solution thereto have already been elaborated upon by the writer.[1] The present year's work corroborates the former conclusions in every detail, but much of the reasoning and general inferences will not be repeated

[1] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 265 et seq.

here, the reader being referred to the previous report. Some additional evidence, however, gathered in southwestern Alaska, will be briefly given.

MARINE TERRACES.

On Mount Sushitna.—On Mount Sushitna, at the mouth of Sushitna River, there is, about halfway up, a well-marked horizontal bench, with another about 500 feet below. Distinct terraces, not so well marked, are found all the way from the bottom three-fourths of the way to the top. The height of Mount Sushitna being 4,280 feet, the highest terraces, therefore, stand at an elevation estimated at about 3,000 feet. Mount Sushitna is almost entirely of granite.

Yenlo Mountain.—Yenlo Mountain, at the junction of the Yentna and Skwentna, is distinctly terraced about two-thirds of the way to the top, and the top itself is leveled off. This mountain is 3,000 feet high and is probably volcanic.

On the Skwentna, below Hayes River.—At the camp of June 14, terraces rise on the hills to a probable height of 1,000 feet above the river, or an actual height of 2,000 feet above sea level. They are cut in the solid rock and along the sides of deep, rock-cut valleys. The streams flow over these successive terraces in waterfalls or cataracts, one of which is 60 or 75 feet high. The rock in this neighborhood consists of the folded volcanics and sedimentaries of the Skwenta series.

Shell Hills.—The Shell Hills, as seen from above the camp of June 14, are distinctly and deeply terraced, the chief bench being three-fifths of the way to the top, although the tops themselves are often distinctly beveled. The Shell Hills are about 1,500 feet high, and are also probably of the folded volcanics and sedimentaries of the Skwentna series.

Near junction of Happy River with the Skwentna.—Mountains above the river valley at this point show well-marked terraces up to nearly 2,000 feet above the river, or at a height of nearly 3,500 feet above sea level. The terraces are cut on all the mountains alike, although their structure is various, the rock being sometimes intrusive and sometimes sedimentary rock of various degrees of hardness and highly folded.

Portage Creek.—Portage Creek, on the Sushitna side of the pass, shows perfect horizontal benches in the drift and also cut in the solid rock, halfway from the river to the tops of the mountains, or up to a maximum height of about 3,500 feet above sea level.

Happy River.—On Happy River, as seen from Portage Creek, are perfect terraces extending halfway from the bed of the stream nearly to the tops of some of the mountains, or up to a height of about 3,500 feet above sea level. The highest bench is the best marked of all and is rock cut, while the lower terraces are largely of stratified drift. The same is the case with the terraces around Portage Creek, where a succession of washed-drift terraces end with a deep rock-cut terrace.

In all these higher valleys, the deep valleys in which the small streams from the mountains flow come to an end at the highest shore line, the water being led off below this in a mere gorge. Only the more considerable streams have excavated definite channels below the terraces, and these are gorges having no resemblance to the deep mountain valleys above. Of course the large streams, such as Portage Creek and Happy River, are exceptions, since they flow in broad valleys which themselves constituted arms of the sea during the period of maximum submergence, and whose sides are terraced. These main lower valleys and the mountain valleys above the highest shore line are remnants of the presubmersion drainage, the minor drainage of the mountain sides below the shore line having been effaced by the shore erosion.

Ptarmigan Valley.—On the mountains on the east side of Ptarmigan Valley, the highest terrace seems to stand at a maximum height of about 4,000 feet, and below this are many well-defined benches. The rocks of these mountains are the highly folded and contorted shales of the Tordrillo series.

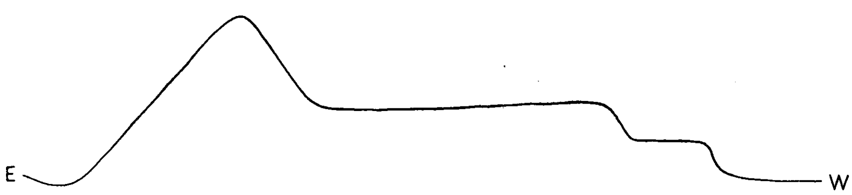

FIG. 15.—Outline of Farewell Mountain, Tordrillo Range, showing marine benching.

At junction of Kuskokwim River and Hartman River.—At this point well-marked terraces, deeply cut in the rock and also in part made up of stratified drift, and strictly horizontal (therefore diverging continually from the river, whose bed has a considerable inclination), were noted at a height of about 500 feet above the stream, or an actual height of about 3,000 feet above sea level. Farther down the river, the highest terrace noted on the Teocalli Mountains, which was also seen across the Kuskokwim Valley on the Terra Cotta Mountains, was estimated to stand at a height of about 4,000 feet above sea level.

Farewell Mountain.—Farewell Mountain is a few miles west of Egypt Mountain (map 6). All the mountains in its vicinity show well-marked terraces high up on their sides. Farewell Mountain is distinctly and deeply terraced two-thirds of the way up, or up to a height of over 2,000 feet above sea level (see fig. 15.)

Lower Kuskokwim.—The mountains on the lower or middle Kuskokwim, especially in the vicinity of Kolmakof, show rounded forms and often distinct terracing up to a height of 1,000 feet above sea level; their tops, which are generally below 2,000 feet in height, are remarkably level and straight, and probably indicate an ancient sea level, like the terraces on their sides. The general plane in which lie the level tops of the hills might be held to represent an ancient peneplain, but the writer believes that the appearance is largely the result of leveling by the sea. Above this general plateau rise isolated hills which are conelike and have somewhat the appearance of volcanoes, but these are probably hills which stood out from the sea as islands, and whose bases were fretted by the waves until they assumed their present form.

Upper Kanektok.—In the vicinity of Lake Kagati beautiful terraces are seen on the mountains up to a great height; these terraces are horizontal and run off down the valley of the Kanektok. The comparatively low mountains (2,500 feet above sea level) directly south of the camp of September 8 are terraced clear to the top, as is the mountain which divides Lake Kagati itself, and which is of about the same height. The deepest-cut benches in these mountains are at heights of about 1,900 and 2,300 feet, respectively.

A little farther up the valley, where it is encumbered with morainal drift, are terraces cut in the moraine and also in the rock of the mountains; they are horizontal and therefore diverge from the valley, and they show leveling action by the sea after the formation of the moraine.

Togiak Lake.—On the western side of the lower end of Togiak Lake are well-marked terraces, up to a height of about 2,500 feet above sea level, on mountains which are made up of folded sedimentary rocks.

Egoushik River.—Above the first large lake, at the head of this river, is a very deep rock-cut terrace 50 or 60 feet above the water and stretching back to the hills. This must be of marine origin, for if the water stood at this elevation it would flow uninterruptedly between Kululuk Bay and Nushagak Bay. Higher terraces are often discernible on the mountains above the river.

Naknek Lake.—The mountains above Naknek Lake are distinctly terraced up to a height of 1,000 feet at least. The terraces which are near the surface of the lake (that is, within 100 feet of it) are almost perfectly fresh sea cliffs with unmodified talus at the bottom. When the water stood at the level of even these lowest terraces it must have flowed continuously through to the sea, and Naknek Lake constituted a bay.

Between the head of Naknek Lake and Katmai Pass there are horizontal well-marked benches in the valley up to 1,000 feet at least. The mountains here are of horizontally stratified arkose, while those on the lower end of the lake are of granite and folded volcanics.

GLACIATION.

TORDRILLO MOUNTAINS.

Existing glaciers.—At the head of Hayes River is a great glacier which fills the whole valley to a point some 20 miles above the mouth and runs continuously to the head. In front of it a ridge runs transversely across the valley, and is evidently an abandoned frontal moraine. The glacier seems to be retreating. The valley of the stream below the glacier is of typical shape, being of high gradient, broad and smooth; it heads in several typical cirques, above which are jagged mountains.

In the heart of the Tordrillo Mountains, especially on the Sushitna side, there are many small glaciers. Portage Creek, which was the only branch ascended, has many at its head, the largest of which was called Stoney Glacier. For several miles below these glaciers are a succession of transverse abandoned frontal moraines. Near the summit of the range, in every little valley and gully, small glaciers occupy splendid cirques.

On the western side of the main range of the Tordrillo Mountains a few small glaciers are found at the very heads of the gullies on the highest mountains, but no large ones such as are found on the east side. The adjoining ranges, such as the Teocalli and the Terra Cotta mountains, show no glaciers whatever, so far as seen.

Former extent of glaciers.—The depth of decayed rock (which is generally at least 20 or 30 feet over nearly the whole of this country) in places where it has been left undisturbed by water erosion shows there has been no general glacier covering the country. To prove this, however, the mountain topography and an examination of the valleys of the present glaciers is sufficient. In the higher mountains the only valleys, which are broad and U-shaped and head in cirques, are those which actually contain glaciers at the present time. In each of these valleys there is generally some little evidence that the glacier has retreated a short distance. This is shown by the unstratified morainal accumulation left behind in the process of melting back. These, however, extend only a short distance in front of the ice and then give way to horizontal stratified drift. Side by side with the valleys which show glacial action, and in whose heads are still glaciers, are others which contain no glaciers and whose topography forms convincing evidence of their never having been glaciated. On the Kuskokwim side of the Tordrillo Mountains any indication of glacial topography in the valleys is rare; on the Sushitna side it is more frequent. This seems to depend upon the greater precipitation of snow on the Sushitna side, as was actually observed by us at the time of our passage in the month of July, the mountains on the Sushitna side being heavily snow-covered, while others of equal height on the west side were already bare.

The great area of gravels which forms an apron on both sides of the Tordrillo Mountains, reaching to Cook Inlet on the one side and to the Kuskokwim flats on the other, contains many scratched pebbles and striated bowlders. The deposits, however, are invariably horizontally stratified, all the way from the sea nearly up to the base of the present glaciers, or to a height on the Sushitna side of the mountains of at least 2,500 feet, and in Ptarmigan Valley on the other side of at least 3,500 feet. Two inferences may be made from these facts: First, that the gravels must have been deposited in the sea (for the sea is the only body of water that could have reached from Cook Inlet to a point 3,500 feet high on the Tordrillo Mountains at one and the same time), and that the bowlders have been dropped into the forming deposit from cakes of ice or icebergs; and, second, that the glaciers of the Tordrillo Mountains and neighboring mountains supplied a considerable part of the material. On the Sushitna side of the Tordrillo Mountains the stratified glacial deposits reach up to the unmodified moraine just below the living glaciers, and it seems evident that these moraines have been formed subsequent to the period of maximum submergence, since stratified glacial deposits are found much higher up in those valleys which do not now contain glaciers. The best of evidence, however, is afforded by the unbroken stratified drift that the glaciers did not extend farther down than the uppermost shore line at the time of maximum submergence, or to any appreciable degree subsequent to this; and the typically unglaciated topography of the mountains shows that the glaciers were never much more extensive than at present, even before the epoch of submergence. It follows that during the epoch of submergence, which has been taken in this report as about the beginning of the Pleistocene, and from that time down to the present day, a period probably in a broad sense contemporaneous with the Glacial, Champlain, and Recent epochs of northeastern North America, the amount of glaciation in the Tordrillo Mountains has remained about the same, being only slightly less at present than when it was at its maximum.

OKLUNE MOUNTAINS.

Existing glaciers.—On the sides of Mount Oratia is a U-shaped valley with a cirque at its head, containing a large mass of snow and ice, which is probably a dying glacier. This was the only glacier seen in the Oklune Mountains.

Former extent of glaciation.—Glacial drift, always stratified, is found all through the Oklune Mountains, probably up to the height of the highest terraces. Where the Kanektok emerges from the mountains is a ridge of stratified drift containing large bowlders deeply striated by ice. This extends all along the front of the mountains and seems to represent a shore conglomerate of Pleistocene age.

Proceeding up the valley of the Kanektok the broad plateau valley is continuously covered by stratified drift, which grows coarser as one ascends. In the neighborhood of lake Kagati large bowlders are common in the drift and the surface of the plateau is rather irregular in detail, giving rise to small ponds; at the lower end of lake Kagati the drift is stratified, but little worn.

In this region, therefore, since the drift, far up on the mountains nearly to the pass, is always horizontally stratified, however coarse it may be, we must conclude that it is all water-laid, and, from its position, that it has been deposited in the sea; nevertheless the large bowlders have evidently been ice-rafted, and they are often scratched by the same agency. It is plain that glaciers have not moved over the country since the period of submergence.

To find out the extent of glaciers, during and before the maximum submergence, we must, as before, consult the topography above the shore-line terraces and the stratified drift. In the head of the little valley which leads to the pass to Togiak Lake, slight moraines were found damming some of the smaller lakes. Horizontal terraces are, however, cut in these moraines, showing that they were formed at or before the period of submergence. Otherwise, no unmodified drift was found.

Studying the topography of the mountains we see no signs of glaciation. The only rounded glacial valleys are one or two which have been mentioned on the sides of Mount Oratia, in the heads of which are small dying glaciers; and in the heads of the gullies on the mountain above the patch of morainal drift just described there are cirque-like forms. Otherwise the topography excludes the idea of there having been general glaciation or even extensive local glaciation. Small glaciers undoubtedly occupied the few rounded valleys, but they were never so numerous and important as the glaciers on the Tordrillo Range at the present day. When we seek for an explanation of the ice-rafted and striated bowlders in the stratified drift we must remember the work of ice other than glacier ice in this subarctic country; we must consider the lake, river, and shore ice, and the immense geologic work that this does in spring.

ALEUTIAN MOUNTAINS.

Existing glaciers.—On the summit of the Aleutian Range, between Naknek Lake and Katmai, there are found, on the northwestern side of the divide, some large well-developed glaciers resting upon the sides of volcanoes. On the southeastern side of the divide the glaciers are few or absent.

Former extent of glaciers.—The mountains around Naknek Lake are deeply eroded, with no signs of glaciation, the valleys being V-shaped. All along the valley leading to the pass are stratified gravels, which near the beginning of the trail across the pass begin to be filled with great angular bowlders; these are, however, beautifully layered. Dotting the level are many sharp hillocks formed of huge striated bowlders, evidently dumps of icebergs. This deposit runs quite up to the foot of the existing glaciers, there being no unmodified drift except recently abandoned moraines.

From these facts we see that in the Aleutian Mountains the conditions have been the same as in the rest of southwestern Alaska. In the favorable places glaciers still exist, but it is quite certain, from the topography of the mountains, that in general no glaciers other than those which now survive have ever existed; and in the vicinity of Katmai Pass it seems that some glaciers have advanced while others have retreated since the period of maximum submergence, which is marked by the terraces on the mountains and by the upper limit of stratified glacial drift.

RÉSUMÉ OF GLACIATION.

The mountain regions which have been described are the only portions of the country examined which are not covered more or less deeply by stratified drift, and so they afford the best clue to the prevailing conditions. Although the gravels which cover the country contain much material which has evidently been derived from ice action, yet at the time these gravels were formed the glaciers were hardly more extensive than at present, and, indeed, were not more extensive even previous to the submergence. There has been no general glaciation of southwestern Alaska, and if what glaciation there was constituted the Glacial period, then Alaska is still in it. For the evidence of ice action shown in the deposits the writer, as before stated, is inclined to look very largely to shore ice and to river ice, for these are undoubtedly very powerful eroding and transporting agents. The writer has already described the moraine on the island of St. Michael, which has apparently been formed under the ocean water by the tides;[1] and the accompanying plate (Pl. XIII) shows a moraine on the shores of the Yukon River below the Lower Ramparts, which is composed of bowlders brought down by the river ice in the spring. Some of the largest of these bowlders rest upon fresh driftwood.

PLEISTOCENE DEPOSITION.

Stratified deposits must have been formed partly while the depression was going on, partly during the time that the land was near its maximum depression, and partly during the period of subsequent elevation. Naturally those deposits formed during the last-named period cover

[1] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, Pl. 42.

the earlier gravels and silts in most places, although in some places, as on the Sushitna River a short distance above the station, harder, slightly consolidated gravels are found, which may belong to the period of depression.

The Pleistocene deposits are marked by universal stratification, by increase in coarseness in the vicinity of the mountains, and by increasing fineness as the distance increases, until they change into fine clays or silts, especially where large rivers emptied, forming deltas, or where shallow bays or inland lakes favorable for sedimentation existed. The great flats of the Upper Kuskokwim, like those on the Yukon,[1] evidently represent the bottom of a shallow lake which existed at a time midway between the period of maximum depression and the present day. The river is exceedingly sluggish and meandering, and its banks for many miles seem to be hardly or not at all below water at the period of flood, for fresh driftwood was found on top of banks of ordinary height. The drainage of this region is therefore in the very first stage subsequent to the disappearance of the shallow lake, whose existence is attested by the uniformity, extent, and fineness of the silts and the unvarying height of the low banks.

Similar deposits are common all through Alaska. Some (like those just mentioned) are perfectly dry, the lakes in which they were formed having been drained as a consequence of the acceleration of the streams dependent upon uplift and warping of the land. Others are only partially drained and have a broad belt of silts and gravels surrounding them, which was formed when they were of greater extent; their bottoms are covered by the same deposit. Still others have only begun to be drained, especially those near the coast, which have only recently, comparatively speaking, emerged from the sea, and so are in the same stage of development as the inland bodies of water were a considerable period ago. Of this latter class Togiak Lake, Naknek Lake, and lakes Clark and Iliamna are examples, while the lakes at the head of the Yukon are types of partially drained lakes. The various causes which led to the formation of these lakes will be briefly discussed below.

Shore-line conglomerates, such as those on the Middle Kuskokwim (p. 130), mark the successive shore lines which were formed by the receding ocean, as well as do the terraces. At each stage of the recession shore deposits of gravel and silts were made, which on further uplift were drained. Therefore, along the lower part of the great rivers we find the greatest thickness of drift, for here the successive delta deposits have been converted into land, so that at present their valleys are filled with horizontal stratified drift. Examples of this are the Lower Yukon, the Lower Kuskokwim, the Nushagak, and the Sushitna. It is of course true that these ancient river valleys were filled up largely during the period of maximum depression, just as

[1] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 204.

Cook Inlet and the bays along the Bering Sea coast have been filled up, but the horizontal gravels which lie upon the surface along the valleys of the large rivers and which show everywhere cross bedding, generally dipping in the direction of the present course of the stream, represent a succession of delta deposits, formed as the sea retreated. The silt deposit at the mouth of the Kuskokwim and the Yukon is plainly a great delta drained very recently. A very slight further uplift would have much more effect in proportion than the past uplifts have done, for an elevation of a few hundred feet would send the shore line far out across the shallow Bering Sea, forming a vast area of level tundra.

PRESENT TOPOGRAPHY AND DRAINAGE.

The topography of southwestern Alaska at the present day has been modified from the Pliocene topography by the effects of the submergence; first, by the degrading influence of the sea, which has carved deep terraces on the mountains and has often completely beveled the softer lowlands; and secondly, by the accumulation of detritus in the valleys. As a consequence of this change the drainage has also been altered, for, the old rock-cut valleys being often choked up, the rivers wander across the gravel and silt plains without finding any definite channel, but split into many branches, which, diverging and reuniting, are the torment of boatmen, until by chance the waters find some half-filled mountain valley and flow through this, in places over former divides, to the sea. It seems probable, for example, that the ancient outlet of the Kuskokwim was by way of the present Nushagak Valley, and that the mouth of the present Kuskokwim was anciently the mouth of the Yukon, while the valley through the Kuskokwim Mountains that the Kuskokwim River now occupies is probably the ancient valley of two streams which flowed in opposite directions, one into the Kuskokwim and the other into the Yukon. For changes in course such as these, irregularities in the drift may be appealed to, and warping, which was attendant upon uplift.[1]

Like the Yukon, the Kuskokwim River cuts its right bank all the way down, with some few exceptions.

ORIGIN OF LAKES OF SOUTHWESTERN ALASKA.

All the lakes of southwestern Alaska, so far as observed by the writer, occupy mountain valleys which are evidently the ancient river valleys of the late Miocene. In this statement, of course, the lakes of the tundra, and the similar small lakes which are scattered over the gravel plains throughout the country, are exceptions, these simply accompanying shallow depressions caused by irregularities in the drift. Togiak and Naknek lakes, and undoubtedly the other lakes of the

[1] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 276.

Alaska Peninsula, as well as Clark and Iliamna, occupy mountain valleys.

Lakes caused by warping of valleys.—In the formation of lakes Clark and Iliamna it seems probable that warping of the crust has been very effectual in forming depressions sufficient to hold such large bodies of water. As a rule, however, the lakes of this region seem to be dammed only by slight irregularities in the distribution of the stratified drift which fills the ancient valleys.

Lakes dammed by elevated bay bars.—Of this type Naknek Lake is a good example. It occupies a deep-cut mountain valley, and is fiord-like in its form. At the lower end of the lake the valley opens out without interruption upon a horizontal drift deposit about 40 or 60 feet above the lake, and this stretches away to the Bering Sea, where the bluffs are of about the same height. On the rock shores of the lake, a short distance above the outlet, are terraces, the lowest of which are very fresh, which have talus fragments almost unattacked by frost or vegetation. When the water stood at the level of even the lowest terrace, the lake must have been a fiord connecting with Bristol Bay, and at the same period the other lakes of the peninsula which appear to have the same characteristics must also have been fiords. Since there is no evidence of warping in the gravel plateau between the lake and Bristol Bay, the only explanation of the slight barrier of drift appears to be that it was formed by the currents during the period when the lake was a fiord. This may be better understood by referring to the conditions in the actually existing bays along the neighboring coast. The tide in the Bering Sea in general is not very great, but in the funnel-shaped bays, such as Nushagak Bay and Bristol Bay, it has a great height and a rapid current. Within a confined mountain valley like that of Naknek Lake, therefore, the tides during the period of depression would have continually scoured out the valley, and on reaching the open water at the mouth of the fiord would become slack and drop much of their material, forming a broad bay bar or an offshore deposit considerably thicker than the deposit in the fiord itself. When this was accomplished, a slight elevation would transform the fiord into a lake. It is probable that if a slight further elevation of the Alaskan coast should take place many of the bays along the Bering Sea would thus be transformed.

The United States Coast and Geodetic Survey's general chart of Alaska shows, in the soundings given, probable bay bars across Kuskokwim Bay and Bristol Bay.

Lakes dammed by landslides.—Several cases of small lakes dammed by landslide were noticed, which will not be described in detail. In each case the landslide blocked a portion of a valley.

OCCURRENCE OF VALUABLE MINERALS.

GOLD.

GOLD IN ROCKS.

Skwentna River.—The rocks of the Skwentna series are frequently altered and slightly mineralized along the contact of the Eocene dike rocks, especially in the district between the second and third canyons. At the camp of June 24 a few small veins interstratified with the bedded rocks contained, in a calcite matrix, iron rust, peacock copper, and copper pyrite. The greatest mineralization, however, was noticed in the third canyon, where the stratified tuffs and basalts are cut by dike rocks in great abundance. The dikes are sometimes well-defined and sometimes irregular bodies, which have in general a trend parallel with the strike of the beds and a mostly vertical dip. Along the contact of these intrusive bodies the rock is mineralized, being impregnated with sulphides of various kinds. Fig. 6 shows a sketch of an irregular body of granite, which is surrounded by a zone of mineralization. The mineralized rock is weathered, brown, and crumbling, and shows fresh sulphides only on broken surfaces where iron pyrite and chalcopyrite appear. An assay made from a sample of this by the Geological Survey showed 0.05 ounce of gold and 0.15 ounce of silver to the ton. Besides the mineralization of the wall rock along the contacts there are also many small quartz veins in the vicinity of the dikes; these, as well as the altered country rock in which they lie, carry sulphides. A sample of these rusty and cavernous veins from the lower end of the canyon was assayed by the Survey and showed 0.1 ounce of gold and 0.25 ounce of silver to the ton. A third manner in which the rock is mineralized is along certain zones not in exact contact with the dikes, although in their neighborhood. These zones are generally conformable to the stratification, following porous strata, for there is very little shearing, and consequently few shear zones.

In this locality the mineralization evidently depends directly upon the intrusive rock, and has been brought about by solutions accompanying the intrusion and very likely separated from the intrusive magma at the time of cooling. The gold-bearing and silver-bearing siliceous and ferruginous solutions have naturally affected the rock at the immediate contact with the igneous body most, although where zones favorable for circulation were found they have penetrated along these and deposited their silica, and their metals as sulphides.

Teocalli Mountains.—Where the Kuskokwim River cuts the Teocalli Mountains many quartz veins are found in the drift, which show much siderite or ankerite, with pyrite, copper stain, and small amounts of galena. Assays of the pebbles yield only traces of gold and silver, but the associated gravels, when washed, showed the presence of gold. These quartz veins are undoubtedly connected with the dikes which cut the slates of the Teocalli Mountains south of this part of the river.

PLACER GOLD.

Yentna and Skwentna rivers.—On the Yentna River, a few miles above the junction of the Sushitna, colors of gold are found in the bar gravels in the immediate vicinity of exposures of the coarse granite and scapolite rock, associated with quartz veins, which here cut the ancient greenish igneous rocks. The quartz veins contain pyrite and pass by all stages into mica-granite. Near the mouth of Hayes River many colors of gold were found in the gravels on the bars of the Skwentna and several grains were of considerable size—nearly large enough to be called coarse gold. In the second canyon of the Skwentna the gravel on the bar showed numerous colors of gold. At this locality the siliceous dike rocks cut the bedded rocks of the Skwentna series. With the exception of the localities noted, the Lower Skwentna shows ordinarily no gold, or only very fine flakes, indicating long transportation and no great proximity to the source of the metal. All the gravels throughout the country, however, both recent and earlier Pleistocene, contain very small quantities of fine gold disseminated throughout.

Source of placer gold on the Yentna and Skwentna.—The localities where the placer gold was chiefly found have an evident connection with the siliceous dike rocks of the Tordrillo Mountains and with the pyritiferous quartz veins which are connected therewith. The gravels themselves, wherever they show gold, are made up largely of these veins and dike rocks. The mineralization of the Tordrillo Mountains, then, is quite distinct in its age, though not in its nature, from that of the Yukon district, being dependent upon processes accompanying the intrusion of Eocene dike rocks, as the Yukon deposits are dependent upon far more ancient intrusions; nevertheless, it is likely that in places this Eocene mineralization has been sufficient to bring about ore deposits which would pay for working if conditions of supply and transportation were sufficiently favorable.

Placer gold on the Kuskokwim.—On the Kuskokwim, below the Styx River, as already mentioned, the gravels which form the Pleistocene bluffs show many colors of gold, and one grain larger than a pin head was found. As soon as the Kuskokwim leaves the vicinity of the Tordrillo Mountains, however, and flows through the Tachatna series and the succeeding Cretaceous rocks it seems to be entirely without any gold in its gravels. An exception to this was at the mouth of the Chagavenapuk, where the gravels contain many colors of fine gold, but these gravels consisted of the characteristic dike rocks of the Terra Cotta Mountains, where the stream heads, and undoubtedly the gold, together with the gravels, had been brought from this source.

In the region below Kolmakof, where siliceous dike rocks again cut through the mountains, it is reported by traders that gold occurs in small quantity.

The gold on the Kuskokwim, therefore, is of the same origin as that on the Skwentna and Yentna, being derived from the mineralized rock and the quartz veins which result from the action of ore-bearing solutions accompanying or following the intrusion of Eocene dikes. The mineralization has been most important in the Tordrillo Mountains, so that the Upper Kuskokwim contains the most gold in its gravels. On the Middle Kuskokwim, where the dike rocks cut again, there is some gold, but in general the river is a very barren one.

Kanektok and Togiak rivers.—No careful examination was made on the Kanektok and Togiak rivers, but the gravels, wherever washed, showed no gold. The only evidence of mineralization was in the occurrence of veins of spathic iron in the immediate vicinity of a siliceous dike cutting the slates of the Oklune series, just below Lake Kagati, on the Kanektok.

Mulchatna River.—As early as 1890 three prospectors, Harry Mellish, Percy Walker, and Al. King, are said to have ascended the Mulchatna 200 miles and there to have found gold, which, however, was too fine and flaky to save. A few prospectors have been wintering on the Mulchatna the past season, but the result of their explorations is not yet known. From one of them, Mr. Murkle, who came back after a month or two, the writer learned that fine colors had been found on the Mulchatna, but none on the Swan.

RÉSUMÉ OF THE OCCURRENCE OF GOLD IN SOUTHWESTERN ALASKA.

The gold in this region is by no means so abundant as it is along the belt of the Yukon geanticline, where the ancient schists, with their inclosed quartz veins, are found. The mineralization of southwestern Alaska is of later date and not so intense or widespread. Within the region examined by the writer's party last summer, the Tordrillo Mountains are undoubtedly the chief seat of mineralization, and this appears to be directly dependent upon the fact that these mountains have also been the chief seat of intrusion of igneous rocks.

CINNABAR.

About 5 miles below Kolmakof, in a cliff on the right side of the river, a trader, Mr. Lind, found, several years ago, a vein of cinnabar, or ore of mercury, which has been mentioned in numerous reports of Alaskan governors and other publications. The vein occurs in a locality where the stratified shales of the Kolmakof series are cut by frequent dikes of siliceous yellow-weathering rock. According to Mr. Lind, the vein is an impregnation of the arkose and other sedimentary beds with red cinnabar, the mineralized rock taking the form of a vertical zone a foot or two wide, often irregular and pinching out. Mr. Lind spent about $2,000 in mining some of the ore and getting it to the States, but on account of the small quantity and the low price of mercury he lost on the venture.

ARSENIC AND ANTIMONY.

From the Kwiklimut River, a tributary of the Kuskokwim entering above Bethel, a specimen was given to the writer by the Rev. Mr. Kilbuck, a missionary at Bethel, who obtained it from an Eskimo. It was a very pretty specimen of crystallized realgar and stibnite, but on assay it showed not even a trace of gold or silver.

MANGANESE.

Dr. Dall[1] reports black oxide of manganese from the Kuskokwim.

COAL.

In the Tyonek beds, on Cook Inlet, a brown lignite, so little altered that the wood which it contains preserves its grain and may be split, forms beds intercalated with the half consolidated sands and clays (see fig. 2). These coals are described by Mr. Eldridge in his report.

Skwentna River.—At the mouth of the Hayes River the Hayes River beds contain seams of coal which are sometimes several feet thick. This coal is dark brown, nearly black, like the better class of Kenai coals—more like the coals at Kachemak Bay than the brown lignite at Tyonek. A piece which was tried in our camp fire burned well. These coals are interstratified in the partly consolidated clays and gravels.

Beluga River.—According to prospectors who ascended Beluga River in 1896, coal occurs about halfway from Cook Inlet to the mountains.

Kuskokwim River.—On the Kuskokwim, below Kolmakof, many of the shales become carbonaceous. Rev. Mr. Kilbuck, the missionary, has found small seams of coal here.

Nunivak Island and Kaluyak Point.—According to Mr. Kilbuck, there are good seams of brown coal on Nunivak Island. Mr. Kilbuck brought some of this coal to Bethel and found it to be very good for common uses.

At Kaluyak Point, on the mainland not far from Nunivak Island, Mr. Kilbuck reports seams of good lignitic coal from 18 inches to 2½ feet thick. Some of the coal was brought to Bethel and burned well.

Alaska Peninsula.—Besides the localities mentioned by Dall,[2] coal is reported on the southeastern side of the southeast one of the Ugashik lakes by Mr. Mittendorf, a trader now at Nushagak. The coal out-

[1] Alaska and Its Resources, p. 478.

[2] Report on the coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I.

crops all over the side of the bluffs on the lake. It is rather poor, resembling cannel coal in appearance, but requiring a considerable heat for burning.

Coal between Controller Bay and Icy Bay on the southeastern coast.—For the following particulars concerning the coal fields in this region, the writer is indebted to Mr. F. H. Shepherd, M. E., of Nanaimo, British Columbia, engineer for the Alaska Development Company, Seattle, Washington. Two fields have been investigated, the upper and lower fields. The upper field is on the shores of Controller Bay and reaches from Cape Martin to the Chilkat village, and the lower field reaches 40 miles westward from Icy Bay. The upper or Chilkat field contains metamorphosed Tertiary rocks which Mr. Shepherd believes to belong to the Kenai. The rocks contain no marine fossils, but abundant plant remains, which, however, have been spoiled by the folding. The strike everywhere for 20 miles is N. 40° E. and the dip of 50° or 60° NW. The structure is therefore monoclinal. As the mountains inland are approached the rocks become silicified and more resistant, and bowlders of crystalline rocks are brought down from the mountains, consisting of pieces of granite and metamorphosed quartzite with slaty rocks. There are no dikes. The coal seams, according to Mr. Shepherd, are sometimes as much as 27 feet thick and are fairly clear, while many are from 10 to 12 feet thick. The coal possesses a bright, black luster and conchoidal fracture, and has all the characteristics of semi-anthracite, with the exception of hardness and specific gravity. The following two analyses were given by Mr. Shepherd as being taken from outcrops at opposite ends of the coal field, to show the uniformity of the coal.

Analyses of coal from Controller Bay and Icy Bay, Alaska.

	Per cent.		Per cent.
Adhering water	0.75	Adhering water	0.78
Fixed carbon	82.40	Fixed carbon	80.30
Volatile matter	13.25	Volatile matter	13.22
Ash	3.60	Ash	5.70
	100.00		100.00
Sulphur	.69	Sulphur	2.90

The difference between this coal and that of Cook Inlet is ascribed to the effects of the folding and of the large bodies of igneous rock in the mountains, which have so altered the coal, at the same time with the accompanying strata, as to increase its commercial value.

Nearer the coast is a heavy series of black shales with a few plant remains and shell casts, which seems to be several thousand feet thick, as also is the supposed Kenai. In these shales oil occurs.

In the lower field, which lies northwest from Icy Bay, as before stated, the Kenai series do not appear and there is no coal, only oil. The structure here is a general anticline parallel to the coast and to the main mountain range, which, however, is well back of the fold. From Cape Yaktag, which is the point immediately west of Icy Bay, fossils, collected by Mr. Shepherd from a point on the mountain 1,000 or 2,000 feet high, were contained in sandstones, thin-bedded limestones, and shales; the same fossils were found on the coast as float. This collection of fossils was submitted by the writer to Dr. W. H. Dall, of the United States National Museum, who makes the following report, showing the beds to be Miocene:

From Cape Yaktag, northwest head of Yakutat Bay, Alaska, mostly waterworn pebbles. Miocene, horizon of Empire beds. The oil or asphalt found in these sandstones is doubtless derived, as elsewhere on the Pacific coast, from the underlying Eocene deposits. The following have been noted in the collection:

Arca (like *microdonta*), *Glycymeris* sp., *Venericardia borealis* Conr. and *V. ventricosa* Gld., *Astarte* sp.?, *Crassatellites* sp.?, *Thyasira bisecta* Conrad, *Lucina acutilineata* Conrad, *Cardium decoratum* Grewingk, *Cardium aleuticum*? Girard, *C.* (like *serratum* L.), *Dione* sp.?, *Callista* sp., *Macoma sabulosa* Spengler, *Macoma* sp.?, *Spisula* sp., *Myacrassa* Grew., *M. truncata* L., *Thracia* sp., *Phos* sp.?, *Tritorium* sp.?, *Sipho* sp., *Trichotropis* sp., *Ranella* sp., *Turritella* sp., *Litorina* sp., *Crepidula princeps* Conrad, *Natica* (like *clausa*), *Polynices* (like *Recluziana*), *Dentalium* sp.

There can be no question as to the Miocene age of nearly all of these, although they are "float" specimens.

A RECONNAISSANCE FROM RESURRECTION BAY TO THE TANANA RIVER, ALASKA, IN 1898

BY

WALTER C. MENDENHALL

Geologist to Military Expedition No. 3, in charge of Capt. Edwin F. Glenn, Twenty-fifth Infantry, U. S. Army.

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A RECONNAISSANCE FROM RESURRECTION BAY TO THE TANANA RIVER, ALASKA, IN 1898.

By W. C. Mendenhall.

INTRODUCTION.

The rich strikes made on the Klondike in 1896 and 1897 and the great rush which took place immediately afterwards, centered the attention of the mining world on Alaska and brought out strongly the lack of accurate geographic and geologic knowledge of the region lying within the limits of the territory.

In response to demands upon our Government for more accurate maps and more complete economic data, several parties equipped for geographic and geologic work were organized in the spring of 1898. Of these, four were sent out by the Geological Survey, in charge, respectively, of Messrs. Eldridge, Spurr, Barnard, and Peters, and two by the War Department, the latter in charge of Captains Glenn and Abercrombie, who were to explore the area lying between the Tanana River, to the north, and Prince William Sound and Cook Inlet, to the south. A third party, in charge of Captain Eldridge, to go into the interior by the usual route down the Yukon and cooperate with Captains Glenn and Abercrombie, had been originally planned, but was abandoned when the war with Spain broke out and created an imperative demand for all officers and men belonging to the Regular Army.

Upon request from the War Department, the Director of the Geological Survey detailed two geologists, one (Mr. Schrader) to accompany Captain Abercrombie's party, known in general orders as Expedition No 2, and the other (the writer) to accompany Captain Glenn's party, Expedition No. 3.

The geologist's duties, as defined in instructions from the Director of the Survey, required him "to ascertain the general distribution of rock masses, their relations, and, so far as may be, the character and origin of each formation; to observe and note all occurrences of valuable minerals, giving special attention to the presence or absence of gold, whether in placers or veins." The observations were not "to be confined to physiographic and geologic facts only, but * * * extended to the features of the fauna and flora, and to the determination of accessible routes for wagon and railroads." We were also instructed "to assure ourselves that the military surveys, and such as we might necessarily make, would constitute a continuous base for the location of observations."

In obedience to these instructions, I reported to General Merriam at Vancouver Barracks, Washington, on the 29th day of March, 1898, for duty in cooperation with Captain Glenn. The interim until the evening of April 7, when the steamer *Valencia*, with the officers and geologists of the exploring parties, sailed from Seattle, was spent in completing the equipment at Portland, Oregon, and at Seattle, Washington, and in arranging details of transportation with the officers in charge of the expeditions. From this time until the end of the summer geological work was carried on in cooperation with the members of the military expedition, and I wish here to express my hearty thanks to the officers and men, as well as to the civilian attachés, for many courtesies extended and privileges shared during a long and interesting period, when hardships were numerous and comforts few.

ITINERARY.

On the evening of the 19th of April, 1898, we anchored in the head of Valdes Inlet, where Expedition No. 2 disembarked and established a base. The next morning an advance party from Captain Glenn's command crossed Prince William Sound on the small steamer *Salmo* to the head of Portage Bay, and there chose a camping place (Pl. XV), which was destined to be used as headquarters, while the shores to the north of Prince William Sound were examined in the hope that some feasible way might be found into the interior from these waters.

On the 23d of April a trip was taken around the head of Portage Bay from camp, some geographic work was done, and a cursory examination made of the rocks en route. On the 24th Captain Glenn arrived with the main force of the expedition, and on the afternoon of the next day we reembarked on the *Salmo* for an inspection of Port Wells in the northwestern part of Prince William Sound. We anchored that night at the mouth of a small stream which enters Port Wells from the east several miles from its head, and the next morning moved on up to the head of the inlet. The day was clear and the scenery superb. The mountains rise steeply from the water's edge, and at this season were snow-covered to the very base. On the west numerous small glaciers, easily distinguished from the unconsolidated snow by the blue color of their fronts and crevasses, hung from the summits or extended down the slopes, while at the head of the bay two large ice streams reached water level from the high mountains to the north. It was evident that no practicable pass existed inland from these waters, but the day was spent in an examination of one of the glaciers (Pl. XIX, A) and the few rock outcrops which were not buried under the snow.

Early the next morning we weighed anchor and steamed down the bay 8 miles to the mouth of a small stream which enters from the east, in order to examine it for an outlet to the north. The clear sky of the previous day had given way to low clouds and snow, so that no general view of the stream valley could be obtained. Three of us, however, struck out on snowshoes and explored it for 6 or 7 miles in the storm. Its general trend was northeast, and it was found to contain several small lakes filling depressions back of morainal dams. For our disagreeable day's work we secured no satisfactory results. We had merely proved the extension of the valley to a point practically as far north as the head of Port Wells itself. The stream occupying the valley at this point was so small that we knew we must be near its source and near the head of the valley; but the clouds would not lift long enough for us to verify this conclusion. Lieutenant Castner, in a later trip, with clear weather, was able to see the limited extent of the valley from its mouth.

The *Salmo* now returned to the base camp at Portage Bay, and the next day, the 29th of April, I joined Corporal Young in a trip across Portage Glacier to the head of the easternmost extension of Cook Inlet, Turnagain Arm. Lieutenant Learnard had already gone across with a small party to investigate conditions about the head of the arm.

The isthmus which connects Kenai Peninsula with the mainland is only about 12 or 13 miles broad from tide water to tide water, and probably stands but little above sea level; but for 5 miles of this distance it is buried under a glacier which flows from the high mountains of the peninsula to the south. This glacier at its highest point is about 1,000 feet above tide, and can be crossed in a few hours from the open waters of Portage Bay by prospectors or others who desire to reach Sunrise City or the headwaters of Cook Inlet before this body of water is open to navigation in the spring. For more than a hundred years it has been used as a route, first, by the Russian and Indian traders, and later by miners, who usually cross it without difficulty in the winter or early spring. In the summer the crevasses open and it is but rarely used, especially since at that season the all-water route is so much easier and cheaper.

On the morning of our first trip across the portage a light rain was falling at the foot of the glacier, but before we reached its highest point we found ourselves enveloped in a blinding blizzard, which obliterated the well-beaten trail and hid completely from our view all landmarks which might serve to guide us. Fortunately the storm was at our backs and helped rather than retarded our progress; but even then, had it not been for bushes which earlier travelers over the same route had stuck in the snow to mark the trail under just such conditions, we should have been hopelessly lost. By noon, however, we were across the glacier and had met Lieutenant Learnard at the foot on the Turnagain Arm side. In the afternoon we moved 3 miles down the valley to the first timber, a clump of cottonwoods, and made a comfortless camp on the snow. Everyone was wet, rain was falling incessantly, wood was scarce and of poor quality, and altogether the outlook was dismal enough.

The next day, after a vain wait for better weather, it was decided to move 3 miles farther down the valley to Spruce Camp, where more wood, less snow, and better shelter were to be found. The move was accomplished with some discomfort, but the new camp itself proved relatively luxurious. It became evident very soon, however, that we were just between the two seasons when mapping or geologic work could be done to advantage. Earlier the snow was firm and fair progress could be made over it with snowshoes. Later it would have disappeared and travel would have been comparatively easy. Just then, however, it varied in depth from a few inches to a few feet, and was so soft and full of water that often a man on his snowshoes would sink to his knees or deeper. Travel under such conditions was so laborious as to be practically impossible.

Since nothing could be accomplished here, on the 2d of May I returned, in company with privates Blitsch and McGregor, to Portage Bay. We found this trip of 12 miles through soft snow, in which one sometimes sank to his thighs, to be one of the hardest half day's work of the season.

Later another trip was made across the glacier and back, and although travel along the flats had improved with the disappearance of much of the snow, that on the glacier and its approaches was daily becoming worse with the opening of crevasses, the rise of streams, and the increasing frequency of snow slides.

During the remainder of May we were confined to the headwaters' camp pretty closely, waiting for the snow to disappear. In the meantime Captain Glenn had satisfied himself that there was no outlet from the northern waters of Prince William Sound toward the interior, and had decided to move the entire command around to Ladd's Station, just above Tyonek in Cook Inlet, and from there investigate the possibilities of a route to the Tanana.

On the 29th of May Messrs. Kelly and Lampe, with a small party, were started north from Portage Bay to find, if possible, a route to Knik Arm which should be practicable as a mail route during the winter season when Cook Inlet was closed, and the main expedition embarked on the same day for Tyonek.

At Resurrection Bay, halfway down the east shore of Kenai Peninsula, Lieutenant Learnard, Mr. Bagg, and myself landed to make a trip through the peninsula to Sunrise City over a route much used by prospectors as far as Lake Kenai and reputed to be free from high divides or other serious obstacles. We were landed on the shore of the bay late in the afternoon of the 30th with our blankets and ten days' provisions. A tramp of a mile or more along the beach brought us opposite the schooner *Bowhead*, owned by a prospecting party, most of whose members were on Lake Kenai. The captain, however, remained on board, and in response to our signal came off after us in a small boat. He entertained us royally on board his vessel that night, and the next morning landed us at the head of the bay, whence a trail starts up the valley of Salmon Creek toward the interior.

The waters were high from the melting snows in the mountains, and Salmon Creek spread well over its valley, so that our progress toward its source was slow and involved almost constant wading; but by midafternoon we had overtaken the main party of the Alaska Hydraulic Syndicate, in charge of Mr. Shackleford. They had a comfortable camp, and brewed each of us a big cup of excellent tea, the universal Alaskan beverage, adopted by everyone as soon as he reaches there, whatever his earlier prejudices, and discarded, perhaps, as soon as civilization is reached again. The tea, a good fire, followed later by a fine supper and a bed on fragrant spruce boughs erased our memory of the day on the trail, and by morning we were ready for another jaunt. Parting regretfully from our hosts of the night, we continued up Salmon Creek Valley to the lake at the head of one of its branches. Ice still covered the lake, but it was soft and treacherous, and we had to scramble through the brush along its shores for 2½ tiresome miles. At the head of the lake the climb of 800 or 900 feet to the divide separating Resurrection Bay from Cook Inlet drainage begins. At the summit we found ourselves on snow again, although but 1,200 feet above the sea. A few hours' tramp brought us to a party of prospectors, also belonging to the Shackleford party, and soon we were drinking tea and eating such bread as none but an old prospector can bake, and even he only in the woods and with a frying pan for a bake oven.

Mr. Clarke, who was in charge of this advance party, kindly arranged for us a passage down Snow River and Lake Kenai with three members of his force on the morrow. We learned from him that we were only 1½ miles from Snow River, the largest tributary of the lake, and that after reaching it we had but 10 or 12 miles to go to the lake itself.

Early next morning we reached the banks of the river. Messrs. Stetson, Robley, and McCrae were already there and had launched the frail-looking little dory that was used to carry us down the lake. The trip to its head was one to be remembered. The river, fortunately for us, was high, so that there was less danger from shoals and sand bars; but the current was swifter, and often it seemed that the frail craft could not escape capsizing or swamping as it swept past the numerous log jams and sunken rocks, now striking, now swinging free and hurrying on.

Before noon we reached the head of the lake and breathed more freely. An ample lunch refreshed us, and rigging an old rubber blanket on two poles we set sail down the lake. The breeze was fresh and we made rapid progress. A couple of hours in the boat carried us as far as we could go in a day on the shore, hampered as we were by our heavy packs.

When well down the lake some member of the party spied a big brown bear up the mountain side feeding on the fresh herbage which had sprung up in the path of an old snowslide. McCrae could not resist his hunter's instinct, so we landed and he started up the slope. Bruin's curiosity, too, had been aroused by the strange object on the water and he was on his way down to investigate it when McCrae met him. The battle was short; the first shot from the 45.90 Winchester settled the bear's fate and assured us fresh steak for supper; and when the rest of us, who had controlled our curiosity until the bear was dead, arrived, McCrae was nonchalantly skinning his game as though 600-pound grizzlies were everyday occurrences.

That night we reached a vacant Indian cabin at the mouth of Quartz Creek and slept under a roof, although a poor one. Next day Learnard and Bagg started up Quartz Creek for Sunrise City. I put in the day at the lower end of the lake, mapping, climbing about the terraces, and panning gravels from them before trying to overtake my companions.

The hospitality of Messrs. Stetson and Robley proved unlimited, as is usually the case with these prospectors, and to the local geographic knowledge of the former much of the information assembled on the map is due.

Meantime McCrae had decided to go through to Sunrise City with me, and early next morning we left the Indian shack on Lake Kenai for the trip up Quartz Creek. There was at that time no trail along this stream, and since the waters were high we avoided the marshy bottoms and kept to the minor ridges within the valley. Much of the district had been burned, and dead and blackened alder snags impeded our progress and made much of the journey very laborious. McCrae's pack was much heavier than mine, but he was more accustomed to the work, and was much fresher than I when, at 9 o'clock, we stopped for the night with not more than 12 miles to our credit. The bed we made then was one of the luxuries of the season, a fine old spruce tree made a roof which would shed any sort of a storm, and great arm loads of dead dry grass which we pulled made an incomparable mattress. It was 11 o'clock, and full twilight, when supper was over and we turned in to sleep until 9 the next morning. As we had planned an early start our surprise, when we awaked, at the lateness of the hour was complete; but we needed the rest, for a longer day's work than the previous one was ahead of us.

A short tramp carried us across the divide to the head of Mills Creek, and then we began to see signs of prospectors; stakes with claim notices on them appeared even out in the midst of swamps. For 5 miles the Polly Mining Company's property yields handsome returns to its owners, and the neighborhood gives value in the eyes of the "buckwheat" prospector.

From this divide we had a trail, now good, now bad, to follow, but at its worst it was far superior to forcing a way through burned and blackened alder brush. Four o'clock found us at the cabin of Mr. Miller, one of the stockholders of the mining company at the mouth of Mills Creek. He insisted upon preparing dinner for us, and our inward craving prevented very emphatic protest. At this time, the 5th of June, the early comers among the claim owners were just arriving along the gulches, but did not expect the water to be low enough for work until two or three weeks later.

We learned from Mr. Miller that Learnard and Bagg had passed Mills Creek earlier in the day, and were probably expecting to spend the night at The Forks, 10 miles below; so, after a rest of a couple of hours, we pushed on. We reached there at 10.30 p. m., and found that our companions had arrived but an hour before. The day's work had netted us about 19 miles. I was satisfied, but McCrae, after leaving his pack to be brought down by the train next day, pushed on to Sunrise, covering a total of 29 miles.

We moved down to Sunrise next morning, expecting to find the steamer *Perry* there to take us to Ladds Station. Our entire trip had been hurried, because Captain Glenn had expected to receive pack animals from the States in time to start into the interior immediately after landing at Ladds, and we wished to reach him there before his expedition could leave; but we might have been much more deliberate, for we had two days' wait at Sunrise for the steamer, and did not reach Ladds until the morning of the 9th. Here we found that but five head of pack animals had arrived, and that Lieutenant Castner had been sent to Knik with these to begin cutting a trail to the interior.

Then began a long period of waiting for transportation. No very long side trips could be made, because it was hoped each day that stock might arrive for the main expedition, and it was the intention to move out immediately after its coming. On the 21st of June, however, no pack animals having been shipped as yet, Mr. Kelly and I left Ladds for Sunrise City again, and on the next afternoon crossed Turnagain Arm to the mouth of Glacier Creek, intending to try to get to Knik Arm across the intervening mountain range. At Sunrise Mr. Kelly engaged a packer, Mr. C. C. Smith, to go with us for a couple of days, and as he was familiar with the lower course of Glacier Creek he proved an efficient guide for that part of the journey.

Landing at the mouth of Glacier Creek late in the evening we found a camp of prospectors, with Dr. Freeman at their head, and spent the night with them. Here we had our first unpleasant experience with mosquitoes. When we crossed Kenai Peninsula it was early in the season for them; now they were just about at their worst. Camped on the beach at Ladds Station, with closed tents to sleep in, we had no trouble escaping them; but here in the woods the conditions were entirely different. Ordinary mosquito bar thrown over the sleeper, or even tucked down into his sleeping bag, proved a very inadequate protection; the creatures are so countless in numbers and so patient and vicious in attack that the slightest opening would be found by dozens of them, and life made miserable for the traveler.

By the end of the second day we had turned out of Glacier Valley and were well up Crow Creek toward its head. One claim was passed, that of Mr. Davidson, who was preparing to do hydraulic work on the flat between two canyons, where there is an abundant gravel deposit; other claims lower down were being developed, but in all cases the work was in its incipient stages.

We camped that night above timber line, and it proved above the mosquito line also, much to our relief. We were in the upper valley of Crow Creek, and could get no information from Mr. Davidson or his men as to what waters we should reach across the divide. We were then only 10 or 12 miles from Turnagain Arm, and yet the prospectors knew nothing about the country beyond, so little was the geography of the district known.

Next morning early we crossed the pass, at 3,750 feet above tide, and found it partially snow-covered. From its highest point we could see something of the ruggedness of the country; sharp peaks all about us rose to 6,000 feet or more, small glaciers were perched here and there in the saddles, and the slopes everywhere were remarkable for their steepness. White mountain sheep were to be seen in groups of from two or three to twenty-five or more on the more accessible parts of the slopes. They are very abundant in these hills, and have not been enough hunted to be shy. Ahead of us a narrow valley opened out to the north for 5 or 6 miles and then joined a broader transverse valley. We felt sure that the waters of this latter must find their way to Knik Arm, and the work of the next few days proved the correctness of this surmise; but the task immediately in hand was to reach the open valley below. We climbed down from the divide along a slope of angular rubble, which gave very precarious footing, and passed the end of a small glacier, the principal feeder of the stream whose valley we were entering. We found one prospecting party here, whose members had called the stream Raven Creek, but they could not tell us whether its waters eventually reached Turnagain Arm or Knik Arm.

By night we had reached the larger creek, whose valley we had seen from the summit. About a mile east of this the stream emerged from beneath a big glacier and wandered over a relatively broad gravel-floored valley below. We camped on one of the bars between the various stream branches, and here escaped many of the mosquitos which were so merciless in the brush.

Next morning our guide turned back, having already come farther than he had originally intended, and Kelly and I continued down the Yukla, as we subsequently learned the stream is called. Its upper valley is a miniature Yosemite. On the south a peak rose to 5,500 or 6,000 feet, with practically sheer walls for half that height; they were so steep as to be entirely void of vegetation and inaccessible even to the mountain sheep. Other cliffs less lofty rose on the north side of the valley and extended toward the glacier at its head. At a point 5 miles downstream, however, the box-like character of the valley gave way to softer and more open forms, which became more and more pronounced as we approached Knik Arm, the immediate stream valley also becoming wider.

On the second day of travel along Yukla Creek we entered a region of forest fires, whose smoke obscured everything until we reached the coast, and at times was so close and heavy as to be stifling, but which never seemed to affect in any way the activity of the insect pests. Several hunting shacks, built during the fall and winter seasons by the Indians, were passed and were usually surrounded by evidence of success in the chase—moose antlers and bones and sheep pelts being plentiful.

For the first 10 miles down Yukla Creek the stream wanders so erratically back and forth across its narrow valley that constant wading was necessary; below this the valley widens and we were able to keep clear of the stream, but were much embarrassed by the swamps in the flats and the fallen timber along the hillsides. Now and again we would find an old Indian or game trail, only to have it fade away within a mile. The heat, too, in midday was oppressive, burdened as we were with heavy packs and closely covered with gloves and veiling.

On the evening of the third day's travel on this stream we came within sight of the coast; but several miles of salt marsh intervened, and long before getting across it we found ourselves so tangled up in the blind tidal sloughs which cut the marshes to such depths inland from these bays of extreme high tide that we were compelled to camp for the night in the midst of the swamp and did not reach the beach until next morning at 11 o'clock. Here we found a party of Indians in camp, and engaged one of their number to take us across the arm to the North American Trading and Transportation Company's store, kept by Mr. Palmer. Here we learned that two hours before our arrival an Indian messenger had been started to Captain Glenn, at Tyonek, and getting into a small sailboat I started down the Arm, hoping to overtake him. Fortunately for us the Indians are timid navigators, and as a fresh wind was blowing the messenger had dropped anchor when but a few miles down the bay. Here he was overtaken, and a day later we reached Ladds, only to learn that nothing had been heard from the States during our absence.

We waited here till the 19th of July, when Captain Glenn determined to buy a pack train which he had learned was for sale at Sunrise City. On the 22d the steamer *Perry* landed us at Knik Station with the animals (25 head), and the next morning we started up the Matanuska Valley, bound for the Tanana. The start should have been made two months earlier and the time for our work thus practically doubled, but the question now was one of accomplishing as much as possible in the short time remaining before freezing weather should set in.

Our progress over the rolling forested floor of the lower valley (Pl. XV, *A*) was without more important incident than the occasional retreat of the pack animals overnight and the consequent delay next day, until we came to the ford of Kings Creek on July 29. This stream, like all those on the western slope of the coastal mountains in Alaska, is turbulent, but ordinarily its volume of water is not great; recent rains, however, had raised it to much beyond the normal. Just below the broad and comparatively shallow ford is a reach of swift, wild water, where the stream is confined in a narrow channel, across which a couple of logs had been placed side by side to serve as a footbridge. Canwell, the ex-cavalryman of the party and an excellent horseman, volunteered to try the ford and mounted the bellmare for the purpose. Everything seemed to be going well until he reached the middle of the channel, when his mount stumbled over a bowlder in the creek bed. She fell far enough for the swift current to catch her pack, and then in an instant was swept off her feet and carried stumbling and struggling into the rapids, Canwell clinging to her and trying to direct her struggles toward the shore. In the swift water she was rolled over and over, now head and pack, now heels, appearing above the muddy current, until man and horse crashed into the footbridge. For an instant it resisted, and then was carried down by the weight. A few yards below Canwell was pulled out, shivering, bruised, and half drowned, but there seemed no hope of saving the old mare. She was rapidly weakening, and even when she regained her feet in the quieter water farther down the stream she could not stand. Fortunately she had on a riding saddle instead of a pack saddle, and the pack finally loosened and came off. Thus relieved of her load, she succeeded in getting ashore, but 200 pounds of our precious provisions were on their way to the Pacific; later we would have given much for them.

Further move was out of the question for that day. We spent the afternoon drying out—for some of the pack mules had followed their leader—and nursing our invalids.

The next day we made a long drive to Chickaloon Creek, where it was intended to divide the party, Sergeant Matthys going up this tributary and connecting, if possible, with Lieutenant Learnard on the Talkeetna, while Captain Glenn pushed on with the main expedition to the Tanana. A day—and a rainy one at that—was spent here in dividing provisions and outfit. I took advantage of the stop to climb back to Castle Mountain and make an examination of the rocks of which it is formed.

With our train reduced to fifteen animals and the party to eight men, we climbed out of Chickaloon Valley next morning and camped that night on the high ground of the Upper Matanuska Valley, at an elevation of more than 1,000 feet above Chickaloon Creek. Here we found Mr. Kelly, who had been with Lieutenant Castner, waiting for us. He reported that the lieutenant, because of the lateness of the season, had given up the idea of receiving reenforcements and had started inland with such stock as he had. From this point began the attempt to overtake him, which did not end until three weeks later, on the Delta River. Castner had several days start of us, but his pack animals were worn out and overloaded, while ours were comparatively fresh.

The march of August 2 was without special incident or difficulty, but when on the afternoon of the 3d we turned up Hicks Creek hard work began. At the mouth of this stream a steep climb of 1,000 feet had to be made around an impassable canyon. All the rest of that afternoon we found traveling very difficult. The lower part of the valley of Hicks Creek is dissected by a series of sharp ravines cut by western tributaries of the stream itself. In one of these ravines we camped that night. The heavily laden animals had great difficulty in getting down into it, for beneath the thin coating of moss which clothed the hillsides on the northern slopes was a layer of ice. Several of the animals slipped on this and packs were scattered from the top of the slope to the bottom.

As we approached the head of the stream the valley became much more open and travel comparatively easy. By an open divide we passed to Caribou Creek, the largest tributary of the Matanuska, crossed it, and traveled north up the valley of Billy Creek. Here we encountered the same difficulties met along the lower course of Hicks Creek. Immediate stream canyons here, as there, were deep and their walls steep. The drizzling rain added to the discomfiture of animals and men. Our camp on Billy Creek was well above timber line, and willow brush had to be depended on for fuel. The altitude, which was about 4,000 feet, and the fresh snow on the mountains all around us kept the temperature low, and this, combined with the cold rain, made this high camp an extremely uncomfortable one. The next day, however, the sun came out bright and warm, and we crossed a high divide in a limestone ridge into the Copper River drainage system. From this gap we secured the first glimpse of the Mount Wrangell group. One magnificent peak stood out over the low intervening mountains against the eastern sky; it was probably Mount Tillman.

We moved down Bubb Creek, as Lieutenant Castner had called the stream we were on, for two and a half days to an old Indian cache. Just before reaching it we met Mr. Hicks and Corporal Young on their way back to Knik. Hicks had guided Castner to a Matanuska Indian village on a small lake drained by the Tazlina River, where he expected to find Indian guides to Tanana. Beyond this point Hicks was not familiar with the country and so turned back. Corporal Young had been in continuous and arduous service with the advance parties practically ever since the expedition landed in Prince William Sound, and was thoroughly worn out. The clothing and shoes of both men were nearly gone, yet they were just beginning a march of 130 miles to Knik Station. Captain Glenn decided to add Young and Hicks to his party and to rest a day at the Indian cache, as the men needed it badly and the stock were beginning to show signs of hard work.

We were now on the southern edge of the great tundra plateau which forms the divide between the Copper and Sushitna drainage systems. It extends from the Chugatch and Talkutna mountains, through which we had just come, to the southern slope of the Alaskan Range, and presents essentially the same characteristics from one limit to the other. After a day's halt we started to cross this plateau, Hicks leading and picking out firm ground for the stock. To the remarkable ability which he displayed at this work much of the success of the expedition was due. In three years of experience in frontier work, during which he had had no guide except the natural features and his own remembrance of them, he had cultivated a power of observation which enabled him, without a compass, to keep a true general direction when lakes and swamps forced him to make his course in detail most tortuous. His work at times seemed almost miraculous to those of us less experienced in such work than he.

Three short days' travel across this waste (Pl. XV, *B*) brought us to the large lake—Lake Louise of the map—on the shores of which we camped on the evening of August 12. We had seen the lake two days before reaching it, and it had been reported to us as 35 miles in length. Our rough measure determined it to be rudely circular, although with very irregular shore lines, and about 8 miles in diameter. To reach it we had followed very near the divide between the Copper and Sushitna rivers, crossing only the extreme heads of streams which flowed sometimes to the east and sometimes to the west. Hundreds of little lakes and ponds were passed, draining in some instances toward the Copper and in others toward the Sushitna, while many seemed to have no surface outlet. Narrow swampy belts usually surrounded the lakes and bordered the streams, and very often the lakes were connected by swampy depressions. The gravel interswamp areas were relatively dry and hard, though usually moss-covered, and gave very good footing for the animals of the pack train. The problem which Hicks had to solve was to find a thread of connected gravel ridges with as few swampy interruptions as might be.

Lake Louise occupies a gentle depression in the broad upland, and on leaving it we gradually climbed the rim of this depression across country exactly similar to that traversed before reaching the lake.

About noon of the 16th of August we came to a large stream, the first seen since leaving Bubb Creek. This stream, from its position, we thought must be the Gakona River of Lieutenant Allen's map. The water was stained by the vegetable matter in the swamps which it drained, but contained almost no sediment. The current was from 2 to 4 miles an hour, and the depth where we forded it about 3 feet. There were remnants of a camp fire on the river's bank and boot tracks and the marks of a dragging rope in the sand. Prospectors had pulled their boat up the stream a few days before. These were the first traces of white men, except those made by one or the other divisions of our own party, which we had seen since long before we left the Matanuska Valley, and the discovery caused no little excitement. The mere sense of racial kinship is a strong bond in the wilderness.

On leaving the stream we quickly climbed out of the valley, but were unable to escape the swamps until late that same evening, when we camped on dry ground by the side of a little creek well up among the foothills toward which we had been traveling for so long. We had now crossed the 60-mile wide flat and trackless tundra from which we had anticipated most trouble, but discovered next day that hills did not necessarily mean freedom from swamps, for although climbing steadily we found about the worst footing of the trip.

The last few days had been cloudy and prevented a clear view of the mountain barrier ahead, so that on the 19th the train remained in camp while Hicks went ahead to study the situation. The next morning it was decided to veer off to the west to an Indian trail reported by Mr. Kelly in that direction, and leading apparently toward a gap in the mountains beyond us. This trail was plain and well beaten and probably connected the winter homes of some of the Copper River Indians with their fall hunting grounds in the caribou district among the foothills of the Alaskan Mountains. We crossed a valley, probably a branch of the Chestochina River, early in the day, and climbed by an easy grade to a higher level, which extended through the first line of outlying hills to the lakes in which Delta River heads. Our first camp on this high level was a rainy and very disagreeable one, because of the cold, wet, and scarcity of wood. The train passed two caribou just before reaching this camp whose curiosity and fearlessness should have placed them on the ration list immediately, but fortune, in the form of poor marksmanship, favored them. The second day's move across this high valley took us to the head of the second of the Tangle Lakes. The constant rain made map work very unsatisfactory, but fortunately the route led us along the crest of a series of morainal gravel hills for a greater part of the distance, so that travel was not difficult. Landmark Gap, in the mountain mass ahead of us, was a prominent feature all day, and a number of undrained glacial lakes were minor features of interest. We crossed the largest branch seen of the Chestochina River, flowing in a little gravel canyon 150 feet deep.

Tangle Lakes evidently drained through the gap east of us, and there was much speculation as to whether they belonged to the Copper, Sushitna, or Tanana systems.

During the last two days of travel in the Upper Chestochina Valley the immense quantity and great size of blue huckleberries was worthy of note. Bushes were of the dwarf variety, usually not over a foot in height, but loaded with the fruit. We had found these berries in more or less profusion all across the interior basin, but nowhere were they so abundant as on these gravel ridges.

We climbed from the Lake Tangle camp over a high divide between two sharp peaks, leaving the lake outlet to our left, where it had cut a gorge in an older and broader gap. From the summit we passed down into another broad gravel-floored valley very like that we had left and opening out to the south toward Copper River. We learned afterwards from Indians that a trail existed through here to the Upper Copper. The stream which we were on and which we afterwards learned to be the Delta River headed well to the westward but north of the hills through which we had just come. Our last camp had been on one of its minor tributaries.

The next day after crossing the gap we passed a camp of Upper Copper River Indians (Pl. XXI, *A*), the first human beings outside of our own party seen in more than 200 miles of travel. They had crossed to the head of Delta River for their fall hunting, but had met with very poor success. We got from them, however, a few pounds of caribou meat in exchange for some tea and flour. These natives were somewhat undersized, usually slight, measured by the white man's standard, but would compare very well physically with the Kenaites about Tyonek. They put on their very finest attire when they saw the pack train coming, and paraded for our benefit before their hunting lodges. By trade through the Lower Copper and Matanuska rivers the men had secured more or less complete outfits of white men's attire, but the women wore their own buckskin garments. They displayed the usual childlike amiability as to the many strange things in our equipment, but showed great gratitude for the very slight gifts which could be spared from our limited supplies. Stiphan, our Knik Indian guide, understood the dialect of the Copper River Indians, so that for the time being he was promoted to the position of interpreter, and his very obvious sense of his greatly increased importance was one of the funny incidents of the trip.

The river valley becomes restricted just below the Indian camp into a little gorge, so that, following Castner's trail, we climbed to the upland here and kept it for 6 or 7 miles until we reached Phelan Creek, which we crossed before camping again. These rolling uplands generally meant easy traveling, because they were relatively level and free from moss and for much of the way the slight inequalities of surface were due to the relief of little gravel hills, which gave firm footing. From this upland we were able to catch occasional glimpses through the clouds down Delta River, and these glimpses revealed to us that the great mass of the Alaskan Mountains was still ahead; the groups of hills through which we had passed were merely outliers, while to the west and east of Delta River rose high snow-clad peaks, but the river valley furnished the desired pathway through them and we kept on.

On the 24th of August our progress downstream, usually difficult only for short stretches because of the broad bars and open meadows in the valley, met with a serious check in the form of a turbulent little stream which flows out from beneath Castner Glacier. The channel is from 20 to 100 feet wide and from 2 to 6 feet deep; but the water is very swift and the bed so rough from the bowlders of all sizes with which it is floored that a ford is extremely difficult and attended with some danger. The temperature of the water, flowing as it does from beneath the glacier, and the blocks of ice floating in it, added to the interest of crossing it. A chilling rain had been falling on us, as usual, all of the morning, and no one in the train was ambitious for an icy bath when the stream was reached. Hicks here, as on many previous and later occasions, revealed the stuff of which he was made; while the rest of us waited, he struck out into the icy water and waded the stream time and again, sometimes up to his armpits, until he found a place where the pack train could cross in safety. It was a severe test of pluck and endurance. A plunge in icy water when one is warm is neither difficult nor harmful; but to wade about in it more or less constantly for half an hour after having been previously very thoroughly chilled is an altogether different matter, and its pleasantness is not increased by the fact that your clothes will have to dry on you after it is all over.

The day after this crossing we overtook Lieutenant Castner in camp on the banks of the Delta. Private Canwell and Stiphan had been sent ahead as runners a couple of days before, to overtake him if possible, the Upper Copper River Indians having told us that he was only three days ahead. Canwell found the party on half rations, all of the pack animals gone except one, which they were expecting to shoot next day and add part of its meat to their supplies. A raft, on which they intended to float down the river, was nearly completed. It was a very hazardous enterprise indeed upon which they were about to embark, and we arrived just in time to prevent it. Delta River, like most of the Alaskan streams, is swift and full of obstructions, and a frail raft has small chance of lasting many miles in its waters. Very many prospectors have lost their entire outfits during the summer by trusting them to such constructions, and occasionally lives have been lost in the same way. Lieutenant Castner himself suffered serious disaster a few weeks later when coming down the Volkmar River on a raft after his plucky attempt to reach Circle City by way of the valley of this stream and Birch Creek.

Our force, now increased by Lieutenant Castner's party of four, pushed on, although the season was so far advanced that the grass was badly frosted and the pack animals were showing the effects of it. The first day we made excellent progress on the gravel bottoms of the river valley, but on the second we found the river walled in by bluffs, through which tributaries had cut deep ravines that could not be crossed by pack animals. These ravines, after we had wasted a day in trying to find a way to cross them, forced us to leave the river to the left and climb out on the upland again toward the foot of Marr Butte, which had been in sight for a couple of days. Here was good traveling, and on the 28th, having made 15 miles, we camped down by a sheltered lake among some morainal ridges. From this point Captain Glenn determined to send back a part of the train, with the weaker animals, giving them a chance to travel slowly and recuperate, while members of the party tried to kill some game, signs of which had been abundant for two or three days. With the reduced force we advanced one more day. From the top of Marr Butte the Tanana could not be seen. Smoke obscured the view to the northeast, and while we could make out an open valley extending in this direction, none of the details of its drainage could be determined. To the north and west, 25 or 30 miles away, cut banks could be seen which might belong to the Delta, the Tanana, or some tributary of either. It seemed probable that the Tanana was at least 20 or 25 miles off, and as the main expedition had already advanced far beyond the limit of safety, it was decided to turn back on the 30th, after reoutfitting Castner for the work ahead. After our return comparison with the work of Peters and Brooks along the Tanana convinced me that we had been much nearer that river than we had at the time supposed, and the stream was mapped accordingly. Lieutenant Castner's work, received later, substantiated this conclusion.

On our return we overtook Corporal Young's party, which had turned back a day earlier than we, at the foot of Marr Butte. They had killed a large moose and a young caribou, so that of meat, at least, there promised to be no dearth for several days. It was welcome, indeed. Our bacon was about gone and rice and flour were getting very low, while 200 miles separated us from the nearest provisions on Bubb Creek. Just the day before we overtook the party with the fresh meat I had shot three ducks on a small lake, and in order to get my game had taken an icy swim; but the prospect of a very slender breakfast unless they were captured proved altogether sufficient as an incentive.

The energies of the party were devoted now to getting back to the seacoast. Long moves were made, and knowing the country and having no trail to cut we made fair progress. Ice was forming every clear night, and after the rainy ones the snow would be found to have crept down the mountain sides a very perceptible distance. On the 4th of September we climed out of Delta River at its head and that night again camped near the Tangle Lakes. The day had been hard on men and animals. A cold rain, almost a snow, was driven into our faces from the start. Water, because of the constant recent rains, was high, each tiny brook giving us a problem in fording. Some of the animals were so weak that constantly falling they could scarcely be induced to rise again; before camp was reached five of them had given out exhausted; two of these were shot in mercy, while the others were driven along with the herd for several days, but did not live to get out. Camp that night was made on a soggy, unsheltered hillside in a pouring rain. The moss beneath us was wet as a soaked sponge, and the heavens above were constantly adding to the supply of moisture. Many of the men were almost barefoot; everyone was worn out, despondent, and ill tempered. Camp Disconsolate marked the ebb of our spirits. Fortunately, we could sleep—one can always do that after a 20-mile march—and when morning came there was a change. The sun came out and warmed us and dried us; an Indian from a near-by camp came in, and some moccasins were bought from him; some of those of us who had clothing and shoes enough divided with those less well provided for; the stock had found good grass and were rested and strengthened. A lot of canvas and other superfluous equipage was abandoned, and we were soon on the trail again, encouraged and cheerful.

Between Chestochina and Gakona rivers Hicks made a cut-off, avoiding the camp of August 18–20 and shortening the trail considerably. On the 8th of September, while preparing to cross a small stream 2 or

3 miles north of the Gakona River, we were surprised by the approach on the other side of four prospectors from Knik, who were following our trail toward the Tanana. They had two good horses and more provisions than they needed for the return to Knik, for we soon convinced them that to continue was worse than useless, since winter was so near at hand and they were wholly unprepared for it. We had then been on half rations of flour for some time, and our supply of moose and caribou meat was almost exhausted; beans and rice were gone and sugar nearly so; so that the supplies secured from these men saved us from much discomfort.

Later this same day we reached the Gakona River, but found it much higher than when we crossed it before, too high, indeed, for fording, so that the animals were unpacked and the outfit rafted over the stream. That evening, having for the first time in several weeks an abundance of flour, we indulged in a long-to-be-remembered feast of flapjacks, and probably no member of the party will ever enjoy the most elaborate dinner more than he did that simplest of all meals under the cottonwoods on the banks of the Gakona.

The next day we met another party of three prospectors, likewise looking for the Tanana. Their stock was exhausted and had been left some distance back on the trail in charge of one of their number, while the others, with more pluck than judgment, were pushing ahead with packs on their backs. Members of neither of these parties had any definite idea of where the Tanana was, nor what they should do after reaching it. They seemed to have some expectation of wintering there with but a month's provisions, and were in a very fair way to contribute to the general Alaskan tragedy when we turned them back. Like most prospectors, they had not the faintest idea of how to use maps, yet were loud in their condemnation of all existing ones. Incomplete as all the Alaskan charts are, they have some value, especially along the usual traveled routes, and even through this region, where the Mount Wrangell group, well located by Lieutenant Allen, is constantly in sight, they enable one accustomed to their use to get a very fair idea of his position.

On the 12th of September we reached Bubb Creek, where some provisions had been cached. We were in great need of them, and feared that the Matanuska Indians, whose reputation for dishonesty among the traders is general, might have stolen them. We were much relieved to find everything just as we had left it, and some of the flour was fed to the pack animals, which showed increasing signs of weakness. Everything was rearranged here, and all articles not absolutely essential were abandoned. Captain Glenn dispatched private Van Schoonoven and the Indian Stiphan ahead to Knik to order forage advanced for the pack train. Van Schoonoven's trip was a remarkable one. He went up Bubb Creek, following our old route as far as Caribou Creek.

Here he shortened this route a little by cutting across to the head of the stream which we have since called Schoonoven Creek. I had estimated the distance from Knik to Bubb Creek cache to be 140 miles; the distance traveled by Schoonoven was probably not less than 120, and included the crossing of two snow-covered divides. Half of the distance was practically without a trail, and over the remainder of it the trail was poor; yet he made the journey in a few hours over four days.

From Bubb Creek the route followed on the return trip diverged to the east of that pursued on the outward journey, in order to enter the Matanuska Valley at its head. Here the divide was broad and relatively low, between the Copper and Matanuska drainage, and offered the least obstacles to travel. Hicks had avoided it when outbound, because a few stretches of burned and fallen timber promised to embarrass a small party with few axmen. This burned tract delayed our larger party but little.

From the Bubb Creek cache we climbed a few hundred feet to a dry gravel ridge, which afforded excellent traveling for a day and a half, or practically to the divide. Our camp on the night of the 12th was about 3,000 feet above tide—one of the coldest of the trip. Heavy ice formed and our summer equipment proved all too light for comfort. From a knob near the camp the Indian boy Andrew pointed out a conspicuous bluff well down the Tazlina Valley, which he informed us was on the farther side of a big lake, doubtless the Lake Pleveznie of Serebrenikoff. A glacier discharges bergs into its upper end, and the Tazlina River drains it. Andrew also told us that a few men had come down this glacier during the past summer and that many men and horses had come in over the one next below. This second one is probably the Valdes Glacier, whose northern branch discharges into the Klutena instead of into the Tazlina Valley.

The head of the Matanuska Valley is one of the most picturesque regions seen during the summer, rivaling that part of Delta River which cuts through the main Alaskan Range. Several big glaciers are visible at the same time, all rising in the névé fields of the higher parts of the Chugatch Mountains, south of the valley. From the central part of this range several high peaks stand out prominently. The valley itself includes the immediate gorge of the river, the broader, upper, older valley, with its numerous lakes and isolated prominences like Glacier Point, here and there.

September 14, after dark, Hicks brought in a lamb which he had shot from a band of mountain sheep. Next morning we had delicious chops for breakfast. The flesh of these wild sheep, which are so very abundant throughout these mountains, is of the finest flavor, and the animals are not specially difficult to kill when once the hunter has attained the high elevations where they live.

On the evening of the 15th we reached the mouth of Caribou Creek, and now felt perfectly safe. There had never been any serious danger for ourselves, but after September 1 freezing weather and snowstorms are possible at any time in the interior, and either heavy ice or deep snow would have proved fatal to the animals, the one because it would have made the crossing of the swamps impossible, and the other because the horses could not have found food through the snow.

In the valley of the Matanuska we found the climate controlled by coastal rather than by interior conditions, and very much milder in consequence. There were many patches of grass in sheltered places which had not been injured by the frost, and the eagerness with which the animals of the pack train attacked these was almost pathetic.

At Caribou Creek we rested for a day, the first full day's stop since the 19th of August, twenty-seven days before. Since then we had traveled about 340 miles. Most of us had to spend this time in patching up our wearing apparel to last us for the remaining 100 miles travel. From this point we reached the mouth of Hicks Creek in one day, although the district of fallen timber intervened. From here a rough climb took us across the hills to our old trail, near a point where it turned out of the main valley. Another day and we were on Chickaloon Creek, where a detachment of Sergeant Matthy's part from Knik met us with grain for the stock and provisions for the party. On the 24th of September we reached Mellishes's cabin again, two months and two days after leaving it, having traveled in the interim about 670 miles, and mapped topographically and geologically some 400 miles of hitherto unexplored territory.

Had the expedition been supplied with pack animals six weeks earlier, a detachment could have been sent to the Yukon without question, and smaller parties might have gone to the Copper and to the Sushitna.

From Mellishes's we moved 8 miles down the beach to the North American Trading and Transportation Company's store, kept by the obliging agent, George Palmer. Here the steamer *Perry* called for us on the 27th instant, and the next morning we landed at Tyonek again. I left here with Mr. Kelly, Mr. Bagg, and a small detachment of soldiers on the steamer *Dora* on October 9, and landed in Seattle, Washington, two weeks later.

PREVIOUS EXPLORATIONS.

RUSSIAN EXPLORATIONS AND DISCOVERIES.[1]

The earliest explorations in Alaska were carried on by the Russians, beginning with the first view of the continent just east of Bering

[1] The following résumé of the Russian explorations is taken from Dr. Dall's very complete account, in Alaska and Its Resources, Boston, 1870.

Strait by the Cossack Popoff in 1711, and continuing up to the time of the transfer to the United States in 1867.

Trade was in almost all cases the motive which prompted the Russian explorers, and careful surveys are rare, even the expedition fitted out by Catherine and intrusted to Capt. Vitus Bering proving almost valueless through the cowardice and incompetency of its commander. In 1725 Bering, with Lieutenants Spanberg and Cherikoff as assistants, was made commander of an expedition for the exploration of the coast of America and eastern Siberia. On the 20th of July, 1728, he sailed from the mouth of the Kamchatka River, discovered and named St. Lawrence Island on the 10th of August, and passing through Bering Strait reached Cape Serdze Kamen. Here the coast trends to the northwest, and Bering, considering that he had proved the separation of the continents of Asia and America, returned, reaching the mouth of the Kamchatka River on Sepetmber 20. In June, 1729, he made another attempt to reach the American coast by sailing eastward from Kamchatka, but returned after going but 60 miles. In 1741, in the vessel *St. Peter*, and accompanied by Cherikoff in the *St. Paul*, he sailed from Avatcha in search of the American coast. Cherikoff anchored near Cross Sound in July, and there lost 21 out of the 70 men in his command. He returned to the Bay of Avatcha on the 9th of October without having accomplished anything worthy of note. Bering saw land on the 18th of July and a boat was sent ashore, but no explorations were carried on here and he put to sea again on the 21st. He saw various islands north of Cross Sound, among them the Shumagins, which were discovered on the 29th of August. He died on Bering Island December 8, and the surviving members of his crew wintered there. The furs brought back by his vessels next spring caused many traders to venture eastward.

For the next twenty-five years desultory explorations were carried on by the promishlemiks or traders, who were prompted by avarice and lust and committed the most inexcusable atrocities. In 1781 Zaikoff explored Chugatch Gulf, or Prince William Sound, and Nagaieff discovered the mouth of Copper River.

In 1790 Gregory Shelikoff organized a company called the Shelikoff Company for the management of the fur trade. In June, 1799, a new charter was issued to this company, changing its name to the Russian-American Company and greatly extending its powers. Alexander Barinoff was put in charge of the Cook Inlet and Kadiak trading posts and continued in charge until his death in April, 1819, while on his way back from Russia. After Barinoff's death the management became more humane, and in 1819 four settlements were reported in Cook Inlet and two on Chugatch Gulf.

In 1824 a trade convention between the United States and Russia was signed at St. Petersburg. It opened the North Pacific to trading companies of both nationalities.

In 1848 the mining engineer, Doroshin, examined Cook Inlet for mineral wealth, and in the same year Serebrenikoff was killed on the Copper River.

By repeated renewals the Russian-American Trading Company's charter had been extended to the year 1862, when it was allowed to expire and rival companies shared with it the fur trade of the American coast. The territory was transferred to the United States in 1867.

ENGLISH EXPLORATIONS.

Captain Cook[1] in June, 1778, while exploring the northwestern coast of America in search of a passage through to the eastern coast, entered the inlet which now bears his name, and explored it as far as Chickaloon Bay and Fire Island, the latter lying between Knik and Turnagain arms. He at that time supposed himself to be in the estuary of a great river which would in the future afford access to a considerable area of country in the interior. He named Point Possession and Turnagain Arm, the latter being considered a river tributary to the greater one up which he had sailed. He took possession of the country in the name of King George, burying, so he records, on Point Possession a bottle containing the name of his ships and the date of its discovery, with some English coins of 1772. After Captain Cook's death the supposed river was named, by direction of Lord Sandwich, Cook River. In May of this same year he carried on some explorations along the eastern shores of Prince William Sound and made valuable observations on the country and natives, but did not visit the western limits of this body of water.

In 1785, and again in 1787, the English navigators Portlock and Dixon visited Cook Inlet and Prince William Sound. English Bay, just below Kachemak Bay, was called by them Coal Bay, from the lignitic beds exposed on its shores.

Among the most valuable of the earlier suveys made of this portion of the shores of Alaska was that carried out by Capt. George Vancouver,[2] who in the sloop *Discovery* entered Cook Inlet on the 12th of April, 1794, and left it for Prince William Sound on the 15th of May, having extended Captain Cook's observations not only as to the details of the western shore of the inlet, but in the matter of the extent of the two branches at its head now known as Turnagain Arm and Knik Arm. The latter Vancouver regarded as the proper head of the inlet, and did not give it a separate name. His sloop was taken well up into this arm, where for a time its safety was seriously threatened by swiftly

[1] Cook's Voyages: A Voyage to the North Pacific Ocean in 1776–1778, 1779, and 1788; by Capt. James Cook; London, 1785, in 3 vols. Vol. II.

[2] Voyages of Discovery: A Voyage of Discovery to the North Pacific Ocean and Around the World, Performed in the Years 1790–91–92–93–94–95, by Capt. George Vancouver; London, 1801, in 6 vols., Vol. V.

flowing tides and the quantities of drift ice which at that season are driven back and forth by the tidal currents. Vancouver made substantial corrections to Captain Cook's charts, particularly in longitude.

In June, 1794, Mr. Whidby, under Captain Vancouver's direction, while exploring the western shores of Prince William Sound, entered Portage Bay and examined it to its head. He recognized it as the inlet to which the Russians portaged from Turnagain Arm, and by comparison with his earlier observations on this latter body of water he estimated the width of the peninsula as about 12 miles—a remarkably close figure. From Portage Bay Whidby explored Port Wells to within 6 miles of its head, when the abundance of ice made further progress hazardous. He discovered the channel separating Esther Island from the mainland, and sailed through it. Snow slides were of frequent occurrence at the time of year when his explorations were carried on, and on one occasion came near cutting off the plucky explorers. He describes graphically the glaciers and stupendous mountains to the north of Prince William Sound.

LATER EXPLORATIONS.

Dr. Dall,[1] in 1868, as director of the scientific corps of the Telegraph Expedition, carried on extensive explorations in the Yukon Valley, and sums up with his account of his own individual work all previous knowledge concerning the Territory. He says of Knik or Fire River:

> It is navigable for only 12 miles and becomes wide and shallow. The Russians are said to have ascended it in skin boats to a lake called Pleveznie, whence by portage and river travel the Copper River may be reached. Our knowledge of it is slight, and it is supposed to be less than a hundred miles long.

Dr. Dall's description applies to Knik Arm and to what is now known as Matanuska River, which heads near but not in Lake Pleveznie. The stream at present called the Knik unites with the Matanuska at the head of Knik Arm. It has not been explored except by hunters and prospectors, who have given us no record of their work. It heads in the high mountains north of Turnagain Arm, 25 or more miles from its mouth.

In Bulletin 84 of the United States Geological Survey, published in 1892, with Professor Harris, Dr. Dall gives a summary of Alaskan geology, in which he describes briefly the Miocene deposits of English Bay and Kachemak Bay, Cook Inlet. In a later work[2] Dr. Dall discusses the economic value of the Cook Inlet coals, and gives careful descriptions and bed sections with considerable correctness in detail of the maps extant.

Lieut. Henry T. Allen[3] ascended the Copper River in 1885, crossed

[1] Alaska and its Resources; W. H. Dall, Boston, 1870.
[2] Report on the coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, 1895–96.
[3] Military Reconnaissance in Alaska, Lieut. Henry T. Allen.

the divide to the Tanana, descended that stream to the Yukon, and during the same summer explored the Koyukuk. No one geographer in recent years has made greater contributions to our knowledge of the Territory in so limited a time and in the face of such obstacles. The Copper and Tanana rivers were almost unknown streams before his exploration of their courses, and have since been drawn on current charts from his maps. Our own work during the past summer connected with that of Lieutenant Allen on the Tanana at the mouth of Delta River, and during the greater part of the journey across the Copper River Plateau we were in sight of the peaks of the Mount Wrangell group, which he had mapped and whose positions thus fixed were of great aid to us in determining our own location.

Dr. C. W. Hayes,[1] of the United States Geological Survey, crossed from Fort Selkirk, on the Yukon, to the coast by way of the White and Copper rivers with Lieutenant Schwatka in 1891. His work bears chiefly upon the region studied this summer, through his discussion of the general physiographic features.[2]

Dr. George F. Becker[3] visited Bear Creek, a tributary of Resurrection Creek, in July, 1895, before the region had been developed to any considerable extent. He describes briefly the placers on Bear Creek and the bedrock geology, and publishes a sketch map of Turnagain Arm and vicinity, giving very much greater detail in drainage than any chart heretofore published.

The published maps covering that part of the interior examined during our explorations this summer, since they have been based either on vague accounts given by prospectors or Indians or else have been the merest guesses drawn in by the cartographer to fill the blank spaces in his map, we could not hope to be accurate. Many persons had crossed Kenai Peninsula by the route which we followed; and it was known that Kenai River drained two lakes, but their positions and outlines had never been accurately drawn. Dr. Becker's map of Turnagain Arm, referred to above, is by far the best for that district, although containing many inaccuracies. North of Turnagain and Knik arms the country west of Lieutenant Allen's route was almost totally unknown.

Mr. Handmore, the Alaska Commercial Company's agent at Tyonek, courteously furnished me a copy of a map in his possession, based upon an old Russian chart and with such additions as he was able to make by carefully sifting the reports of Indian traders. This chart, while not correct in detail, gave a very good general idea of the course of the Matanuska River and was much more nearly correct than any of the published Government maps.

[1] An expedition through the Yukon district: Nat. Geog. Mag., Vol. IV, pp. 117-162.

[2] The Yukon plateau: Jour. School Geog., Vol. I, Nos. 8, 9, 1897.

[3] Reconnaissance of the gold fields of southern Alaska: George F. Becker, Eighteenth Ann. Rept. U S. Geol. Survey, Part III, 1896-97.

Among the prospectors at the head of Cook Inlet but one was found who was acquainted with the Matanuska country. This gentleman, Mr. H. H. Hicks, Captain Glenn was so fortunate as to secure as a guide for the expedition, but neither he nor anyone else could give us any definite idea of the character of the interior beyond the head of the Matanuska.

SCOPE AND CHARACTER OF WORK.

On the trip with Lieutenant Learnard from Resurrection Bay to Sunrise City, and that with Mr. Kelly from the mouth of Glacier Creek, near the head of Turnagain Arm to Knik Arm, a rough compass traverse was maintained and distance was estimated by pacing when traveling on land and by timing when traveling by water. Elevations were determined by aneroid barometer along the path of the traverse, and the amount of relief near by was estimated and expressed by rough sketch contours drawn with a large interval. Both of these lines are relatively short and are tied in elevation by sea-level checks at either end, and in geographic position by fairly well-determined points, so that it is believed that they express without gross inaccuracies the character of the country over which we traveled. Both of these journeys were made hastily and there was not much opportunity to study outcrops off the direct line of travel, but along this line careful notes were taken.

The conditions governing my work while with the main expedition permitted more careful, although hurried, observations. For topographic purposes a small 15-inch plane table and a Wilson alidade were carried, so that the paced distance could frequently be checked by rough triangulation. The elevations along the line of the traverse were obtained as before by aneroid readings, and the highest points near the line were measured by rough vertical angles. Land forms were sketched as completely as was practicable in the field, but our rate of travel prevented complete drawing there. Photographs were found later to be of great aid in giving detail. At the mouth of Delta River the line is tied to the accurate work of Messrs. Peters and Brooks along the Tanana, while on the south the position of Knik Station, the starting point, is known with approximate accuracy. Hence it is believed that the map which is reproduced here on a much reduced scale—the work being done on a scale of 1-180,000—will give an adequate idea of the character of this part of the interior of the Territory.

GEOGRAPHY.

GENERAL TOPOGRAPHIC FEATURES.

Between the coast at Resurrection Bay and the Tanana River lie two magnificent mountain ranges with a broad plateau belt between. These three tracts may together be regarded as a more complex representative of the St. Elias Range to the southeast, since they have the same general boundaries, the Yukon Plateau to the north and the Pacific Ocean to the south.

Trending westward the St. Elias Range is divided by the two main branches of Copper River into three ranges. The broad valley of the Chittena separates the Mount Wrangell group, lying within the great bend of the Copper, from the coastal belt to the south. This latter incloses the archipelago of Prince William Sound, around which it swings to the southwest, then continues across Kenai Peninsula, whose backbone it forms, and terminates in the Kadiak group of islands.

The Mount Wrangell group is much shorter than the chains on either side. It extends northwestward from Scolai Pass 140 miles, and there falls away abruptly to the Copper River Plateau. Northward the wide upper valley of the Copper separates it from the great Alaskan Range.

This range trends from the unexplored area in which the Tanana and Copper rivers head northwestward between the Tanana Valley and the Copper River Plateau to beyond the Cantwell River; then swings south, along the divide between the Sushitna and Kuskokwin drainage basins, and continuing west of Cook Inlet, into the Alaska Peninsula, is represented, partially submerged, in the Aleutian Islands. It is a complex mass culminating, west of the Upper Sushitna in Mount McKinley, more than 20,000 feet high, and including in its southwestern extension many active volcanoes. That part of it which lies immediately south of the Tanana is essentially irregular and consists of more or less isolated groups of mountains frequently very lofty with broad gaps between them. Mount Hayes, 14,000 feet, is the highest point of one of these groups, which lies just west of Delta River, and Mount Kimball, 10,000 feet, is the loftiest peak of a group farther east.

The Kenai Mountains, as that part of the St. Elias system which forms the axis of the Kenai Peninsula is called, form a belt 60 miles wide in the northern part of the peninsula and somewhat narrower toward the south. But little is known in detail of the interior of these hills, but that little indicates that they reach altitudes of 6,000 or 8,000 feet; that they have been dissected by a drainage system which became fairly mature before it was disturbed, and that therefore they are intersected by rather broad, high valleys. All their higher parts are snow clad, and numerous glaciers flow down from them to the inlets of the Pacific and become the sources of the streams which drain the peninsula.

The Chugatch Mountains, which extend from Turnagain Arm and Portage Bay, on the south, around Prince William Sound to the Copper River, are higher and more forbidding than their southern neighbors, the Kenai Mountains. A group of high peaks north of Port

Wells is probably the highest part of the range, and from this center elevations decline east and west. The extreme western point, lying between Turnagain and Knik arms, was the only part of the range which I had an opportunity to examine this season. Here the forms are very rugged, and the valleys, where not filled by ice, are frequently boxlike, with practically vertical walls. The glimpses into the range from Prince William Sound and the Copper River Plateau reveal a wilderness of snow-covered points projecting above extensive névé fields, from which ice streams flow north and south.

North of the western end of the Chugatch Mountains, and separated from them by the valley of the Matanuska River, is a somewhat lower group, the Talkutna Mountains, which is bounded on the west and north by the Sushitna River. It has not been thoroughly explored, so is not known in detail, but is believed not to exceed 6,000 or 7,000 feet in height and to be generally free from the permanent snow fields and glaciers which are characteristic of the ranges bordering the coast to the south and the more lofty Alaskan Mountains to the north.

North of the Chugatch Mountains lies the Copper River Plateau (Pl. XV, *B*). It is an interior basin of faint relief standing at 2,700 to 3,000 feet above sea level and inclosed on all sides by rough mountain tracts. The larger part of it is drained by the Copper River, which has cut a trench across it from north to south just west of the Wrangell Mountains. The basin has two arms, one extending up the main Copper River and the other, according to Dr. Hayes, up the Chittena, the eastern branch of the same stream. The western part of the plateau is drained, not by the Copper, but by branches of the Sushitna, and the Delta and perhaps other tributaries of the Tanana rise in its northern edge, so that this flat basin is a general divide, a fact of much physiographic significance and of a great deal of importance when access to the country is considered.

Along the line of our route the plateau is poorly drained, containing hundreds of small lakes and ponds, some of them without surface outlet, and many gravel hills and ridges of characteristically glacial form. East of us the plateau seemed to fall away into a region of lower elevation, in which were many lakes of considerable size, drained by western tributaries of the Copper. The part of this lower belt unoccupied by lakes seemed to be almost exclusively marsh, but as Copper River is approached drainage is doubtless better. Toward the Alaskan Mountains to the north a series of foothills rise above the plateau and inclose valleys which are really extensions of it.

DRAINAGE.

Kenai Peninsula drains principally to the west into Cook Inlet, because the axis of the Kenai Mountains lies near the eastern shore of the peninsula. This eastern shore is essentially irregular, and is indented by a maze of fiord-like bays and inlets, none of which receive large rivers, but some of which do receive glacial drainage. Resurrection Creek is perhaps the largest stream flowing eastward from the peninsula. It empties into Resurrection Bay from a reported glacial source 25 or 30 miles west of its mouth. Salmon Creek, a somewhat smaller stream, rises near Lake Kenai and flows south into the same bay.

The Kussilof and Kenai, or Kaknu, rivers are the largest westward-flowing streams of the peninsula. The former drains a large lake, Tustumena, but has not been explored or accurately mapped. The latter rises in a glacier near the eastern shore of the peninsula and flows, under the name of Snow River, to Lake Kenai, which is merely an expansion of the river due to a gravel barrier at its outlet, thence to Lake Sillokh, and finally empties into the inlet at Fort Kenai, the old Redoubt St. Nicholas of the Russian régime.

The lower courses of each of these streams lie within the Tertiary platform, which makes the western third of the peninsula and which, within geologically recent times, has probably been below sea level. It is likely that the upper courses of the rivers were established then, so that the drainage, when first developed, was not so markedly unsymmetrical as at present. Quartz, Sixmile, Resurrection, and Chickaloon creeks are considerable streams which drain northward from the peninsula into Turnagain Arm.

From the mainland this arm receives Indian, Bird, and Glacier creeks and Twentymile River, the latter stream entering the arm at its head from the east.

Knik Arm receives two or three small streams from the east, of which Yukla Creek, 35 miles long, is probably the largest. Its western tributaries are unimportant, the greater part of the plain, lying between the Knik Arm and the Sushitna River, being drained by the Little Sushitna. The upper part of Knik Arm merges into the delta of the Knik and Matanuska rivers, which unite just above tide limits. Nothing definite is known concerning the source of the Knik. Indians report a glacier at its head, and the traders account for the disastrous flood, which came down this stream and destroyed the buildings of the Alaska Commercial Company, near its mouth, a few years ago, by the theory that it rises in a lake formed by a glacial dam. This ice dam, giving way under the pressure of high waters due to heavy rains and melting snow, released suddenly the waters of the lake and caused the flood. Other just as intelligent local observers think that the flood requires no other explanation than the continuous and heavy rains which prevailed previous to its occurrence.

The view up the Knik from a point opposite its mouth, in the valley of the Matanuska, shows a broad, open valley, heading somewhat south of east of its mouth in snow-capped mountains. Its course is nearly straight for an estimated distance of 25 miles to these mountains, where the stream probably takes its source in several glaciers.

The Matanuska is the most important stream entering Knik Arm, and is the second in size of the tributaries of Cook Inlet. It rises on the northern side of the coastal mountain belt, just within the southern edge of the Copper River plateau, and flows for more than 100 miles, S. 70° W., between the Chugatch and the Talkeetna Mountains to its junction with Knik River.

All of its more important tributaries flow from the northwest, and are, in order, beginning at the mouth of the river, Tsadaka or Moose Creek, Granite Creek, King's Creek, Chickaloon Creek, Hicks Creek, and Caribou Creek. Chickaloon and Caribou are the largest of these, each draining considerable areas of the Talkeetna Mountains.

From the southeast the Matanuska receives several small streams, among them Prince and Sheep creeks, but the largest tributary received from this side is an ice stream, the Matanuska Glacier, which enters Matanuska Valley opposite the mouth of Caribou Creek. From the top of Glacier Point, from which the photograph (reproduced as Pl. XIX, *B*) was taken, the course of this glacier is visible for 20 or 25 miles. It probably heads in the same névé fields, which give rise to the glaciers of Port Wells and adjacent parts of Prince William Sound. Twelve or 13 miles farther up the valley another smaller glacier drains into the Matanuska River by a small stream 4 or 5 miles long.

Heading against the Matanuska and flowing northeast along the northern base of the Chugatch Mountains is the Tazlina River, whose principal source is a large glacier, which I have called Tazlina Glacier. About 20 miles beyond it the river enters Lake Pleveznie, discovered and explored by the unfortunate Russian, Serebrenikoff, in 1848. Prospectors who crossed from Copper River to Knik by way of the Tazlina and Matanuska rivers, during the past summer, report this lake to be 35 miles in length, and one of our Indian guides, Andrew, told us that a glacier discharges bergs into its upper end.

The most important of the upper tributaries of the Tazlina River is a stream about 50 miles long which Lieutenant Castner has named Bubb Creek. Its main source is near Limestone Gap, whence it flows east and southeast to its junction with the Tazlina River above Lake Pleveznie. One of its tributaries heads in Lake Leila, near the source of the Matanuska. Six or 7 miles east of our route at the nearest point and about 12 miles beyond the crossing of Bubb Creek is a lake 3 or 4 miles in length, on the east shore of which Lieutenant Castner reports a small Indian village. This lake drains into Lake Pleveznie, and so belongs to the Tazlina River system.

Lake Louise, a nearly circular body of water, with a very irregular eastern shore line, and lying south of the center of the Copper River plateau, was the largest lake which we were near enough to measure or locate definitely, although it is believed that others fully as large exist in the lowland to the east of our route. Lake Louise is 6 or 7 miles in diameter, and, although far south of the position usually assigned, is probably the large lake which has been represented under various names on maps of earlier issue as the source of one of the branches of the Sushitna. It undoubtedly drains to the west, but by which of the eastern tributaries of the Sushitna we were unable to tell.

Thirty miles beyond Lake Louise, in a broad valley somewhat below the general plateau level and lying along the southern edge of the first line of foothills north of the plateau, we crossed a considerable stream flowing eastward in a tortuous course toward the Copper. Our guide, Stiphan, told us that some distance below where we crossed it the stream entered a large lake and, judging from the volume of water which it carried, its source must have been 40 or 50 miles farther west. The stream is certainly either the Gakona or the Chestochina, of Lieutenant Allen's maps, and it seemed from its position most likely to be the latter.

Beyond these foothills we crossed three branches of another tributary of the Copper, probably the Chestochina. This stream here drains the northern slope of the same line of foothills whose southern slope is drained by the Gakona, and it shares the drainage of the valley north of these foothills with branches of Delta River.

This latter stream rises south of the Alaskan Mountains and some of its branches head well within the open valley south of Landmark Gap, which may be considered a part of the plateau. The branch down which we followed finds its source in the Tangle Lakes, and flows out through a conspicuous gap in the ridge which limits the valley in this direction. Beyond this ridge it receives, from the west, a large tributary which drains the northern slope of the same hills and the open valley which separates them from the main Alaskan range beyond. Wilder Creek enters from the west a few miles below the gap, and Phelan Creek joins the main stream from the east at the foot of the main range.

Within the Alaskan Mountains all the important tributaries which Delta River receives are glacial streams, which usually emerge from the ice within a short distance of the point where they join the river. Castner and Canwell glaciers on the east are sources of such streams, and there are two or three western glacial tributaries. Beyond the mountains Jarvis Creek joins Delta River within a dozen miles of its mouth.

ROUTES.

FROM PORTAGE BAY TO COOK INLET.

During the summer months, or from May to October, inclusive, Cook Inlet may be navigated by deep-sea vessels to Fire Island, and by those of lighter draft to Sunrise City and Knik, hence, at this season, parties who desire to reach the interior by way of the head of the inlet, disembark at the starting point of their land journey.

For several years, however, a considerable number of prospectors have desired to reach the Sunrise mining district in the spring before Cook Inlet was open to navigation. In such cases the shorter route and the one usually followed is by way of Portage Bay. This inlet, like all of Prince William Sound waters, is open throughout the year to ocean-going vessels.

Landing at the head of the bay, the isthmus connecting Kenai peninsula and the mainland is crossed in a portage of about 12 miles to the head of Turnagain Arm. A glacier covers 4 or 5 miles of this isthmus, and its highest point is 1,000 or 1,100 feet above the sea, with a steep approach from the east. This climb is the only serious obstacle to the portage, and in order to surmount it with heavily loaded sleds, it is usually necessary to resort to a system of ropes and pulleys. After getting to the head of Turnagain Arm, experienced boatmen, by taking advantage of the tide, may reach Sunrise City by water after the ice has ceased running, but those who are not familiar with boats, or do not thoroughly know the waters of the arm and their dangerous tides, are inviting disaster by attempting the trip.

Sunrise may also be reached by a trail along the beach from the head of the arm, or in winter, when the snow is firm, by going up the valley of Quartz Creek, and crossing a low divide at its head into Granite Creek, one of the tributaries of Sixmile, and thence following the miners' trail down this creek to Sunrise. This last is the favorite sled route among those familiar with the district. The distance between the mouth of Quartz Creek and Sunrise by this route is reported to be about 40 miles, which is considerably longer than the trail along the shore of Turnagain Arm.

Last spring Messrs. Kelly and Lampe crossed from the valley of a small creek which enters the north side of Portage Bay, 4 or 5 miles from its head, by way of a pass 2,800 feet high, to Twentymile River. This stream enters the extreme head of Turnagain Arm near the mouth of Quartz Creek, so that Kelly's route permits of an approach to the head of Cook Inlet from Portage Bay without crossing the glacier.

In the winter the glacial route has no objections for sleds or dog teams, since it makes a smooth highway, and its elevation is not great. In the summer it is reported to be dangerous from the opening of crevasses, but at this season there is no demand for an approach by way of Prince William Sound, because Cook Inlet is then navigable. This portage over the glacier is one of the oldest routes in Alaska, since more than a hundred years ago Captain George Vancouver reported that it had been long used by Russian and Indian traders as a means of communication between Cook Inlet and Chugatch Gulf.

FROM RESURRECTION BAY TO COOK INLET.

Halfway down the eastern shore of Kenai Peninsula is Resurrection Bay, a well-sheltered harbor, at one time the seat of a small Russian shipbuilding industry. From this bay the interior of the peninsula is easily reached by way of the valleys of Salmon Creek and Snow River. The latter empties into Lake Kenai, and is thus really the upper course of Kenai River. The pass usually crossed to reach Snow River from Resurrection Bay is about 8 miles from salt water and stands 1,200 feet above tide. The approach is very steep but not long. By following Salmon Creek toward its head and crossing the divide nearer the mouth of Snow River it is believed that a pass somewhat lower and with a considerably longer approach could be found. Such a route would be desirable if a wagon road or a railroad were to be built to the head of the lake. The route which we followed, and which appears on the accompanying map, is chosen by those who may make packing trips, because, Snow River once reached, the journey can be continued to the head of the lake by boat.

From Lake Kenai, Turnagain Arm may be reached by several ways. Perhaps the most direct, from the lower end of the lake, is that up Quartz Creek to the head of Canyon Creek, thence by way of this stream and Sixmile Creek to Sunrise. A pack trail has existed for two or three years from Mills Creek to Sunrise, and was extended during the past summer to the lake, although when the writer made the trip in early June no trail existed over this latter part of the route.

Another very low pass is reported, and I have indicated its position on the map, between Trail Creek, which enters near the east end of Lake Kenai, and Bench Creek, one of the branches of the east fork of Sixmile. From the mouth of Bench Creek one can reach the head of Turnagain Arm by way of Granite Creek and Quartz Creek (the two streams of this name must not be confused; one empties into Lake Kenai, the other into Turnagain Arm), or by following down Sixmile Creek, reach Sunrise as before.

Juneau Creek empties into Kenai River just below the outlet of the lake and by way of its valley and that of Resurrection Creek, Hope City can be reached directly from Lake Kenai, or from the latter the trip can be made by boat down to Lake Sillokh and thence to Cook Inlet at the mouth of Kenai River.

All of these routes are traveled at present by trail and boat in the summer or on snowshoes and with sleds in the winter. The pack trail could probably be extended around Lake Kenai and on to Resurrection Bay, if there were need, by doing some work along the steep part of the lake shores, and it is likely that the route by way of Bench and Trail creeks would prove feasible for a railroad. The greatest difficulty in building the latter would be encountered along Sixmile Creek above The Forks, where the stream valley is gorge-like in character, and one of the problems of maintenance would be presented by the frequent heavy snowslides there and along the abrupt shores of the lake during the spring season.

BETWEEN KNIK AND TURNAGAIN ARMS.

During the winter months communication by water between these two branches of Cook Inlet is out of the question, because of the floating ice which makes navigation so very hazardous, but there are at least two routes by land which may be used. One, much the shortest, easiest, and best known, is by way of the small stream called Indian Creek, which enters Turnagain Arm at the mouth of Bird Creek, nearly opposite Sunrise. The divide at the head of this stream is reported to be but 1,200 feet above tide and easy of approach. Knik Arm is reached some distance below the mouth of Yukla Creek, within a total distance of 25 or 30 miles from Turnagain Arm.

Another route, followed by the writer in company with Mr. Kelly this summer, is by way of Glacier and Yukla creeks, and appears on the general map of the season's routes. The divide stands at 3,750 feet above tide, and is reached only by rather difficult climbs over rubble slopes, which give uncertain footing. This route appears not to have been known before, and although starting from near the head of Turnagain Arm will probably not be much used except by prospectors who may wish to reach Raven Creek or other of the upper tributaries of the Yukla, from Sunrise. A pack trail could be constructed over it, but not without considerable outlay.

INTO THE INTERIOR.

From the head of Knik Arm the Copper River Plateau and all of the interior accessible from it is reached by way of the Matanuska Valley. For the greater part of the way from Palmer's store on Knik Arm to Tahneta Pass, at the head of the river, travel is easy. A sharp climb of 1,000 feet after crossing Chickaloon Creek, a little rough work in getting across the canyon of Hicks Creek, and a short steep climb out of the valley of Caribou, are the principal obstacles. The variation of this route affected by turning up Hicks Creek, crossing Caribou several miles from its mouth, and reaching Bubb Creek near its head, is rougher and somewhat longer to a common point on Bubb Creek than that by way of Tahneta Pass. The Tazlina River heads east of this gap, and by following it the Copper will be reached a few miles above the new town of Copper Center. This route has been followed by the Copper River Indians for many years in their annual trading trips to the stores on Cook Inlet.

From Bubb Creek the plateau can be crossed to the foothills of the

Alaskan Mountains by traveling magnetic north. East of this course the country is lower and marshy, with numerous large lakes.

Soon after crossing the Gakona River we found and followed an old Indian trail, which led us through low gaps in the foothills to the headwaters of the Delta River, down which relatively easy traveling takes one to the Tanana.

From the crossing of the Chestochina River it is believed that a pack train would have no difficulty whatever in working eastward along the low hills to Mentasta Pass or beyond to the upper Copper River. From this same point or farther south, by turning westward from our trail, the pass at the head of Cantwell River, mapped this year by Mr. Muldrow, could probably be reached without difficulty, and by traveling close to the foot of the main range it is likely that a low gap would be found without going so far west.

Both the northern and southern margins of the plateau may be traversed easily east or west by pack animals, but travel throughout the central part of the plateau region is less certain on account of the lakes and surrounding marshes.

Railway possibilities.—The route mapped from Cook Inlet to the Tanana presents no serious obstacles to the construction of a railway. The principal divides crossed, those at the head of the Matanuska and at the head of the delta, leading respectively through the coastal and the Alaskan ranges, are each only about 3,000 feet high and have long easy approaches. The canyons of the middle course of the Matanuska and of the tributaries which enter it here offer more serious engineering difficulties than the divides themselves, but the important physiographic fact that these gorges are cut in an old broad valley whose smooth floor somewhat dissected in detail is only a few hundred feet above the present stream level, and which once attained will be easily followed by the roadbed, suggests a solution for the problem of location over this part of the route.

Beyond the head of the Matanuska no obstacle worthy of note is met until after the plateau has been crossed; then, near the source of Delta River there is another sharp descent of 400 or 500 feet to the valley of this stream at the mouth of Phelan Creek, but a distance of 15 miles is available for overcoming this grade, and once the immediate valley of the Delta is attained there is abundant broad bottom land for a railway line clear to the Tanana. The total distance from the head of Knik Arm to the mouth of the Delta by our route, including all the windings of the trail, is about 350 miles. By taking a more direct course a railway would shorten this considerably. Altogether the route is believed to be a very favorable one, and if the shorter way from Port Valdes should prove to be impossible, because of the mountain barrier at the coast, the attention of engineers should be directed to this route. In order to connect the terminus at Knik with an open harbor (the head of Cook Inlet being closed during the winter by ice), the road would have to cross the Sushitna River from Knik and run down the west shore of the inlet to open water.

Availability as a pack trail or wagon route.—Under present conditions of development the route seems too long for permanent use by pack trains or wagons as a means of forwarding supplies to the gold belt between the Yukon and the Tanana. It will always be much cheaper to ship by the Upper or Lower Yukon. Should paying mining districts, however, ever be developed south of the Tanana, they would probably be best reached from salt water by way of Cook Inlet and the Matanuska or Sushitna rivers.

Food animals may be driven into the interior by this route between June 1 and September 15, since abundant nutritive grasses are distributed all along it. The best varieties are found in greatest abundance at the lower altitudes, as in the Matanuska and Delta River valleys, but they are found in sufficient quantity about the margins of the lakes which cover the plateau to support considerable droves of stock cattle during the brief summer season.

GEOLOGY.

SUNRISE SERIES.

About the mining district of Turnagain Arm and vicinity, of which Sunrise City is the center, is distributed a series of metamorphic gold-bearing rocks to which the name of Sunrise series has been given.

CHARACTER.

These rocks, wherever examined, consist of interbedded, fine blue-black slates and dark-gray arkoses, all having been subjected to varying degrees of alteration.

The best opportunity for examining them was afforded by the long wait during May about the head of Portage Bay. Here, although cleavage was well developed in the slates, bedding was usually plainly distinguishable and fairly regular in strike and dip. The strike is here approximately parallel with the shore of the bay, that is, about N. 10° E., while the dip varies from 60° to 80°.

The slates are generally clean and fine in grain with here and there more sandy layers, approaching the arkoses in coarseness. The latter are fine-grained detrital rocks made up chiefly of fragments of quartz and feldspar crystals, with some bits of shale and a little clayey matrix. The feldspars are more usually orthoclase and acid plagioclase, generally angular, but sometimes slightly rounded. They are all remarkable for their freshness, and indicate a very complete and rapid breaking up without weathering of the igneous rocks from which they were derived.

The coarser beds often contain angular fragments and sometimes well-rounded pebbles of the slates, indicating rapid but brief interruptions in the sedimentation which produced them. Along the rock walls in the northern shore of Portage Bay the slates and arkoses alternate in belts of varying thickness, approximately parallel to the shore line. The slates are much less able to resist the denuding agents than the arkoses, and, weathering away more rapidly, produce benches along the mountain side which closely resemble old sea cliffs (Pl. XVI, *B*).

The dynamical stresses to which these rocks have been subjected have not been so great but that nearly all the movement could be taken up by the softer members of the series, producing the cleavage of the slates. The arkoses have well-developed joints and contain numbers of quartz veins and stringers, but otherwise exhibit little evidence of crushing. The veins occur almost exclusively in the harder rocks, where they usually fill clear-cut fissures several inches wide, but feather out within less than a foot after passing the boundary into the slates. Only one generation of veins was observed certainly. They filled two sets of fissures at approximately right angles and cut one another indifferently. Generally they are solid and free from sulphides, pyrite alone being observed on Portage Bay, with some small quantities of fluorite, but across the isthmus, on a claim recently staked on Sawmill Creek, near the head of Turnagain Arm, sphalerite and galena also appeared, and perhaps more complete exploitation of the veins would reveal a greater variety.

Later than the general metamorphism and probably synchronously with the filling of the veins the slates and arkoses were intruded by a series of dikes, chiefly aplitic in character, but in a few instances at least much more basic.

DISTRIBUTION.

All about the western waters of Prince William Sound, wherever the shores were examined, rocks of this group were found to outcrop, and they were the only hard rocks seen on the journey across Kenai Peninsula from Resurrection Bay to Turnagain Arm. They appear again on the mainland between the latter branch of Cook Inlet and Knik Arm, but are not to be found in the Matanuska Valley. It is probable, then, that they make up the entire group of the Kenai Mountains, which occupy two-thirds of the peninsula, and apparently are to be found in the extension of these mountains in the Kadiak group of islands to the southwest, where, in Uyak Bay, Dr. Becker[1] describes the country rock as a carbonaceous slate interbedded with sandstone somewhat fractured and fissured.

To the northeast we do not know their limits. They extend at least

[1] Reconnaissance of the gold fields of southern Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, part 3, pp. 81-82.

as far as the head of Port Wells, where they were examined in outcrop, and probably swing east with the Chugatch Mountains around the head of Prince William Sound, forming, perhaps, a continuous belt with the similar and possibly equivalent sediments which Mr. Schrader describes in another part of this volume as the Valdes series.

The northern and northwestern slopes of the Chugatch Mountains, as studied in the Matanuska Valley, are made up of a distinct class of rocks, and the contact between the two series must occur somewhere within the range.

AGE.

No fossils have been found anywhere within the Sunrise series. Mr. Schrader collected some doubtful plant remains from the Valdes series, and these have been assigned tentatively to the Cretaceous, but the very much less metamorphism and generally younger aspect of the Matanuska rocks, presently to be described, which probably overlap from the northwest upon the Sunrise series and which are in part, at least, Lower Cretaceous, indicate a pre-Cretaceous age for these rocks, which are, therefore, assigned, pending the finding of further evidence, to the Upper Paleozoic.

MATANUSKA SERIES.

After leaving Knik Arm for the trip to the interior by way of the valley of the Matanuska River, no hard rocks are found in place until the trail descends into the valley of Tsadaka Creek, 40 miles from Palmer's store. For 40 or 50 feet above the bed of this creek, and underlying the loose gravels which fill all this part of the valley of the Matanuska, is to be seen an exposure of shales and sandstones with a few thin streaks of bright, hard coal. The beds remind one strongly in lithologic characteristics of the sediments of the lower coal measures in the Appalachian region. They are completely consolidated, although here not altered in the least, and have been disturbed so as to dip now about 25° NW. Across the Matanuska similar beds make the bluffs of the stream.

Opposite the mouth of Granite Creek the same beds are exposed, showing a fault of probably slight throw (Pl. XVIII, *A*), and from this time until the Copper River Plateau is reached all rock exposures are of related sediments and intrusive beds.

With the data gathered on this reconnaissance it has not been found possible to subdivide them, so that they are all treated here as the Matanuska series.

CHARACTER.

The great mass of these beds are shales, similar physically to those first seen at Tsadaka Creek, and displaying many colors, red, green, buff, and black being especially abundant. Besides shales, many coarser beds occur. Much the most important of these is the heavy conglomerate which makes the base of Castle Mountain (Pl. XVIII, *B*) and gives it its pinnacled and castellated outlines, so strikingly different from any of the neighboring hills and at once suggesting its name. This bed is probably not less than 1,000 feet thick, 600 feet of it having been measured, and the estimated height of the cliff above me at the time of the measurement being 300 to 400 feet. The heavy conglomerate plates, which together make up the mountain, are separated by thin sandy shale sheets, which constitute but an insignificant quantity of the mass. The pebbles of the conglomerate contain a great variety of rocks, among them many igneous types. They are well rounded and vary in size up to a foot in diameter. Overlying the Castle Mountain bed is a body of soft green shales with a cap of red sandstone. To the southwest this conglomerate is cut off by a great intrusive mass of porphyry, and northeastward it is probably dropped down by a fault of slight throw.

Other conglomerates occur on Hicks Creek and the headwaters of Caribou. These, however, are wholly different in character from the Castle Mountain bed, consisting generally of small, well-rounded pebbles of white quartz with but little extraneous material. The irregular occurrence of the Caribou Creek deposits appears to be best explained by the supposition that they were laid down in local channels cut in shales rather than in sheets. On Bubb Creek, a few miles below our camp of August 7 and 8, conglomerate cliffs about 200 feet high extend for half a mile along the stream, and represent either a broad channel or a slight anticline in the strata.

Limestone nodules occur at a number of places in the shale, but only one bed of any extent appears along our route. It was first seen as a gray cliff forming a scarp around the hilltops just before Limestone Gap was reached. Dips bring it lower as the gap is approached, and the trail passed over it, but it rises again and disappears from the hills along the upper course of Bubb Creek within a few miles of its source. The thickness is about 300 feet.

STRUCTURE.

The Matanuska River flows nearly along the strike of the series, although both strike and dip exhibit great local variations. The former is generally about N. 60° or 70° E. and the latter is to the northwest at various angles, which increase toward the Chugatch Mountains and often become zero in the upper courses of Caribou and Bubb creeks. A shallow syncline, pitching to the north and crossing Bubb creek near its head, brings the limestone just described down to the hilltops. Twenty-five miles farther down the same stream what appears to be a distinct anticlinal axis with a north-and-south trend crosses its course.

The beds are everywhere full of small faults, as though folded under slight load. One opposite the mouth of Granite Creek and another east of Castle Mountain have already been mentioned. With the larger fault at Granite Creek are innumerable smaller ones with a throw of a few inches only. Some of these tend to compensate for and others to accentuate the displacements of the greater fracture. Near the headwaters of Billy Creek a fault of 300 or 400 feet throw is displayed diagrammatically on the mountain slope. The south side is dropped here, and the fault, like the rest of those studied, is a normal one.

As a whole the faults seem to represent but slight dislocations and are believed to be but incidents in the general conditions expressed by the dips and the land relief; that is, a locus of maximum uplift somewhere within the Chugatch Mountains, where the upward movement and the accompanying folding were greatest and from which they lessen as the distance from this center increases.

AGE.

A few fossils were collected at the base of the limestone bed at the head of Bubb Creek and submitted to Mr. T. W. Stanton for examination. He says:

> The fossils * * * have been examined and found to consist of numerous examples of *Aucella crassicollis* Keyserling and a few fragments of a *Belemnites* which can not be identified specifically. The species determined is sufficient to fix the age of the bed from which they came as lower Cretaceous.

On the basis of this determination the whole series is tentatively assigned to lower Cretaceous, or an older period, since the limestone bed appears to occur near the top of the series. Fragmentary fossil leaves of well-developed exogenous types were collected at a number of places, but, being impressions on a very fragile matrix, were crushed in the attempt to transport them to the coast by pack trains.

IGNEOUS PHENOMENA.

Diorite.—The rocks of the Matanuska Valley have been extensively affected by intrusives of considerable variety which extend through certain broad time limits. These rocks seem to be much more numerous along the main valley than farther northward; that is, where folding has been sharpest intrusives have been found in greatest abundance. The first mass detected in the summer's reconnaissance forms a part of the north wall of the valley just below Kings Creek. Although its limits are not known except on the valley side, it is presumably of considerable extent, since the mountain from which this specimen was collected appears to be homogeneous and continuous for several miles northeast and southwest from Kings Creek crossing. The rock is a light-gray fine-grained porphyritic mass, which appears under the microscope to be a quartz-diorite-porphyry carrying a light-green hornblende. Microscopically it exhibits no evidence of mechanical deformation. There was no opportunity to search for a contact, but the porphyry is considered to be later than the surrounding sediments and intrusive in them, because these latter do not exhibit either the structure or the lithologic characteristics which we would expect had the porphyry served as a base upon which the sediments were deposited. The shales and sandstones just above the crossing of Kings Creek dip away from the porphyry mountain, but the heavy conglomerate just across Kings Creek strikes directly toward it and has a gentle dip northwest. The pebbles composing it are of great variety, but none of those examined were derived from the porphyry.

Diabase.—At two points on the south side of Chickaloon Creek and at frequent intervals in the region between Chickaloon and Hicks creeks, as well as in the valley of the latter, normal diabase dikes occur abundantly, with a limited number which are olivine-bearing. They vary in width from a few inches to 400 feet, and cut the sediments in all directions. The most prominent of these dikes strikes across the valley at the head of Chickaloon Creek, making a prominent ridge nearly 1,000 feet above the old valley floor. In weathering, this dike exhibits the usual strong tendency to produce the spherical forms characteristic of basic rocks. One narrow dike was found north of Caribou Creek. It stands out like a low wall from the flat just east of Limestone Gap. This was the only intrusive observed on the Upper Caribou or Bubb Creek drainage. Opposite the southern margin of Matanuska Glacier occurs an intrusion 30 or 40 feet broad, which is the only one of this series exhibiting in any marked degree the effects of mechanical deformation. It has been fissured and the fissures filled with vein quartz. Quartz also appears microscopically with calcite as a secondary mineral.

Granitic intrusives.—From the mouth of Caribou Creek northeastward the intrusives examined are all mineralogically granitic. Glacier Point itself is a resistant mass of fine-grained granite-porphyry, with areas of micropegmatite in the groundmass and a general granophyric tendency.

Three miles above Glacier Point a fine aplite dike, with a cryptocrystalline groundmass and orthoclase phenocrysts, cuts the shales of the valley floor and is well exposed in a little ravine crossed by the trail.

A mile above this point an augite-granite occurs as part of the north side of the valley, and is probably continued across the river in a conspicuous knob which protrudes from the southern valley wall.

Pyroclastics.—The sediments of the series are usually clear fine muds, well-washed sands, or well-rounded conglomerates, but a few cases were noted where they were immediately derived from volcanic sources. Capping the hills east of the middle course of Hicks Creek is a bed of volcanic tuff, the fragments but loosely cemented, and often fresh enough for identification. The effusive rocks represented in this bed were not encountered anywhere within the area studied. Near the head of the Matanuska, arkoses containing much fresh and angular feldspathic material make up a considerable proportion of the sediments.

Alteration.—The phenomena of contact metamorphism are to be observed in the sediments everywhere in proximity to intrusive masses. Elsewhere there is but little evidence of alteration. I myself saw no veining except that mentioned in the dikes, but Mr. Hicks collected samples of quartz from a vein a few feet broad along the Lower Chickaloon. This is probably genetically associated with the diabase dikes which occur abundantly there.

Period of intrusion.—The time at which the dikes appeared can only be approximated. They are, of course, later than the sediments which they cut; that is, later than the Lower Cretaceous. They are also older than the oldest erosional feature—the fossil valley of the Matanuska—in the production of which they have been reduced. This upper valley is probably late Tertiary or Pleistocene, so that by this line of investigation we can only limit them between such widely divergent dates as the beginning of the Cretaceous and the end of the Tertiary. But it seems reasonable to assume that they are synchronous with the movement which faulted, fractured, and weakened the rocks which they penetrate, a movement resulting in the earlier uplift of the St. Elias and Chugatch ranges. The latest uplift, which gives this range its present altitude, is post-Tertiary, as determined by Professor Russell,[1] and supported by the altitude of Pleistocene gravels in the Cook Inlet region. But this movement added not more than 3,000 feet to the elevation of the part of the range under discussion and probably produced no close folding or faulting, but only a broad warping. It elevated the Oligocene sediments, which Dr. Dall describes, about Kachemak Bay, and revealed the fact that, although lying off the flank of the Kenai Mountains, they are not folded, except locally. Hence the more violent movement was probably earlier than the Oligocene, perhaps in early Tertiary. It seems likely that the intrusives appeared at this time.

GREENSTONE SERIES.

Leaving the northern base of the coastal ranges of the Chugatch and Talkeetna mountains at Bubb Creek, no hard rocks are to be seen until Copper River Plateau is passed and the foothills of the Alaskan Mountains are entered beyond Gakona River.

Within the area drained by the Chestochina and the northern tributaries of the Gakona a rather complex series of related basic rocks, whose details of occurrence and structure are as yet rather obscure, outcrop and will be briefly treated under the above general name.

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[1] An expedition to Mount St. Elias, Nat. Geog. Mag., Vol. III, p. 175.

The exposures near the camp of August 18 and 20 are of a green sheared rock, originally granular in texture, and consisting essentially of augite and plagioclase, a schistose gabbro. By the shearing the original augite grains have been crushed and the fragments dragged out into long trains. At the same time, or perhaps earlier, considerable proportions of the augite have been altered to uralite. The feldspar crystals have suffered less than the dark silicates in the mechanical deformation, but are broken up into small fragments which have been moved considerably from their original positions so that they no longer have the same orientation. With the crushing, fissures, varying from microscopic dimensions to a foot or more in width, have been opened and filled with quartz, which, however, does not seem to have penetrated the rock mass except along these cracks.

Just north of the camp of September 6 and 7 is a greenstone of much finer grain, lighter color, and of more doubtful origin. Alteration has obscured the original structure, but the clouded and uncertain feldspars appear to have an ophitic arrangement, suggesting that the rock was originally a fine-grained diabase. Considerable epidote is present in this specimen.

The hills at the base of which we camped on the night of August 20, when viewed from a distance, presented terraced outlines very suggestive of flows, but the rock examined at the base of the hill, the only point where there was time for an examination, proved to be a very coarse diabase of the usual type. Whether this was a large dike which served as a vent for the lava which gave the mountains their peculiar form, or whether the terracing should be explained in some other way, could not be determined. Later a view from near the center of Copper River Plateau disclosed the fact that this terracing is not local, but is a marked feature of the foothills for at least 40 or 50 miles to the west of the gap by which we crossed them.

Across the valley of the Chestochina, at the foot of the slope beyond Tangle Lakes, a heavy intrusive mass of quartz-augite-diorite occurs. It is closely related mineralogically to the gabbros and diabases just described, differing from them mainly in the original free quartz and pegmatitic intergrowths of quartz and feldspar which it contains.

The first rock encountered after leaving Gakona River is not a member of the greenstone series with which it is associated, but is probably a late intrusive in it. It is a coarse-grained biotite-granite, well shown in outcrop at the camp of August 17 and 18, and probably making the rounded hill to the south of this camp. Its most striking feature is the number of large biotite phenocrysts, frequently an inch in diameter, which it carries. The entire absence of evidence of mechanical deformation, which is so marked in the greenstone immediately to the north, indicates that the granite is much later and intrusive. This intrusion may be in part responsible for the alteration in the more basic rocks.

AGE.

No estimate of any value can be formed as to the age of these rocks beyond the fact that they antedate the formation of the valleys and broad gaps in the hills which they make. If these broad gaps be correlated, as seems reasonable, with the Yukon Plateau, which is early or middle Tertiary, the greenstone may be regarded as pre-Tertiary. The intruded granite is, of course, later, but antedates the latest glacial activity, which is probably recent Pleistocene.

ACID EFFUSIVES AND ASSOCIATED ROCKS.

The line of foothills to the north of the Tangle Lakes exhibit much variety in rocks. At the base of the climb to the gap by which we crossed them is the diorite described among the greenstones. Outcropping near it is an exposure of fine-grained siliceous rock, apparently bedded, but altered, by the intrusives which occur near it, into a compact hornstone. It was the only sediment closely examined anywhere in the region, but across Delta River, toward Landmark Gap, the rocks appeared to be stratified.

The hills to the north and south of the gap through which the trail passes are capped by a porphyritic rhyolite which overlies the diorite and hornstone and continues as far as hard rocks are exposed toward the camp of September 2–3, and is found again on the long point between Delta River and its tributary, Phelan Creek. Just north of the junction of these streams the rhyolites assume a more glassy phase than is exhibited in the outcrops farther south. Near the camp of September 2–3 is a badly altered exposure representing, apparently, a more coarsely textured phase of the rhyolites, approaching in grain the granites. Tuffs derived from these acid effusives outcrop to the north of Phelan Creek.

TANANA SCHISTS.

From a point a short distance from the upper margin of Canwell Glacier the rocks within Delta River Valley all belong to a series of quartz-sericite-schists, with acid and basic intrusives. These are believed to be an extension of the terrain which outcrops along the Tanana River, and is described there by Mr. Brooks as the Tanana schists. The rocks, as their name indicates, consist essentially of quartz and sericite from which all original structure has entirely disappeared, and the usual exposure gives no hint of the character of the rocks from which they were derived, but at several points along the river bank between the camps of August 23–24 and August 25–26, infolded with schists of the usual type, are graphitic beds, which indicate that the whole series of which they are a part is probably sedimentary in origin.

The schistose planes generally strike about east and west across the valley and parallel to the Alaskan Range. They stand at all angles to the plane of the horizon, exhibiting dips of from 0 to 90°, and seem to have been faulted as well as highly folded since the schistosity was induced.

At least two systems of quartz veins following two periods of fissuring may be discovered. The earliest of these partakes of at least a part of the general schistosity, and lies in blebs and knots generally parallel to it in their long axes, but noncontinuous or connected only by ribbons. Nearly at right angles to it is another system unaffected by crushing, but exhibiting occasionally slight displacement due to faulting. These veins are usually not more than a finger's breadth in thickness, but the quartz is comparatively open and well mineralized; the principal sulphides present are pyrite, chalcopyrite, and mispickle. The first of these, not infrequently, is found in cubes an inch in diameter.

DIKES.

The schists have been intruded at various periods, and the intrusives are in some cases so altered as to be indeterminable, but among the older dikes, as in the more recent ones, both acid and basic rocks are represented.

A metadiabase cuts the schists about a mile above the camp of September 1–2. The dike itself is but slightly schistose, and contains numbers of quartz veins, all belonging to the second system just described. Therefore it was intruded after the major schistosity was produced and the first vein system formed, but before the production of the secondary vein system. This intrusive is but 75 or 100 feet in thickness and dips now at an angle of 10° or 12° E. Its attitude is probably the consequence of later folding. It has followed the schistose planes in its intrusion and along its upper contact, instead of an abrupt boundary, a number of sheets diminishing in thickness as the distance from the main mass increases, are to be observed, alternating with thin beds of the schists. Parallel with and adjacent to the quartz veins within this dike are extensive zones of alteration.

Opposite Castner Glacier and standing out as a low knob in the middle of the valley is a mass of fresh biotite-granite, which has suffered from none of the metamorphism of the surrounding schists. Its intrusion, therefore, is to be regarded as one of the latest phenomena. The rock itself is of medium grain and contains, besides the quartz, orthoclase, and biotite, some albite and perthite, and, in more basic secretions, which occur here and there in it, a little hornblende. Several older and much less extensive dikes were observed, chiefly near the southern limit of the schist area.

DISTRIBUTION.

These beds outcrop in Delta River Valley below Canwell Glacier, wherever the rock walls of the valley were examined. The morainal material, brought down by Canwell and Castner glaciers, is made up wholly of débris derived from them and the quartz veins which are so abundant in them. Much of the morainal material brought in by the glaciers to the west of Delta River is schistose, but it contains also a large proportion of granitic bowlders. The schists make Marr Butte, which rises from the gravels in the lower open valley of the delta and is the most northerly bedrock exposure examined. From these relations it seems certain that the northern slope, and probably the axis of this part of the Alaskan Range, at least, is composed of the Tanana schists.

AGE.

The schists, judging from their general aspect and extensive metamorphism, are the oldest rocks encountered during the summer, but from the evidence collected along Delta River could not be definitely placed in the stratigraphic column, since no relations were discoverable there with terranes of known age. Mr. Brooks's opportunities for more extensive study, however, gave him evidence for calling them pre-Silurian, and that classification is accepted here.

THE GRAVELS.

By far the most extensive deposit observed during the summer was the one which is geologically the most recent—the gravel sheet. It appeared not to be represented about the western waters of Prince William Sound, but in crossing Kenai Peninsula it became prominent as soon as the axis of the Kenai Mountains was passed, since it stands 500 feet above Lake Kenai at its outlet in a series of more or less well-marked benches. The divide between Quartz Creek and Canyon Creek is buried under these unconsolidated sediments, probably to a depth of 200 feet or more, and about the mouth of Mills Creek terraces are conspicuous.

The shores of all the upper end of Cook Inlet, with the exception of Turnagain Arm and limited outcrops of Kenai or Neocene sediments along the west side below Tyonek, are gravel bluffs of varying heights. The old floor of the Matanuska Valley as far as Chickaloon Creek is buried under these same loose beds, which extend from 50 to 300 feet above the river level and reach elevations of 1,200 or 1,300 feet above tide. The Middle Matanuska Valley, between Chickaloon and Caribou creeks, is generally free from them, only an occasional moraine or a very thin film of sand and pebbles covering this relatively high portion of the old abandoned floor.

In Tahneta Pass the gravels are encountered again and cover all that part of the Copper River plateau traversed. Here they exhibit but faint, although irregular relief. Somewhat farther east, where the Copper River has cut into them, exposing their true character, Messrs. Hayes and Schrader report that the deposits consist for the most part of fine silts, probably lake beds. This phase did not appear along our route, where drainage is young, exposures are poor, and the surface deposit, at least, is of gravel.

The valleys within the foothills of the Upper Chestochina, and between these and the Alaskan Mountains, are again buried beneath sands and gravels rudely stratified and of varying degrees of coarseness. These, again, have been terraced in the recent drainage development. Beyond the Alaskan Mountains to the north, the Lower Delta River and adjacent portions of the Tanana Valley are filled with similar sediments which are there without question largely morainal.

The beds whose general extent is thus roughly outlined have a history which varies much in different areas, but is all a part of the most recent geologic record. Their interpretation belongs to the physiographic and glacial problems, and their further discussion is deferred until these questions are taken up.

For the sake of clearness the following table of provisional correlations is here introduced, after a careful comparison of notes with the geologists who have worked in the areas indicated. The classifications are necessarily general, but indicate the conclusions arrived at from a study of the evidence available. Further evidence will doubtless lead to changes in some cases; in others, the evidence already gathered is of sufficient weight to definitely settle the position of a formation in the stratigraphic column.

Table of provisional correlation.

PERIOD.	Spurr, Yukon district, 1896.	Brooks, White River, and Tanana district, 1898.	Mendenhall, Resurrection Bay, to the Tanana River, 1898.	Spurr, Southwestern Alaska, 1898.	Eldridge, Sushitna Valley, Alaskan Range, and Cantwell River, 1898.	Schrader. Copper River district, 1898.
Pleistocene..........	Silts and gravels........	Silts and gravels......	Sands and gravels......	Silts, sands, and gravels.	Sands, gravels, and bowlder clays.	Silts and gravels.
Neocene.............	Twelvemile beds, Porcupine beds, Nulato sandstone, Palisade conglomerate.	Tok sandstone.		Tyonek beds, Hayes River beds, Nushagak beds.		
Eocene or Oligocene.	Kenai series.			Yentna beds...........	Kenai series...........	Valdes series (?).
Cretaceous...........	Mission Creek series.		Matanuska series.......	Tordrillo series, Holiknuk series, Kolmakof series, Oklune series.	Cantwell conglomerate (?).	Valdes series (?).
Jurassic..............				Katmai series, Skwentna series, Terra Cotta series.		
Devonian and Carboniferous.	Tahkandit series.......	Wellesley series, Nilkoko beds.	Sunrise series (?)	Tachatna series.........	Cantwell conglomerate (?).	Valdes series (?).
Silurian	Rampart series.........	Greenstone schists (?).	Greenstones.			Copper Mountain series.?
Pre-Silurian sediments.	Birch Creek series, Fortymile series.	Tanana schists, Nasina series.	Tanana schists.		Sushitna schists........	Klutena series.
Archean.............	Basal granite...........	Gneissic series.			Basal granite and gneissic series.	

ECONOMIC GEOLOGY.

GOLD.

SUNRISE DISTRICT.

Development.—Since 1896, when the first considerable influx of miners reached the Cook Inlet region in response to the strike made on Sixmile Creek during the previous year, it has been fairly well known as a mining center, and has attracted a modest share of the Alaskan immigration each season.

Previous to 1896 gold had been mined for two or three years on Bear Creek, a tributary of Resurrection Creek,[1] and colors were found in all the streams thereabout, but the district was not well known and had been prospected but little.

Since 1896 more systematic work has been done by the few among the usual throng of prospectors who have any idea of such work, and most of the streams which enter Turnagain Arm have been examined more or less thoroughly to their sources. As a result the productive parts of the district have been extended from Bear Creek to include other tributaries of Resurrection Creek, most of Sixmile and its branches, and, on the north side of the arm, Bird Creek and Glacier Creek.

Work has as yet not been generally carried across the divide north of Turnagain Arm, although one or two claims were staked on Knik drainage in 1898, because the region in this direction is difficult of access and prospectors are usually without pack animals.

Within the peninsula, south of Turnagain Arm, some prospecting has been done along Kenai lake and river, and during 1898 one or two expensive attempts were made to develop hydraulic properties here.

Hope City, at the mouth of Resurrection Creek, was at first the leading camp of the district, but with the more rapid development of the Sixmile diggings Sunrise City, at the mouth of this stream, became the larger town and is now the center of distribution for the region.

So far only placer work has been done, and this has been confined to the short summer season of about three months, when the year's wages must be made, so that here, as in other parts of Alaska, the operator must work in very much richer ground than would be necessary in the States in order to make mining pay.

Occurrence.—Mills Creek, Canyon Creek, and probably the other branches of Sixmile Creek have their sources in the gravel sheet which buries the broad divides in this part of the peninsula. These gravels are coarse or fine, rudely stratified, and are here always of local deriva-

[1] George F. Becker, Reconnaissance of the gold fields of southern Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 81.

tion; that is, practically the only rocks in them are fragments of the slates, arkoses, and associated quartz veins and acid dikes which constitute the Sunrise series. They were probably distributed as aprons along the front of the valley glaciers as they retreated after the last advance, and appear to have been deposited near sea level. But the ice streams at that time occupied about the same basins as are now drained by the creeks and their tributaries, so that, except for their great extent, these fluvioglacial gravels do not differ from those of exclusively fluvial origin. It is not likely that the gold was well concentrated in the gravels when they were first deposited, because of the rapidity of their deposition and the probability that ice was the chief carrier. This inference is borne out by the fact that fairly heavy colors can be panned from the gravels in the undisturbed terraces at almost any point. But with the birth of the present streams and the elevation of the land to or nearly to its present position concentration began. The creeks cutting down through the gold-bearing gravels acted exactly like sluices on a large scale, and where the cutting has reached bed rock the gold content of all the removed gravels is found. This makes the rich ground which has yielded the best returns in the district—as, for instance, on the property of the Polly Mining Company along the lower course of Mills Creek.

It thus becomes evident that the situations which promise good returns are exceptional, for, granted the always essential primary condition that the stream whose glacial ancestor deposited the gravels must flow through an auriferous belt, if the modern stream is still working in gravels and in its cutting has not approached sufficiently near to bed rock to enable the operator to reach it at reasonable cost, property will not prove profitable when handled by ordinary methods, although the gravels may be as rich as those which furnish the natural concentrates of Mills Creek. Or, if the stream has long since cut through the gravels and is working in bed rock, as along the gorge of Canyon Creek, the concentrates will frequently have been removed from the bed of the rapidly cutting stream, leaving it nearly barren. The Mills Creek property, which is the richest developed as yet in the district, is thus fortunately situated, since this particular part of the Sixmile drainage system has just cut through the gravels, but has not as yet penetrated the bed rock to any considerable depth.

The greater part of Canyon Creek, above the mouth of Mills, is still in gravel, and consequently is not of value. Below Mills Creek the gorge which has given Canyon Creek its name begins. It is a sharp, new box canyon, and continues with increasing depth to its junction with the East Fork of Sixmile at the Forks. Here the concentrates, which probably had collected on the bed rock at an earlier stage in the stream's development, have been largely swept away, and the steep grade and swift current permit of the formation of only occasional and rather meager bars, where the probably constant supply of gold from the upper reaches of the creek is caught. Consequently Canyon Creek is "spotted." Of two adjoining claims, one may carry one of these bars of coarse auriferous gravel and be a paying property while its neighbor is quite barren.

The water here, too, is considerable in volume and is so closely confined by the narrow canyon walls as to be difficult to control. The method usually employed is to build a "wing dam," inclosing and protecting from the current one-half of the stream bed, whose gravels are then sluiced. The current is then shifted to this half of the channel and the gravels of the other half washed. These dams are not infrequently destroyed by high water, and a season's labor is thus lost. Below The Forks the diggings along Sixmile Creek are rendered uncertain by the uneven depth of the bed rock and the difficulty sometimes encountered in reaching it.

Although at present the best-paying properties within the district are in streams which derive their gravels from the general gravel sheet, others are supplied in the usual way—directly from the rocks forming the stream bed and valley walls. Among the streams in this latter class may be mentioned Bear Creek and Glacier Creek. The chief difference between the two types of streams is to be found in the fact that those which are cutting through the old gravels generally derive their gold from a somewhat greater area than those which act directly upon bed rock. In both cases the gravels are of local origin.

During the summers of 1897 and 1898 some work was done on the tributaries of Kenai River and the streams which flow into the lower end of Lake Kenai. Cooper Creek and its western branch, Stetson Creek, were reported to contain the richest diggings in this part of the peninsula, and contain perhaps the only ground there carrying gold enough to pay for sluicing. Fairly good indications are reported, also, from some of the eastern tributaries of Lake Kenai.

Prospectors say that no colors have been found in the Resurrection Bay drainage basin, although the same rocks which are gold-bearing farther north outcrop over a part and probably over the whole of its area.

Bird Creek, which enters Turnagain Arm opposite the mouth of Sixmile Creek, has attracted considerable attention for a year or two past, and is believed by those familiar with the district to hold some paying claims, although upon development many have proved disappointing to their owners.

Crow Creek, a tributary of Glacier, promises well and is now being developed by the claim owners. Preliminary work has shown rather coarse gold, a $50 nugget from this stream having been brought into Sunrise during July.

Hydraulic work.—In the spring of 1898 the Alaskan Hydraulic

Syndicate brought a hydraulic outfit to the gravel banks about the lower end of Kenai Lake, where prospects appeared favorable. By autumn the managers had satisfied themselves that the gravel, of which there was an unlimited amount in sight, was not rich enough for profitable manipulation, and withdrew. Their property occupied the north bank of Kenai River about the mouth of Juneau Creek, which enters the river but a short distance below the lake. Some gravel banks along Sixmile and Canyon creeks show good indications, and it is to be hoped that they will be developed in the near future. They belong to the older, the fluvioglacial series of gravels, which have been sluiced by Mills Creek and Canyon Creek.

An attempt was made during the past summer to develop the gravels along the beach on the west shore of Cook Inlet between Tyonek and Ladds Station, but the experiment ended in commercial disaster.

Quartz.—Some quartz properties have been staked in the district, but have not been developed. Near the mouth of Sawmill Creek, which flows into the south side of the Arm, a few miles above Sunrise, a ledge of doubtful extent is reported. On Bird Creek, a property for whose richness most extravagant claims were made, was located by one of the local prospectors. A sample, given to the writer, proved to be a fragment of one of the aplite dikes so numerous in the Sunrise series. It assayed about $7.50 per ton, mostly in gold.

Summary.—On the whole, it may be said that few of the claims about Turnagain Arm are profitable. The shortness of the season for work here, as in other parts of Alaska, is an element in bringing about this result. Less than $5 per day to the man during the working season of about three months will scarcely pay the prospectors' expenses during the long idle period. The Mills Creek property has paid in its richest parts as high as $120 per day to the man for short periods, but this is a maximum very rarely reached. The series of 5 claims included in this property yield a revenue of about $25,000 a year and are regarded as the best properties within the district. Many placers which are worked pay less than $3 per day and are disposed of by the owners as quickly as possible. The only mining so far done is placer work. The outlook for paying quartz is not good, but conditions seem favorable for profitable hydraulic work in a few localities.

THE MATANUSKA FIELD.

The rocks of the Matanuska series carry gold in unknown but probably small quantities. Mr. Hicks reports it fairly coarse on Caribou Creek near its mouth, and a few claims have been staked higher up on this stream. The Marshall and Monroe parties report fine gold on Marshall Creek, a small stream just below Chickaloon, but this stream flows throughout its course in the gravels of the general gravel sheet from which the gold may be derived, and these gravels here differ from those within the Sunrise district in that they are not of local origin, but are frequently brought from very distant sources, some of the pebbles probably not occurring in place nearer than the Alaskan Mountains. Chickaloon Creek below the mouth of Schoonoven yields colors, but its upper course is barren. In Schoonoven Creek itself the best prospects are found, and these all in and below the canyon. No traces of gold were found in the flats above. Within the canyon the stream flows through a portion of the Matanuska sediments most affected by the diabase intrusions, and these probably have a genetic relation to the gold content. All along the Matanuska itself fine colors are found, but these are not significant, since the stream rises in the gravels of the Copper River Plateau. A quartz vein is reported on the lower Chickaloon which assays $7 or $8, but it was not seen by the writer.

Some local excitement was created during the latter part of the summer of 1898 by the reported discovery, by the Andrews party, of rich placer ground on a stream draining into the Sushitna, 30 or 35 miles northwest of Mellishes's cabin. A trail leads from the latter point over to the new property, and several parties were preparing during the autumn to sled supplies across as soon as the snow should fall. The gold is reported to be rough, full of quartz, and evidently very near its source.

Northward from the base of the Chugatch and Talkeetna mountains our rate of travel made determinative prospecting impossible, but the indications, so far as I was able to interpret them, were unfavorable.

Across the flat wastes of the Copper River Plateau, built up by an unknown depth of gravels and silts, there is of course no possibility of finding paying quantities of gold. Hurried and superficial panning in the tributaries of the upper Chestochina where the latter stream drains the greenstone foothills gave no colors. The rhyolite knobs of the second range of foothills, north of the Tangle Lakes, are unpromising, although if, as is possible, these same hills farther west are made up of intruded sediments they may be worthy of investigation.

The schists of the Tanana series are full of quartz veins and the quartz is well mineralized, but two samples taken from the most promising outcrops proved, when assayed, to contain no gold. Careful panning over bed rock at two or three localities on tributaries which flow entirely in the schist gave the same result, although the pan caught an abundance of sulphides. The evidence then gathered by our party is unfavorable, but is so scant as to be inconclusive.

The Delta River Valley is off the usual prospector's route and is difficult of access, so that it is unlikely that it has ever been systematically prospected. Lieutenant Castner reports that at least one party of white men had been along the lower river ahead of him, but we have no reports from them.

IN THE GRAVEL SHEET.

The Matanuska, the Copper, the Sushitna, the Tanana, and all the larger rivers of Alaska yield colors of fine gold wherever their sands or gravels are carefully panned. Even the beach bluffs about the head of Cook Inlet, and probably anywhere along tide water where they occur, yield light gold.

These colors are derived from the widespread gravel beds which have been described, and which probably represent very extensive beach or delta deposits. The pebbles of this gravel generally, like that mentioned in the valley of the Matanuska, are derived from widely separate sources, those within Kenai Peninsula being an exception. Probably at several places from which these pebbles came gold occurs, and it has been comminuted and very thoroughly distributed through the gravels by the glaciers and streams which carried them to their present position. But, as the occurrence of a pebble of a peculiar rock type within a stream basin, covered in part by the gravel sheet, does not mean that the terrane from which this pebble came outcrops within the basin, so the occurrence of gold in the bluffs and bars of a stream is not proof of its occurrence within the territory drained by it.

Because of the lack of an understanding of these relations prospectors have formed erroneous and costly conclusions as to the occurrence of gold in particular stream basins and have found themselves following a will-o'-the-wisp in their endeavors to reach its source. In short, when prospecting in streams flowing through the gravel-covered area, the finding of colors gives no clue as to where the gold occurs, and, to be sure that his results are reliable, the prospector must work on tributaries whose source is beyond the gravel sheet. These Pleistocene beds do not occur anywhere within the area studied at more than 3,000 feet above tide, and, in the northern end of the Kenai Peninsula, 1,500 feet above sea level seems to be their limit. Toward the interior of the continent they rise higher, reaching a maximum of 3,000 feet about the foothills of the Alaskan Mountains. Gravels taken from above these elevations will give safe results, and, because of local conditions, many streams flowing at lower elevations may not lie within the gravel-covered area. The meager gold content of the gravels will not permit of profitable extraction until methods become much more refined than they are present.

COAL.

The only coal-bearing rocks encountered on the reconnoissance are those of the Matanuska series. Thin seams of this mineral, bright, hard, and seemingly of good steam-producing quality, were frequently seen in the outcrops of these beds, but the writer did not personally examine any of sufficient thickness for mining, either locally or commercially.

Mr. Hicks, however, reports a seam 6 feet thick on the south side of the Matanuska. It outcrops in the bed of a small stream called Coal Creek, which empties into the river opposite the mouth of Chickaloon. Coal of sufficient thickness to have value is also reported along the upper source of this latter stream. Halfway between Schoonoven and Hicks creeks fragments were found in a gully which heads well up on the north wall of the valley. Along these slopes dark bands parallel to the bedding were visible and are probably the outcrops of coal beds.

Along the upper course of Bubb Creek, as within the valley of the Matanuska, thin coals may occasionally be seen interbedded with the shales and sandstones forming the stream bluffs.

The character of the sediments and the attitude of the rocks away from the intrusive centers in this series are favorable to the occurrence and preservation of coal, and it is highly probable that more systematic search would disclose beds of sufficient thickness and extent to deserve attention if ever there should arise local need of the mineral as a fuel. From Bubb Creek north to the Tanana none of the formations examined are coal bearing.

GLACIATION.

PRESENT GLACIERS.

The main centers of distribution of the present ice streams are the two principal mountain ranges of the region—the St. Elias system, adjacent to and closely following the coast, and the equally prominent Alaskan Range, 150 miles farther inland.

The St. Elias system is probably wider and more uniformly continuous than the less well-known interior range, but it does not reach such great altitudes. At any rate its névé fields are more extensive and the glaciers which rise in them more numerous and larger, but this is due, as explained by Hayes,[1] to its location as the barrier range adjacent to the coast and the greater precipitation due to its position rather than to any difference in extent. Many of the seaward-flowing glaciers along the southern part of this range have become well known

[1] The expedition through the Yukon district, by C. W. Hayes: Nat. Geog. Mag., Vol. IV, p. 150.

through the studies of Russell, Reid, and others, and the more accessible ones, which reach sea level about the northern inlets of the Alexander Archipelago, are annually visited by numbers of tourists.

Hayes[1] has contributed an account of the glaciers tributary to the White and Nizzena rivers, and has added to the earlier accounts by Allen and others of the great ice streams along the lower course of the Copper.

Prince William Sound and its inland fiord-like extensions receive many glacial tributaries from the high mountains to the north and west. Port Wells, which extends 25 miles northeast into the Chugatch Mountains from the western end of the great gulf, divides, about 10 miles from its head, into two arms. Into the easternmost of these, two glaciers, each with a seaward front of 2 or 3 miles, discharge fragments of ice scarcely large enough to be called bergs. These glaciers, like almost all those of Alaska, are less active now than in the recent past, and only the eastern half of the one illustrated by Pl. XIX, *A*, exhibit the rough pinnacled front of a still-advancing stream. Its western front is of dead-white ice.

Barry Glacier is more extensive than either of the two entering the head of the inlet, and is itself tributary to the western arm of Port Wells. Just above the mouth of Barry Inlet, but on the eastern shore of the arm, a valley from which the ice has recently withdrawn extends for 10 or 12 miles back into the mainland. A low morainic ridge crosses this valley near its outlet and confines back of it a little lake—Lake Cecelia. The moraine may be the terminal of the glacier now in retreat at the head of the valley, or it may be a lateral left by a tributary ice stream which enters from the east.

Portage Bay receives several glacial tributaries. Southwest of Point Pigott, which separates this bay from Port Wells, is the mouth of Blackstone Bay, which receives Blackstone Glacier from the south. Both the bay and glacier are named for a miner who lost his life there a few years ago.

Three glaciers approach sea level at the head of Portage Bay. One of these is Portage Glacier, whose foot is about a mile back from the beach. Its outlet is toward Turnagain Arm, and it probably has never discharged into Prince William Sound. A second glacier spills over the mountain rim 2,000 feet above tide in an ice cataract on the southeast side of the bay. The third and smallest, now rapidly retreating, flows down from the mountains to the northwest, and has, until very recently, reached across the belt of gravel delta which separates the foot of the mountain slope from the head of the bay, but has now dwindled until the portion reaching the gravel plain is small and composed wholly of white ice.

This little glacier illustrates very well the rapidity of the ice retreat

[1] Op. cit.

and shows us the processes whose results only remain in portions of the New England landscape. One quarter of a mile out from its present terminus is a hillock 220 feet high and half a mile long, with its longer axis parallel with the glacier front. It is now separated from this latter by an open valley paved with bowlders. At first sight this elevation was supposed to be a simple terminal moraine, but upon examination it proved to consist mostly of ice deeply covered with angular débris, which is also disseminated through it. This remnant of the glacier seems to stand near a position which the ice front occupied long enough to become covered by a sufficiently thick mantle of protective débris, so that melting was not so rapid as in the less well-protected part of the glacier just back of the front. The separation from the glacier was probably facilitated by the exit of the subglacial stream through a tunnel back of the protecting mantle. The combined melting from above and below soon removed this neck, leaving the former front isolated as it stands to-day. Since its isolation it has been shrinking each summer, and now occupies less than half of its original area. Around its seaward side is a belt of rough ground of slight relief covered with angular and unsorted material, which has been let down into position by the melting of the ice front. The outer rim of this zone is somewhat higher than the inner portion, giving it the form of a shallow amphitheater facing the remnant of the glacier which remains. The stability of the position of maximum advance for a short time due to the balance between flow and melting at the front accounts for the slightly greater accumulation there and the building of the low rubble wall.

These recent glacial details of topography are the more striking since they are built upon a smooth water-laid deposit of relatively fine material. This delta is of the type which usually forms before glaciers in these fiords, and gives about the only level areas to be found near sea level in a region of sharp topographic forms. At its outer margin, a short distance seaward from low-tide level, the delta slopes abruptly to the profound depths so often found in these inlets.

The route from Resurrection Bay to Sunrise City avoids the glaciers which are so well developed in other parts of the peninsula. Resurrection Creek rises in an ice stream which probably originates in the same snow fields that serves as the glacial sources of many tributaries of the Kussilof and Kenai rivers, while the ice cap from which a glacier occupying the upper part of Snow River Valley flows may be a part of the same névé which feeds Portage and Davidson glaciers.

North of Turnagain Arm, Glacier Creek heads in three small streams which give it its name, and about the divide between Crow and Raven creeks remnants of formerly more extensive ice masses remain in cirques among the higher peaks. Raven Creek itself is fed by a small stream which reaches down 1,000 feet below the divide, and 1 mile above the point where it enters the valley of Yukla Creek stands the front of an extensive glacier which has very recently withdrawn from the lower valley of Yukla.

No glaciers enter the Matanuska Valley directly from the north, but Chickaloon Creek, and perhaps others of its northern affluents, rise in them. Its chief glacial tributaries, however, come from the south.

Along the middle course of the river several small ice streams are to be seen at the heads of the canyons which furrow the southern valley wall, but the largest glacier of the valley is the Matanuska Glacier (Pl. XIX, *B*), with a frontage of 3 miles along the river. The course of this stream can be traced from the top of Glacier Point for 25 or 30 miles to the southeast. Its source here is probably in the névé which follows the crest of the Chugatch Range to the east, and gives rise to the various glaciers which flow down to Prince William Sound on the south and to the Tazlina and Klutena rivers on the north. While its east front is buried under moraine which supports a considerable spruce forest, the west front is clear of débris to the edge. A well-marked medial moraine divides the main stream into two parts, representing branches which unite near the source. Local conditions of precipitation controlling the rate of flow of these tributaries seem to be slightly different, so that the western branch is somewhat more active than the eastern one.

Within 10 miles of its source the Matanuska River receives the waters from another glacier, smaller than that just described and more actively retreating. Its front has now receded several miles from the river and the draining stream flows through a gravel-filled valley with a very high gradient.

Tazlina Glacier, so called because it is the principal source of the Tazlina River, reaches the level of the interior basin a few miles east of Tahneta Pass. We were not nearer than 12 miles, but at that distance it could plainly be seen to be a large stream forking a few miles above its present front.

Of the series of glaciers which flow toward the interior from the Chugatch Mountains that discharging into Lake Pleveznie was the most easterly whose position could be approximately determined. The Indians report that bergs break from its front into the lake.

The high peaks of the Alaskan Range are sources of numerous glaciers which drain into the Yukon, Sushitna, Kuskokwim, and Copper River basins. Before we reached the foot of the range, during our approach from the south, we could see several large ice streams east of our route, which are probably drained by branches of the Chestochina; and when looking back from the northern side in the neighborhood of Marr Butte toward Mount Hayes and its neighboring peaks even more extensive glaciers heading in this high group and flowing to the north were visible.

Within the Delta River Valley are three principal ice streams. Two, Canwell and Castner glaciers, flowing from the east, and another, 12 miles below, which rises in the mountains to the west of the river. This latter has very recently extended across the present river channel, as indicated by a fresh moraine opposite its valley, but evidently this maximum extension was of very brief duration. This glacier seems to be subject to more rapid fluctuations than either of those above, which are stagnant and appear to have maintained their fronts at about their present position during the time when the lower one was advancing across Delta River and retreating to its present position several miles back. Castner and Canwell glaciers are gravel covered as far back as can be seen from the valley below, and this gravel overlying the ice in many pleces supports an extensive growth of trees, shrubs, and bushes. Streams in each instance issue from tunnels beneath the ice, and their combined volumes make one of the largest tributaries of Delta River.

FORMER GLACIATION.

Throughout the entire region studied the explorer is constantly confronted with evidence to prove that the present glaciers are but remnants of a system of vastly greater extent. Glacial scratches, polished surfaces, erratic bowlders, typically glacial topographic features, nearly all of the usual forms of evidence, are abundant. It is difficult to decide just how extensive the older system was, but the conclusion reached is that a general ice cap has not at any time buried this part of the continent, but rather that the greatest advance of which records remain was an expansion of the present system, essentially alpine, with its centers of accumulation, as now, in the two great ranges, the one along the coast, the other in the interior, and that from these centers ice streams flowed down the valleys, and, spreading, fan-shaped sheets, of the type which Professor Russell has called piedmont glaciers, rode out over the adjacent lowlands.

Within Kenai Peninsula the rock walls and floor of the valley of Kenai Lake and Snow River are glaciated to considerable heights above the present water level. The remnant of the valley glacier which once filled this trough is still visible at the head of Snow River. One of its halting places, though probably not the most advanced position of its front, is marked by the outlet of Lake Kenai. Here the ice front stood while the gravels which cover the plain west to Cook Inlet were deposited against it and were doubtless in part supplied by it. These gravels now stand at an elevation of 500 feet above the surface of the lake. After their deposition the withdrawal of the ice left a basin back of the gravel dam, which immediately filling became Kenai Lake. Since then the dam has been cut down 500 feet with two or three short halts marked by terraces, and is even now being very rapidly lowered. Hayes explains Lake Ahklen in a similar way, and the occurrence of such lakes furnishes one of the arguments for supposing that the deposits of silt and gravel which are so extensively distributed over the interior of Alaska are nearly synchronous with the glacial retreat after its latest advance.

As these loose materials seem to have been laid in large bodies of water whose extent and relations sometimes point to their having been large bays, and at other times lakes, but probably, even in the latter case, standing nearly at sea level, the ice must have been much in advance of its present position, although probably in rapid retreat, while the general land surface was much lower than now, the amount of elevation since being measured by the height of these deposits above tide.

Turnagain Arm, like the interior valleys, bears proof of recent occupation by ice in polished rock surfaces along its shores. These are particularly prominent in the exposures at Snipers Point, just east of the mouth of Sixmile Creek. The ice stream which filled this valley was doubtless an extension of Portage Glacier, which now covers the isthmus connecting Kenai Peninsula with the mainland. From the evidence at hand the outward limit of this glacier can not be given. It is probable, however, that it extended at least to the head of Cook Inlet proper, and probably became confluent there with other glaciers from the east, west, and north.

In the mountains between Turnagain Arm and Knik Arm the present glaciers are, as everywhere else, rapidly diminishing remnants of the ice streams which not very far in the past have filled the river valleys far beyond their present fronts. The upper valley of Yukla Creek has probably been excavated in part by ice action. Its walls are not of the V-type which usually marks the most vigorous river work, but are practically sheer for 3,000 feet or more and the stream bed is filled by gravels, so that the rock bottom may be several hundred feet lower than the gravel floor.

Along the Matanuska the valley wall north of the crossing of Kings Creek, where it happens to be formed of hard rock well calculated to preserve such records, is beautifully scored and polished to an elevation of 3,000 or 3,500 feet above tide.

The trap ridges east of Schoonoven Creek exhibit moutonéed forms and scattered about over them are pebbles belonging to rock types not outcropping in the vicinity. Evidence of this kind proves that an ice stream at least 2,000 feet deep at Kings Creek has recently filled the valley and probably extended out into the head of Cook Inlet, where, spreading out into a glacier of the Piedmont form, it united with that from Turnagain Arm and others from the surrounding mountains.

Matanuska Valley is probably due to river erosion almost entirely, but has been slightly modified by the ice. This latter has done much to smooth off the broad point east of the mouth of Caribou Creek and may have cut down the valley floor somewhat above the barrier trap ridges mentioned before. There appear to be no distinct moraines within the valley, indicating that the ice retreat was rapid and without halts long enough to permit of the accumulation of débris. This absence of definite moraines within valleys is everywhere a most striking phenomenon.

Very late in its history the Copper River Plateau has been, in part at least, covered with ice probably belonging to glaciers of the piedmont type. The gravels along our course over the plateau, while generally water-worn, contain angular blocks and are everywhere deposited in a succession of confused ridges, mounds, or kettles, the latter usually occupied by lakes, many of them without surface outlet. Pl. XVII, *B*, illustrates this type of topography as exhibited north of the Chestochina River.

In the gap through which we passed north of the Tangle Lakes are shallow, ice-cut rock basins occupied by ponds, and the very slight accumulation of talus in this gap from the sharp rhyolite points on either side indicates a very recent withdrawal of the ice.

The rounded form of the greenstone hills north of the Gakona River and the occurrence of erratics on their summits prove that ice has covered them and hence must have been at least 1,000 feet deep over adjacent parts of the plateau. In the middle of August occasional snow banks nestled in sheltered ravines on the north slopes of these hills, whence they probably did not disappear during the remainder of the summer. The camp of August 18–20 was under the lee of a small terminal moraine, representing the last advance of a little glacier, a remnant of whose névé appears as one of these drifts. Drainage here too is ill adjusted, and small examples of reversals and temporary changes, due to the rearrangement of topography by the ice, are constantly encountered.

Delta River Valley, when viewed from the point between Phelan Creek and the main stream, exhibits a symmetrical U-form very slightly trenched at the bottom by the present bed of the river. Along its lower course, near the junction of the Tanana, are most pronounced morainal deposits, mostly lying between Marr Butte and Jarvis Creek, while west of the river a series of ridges, increasing in height toward the base of the Alaskan Mountains, very strikingly suggest moraines. Extensive remnants of the glaciers which produced these moraines are visible from Marr Butte, from which they are seen to rise in an extensive snow field about Mount Hayes.

In the Alaskan Mountains, as in those along the coast, the higher slopes are all angular, while the lower bear marks of ice action, so that the maximum glaciation seems here, as farther south, to have been merely a very considerable expansion of the present system, filling the mountain valleys with the ice streams and sending the fan-shaped lobes out over the adjoining plains.

It is possible that the Copper River Plateau may have been completely buried under these confluent lobes from the surrounding high mountain groups, but it is more probable that a central area was generally free from ice and occupied by a lake in which the silts now trenched by the Copper and its tributaries were deposited. The lake shores were frequently overridden and modified in form by the ice, and floating masses breaking from its front carried out the bowlders which are found scattered through the silts.

PHYSIOGRAPHIC DEVELOPMENT.

It is impossible with the relatively scant stratigraphic evidence available to trace the development of land forms since the beginning of sedimentation, but many records bearing on the later history are preserved, and their consideration leads to a few tentative conclusions which are believed to be of value. Some time after the deposition, consolidation, and uplift into mountain ranges of the Cretaceous sediments of the Matanuska Valley the land mass thus formed maintained for a considerable period a constant position relative to the sea at a somewhat lower level than it now occupies. This period was marked by the development of strong drainage systems along about the same lines occupied by the rivers of to-day, but the streams of this period became much more mature than any of the present rivers. They cut broad, flat valleys for themselves, and, in many instances at least, reduced divides to inconsiderable features, but had made but little progress in the reduction of interstream areas before they were disturbed.

Along the shores of Kenai Lake a number of flat-topped spurs are noticeable at about 400 or 500 feet above lake level, and small tributaries which enter the lake flow in flat-bottomed valleys which projected would reach the lake basin at about the same elevation. Quartz Creek occupies a compound valley consisting, besides the present gorge of the stream, of a series of ridges which reach an approximately uniform height and doubtless belong to the same series.

Near the mouth of Quartz Creek the greater part of this old valley floor has been removed by modern erosion, while nearer its source the recent gorges are but insignificant trenches in the older feature which is here dominant. Passing the modern divide, which is of gravels that bury the old valley to a depth of about 200 feet, we find along Sixmile Creek drainage features exactly similar to those encountered on Quartz Creek. Canyon Creek flows in a very new gorge cut into the floor of the older valley, which has suffered but slight etching near the source of the stream, but is represented by much reduced remnants along the lower course of Sixmile Creek, near Sunrise City. Even here, however, it is easily recognizable as an older valley.

Along the Matanuska a feature similar to that within Kenai Peninsula, and probably belonging to the same epoch, is conspicuous. In the lower valley it is much obscured by the later gravel deposits, but, climbing down into the gorge of Tsadaka Creek from these gravel uplands, one finds for 30 or 40 feet above the stream bed the highly tilted sediments of the Matanuska series with their upturned edges planed off to a fairly uniform level and buried under the gravels. On the opposite bank of the Matanuska exposures are better and the same conditions are indicated.

As we pass up the river from this point the old valley floor emerges more and more from beneath its gravel covering and its character becomes clearer. At King's cabin the river flows out from the canyon which it has cut in the old valley. At the mouth of Chickaloon Creek the canyon is deeper, and this tributary has also intrenched itself well in the old floor. Above Chickaloon Creek the network of trap ridges, described as intruding the sediments, evidently formed a barrier across the older stream as it does across that of the modern, and the grade of the ancient valley suddenly increases until the dam is passed. Above it the level was probably less perfect, as the local baselevel, for this part of the stream's course, controlled by the diabase obstruction, was not permanent and was being constantly, although slowly, lowered by the river's action. Yet, as a glimpse across Schoonoven Creek or northeast from Glacier Point (Pl. XX, *A*) shows, it is a dominant feature in the landscape. This double character of the valleys is everywhere noticeable, and extends even to the head waters of the present streams, where the rounded and gentle outlines of the older feature are interrupted by the sharp gullies of the present drainage.

The period of quiescence which resulted in the formation of the valleys just described was brought to an end by an uplift, with a revival of the drainage and the inception of an era of dissection. This uplift seems to have been one which brought a great increase of precipitation and inaugurated an ice advance. The glaciers filled the old valleys and the new canyons which had begun to form in their lower courses, broadening and greatly modifying the latter.

A subsidence followed, carrying the land considerably below its present position and greatly lessening the glacial activity. As the ice retired the detrital products of its action were spread out in frontal deposits and as deltas of the draining streams, giving the great gravel beds of Cook Inlet and the Copper River Plateau, while the silt deposits of the latter represent offshore phases of the same activity.

Finally, the present period of uplift began with the remnants of the great ice lobes still in retreat. The gravels deposited during the subsidence were lifted to their present elevations of from 1,000 to 3,000 feet above sea level, and the rivers again became active, cutting first through the gravel deposit, then cleaning out their older channels and sinking into the floor of the Tertiary valleys. The sharp gorges still being actively deepened are results of this latest erosion.

The final uplift was differential in at least a part of the area, as proved by the attitude of the old valley and the relations of the gravels of the coast to those of the interior. Matanuska River at present is a stream of very swift current and high gradient; its rate of flow averages probably 10 miles per hour, and it descends more than 2,000 feet in 100 miles. These are characteristics of extreme youth, or recent revival, and it is inconceivable that with such a grade the stream could cut a broad valley comparable to the older one in which its present gorge is incised. Yet the grade of this old valley floor is now considerably steeper than that of the present stream. Above Glacier Point (Pl. XX, *A*) it stands 400 or 500 feet above the river bed. At the great bend below Tsadaka Creek it is near the present river level.

Obviously, this slope could have been acquired only after the valley was formed, and it might have been acquired at any time after, so far as the inherent evidence is concerned, but relative levels of the Pleistocene gravels of Cook Inlet and of the Copper River Plateau, which were deposited just before the latest upward movement, indicate that the difference of grade dates from this movement. The gravels at the head of the Matanuska, belonging to the Copper River series, stand at an elevation of about 2,700 feet. Those about the head of Cook Inlet are but little above sea level. The Copper River silts and gravels were probably deposited at or near sea level, since they stand at about the same elevation as the similar deposits on the Upper White and Tanana, and are very nearly, if not quite, continuous with these, which are believed by Dawson and others to have been deposited in large bays or lakes near the same level.

The difference, more than 2,500 feet, represents the excess of uplift of the Copper River Plateau over the head of Cook Inlet, and gives a measure of the addition to the height of the Chugatch and Talkeetna mountains by the last movement.

Southward as well as northward from the head of Cook Inlet the uplift seems to have been greater than in its immediate vicinity, since the Kenai platform, forming the northwestern part of the peninsula, stands, according to Dr. Dall,[1] at 1,800 feet above sea level near the entrance to Kachemak Bay, and declines in a series of gentle waves until along the southern shore of Turnagain Arm the land is but a few feet above tide. The beach bluffs here are composed of the overlying gravels, the Kenai rocks having disappeared below sea level before Turnagain Arm is reached.

[1] Report on coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Part I, p. 787.

At least a part of this dip, probably the greater part, was imparted to the Tertiary platform by the same movement that has increased the grade of the older Matanuska Valley, since the gravels, which stand at but 50 feet above sea level in Chickaloon Bay, are approximately 800 feet higher at the point where the Kenai River emerges from the mountains and cuts across the platform toward its outlet at Fort Kenai. We have no statement as to whether the Tertiary beds at their highest point at Kachemak Bay are gravel covered.

The configuration of the coast line about the northern end of Kenai Peninsula tends to support the idea of an unequal uplift (see map 17). A nearly east-and-west line, drawn from Orca, on the east shore of Prince William Sound, to the western shore of Cook Inlet, near the mouth of the Sushitna River, lies along the greatest east-west dimension of both the inlet and the sound, and crosses the isthmus connecting the peninsula with the mainland; the lowest pass north of Cape Elizabeth, through the land barrier separating Cook Inlet from the Pacific. This line is very suggestive indeed of an axis of relative depression.

It is probable that the general movements which have been sketched for the particular part of the coastal belt examined were epirogenic in character and affected the interior and the Alaskan Mountains in the same manner, if not to the same degree, as the coast (see A. H. Brooks's report on the White and Tanana River basins, p. 425, et seq., this volume), but the history outlined for the latter probably begins after or toward the close of the long base-leveling period, Eocene according to Dawson,[1] Miocene according to Spurr,[2] which produced the Yukon Plateau. During this base-leveling period, in the interior, the coastal mountains were probably building to approximately their present altitude, while within the Alaskan Mountains, the broad, low gaps, which are so conspicuous a feature at near the level of the Yukon Plateau, were cut.

The partially buried old topography of the Copper River Plateau seems to have been reduced during the Pliocene and the earliest Pleistocene periods of erosion, and was filled, as were the valleys of this same age, which drain more directly to the coast, at the time of the later depression which closed the period of greatest glacial activity.

The constructional topography of this basin has not been so deeply scored as yet by the new rivers which flow over it as to reveal the older buried forms, so that we can not even approximately restore the drainage system, which is hidden by the gravels. The most probable supposition seems to be that the old Sushitna received the waters from the region now drained by the Copper, for the mountain barrier in

[1] Proc. Trans. Royal Soc. Canada, 1890, Vol. VIII, section 4, p. 11.
[2] Geology of the Yukon district: Eighteenth Ann. Rept., U. S. Geol. Survey, Part III, p. 260.

this direction is even now very low, and if reduced by 3,000 feet, the approximate amount of the last uplift, would practically disappear.

All the surrounding streams are encroaching upon the Copper River Plateau, even the Tanana, beyond the Alaskan Range, with a long course to the Pacific, finding sources for several of its southern tributaries in the gravels of the northern border of the plateau. The Sushitna drains much of its western margin, and the Matanuska heads in its southwestern edge. These facts seem to point to the birth of the Copper River system since the deposit of the gravels, rather than to the idea that it is a rejuvenated older stream. The other streams mentioned, although doubtless much modified by the late movements, are flowing along lines generally determined during the long, earlier period of stability—lines in which they are well established and from which they are able to drain all of their geographic basins and reach out into that of the Copper, but the latter stream does not drain all of the region which geographically belongs to it. As a river system, it seems to date back only to the time when a relatively small stream draining into the Pacific, along the lower course of the present Copper, cut through the barrier of the Chugatch Mountains by headward erosion and tapped the lake which at that time occupied the present basin. With the greater volume of water thus acquired it quickly deepened its gorge through the barrier range, drained the lake, and has begun to establish itself in the old bed of the latter. But the other streams adjacent to the plateau had meanwhile been working headward toward it, and in the cases mentioned above have added small portions of its drainage to their own systems. If present conditions continue the Copper may in time recapture most of these.

Scheme of late physiographic history about the head of Cook Inlet, the Matanuska River, and Copper River Plateau.

Period.	Process.
Present	Uplift—differential—maximum, 3,000 feet. Revival of drainage, dissection and terracing of gravels, and cutting of modern gorges.
Pleistocene	Subsidence. Glacial retreat. Deposit of gravel sheet and silt.
	Uplift. Partial dissection of old valleys. Glacial advance, reaching maximum.
Pliocene	Stability, with valley cutting.

VEGETATION.

The low islands within Prince William Sound are usually covered with spruce forests, and the same timber clothes the shores of the mainland to varying altitudes up to a maximum of about 2,000 feet. The occasional flats near the heads of the inlets sustain a vigorous growth of alder and willow and are carpeted with rank grasses.

Within Kenai Peninsula, in addition to the spruce and alder which are everywhere present, groves of birch cover the gravel uplands and clumps of cottonwood are found here and there.

The vegetation of the Matanuska Valley is very similar to that along the coast, but the timber line gradually rises toward the interior. Its upper limit is about 2,200 feet along the shores of Turnagain Arm, but it reaches 2,500 feet along the Middle Matanuska, 3,000 feet at its head and 3,500 feet among the foothills of the Alaskan Mountains.

The Copper River Plateau is just below the upper limit of the spruce and is covered sparingly by dwarfed specimens, except in the more sheltered, shallow valleys of streams like the Gakona, where the tree attains a very considerable size. The dry gravel knolls everywhere within the marshes are marked by cottonwoods, whose light-green foliage in spring and summer and yellow colors after the autumn frosts are very conspicuous, as contrasted with the unchanging dull greens of the spruce. The valley of the Delta River contains much good spruce timber, but instead of covering the lowlands completely, as it does nearer the coast, it grows in clumps which alternate with prairie-like meadows, in which no trees are found.

The largest trees seen were cottonwoods, growing in the Lower Matanuska Valley, and these would not measure more than 4 feet through at the butt, and taper rapidly to an average much less than this. None of the timber can have other than a local value, for it is too small and knotty to furnish even second grade lumber.

Grasses have been mentioned as growing all along the routes explored. They grow more luxuriantly and in greater variety near the coast than toward the interior, but were everywhere abundant enough to supply food for the animals of the pack train. In the swamps a variety grows in bunches which increase in height year after year until they stand well above the intermediate swampy spaces. These clumps have been called "têtes des femmes" by Alaskan writers generally. The miners style them "nigger heads" from a fancied resemblance, after being burned over, but the soldiers of the expedition dubbed the grass which forms these clumps "waltzing grass," after much experience in trying to cross the swamps by stepping from bunch to bunch.

The controlling coloring element in the higher landscapes is contributed by mosses and lichens which grow in much profusion and variety. The shades are usually somber greens, but clear pearl grays, canary yellows, browns, and crimsons, add touches of color here and there. Mosses grow within the forests as well as above timber line and take the place of the grasses and flowers of our eastern woods. They form a thick, soft, sponge-like carpet which holds the moisture and gives swampy conditions even on steep hillsides. They quickly cover all the fallen timber and even drape the living trees. Some of the lichens are used by the Indians for medicinal purposes.

Several varieties of berries grow in the woods and uplands. Among them are wild currants, cranberries, salmon berries, moss berries, and blue huckleberries. Both the latter are abundant enough in the fall to help out a depleted commissary very materially, and are evidently relished by the black bears and to a lesser degree by the bigger brown fellows.

FISH AND GAME.

Salmon canneries are established at several points in Cook Inlet and Prince William Sound, and the industry is growing in importance yearly. Other varieties of food-fishes inhabit these waters, cod and halibut among them, but are not yet caught except for local consumption. The salmon are and long have been the most important source of food for the natives in the interior as well as along the coast, and much suffering would result if the supply were sensibly diminished, as it promises to be with the growth of the canning industry. A variety of smelt appears in great schools along the shores of the upper inlet and the mouths of its tributaries in the spring. Immediately after a storm they may be gathered up from the beach in great quantities, many of them still alive and all perfectly fresh. They are a delicious food-fish. In the streams of the interior members of our party caught both trout and grayling; the latter are more abundant, but neither seems to attain very large size.

The country around Cook Inlet is reputed to be the finest game belt in Alaska. A few woodland caribou are found in Kenai Peninsula, and the barren ground variety reaches salt water along the western shore of the inlet. This deer is abundant along the northern base of the Talkeetna Mountains, in the hill country of the Middle Sushitna, and on the uplands along both flanks of the Alaskan Range. It inhabits the high, rolling country, above timber line, but no trace of it appeared in the lower and moister region of the Copper River Plateau. The animal has, of course, not been systematically hunted in the interior, where, as yet, its only human enemies are the Indians, and has not developed the instinctive fear of man, which makes all varieties of game in the United States so difficult to approach; hence it falls an easy victim to the hunter and within its feeding grounds may become an important source of food to the explorer or prospector.

Moose are plentiful in the wooded valleys everywhere except in the immediate proximity of the mining camps. In Kenai Peninsula, Matanuska Valley, and the valley of Delta River we were constantly finding evidence of their presence, but though abundant, they are shy and difficult game for the novice to kill, and may not be relied upon too confidently for food. They are most easily shot during the fall months of September and October, or in the late winter when the deep snow drives them down into the lower valleys and forces them to collect in large droves in "moose yards."

The White Mountain sheep (*Ovis dalli*) inhabits the Kenai, the Chugatch, and the Talkeetna Mountains in great numbers. During the summer it stays entirely above timber line, but is sometimes forced by the heavy snows in winter to lower altitudes. The chief difficulty in hunting it arises from the fact that its favorite haunts are in the rougher and less accessible parts of the mountain ranges. When the hunter has reached the locality where the sheep are abundant they are not difficult to capture.

The mutton as a food is equal or superior to that from the best of our domesticated sheep. A few of these animals were seen in the Alaskan Mountains, but they do not seem to be nearly so abundant here as in the mcre southerly ranges. They are not found at all in the valleys or plains.

A variety of brown bear (*Ursus richardsonii*) is abundant within the Kenai Peninsula and in the mountains to the west of Cook Inlet. The local hunters call this bear the "grizzly," and it probably grows to as great size as the true grizzly of the Rocky Mountains. One killed by our party on Lake Kenai is estimated to have weighed 600 pounds. They are ferocious beasts, and it is not uncommon to hear of their having attacked and killed or seriously injured hunters. They are found within the Matanuska Valley, although not so abundant here as farther south, and many of their tracks were observed along Delta River. The little black bear inhabits the mountainous districts of the coast and interior. His pelt is one of the valuable furs of this part of Alaska and causes him to be much sought for by Indian hunters. Other fur-bearing animals which are found in limited and constantly decreasing numbers are the silver-gray, the black, the red, and the cross fox, the wolverine, lynx, otter, bear, and gray wolf.

Waterfowl are found along the coast and the interior in great variety and abundance. In the spring the salt marshes about Prince William Sound and Cook Inlet are alive with geese, brant, many varieties of ducks, curlew, snipe of several kinds, and now and then a flock of swan. As the ice breaks up in the spring they follow the rivers and valleys toward the interior and breed in the lakes and ponds of the interior tundras and plateaus.

Among land game birds the blue grouse, abundant in the spruce woods, and the ptarmigan, which lives in the alder thickets during the winter and on the untimbered uplands in the summer, are most important. We secured many of them as well as a great many waterfowl during our trip, and they made a very agreeable addition to our food supply.

INHABITANTS.

Native.—The native inhabitants of the region about the head of Cook Inlet belong to the true Indian stock, as distinguished from the Eskimo tribes of the coast. They are now collected into a few small villages, as at Tyonek (Pl. XXI, *B*), Ladds Station, and Knik, where their original customs have been much modified by white traders, upon whom they are becoming more and more dependent. Physically they are slight and will average less in stature than the whites. They are good-natured, timid, disinclined to quarrel, and are generally honest, although idlers. They still depend in a measure upon the summer's catch of salmon to keep them from starvation during the winter season, but secure clothing of white manufacture and many articles of food from the stores of the various trading companies in exchange for furs. Their winter habitations are rude cabins, which are sometimes occupied throughout the summer months also, but are quite as often discarded for tents until severe weather begins again.

Pulmonary and inherited diseases are making constant inroads on their numbers, particularly at the stations, where their native customs have been most modified by white influence. The Indians of Knik, for instance, are much more robust than those at Ladds Station.

The Matanuskas dwell about the southern edge of the Copper River Plateau, generally on Copper River drainage. They are more active than the coast tribes and are held in much awe by them. Once or twice during each winter season they come down the Matanuska River on the ice to exchange their furs with the traders at the head of Knik Arm for firearms, ammunition, clothing, or food. The journey of more than 100 miles is usually very leisurely performed and occupies several weeks. At such times the women and children are often left behind, very scantily provided for, and the supplies purchased from the traders are usually consumed before the braves reach their homes again. Among white traders the members of this small band are regarded with more or less suspicion. A few years since one of their number murdered the storekeeper at Knik and was promptly hanged for it by the latter's associates. The lesson seems to have been effective and no further trouble has occurred.

The Matanuskas penetrate the Sushitna Basin, at least to the upper waters of the Talkeetna, one of their caribou hunting grounds, and also meet the Lower Copper Indians to the east. There are probably not 100 of them all told.

We met but two small parties of Upper Copper Rivers during the summer of 1898. They were at the time on the head waters of the Delta River, on one of their annual hunting trips to this region. The first party consisted of four men, three women and several children (Pl. XXI, *A*). One of the men had been as far as the coast at Knik, and all of them, by trade with intermediate tribes, had secured more or less complete suits of white man's clothing. The women, however, were dressed in buckskin garments of their own manufacture. Their lodges were of heavy drilling stretched over a frame of poles, and in moving from place to place each member of the community and all of the dogs were given an appropriate load. They were fairly cleanly in appearance and, although slight, were well developed physically.

The smoke from several camps of Tanana Indians was visible east of Marr Butte, and the frames of their hunting shacks were encountered along the lower delta, but we did not see any of the Indians themselves.

White.—Cook Inlet and Prince William Sound have a semipermanent white population, consisting of traders, claim owners, prospectors, fishermen, and Russians, some of whom stay in the country from year to year, others going to some point in the States occasionally to spend a winter. A much larger percentage of the whites found there in the summer, however, are transients, who never winter in the country.

The principal trading and mining centers are Sunrise, Hope, Tyonek, and Knik, and in these camps or the mining regions adjacent to them most of the whites may be found. A few each year penetrate some distance beyond the borders of the well-known districts and reach the interior of Kenai Peninsula or prospect within the Matanuska Valley. Two small parties this year (1898) succeeded in getting nearly across the Copper River Plateau, and a few hardy traders or prospectors in previous years have reached the interior, but they have left no records.

A RECONNAISSANCE OF A PART OF PRINCE WILLIAM SOUND AND THE COPPER RIVER DISTRICT, ALASKA, IN 1898

BY

F. C. SCHRADER

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A RECONNAISSANCE OF A PART OF PRINCE WILLIAM SOUND AND THE COPPER RIVER DISTRICT, ALASKA, IN 1898.

By F. C. Schrader.

INTRODUCTION.

The field work on which the following report is mainly based was done during the summer of 1898, while the writer was attached as geologist to the Copper River Alaskan Military Expedition No. 2, in command of Capt. W. R. Abercrombie. It enabled the writer to make some hasty observations on a part of Prince William Sound and the Copper River district.

The principal object of the expedition, as set forth in General Orders No. 8 of the War Department, was to gather all information of general and economic value, and to find, if possible, an all-American route, railroad or otherwise, from tide water to the gold districts of the Upper Yukon in the interior.

Practically the whole of the western and northern part of the Copper River district had never been visited by any geologist. Of the geology in this part of the district nothing was known. The same is largely true of the topography, especially in the west, where the district merges into the hitherto unexplored region between the coast, and on the Tanana River. It is not the remoteness of the region so much as its difficulty of access that has kept scientists cruising along the coast from entering the Copper River country, and has kept their pens silent concerning it.

Besides for opportunities and aid furnished by the expedition through its commander, officers, and men, the writer would here record his thanks for many courtesies and great assistance received; to the ever hospitable prospectors on the trail, to members of the Pacific Steam Whaling Company, the Alaska Commercial Company, and to miners about Prince William Sound; also to Mr. Emil Mahlo for pains taken in sketching special topographic features in the field, at the request of the writer; to Mr. F. H. Knowlton for examination of fossil plants collected; to Prof. F. W. Clarke, H. N. Stokes, and George Steiger,

of the chemical laboratory of the Survey, for assays of the ores and chemical analyses of specimens, and to Mr. J. E. Spurr for petrographic aid in the microscopic determination of certain feldspars and difficult thin sections. During most of the time in the interior, from late in August till we returned to Valdes, late in October, one party of the expedition was in charge of the writer, who carried on the geologic work, while the topography was done principally by Mr. Mahlo with the transit. Owing to the general inaccessibility of much of the country, and to the short space of time—less than three months—spent in the field, the report can not aim at anything like completeness.

ITINERARY AND METHODS OF WORK.

The expedition left Seattle April 7 on the ocean steamship *Valencia*, with several hundred other north-bound passengers, mostly prospectors and gold seekers, with their outfits, consisting of from one to three years' grub stake, and pack animals, horses, mules, burros, and dogs. There were also aboard several score of Chinese from San Francisco—summer laborers in the salmon canneries about Prince William Sound.

From Seattle to Lynn Canal the vessel took the inland route, stopping at Haines Mission on the 12th. After a lighter of supplies had been taken on board, and a storm which had so roughened the canal as to prevent navigation for a day or so had subsided, the vessel reached Dyea on the 14th. Here the main bulk of supplies for the expedition, previously intended for the relief of miners in the interior, was taken on. That night we returned to Haines Mission, where the vessel anchored and remained until the morning of the 16th, when, at about 4 o'clock, we set out down the canal for Port Valdes. Late in the afternoon we passed out through Icy Strait and Cross Sound into real ocean water, which continued rough all of the way across the head of the Gulf of Alaska until the sheltered waters of Prince William Sound were entered late on the evening of the 17th. On the following morning the vessel touched at Orca, the site of the Pacific Steam Whaling Company's cannery, where some stock and the most of our celestial passengers were discharged. The sight of soft snow here, about 5 feet in depth on the level at the beach, together with the report that it was much deeper at Port Valdes, rendering pedestrianism almost impossible, caused several of the wavering and less stout-hearted of the gold seekers to fully decide that their line of duty lay in an immediate return to home and friends, and they at once began to dispose of their outfits accordingly.

Leaving Orca early in the afternoon the vessel anchored in the head of Port Valdes on the night of the 18th. Port Valdes is the most inland arm of Prince William Sound, and our arrival here terminated the ocean voyage of the Copper River expedition and of most of the prospectors and passengers.

The several succeeding days, especially the 20th and the 21st, were devoted to separating and unloading the very promiscuous cargo of freight, supplies, outfits, passengers, and live stock. As there is no pier or dock here, the landing was made by transferring the cargo to several stern-wheel fishing steamers as lighters, which on being beached at flood tide were left high and dry at ebb about 400 yards from the snow scarp delimiting at the time the encroachment of the sea. This scarp is simply the vertical edge of the snow sheet, which here on the level was 6¼ feet in thickness.

From the steamboats or lighters to the edge of this snow sheet the cargo of the expedition, amounting to some 20 tons, was packed, mostly on the backs of the men. As the work could proceed at low tide only, and as many of the prospectors were feverish to get their outfits ashore and start for the gold country of the interior, all available help, both native and imported, was pressed into service at remunerative prices. Whites, natives, mules, burros, and dogs struggled together promiscuously, dragging, sledding, and packing supplies across the beach. Those in possession of stock at this hour regarded themselves fortunate, as a man and horse readily earned about $25 a day.

At Valdes, and strung out with their tents and outfits along the trail toward the glacier, we found hundreds of prospectors who had preceded us into the snowy country, the immigration having begun early in February. Some who were less ambitious than others to get over the glacier had drawn together at the edge of the cottonwood grove on the beach, where their tents, pitched on the snow, and some half dozen log cabins and rough lumber shanties formed the nucleus of what is now known as Valdes. It was then called Copper City, but about a month later, in a "town meeting," the people decided that the place should henceforth be known as Valdes.

Hardly had our supplies been cached upon the edge of the snow sheet when it was found necessary to remove them from there to a safer position on higher ground, as the edge of the snow sheet on which they rested was being rapidly undermined and cut back by the tide. This transfer of about one-half mile to the lower end of Copper City was accomplished principally during the several succeeding nights and the early morning hours, while the surface of the snow was frozen to a supporting crust, for during the day the deep snow became so softened by the sun as to render locomotion difficult, if not impossible, even with snowshoes.

Upon the completion of the transfer we proceeded to pitch our tents in pits or cellars dug 6½ feet deep in the snow. Up to this time, since leaving the vessel, we had been sleeping and eating out upon the snow. Our tents were the Sibley conical wall tents, about 16½ feet in diameter. Scarce were they ready for occupancy when a wet snowfall set in on the 25th and continued most of the day. As the route over Valdes Glacier had been supposed to lead within a short distance to a small lake, the supposed source of the Tasnuna River, which river was known to lie about due east of Valdes, the band of prospectors who for more than a month had been slowly forging their way a score or more miles up the glacier in the bleak mountainous waste of snow and ice, with no indications of the Tasnuna country in sight and no idea as to whither they might be going, held a meeting and sent a committee to the commander of our camp for such geographic information of the route and region as might be furnished. As such information was not extant, the region being practically unknown, Lieutenant Brookfield and the writer were detailed to make a hasty reconnoissance to the summit of the glacier and mountains and return to camp with the results of the observations. We set out from Valdes on the morning of the 26th, drawing our own outfits and some additional supplies of the expedition on a Yukon sled, as our camp now had no pack-animal transportation of any sort.

From Valdes the trail, as broken by prospectors on the snow, led eastward for 5 miles, with scarcely perceptible rise, almost directly to the eastern edge of the foot of the glacier at the base of the mountains, whence the ascent of some 500 feet up the front edge of the glacier was made in the course of a mile or so, mostly over rough lateral moraine and ice, by following the gulch along the eastern edge of the glacier at the base of the mountains. This rise up the foot or lower end of the glacier is not gradual, but is broken into terraces limited by sharp scarps or steep rises of about 100 or more feet each, and known by the prospectors as first, second, and third benches. Here long ropes, with block and tackle, operated by the men themselves, were used for sledding up supplies, some of the slopes being too steep for any pack animal to ascend.

Along the trail at the foot of the glacier we found tented a camp of 300 people, most of whom were engaged in working their outfits from Valdes hither or from here up the glacier toward the summit. The source of water supply for this camp was a spring about 2 miles distant, whence the water was brought by pail over the soft snow. The fuel, mostly green cottonwood, was sledded about 3 miles.

By cooperating with prospectors in getting our load up the benches we almost reached the top of the third bench by night. Here our first night's camp on the glacier was made, at about 7 miles by trail from Valdes. Once on top of the bench the trail bore northwestward well toward the western edge of the glacier. During the night a storm began, which on the following day developed into a wet snowfall of such proportions as to completely cover the trail in a short time and prevent for the time being all farther progress. So forbidding became the aspect of the weather that after a couple of miles of heavy sledding we decided at about 2 p. m. to cache our outfits, sled, etc., with the many prospectors' outfits which lined the trail, and endeavor to wend our way back to Valdes, which we reached toward night in a drenched condition, often having waded through slush 3 feet deep on the way. The storm continued constantly, with heavy precipitation, chiefly snow, absolutely without interruption for more than five days, or one hundred and twenty hours, until the morning of May 2, when it ended in rain. Tents were kept from being crushed in only by removing or shoveling off the heavy snow several times during each day and night. As soon as the storm ceased, Lieutenant Brookfield and the writer again set out from Valdes to resume the journey up the glacier to the Summit. In the gulch at the base of the mountains, near the top of the second bench, a snowslide or avalanche had taken place on the trail, burying some caches beyond recovery and killing eight or ten horses, mules, and burros, and a number of dogs. As the snow was soft and the trail heavy, our outfits were this time left behind, our reliance for subsistence being upon the hospitality of prospectors, who were everywhere working along the trail, and in whom, it is gratifying to say, we were not disappointed. At the point on the glacier then known as Fivemile Cache, owing to its being about 5 miles from the foot, there was another collection of about 100 tents, with their occupants, along the trail.

By night we arrived at the foot of the fourth bench, or Twelvemile Camp, another snow-white village of 300 or 400 people, about 12 miles from the foot of the glacier and 2,600 feet above tide, where the night of May 2 was comfortably passed with the Meyers prospecting party from Sterling, Illinois. Beyond this point the trail had not yet been broken since the storm.

On the following day, mostly through a storm of rain, fog, sleet, and snow, the traverse was continued by the writer, with compass and barometer, 6 miles farther, to the Summit or point where the trail crosses the divide and descends into the Copper River Basin, which was found to have an elevation of about 4,800 feet, or nearly a mile above tide. Up to this time it had been erroneously supposed and reported by the people to be about 1,500 feet above tide, or less than 2,000 feet at the most. From the top of the fourth bench to the foot of the summit or last climb the rise is gradual. Then comes a steep rise of more than a thousand feet, at an angle of nearly 20°, to the summit. As the slope here was too steep for sledding, the supplies were mostly raised by block and tackle, or packed upon the backs of the men. Both upon the summit and at its foot were temporary camps of considerable size, and accompanying them large caches of supplies, of which the owners might well be proud, for they represented unusual value in the form of severe labor and hardship which, in most cases at least, naught but the alluring hope of a rich find of gold or its equivalent would tempt even the most sturdy to undergo.

During the week's snowstorm already noted the fall of snow on the summit and the upper reaches of the glacier seems to have been phenomenally great. Along the trail on the summit the exhuming of buried caches and tents revealed a new snow sheet of from 8 to 12 feet in thickness. Drift may possibly have contributed some to this, but the men on the ground during the storm say not. Toward the close of the storm a large snow slide had taken place on the western side, which extended to the edge of the camp at the base of the summit, where it buried some caches, tents, etc., beyond recovery. It also buried eight or ten people, of whom, so far as known, all but two were dug out alive. The bodies of the dead were transferred to the head waters of the Klutena for burial. The incident, though similar to the Chilkoot Pass disaster of about a month before was fortunately not so fatal as that.

In the region of the summit and upper reaches of the glacier fuel and water for camping were scarce necessities. Some of the more experienced had brought small oil stoves and the requisite oil for meager cooking. Wood, all of which had to be brought 15 or more miles from either end of the glacier, readily sold for $1 a pound. The sole source of water supply was by melting snow, which, in view of the scarcity of fuel, became quite an item. For subsistence and lodging while on the summit the writer is indebted to the hospitality of Colonel Creighton's Keystone party, from Pittsburg, Pennsylvania, and to the Brown party, from Chicago, Illinois. When the summit was reached by the writer it was enveloped in dense fog and storm, with some snow falling, so that no observation of the country could then be made. Though the weather was severe, roping and packing of supplies up the summit continued till far into the night. The movement of the people in the search for gold was remarkable. It was estimated that about 2,000 had already crossed the summit and that fully 1,500 were strung out along the trail between the summit and the beach. The storm continued till early the following morning of May 4, with the night very cold and a high west wind. Fortunately, at early dawn it cleared and was almost calm, affording an excellent opportunity for topographic work. The mountainous snow-covered landscape presented a sight beautiful to behold. The summit was now seen to be a slight sway, col, or saddle in the contracted ridge of mountains running northward along the eastern edge of Valdes Glacier and forming the watershed between the coastal drainage (here the Valdes Glacier on the southwest) and the Copper River drainage (here the Klutena Glacier on the northeast).

Valdes Glacier, whose true trend was now for the first time observed, was found to head some miles northwestward beyond the summit in a vast mountainous névé. Its general course from near the summit to the foot of the glacier at the head of Port Valdes was found to be a little east of south and its width about 2 miles. Though the summit has been referred to as a gentle sway, it is not flat, but soon begins to slope off gently northeastward down to the Klutena Glacier. The Klutena occupies a canyon about two miles in width on the Copper River side. The foot or terminus of this glacier, which is the source of the Klutena River, is about 6 miles from the summit, where the elevation is 2,000 feet. From the summit down a gentle slope to this point, where the trail for the most part was good, the prospectors made good time at sledding, one man sometimes hauling 500 or 600 pounds to a sled load.

On our return down Valdes Glacier many prospectors, wandering about on snowshoes, were seen probing the snow sheet at various points with long poles in quest of lost caches which had been buried during the storm. The task was a tedious and sometimes fruitless one, owing to the loss of locality, for, though the caches had originally been deposited along the trail before the storm, so completely had the new snow buried everything that the new trail, which had been broken after the storm, was often found to lie a half mile to one side or the other of the old trail.

On the lower reaches of the glacier, owing to the warm spring sun, the trail was now becoming so soft that work by day was given up. The hours for labor now extended from about 10 p. m. to the following morning, during which time the trail was all night lined with hardy prospectors and their various kinds of live stock, sledding and packing up the glacier with an energy and determination known to the gold seeker alone.

This trip up the glacier to the summit yielded but little actual contact with geology, since the trail generally kept away from the base of the mountains, whose almost vertical slopes alone were not covered by the snow sheet. These, however, were sufficient along the edges of the glacier to indicate the probable northward continuation of the rocks found at Valdes. With more time and labor some of the outcrops could probably have been approached on snowshoes, but the many dangerous snowslides which at every moment, without warning, constantly descended the mountains on every side would have rendered such undertakings hazardous and ill advised. From a topographic standpoint the trip was a very material success, as it for the first time determined the size and trend of the Valdes Glacier, the character of the country in which it lies, the altitude of the summit and surrounding mountains, and the nature of the country at the head of the Klutena River on the inland side of the divide.

Since learning, upon return to camp at Valdes, that the expedition would wait for pack-train transportation into the country, it was thought best, as time permitted, to connect our work if possible with some known base from which it could be projected into the Copper River country. This was decided could best be done by triangulating from the known United States Coast and Geodetic Survey stations about Orca to Valdes. This distance, which is about 80 miles by steamer route, but very much farther by the route required in triangulation, was covered by a small sloop or sailboat, the *Fox*, which was equipped with covered quarters for three men. The party consisted of Lieutenant Lowe, Mr. Mahlo, Mr. Thurstonson, as boatman, and the writer. The triangulation and most of the topographic work was done by Mr. Mahlo, who, fortunately, had recently arrived in camp with a transit, as topographer for the expedition. At such points only as it was necessary to land for triangulation the writer made some geologic observations, took some photographs, and aided in topographic work. As but few landings were made and the snow sheet, still several feet thick, usually descended down to near the beach, the geologic observations were necessarily very few and somewhat local. Progress in this triangulation work was slow, on account of the rain and fog which for days delayed observation, and of storms which so roughened the sound as to compel our craft to seek shelter until the swells subsided. The work was begun below Orca, near Eyak, May 8 and completed at Valdes on the 21st. Our supply of provisions, which had become exhausted by delay during the work, was kindly replenished by Mr. Thurstonson at Goose Island.

Subsequently, from May 25 to 29, the writer made a hasty geologic and topographic reconnaissance of Port Fidalgo and Landlocked and Galena bays. On this trip transportation, which was kindly furnished by the expedition, consisted of a three-holed bidarky, or seal-skin boat, paddled by two natives. Pl. XXIII, taken in rain, which fell most of the time, shows somewhat the character of the topography about the head of Port Fidalgo.

A subsequent trip down the sound, made late in June by Mr. Mahlo, added some valuable contributions to the topography of Montague, Knight, and Latouche islands, and was also helpful in suggestions on the geology and ore deposits of that region. With the exception of the above explorations, the wait for pack-train transportation into the Copper River country extended from about April 20 to early in August. The pack train, which in the meantime had been procured by the commander of the expedition, through the War Department, from the States, arrived in Port Valdes July 5, but as most of the horses were wild from the range and had never been broken to service, some time was required for breaking them, and later for partially shoeing them for the trip across the glacier. It had been hoped that the much-advertised so-called summer trail up Lowe River would prove practicable by this time, but the volume and swiftness of the stream issuing from Valdes Glacier, and that which flowed through Keystone Canyòn on Lowe River, making it impassable for man or beast, caused all further attempts in this direction to be abandoned for the time being.

Finally, on the morning of August 5, the main part of the expedition to which the writer was attached, consisting of 23 horses and mules and about as many men, in charge of its commander, made a hasty and somewhat hazardous trip of nearly two days across Valdes Glacier over the Coast Mountains, nearly 5,000 feet high, and into the drainage of the Copper River Basin—our objective field of work. The trip of this pack train across the glacier was in many respects remarkable, surpassing, perhaps, anything of the kind that had ever before been undertaken. The ascent at the partially moraine-covered steep foot of the glacier, where the ice topography is much roughened by ridges and crevasses (Pl. XXII, *B*), was accomplished at the more difficult points by chopping a series of steps or stairways in the ice on the sloping crest of the ridges, up which the pack animals with their burdens were persuaded to climb. They were sometimes aided by a number of men pulling at their halter ropes in the lead. Not rarely, on the animal's strength giving way, or upon his losing his balance upon the treacherous foothold, horse, pack, and all rolled and slid some 40 feet or more down the crevasses which, fortunately, at this point were not deep, so that in every case, though often with great labor, the animal was extricated with no other damage than profuse lacerations, cuts, and bruises, chiefly about the feet and legs, which at times were so severe that tight bandaging was necessary to prevent death from loss of blood.

After a few miles of this sort of struggle the top of the third bench was reached, whence better progress was made. During the afternoon the fresh-snow line along the mountains was found to be about 1,000 feet above the edge of the glacier. By night the site of the former Twelvemile Camp, at the foot of the fourth bench, was reached, where, in the rain, sleet, and fog which had prevailed most of the day, the party went into camp on the bare ice, as the snow had now almost totally disappeared from the lower reaches of the glacier, except where remnants partially filled and bridged over some of the crevasses. These snow bridges which arched the deep crevasses formed the most dangerous part of the trip, as the snow was in a decaying state and liable to slump down at any moment, especially when disturbed by the weight of man or horse in crossing. The span varied from a few to nearly a score of feet, with the crevasses descending hundreds, in some places probably thousands, of feet in depth. Over many of the narrower crevasses some of the horses leaped with courage and skill that would do credit to the most highly-trained animals. They excelled the mules both in ability in leaping and in courage, skill, and effort toward aiding in their self-extrication at the critical moment.

On the fourth bench the crevasses were many, and usually had a trend slightly diagonal across the glacier, but often nearly transverse. At one point they were so numerous as to form a most labyrinthine maze. For awhile during the forenoon our course was so irregular and zigzag around crevasses that we probably traveled 3 or more miles to make a mile in advance. At one point the van of the train after traveling for half an hour had not gained more than 300 feet on the course, being yet within a stone's throw of the rear of the train, which still had to make the half hour's travel to gain this stone's-throw distance. The risk taken by the men in extricating some of the animals was often considerable. Toward the foot of the summit the snow, still soft, increased in depth. The summit was, as usual, enveloped in a storm of rain, fog, and sleet, and was swept by a fierce wind from the southwest. The summit was not so cold, however, as when first visited by the writer in May, yet cold enough to cause man and beast to hasten away. By evening we had descended to Onemile Camp, about a mile below the foot of Klutena Glacier. Here the wind which descended from the summit and the glacier, having lost its moisture, was cold and very dry. Farther down the valley the hillsides were clothed with variegated flowers, moss, grass, and timber. Here, at Onemile Camp, a day's rest was taken and the parties were organized for work. Mr. Mahlo, topographer, and the writer were each furnished with several men, pack horses, and a saddle horse. On account of the roughness of the country horses could be ridden but very little, yet they were of service in transporting the camera, instruments, and other luggage of a personal nature.

As the season was now already far advanced, it was quite apparent that a survey to the head of the Copper and the Mount Wrangell district, as originally intended, would be impossible. The work of the writer was therefore carried down the Klutena River to Copper Center, on the Copper River, then down the Copper to the mouth of the Tasnuna, and thence westward, closing the circuit to Valdes by way of the Tasnuna and Lowe rivers (map 21).

After a day's rest at Onemile Camp, the writer, on the morning of the 8th, returned to the summit to make a hasty examination of such geology and topography as might be exposed and procure photographs, if possible, of that little-known region. The atmosphere, however, continued so thick with rain, sleet, and fog as to delay the completion of this work until the 10th. For shelter and subsistence during this time on the summit thanks are due to Messrs. Joseph F. Kaher and Barney Stevens, who at the time happened to be camped on the summit. These men reported that the storm of rain, sleet, and fog, with occasional snow, had been constant for over three weeks. Fortunately, however, toward midnight on the 9th it began to clear, so that work could be done on the following day, after which the writer returned to camp. In the meantime Mr. Mahlo had taken up the topography in the head of Klutena Valley, so that on the 11th the work was continued 3 miles farther down the narrow canyon valley to Twelvemile Camp, so called from its supposed distance of 12 miles from the summit. Here the valley naturally widens to receive Stephens Creek, or the southwest fork of the Klutena. Here also the first good timber occurs, this being practically on the timber line. In crossing the Klutena above Twelvemile Camp two of our pack animals were caught by the current and swept downstream for some distance, but were heroically rescued by the men. The fall of the river for some miles here was found to be 60 feet to the mile.

Twelvemile Camp, which at the time of our visit had about 100 people, is practically on timber line. Here the great majority of prospectors during the spring abandoned sledding and packing and began boating down the Klutena, the boats being built from the rough lumber whipsawed from the native green spruce. Later a sawmill, which was set up about 3 miles farther down the river, at the confluence of the forks—the present site of Sawmill Camp—was for some time very prosperous.

From Twelvemile Camp the trail continued down the northwestern side of the river, soon crossing Stephens Creek, which was found to be as large and swift a stream as the main fork of the Klutena, and had to be waded and swum with care. It, like the main fork, was seen to head in glaciers of considerable size, at apparently less than 10 miles above the confluence. From the glaciers the stream has brought down much gravel.

From the confluence northward to the head of Lake Klutena a gradual widening in the valley is perceptible. The main part of the river holds to the south side of the valley, with one or more sloughs meandering along the north side. On slate outliers at its delta, or where it enters the head of the lake, is the site of Twentyfourmile Camp, so called from its supposed distance from the summit of Valdes Glacier. It was found to contain about 100 people.

Hallet River, which enters the head of the lake from the southwest, was found to be a stream similar to the main forks of the Klutena. Judging from the milky color of the stream, it is obviously of glacial origin. The trail during much of this distance meanders over foothills, some of which are pretty rough. At the time of our passing it was much obstructed by fallen, partially burned, and burning timber. West of the head of the lake the obstruction from this cause—the burning timber—became serious. Below this the trail for the most part followed the lowest gravel terrace near the shore, and was good.

Cranberry Marsh, a camp of some eighty or more people at the northwestern elbow of the lake, was reached on the 18th, whence the writer made the ascent of Cranberry Peak, from which observations were taken. Starting from here, some topographic and geologic work, covering a period of several days, was done about the lake by boat. At the foot of the lake was found a camp of more than 200 tents, shacks, and cabins, occupied by about 350 people, many of whom were prospecting in various directions in the surrounding region. It was located principally on the northern side, but some tents were also on the southern side of the lake. Here the tops of Sunny and Carter mountains were visited by the writer for observations of the country toward the north, in the direction of and beyond the Tazlina. From here an excellent view is also obtained of most of the upper part of the Copper River Valley and of the western side of the snow-covered Wrangell group of mountains, some 50 miles distant, on the eastern side of the Copper River Basin.

To accommodate the Klutena exodus of prospectors from the Copper River country, a small steam yacht plied from the foot to the head of the lake, doing a very prosperous business. Almost every day small parties of these people were encountered who had lost their outfits in the fierce rapids of the Klutena and were trying to wend their way out to Valdes, often in a stranded condition (see Pl. XXII, *A*).

Upon leaving the mountains at the foot of the lake the trail follows down the north side of the Klutena, which here flows between clay and gravel bluffs 500 or 600 feet high (Pl. XXVII, *B*), to the Copper River at Copper Center. During the most of this distance the trail is down near the river, but at times is on the bluff. Copper Center was reached August 29. It is located on a low terrace or flat, mostly along the western bank of the Copper and northern bank of the Klutena. This place, namely, the Copper River at the mouth of the Klutena, was found by the transit work carried on by Mr. Mahlo from Valdes to lie in longitude 28 miles east of that given on all previous maps and charts; and in closing our work on to Valdes the Copper River at the mouth of the Tasnuna was found to lie 13 miles east of the longitude previously given for it. The first change or correction, that for the Upper Copper at the mouth of the Klutena, harmonized with the traverse work of Mr. W. C. Mendenhall, extending from Cook Inlet northward to the Tanana River, during the summer of 1898, while the correction at the mouth of the Tasnuna seems to agree well with that made by the Ritter party, of the United States Coast and Geodetic Survey, during the same season, in locating the mouth of the Copper 10 miles farther east than is given by all previous maps. The population of Copper Center at the time of our visit was about 500 or 600, dwelling mostly in tents, and a few in log cabins. A store, post-office, and hotel were also kept here in tents by Mr. Hollman. Many of the prospectors were actively engaged in felling timber and building log cabins for winter use. From Copper Center one part of the expedition, consisting of 13 men and a pack train of 17 horses, in charge of the writer, proceeded across the Klutena and down the west bank of the Copper to Valdes, while two other parties, in charge of Captain Abercrombie and Lieutenant Lowe, respectively, proceeded to Mentasta Pass and Fortymile, on the Yukon.

The members of the downriver party, besides the writer, consisted of Mr. Mahlo, as topographer; Messrs. Cahill and McFarland, as packers; Mr. Bjornstad, as cook; Corporal Koehler and Privates Hallet, Bence, Garrett, Archer, and Gardner, as scouts, explorers, camp hands, and axmen; and Messrs. Jaffey and Hincky, as boatmen.

Hitherto our route down the Klutena had followed a well-beaten trail traveled by several thousand prospectors; but now, as the country ahead of us was unknown, to lighten the load of the horses, some having very sore backs and others being lame, the bulk of our provisions, procured mostly from prospectors at Copper Center, was sent down the river in boats in charge of Jaffey and Hincky, with instructions to leave a small part of the same at Taral, about 60 miles below Copper Center, and to hold the balance, with the boat, at the mouth of the Konsina, some 40 miles farther down, until our arrival at that point.

Having swum our horses and boated our outfits across the Klutena the day previous, on August 31 we set out with the pack train down the Copper River. We had hoped to make 7 or 8 miles a day, but the nature of the country soon convinced us that hard work would be required to average 3 or 4. There was no continuous trail, though at times short portions of Indian trails were found in the river flats or occasionally on the edge of the overlooking bluffs, but even here considerable cutting was required to get the pack train through. Adherence to the bluff was prevented by the steep-sided canyons cut far back into the plateau, while the frequent termination of the river flats, where the stream was undercutting the bluff, compelled a climb of 500 to 600 feet to the bluffs again. In the flats, often traversed by sloughs, were encountered mire and quicksands, from which the animals were extricated only with much difficulty and labor. The same is true of deposits met with in some of the canyons.

Two or more men were kept in advance to explore and find out a possible route and cut trail accordingly. At one point the train phenomenally worked its way up a 600-foot bluff, which under less pressure would have been considered impossible. Two of the animals, becoming overbalanced, rolled down nearly 100 feet, but fortunately were rescued without serious injury.

The second chief of the Stiphan natives gave some valuable assistance as guide, but could not be persuaded to go far from his village, nor were his ideas of the trail required by a pack train of much true value.

When the Tonsina was reached, on the evening of September 9, this stream, which had been reported as only a creek and easily fordable at any point, was found to be bank full and about as large as the Klutena and fully as swift. After reconnoitering the stream as far as 7 or 8 miles above its mouth it was decided to swim the horses and cross with our outfits on a raft, as there was no boat at hand. Timber was felled for the purpose, and the logs were tightly lashed together by ropes, under the direction of our cook, Bjornstad, who was also an experienced seaman. The raft as finished on the 14th was about 12 feet wide by 20 feet long and equipped with a pair of strong rowlocks and a sweep lock for the rudder. Having swum our horses across, at noon of the 14th the raft, with our outfits and all on board, was pushed out into the stream, but was soon aground on a sand bar at less than one-third of the way across. By fording and swimming one of the best mules, heroic efforts were now made by Hallet to carry one end of the rope from the raft to the opposite shore, but after three trials this was given up and the raft was pushed off the bar into the swift current, whose velocity was about 12 or 15 miles an hour. Though our best men were at the oars and sweep, the selected landing on the opposite shore could not be made. The raft, seized by the current, soon became unmanageable and was carried downstream under some long overhanging trees known as "sweepers" by Alaskan boatmen. Here two of the men, apprehending danger, jumped from the raft, seizing the overhanging trees, by means of which they hoped to gain the north shore. In this one of them, Gardner, was successful, but the other, Archer, who, unfortunately, could not swim, failed and was drowned.

In its downstream course the raft was soon carried near the opposite shore, where a couple more of the men jumped off and gained the south shore in safety. Soon after the raft was hard aground on the head of a small island in midstream. So great was the impact of the current in the rear and the weight of the raft that the latter could not be moved with the help at hand. The cargo was therefore unloaded and the raft taken apart and reconstructed after the heavier logs had been discarded. It was then reloaded, and from it a couple of ropes passed to the opposite shore and coiled about trees, where, operated by the men on shore, they were designed to make sure of drawing the raft ashore, when it was again launched into the current, for it was now growing quite dark. This, however, failed, as the ropes were let go or became loosened, and the raft again started on its wild career down the stream. As it neared shallow water along the south shore another of the men jumped off and gained the shore, calling to the rest to jump for their lives, which all would gladly have done but for our cargo, which we knew would have been a total loss, and its loss meant the stranding and failure of our expedition. The small island and distributary were quickly passed and the raft was madly seized by the mainly current of the river. At about three-fourths of a mile farther down, where the river makes a sharp bend to the left, the raft struck the edge of a large log jam and was partially overturned and drawn under by the force of the current. Much of the cargo also was lost, but fortunately none of the men, who now were but five in number, consisting, besides the writer and Mr. Mahlo, of our two packers, Messrs. Cahill and McFarland, and our cook, Mr. Bjornstad. To these men, for aiding at this moment of peril in the rescue of such part of the cargo as could be seized, the special thanks of the writer and of the expedition are due, for without the rescue of this material the circuit to Valdes would probably not have been completed.

By wading, poling, and bridging about a quarter of a mile over the log jam, beneath which the water flowed from 7 to 10 feet deep, our little party of five, groping its way in the dark, finally reached the south shore, where the night was passed about a smoldering log fire, for the bedding and blankets which had been rescued could not be brought ashore in the dark. On the following morning, upon the balance of the men coming down the river, the party, with the exception of Archer, was reunited. The remnants of our swamped outfits were next towed ashore and an effort made to dry them by sun, wind, and fire during this and the next day. To take the place of the lost pack saddles and aparejos, girths and packing equipments of an impromptu nature were improvised for the animals by the packers. Our provisions, which on account of the unexpectedly slow progress and hard work down the Copper had been nearly exhausted, had now totally disappeared in the river. Fortunately a slender allowance—all that could be spared—was kindly furnished by the Colonel Fritz prospecting party from a few miles up the Copper; so, on the morning of the 17th, after a last ineffectual search for Archer's body, with but a pittance of flour, evaporated potatoes, and tea in our commissary, we set set out for Taral, 40 miles distant, and reached it on the 21st, after five days of hard work. In the last 10 miles above Taral much of the trail was over foothills indescribably rough and some of them dangerous. During this time salt, baking powder, and sugar were luxuries not to be thought of. From the Stiphan or "Stick" natives, about 12 miles above Taral, some fresh salmon were obtained, which in the absence of seasoning and salt were boiled and eaten with comparative relish in true Siwash style. As our hunger during this time surpassed anything ever before experienced by any of the party, and as all were much weakened for want of food, the gratification at finding our supplies, left here at Taral by Jaffey and Hincky, all in good condition, was more than ordinary. We were now at the head of Wood Canyon, where the Copper River enters the Chugatch Mountains of the St. Elias Chain. A few days were taken here for rest and recuperation, during which time information gathered from the natives and prospectors of the region and reconnoitering by our own party developed the fact that to proceed farther with a pack train down the river would be impossible on account of the ruggedness of the mountains on the sides of the canyon. The horses were accordingly left behind, with letters concerning them in the hands of the natives and prospectors, to the commander of the expedition, should he come that way, and on the morning of the 27th, in a large boat kindly furnished by the Downey and Pennelle prospecting party at the foot of Wood Canyon, the work was continued on down the river by boat. A light portage over several miles of rugged trail was previously made by the party from the head to the foot of Wood Canyon, the bulk of our outfits being carried through the canyon in the boats of prospectors.

Upon leaving the pack animals our two packers, Cahill and McFarland, volunteered to remain with the party and help carry the work through to Valdes, which they did with credit.

At the mouth of the Konsina we found Jaffey and Hincky, with our supplies, awaiting us. The instructions of the commander to the writer had been to ascend the Konsina with the pack train to Valdes if practicable; but a day's reconnoitering from adjacent mountains in the mouth of the valley demonstrated that on account of the ruggedness of the mountains and canyons (Pl. XXIX) the ascent would be impossible for a pack train, and since the valley seemed to head well up in snow districts it seemed unwise for our party in its present condition to attempt its exploration afoot with no other supplies than which could be packed on our backs, for the weather was now becoming cold. Most of our heavy clothing and some foot gear had been lost in the Tonsina, so that most of us were but lightly clad and some of the men were rapidly becoming barefoot. It was therefore decided instead to carry the work up the Tasnuna—a more open valley.

Before leaving camp at Dewey Creek (Pl. XXIX), just opposite the mouth of the Konsina, our food supply was further replenished by provisions from prospectors, and still further reinforced by some from the commander of the expedition, who arrived just as we were about to embark. The next day was taken to investigate Cleave Creek, which the writer ascended to the foot of the glacier (Pl. XXX). It is a good type of the foot or terminus of the valley glaciers in the region. This valley had been erroneously reported by a couple of members of our party who had visited it to be a wide open valley and was thought to connect with Lowe River, but it does not. The creek is named in honor of the hospital steward, who in company with Corporal Heiden was among the first of our expedition to explore the Lowe and Tasnuna rivers and much of the rough country about Valdes.

Continuing down the Copper River by boat, our party camped in the mouth of the Tasnuna valley October 1. The boat was beached and cached, and during the next two days some observations were made and the nature of the neighboring country was investigated to ascertain a practicable route for an overland trail up the valley. The valley was found to be wide and flat, being here filled by silts from the Tasnuna Glacier, and by backwater of the Copper at flood season. These flats were soft and traversed by sloughs and lagoons and dotted by ponds, compelling the pedestrian to hug the base of the steep mountains to avoid mire. This unfortunately meant the expenditure of some time and labor in cutting trail, for every inch of the surface not claimed by the frequently overflowed flats was covered with a dense growth of tall alder and devil's club, which extended high up the mountains.

Shortly after midnight on the morning of the 3d, on which day we planned to set out up the valley, Mr. Mahlo was seriously attacked by heart disease, which exhausted him completely, and for many hours threatened to prove fatal. Not until the following forenoon was relief or rest obtained. As weakness throughout the day continued extreme, it became quite apparent that, with no medical aid or remedies of any sort at hand, he would not for some time be able to proceed with the party over the trail, though he frequently expressed determination to try it, for the trip, though not more than 50 miles across the mountains, was, owing to the lateness of the season, somewhat doubtful, and promised, in some respects, to be more severe than any part of the journey yet made; for, beside the ruggedness of the country, in some previous seasons 7 feet of snow was known to have fallen on the mountains before the 1st of October. This, with the present coldness of the nights and the gradual downward creeping of the fresh snow line on the mountains above us, seemed to be a warning that it was time to get out of the country. Besides we were due in Valdes by the 23d, if we hoped to catch the last steamer out to the States. Therefore, two of the men, Garrett and Gardner, were detailed to escort Mr. Mahlo down the river by boat as soon as he should regain sufficient strength to be moved, while the circuit and topography was closed to Valdes by the writer. Accordingly, on the following morning, October 4, the balance of the party, with packs, set out up the valley. Toward noon another of our men, Corporal Koehler, giving out, returned to camp and joined the hospital party, with which later he proceeded down the river by boat.

At the outset our trail up the Tasnuna was on the steep sloping base of the mountains along the north edge of the flats. The first day, being aided by trail which had already been cut on the several previous days, the distance made was about 2 miles. On the several succeeding days, however, owing to the density of the alder and devil's clubs and the labor required to cut trail through it, a distance of about a mile was found to be a heavy day's work. This was very discouraging to the men, for at this rate, with our provisions, Valdes could not be reached, and the character of the country ahead of us was unknown. Feeling assured, however, that the mud flats could not continue long, and hoping for better progress as soon as they should be passed, we pressed on, and toward noon on the 6th were able to descend to the flats, which were here gravel, being the periphery of Schwan Glacier[1] delta. From here on better progress—from 3 to 5 miles a day—was made, the best being on the moraine gravel delta of the Schwan and Woodworth glaciers, which here crowd the Tasnuna River to the extreme north side of the valley. Often we traveled by following game trails and wading for long stretches upstream in the river and its sloughs of ice water, sometimes waist deep, where the banks were overhung by underbrush and devil's club too dense for penetration.

For about 15 miles up from the Copper, nearly to Woodworth Glacier, the Tasnuna is not nearly so swift as the tributaries of the Upper Copper. So far as seen, it could probably be ascended to the upper edge of the silt or mud flats, some 6 or 7 miles, by a small steamboat. Above Woodworth Glacier the stream becomes quite torrential, and the valley, which for some time has been narrowing, contracts into a canyon of mild form a couple of miles in length (Pl. XXXI), at the upper end of which is a narrow, impassable gorge (Pl. XXIV) only 4 or 5 feet wide and a couple of hundred feet deep, through which the stream debouches in a torrent of foam. The trip up the canyon was anything but pleasant; the bed of the stream, which had to be crossed frequently and waded for long stretches, was very rough and bowldery and covered with a thick coat of slippery ground or anchor ice, which in the swift current made footing very insecure for a man with a pack on his back. The gorge was passed by cutting trail and climbing 400 feet up the steep sides of the canyon. Beyond this the rest of the Tasnuna Valley was for the most part open, with a low divide at its head (map 20).

The divide, which was crossed on the 13th, was found to be 1,800 feet high, with high snow mountains on the north and south. On the opposite or west side of the divide the drainage flows westward into Lowe River. Here, on the night of the 12th, water froze to ice an inch in thickness; also on the night of the 13th. On both of these nights our camps were in green alder near the divide, and the men were beginning to "freeze out."

From the divide down Lowe River to Dutch Camp Basin, a distance of about 10 miles, the route, following for the most part well-beaten bear trails on the benches along the north side of Heiden Canyon, was

[1] Named in honor of Theodore Schwan, colonel and assistant adjutant-general U. S. Army, and brigadier-general of volunteers.

good. At Dutch Camp Basin, which was reached on the 15th, we had descended to 630 feet, and found a heavy growth of tall spruce. Here we also met Corporal Heiden's detachment, with pack animals from Valdes, cutting trail over the proposed new route northward through Thompson Pass. The next day Mr. Powell, who had been triangulating up from Port Valdes, arrived in camp. From Dutch Camp Basin our outfits were borne to Valdes on pack animals of the Heiden party by way of the steep trail over the south end of Hogback Mountain, where it rises about a thousand feet above Lowe River, to avoid the impassable Keystone Canyon, which begins at the foot of Dutch Camp Basin and continues for about 4 miles down the river. This mountain was crossed on the 17th, in fresh snow about a foot deep, during a snowstorm which had begun on the 5th and was more or less continuous, with some rain, until we arrived at Valdes, several days later; but as our foothill camp on the 17th placed our horses beyond danger of being cut off by snowslides, for which this district is noted, there was no further ground for apprehension. The remainder of the route was down the north side of Lowe River Valley, sometimes on the edge of the valley flat, but mostly over foothills, especially below Camp Comfort, and finally over the gravel delta to Valdes, which was reached on the evening of the 19th. From Valdes the Copper River expedition embarked October 26 on the home-bound vessel *Excelsior*, which, after touching at Orca and Yakutat and being delayed for some time at Juneau and Hunters Bay, on the southern side of Prince of Wales Island, finally arrived at Seattle on November 10.

ROUTES AND TRAILS.

The only route used for getting into the Copper River country from Valdes during the season of 1898 was the Valdes Glacier route, (see table of distances p. 366.) Starting from Valdes the trail leads 4 miles northeast, with a very gentle rise over the delta gravels, to the foot of Valdes Glacier, thence about north for 18 miles up the glacier to the summit, which is 4,800 feet high. The glacier is broken or transversely marked by four or five successive long benches or terraces, from one to the other of which the rise of 100 feet or more is usually sharp and sometimes difficult, the topography of the ice being very rugged, with crevasses, ridges, and turrets (Pl. XXII, *B*). With the exception of these benches, the ascent from the foot of the glacier to near the summit is gradual, but just before reaching the top there is a steep rise of 1,000 feet at an angle of 15° to 20°. The pass is guarded by two prominent peaks, one on each side, standing about a mile apart. From the summit the trail descends rapidly, but nowhere abruptly, for a distance of 6 miles through a canyon-like valley to the foot of Klutena Glacier, which is the source of the Klutena River.

From the foot of Valdes Glacier to the foot of Klutena Glacier, a distance of 25 miles, there is neither vegetation, timber, nor brush, but only a waste of barren rock walls, peaks, and snow and ice, so that fuel for camping while on the glacier must be brought from either end. From the foot of Klutena Glacier the trail continues down the north side of the river and lake to Copper Center, where the elevation is about 1,050 feet.

From Copper Center to the Tanana, Yukon, and Fortymile rivers the best and shortest route is the Millard trail by way of Mentasta Pass. This trail, crossing the Copper, bears northeastward somewhat near the base of Mounts Drum and Sanford, over the high ground of the big bend of the Copper, and is said to be a good cut horse trail from Copper Center to near the Copper River below the mouth of the Slana.

Table of approximate distances by glacier trail.

Place.	Miles.	Elevation in feet.
Valdes	0	0
Foot of Valdes Glacier	4	210
Top of third bench	8	830
Twelvemile Camp, at foot of fourth bench	16	2,750
Foot of summit	22	3,800
Summit	23	4,800
Foot of Klutena Glacier	29	2,020
Onemile Camp	30	1,960
Twelvemile Camp	33	1,930
Sawmill Camp	35	1,740
Twentyfourmile Camp, at head of Lake Klutena	46	1,673
Cranberry Marsh	64	1,673
Foot of Lake Klutena	79	1,670
Amys Landing	85	1,370
Cox Landing	90	1,320
Cooks Bend	95	1,240
Bowlder Spring, on bluff	97	1,590
Copper Center, at mouth of Klutena	112	1,050
Mentasta Pass (by Millard trail)	205	2,300

From Copper Center another route leads along the northwestern side of the Copper River to the mouth of the Slana. This trail, however, is much longer than, and not so good as, the Millard trail.

From the northwest bend of Lake Klutena at Cranberry Marsh a trail branches up Salmon Creek Valley and leads by way of Lake Lilly northward to the Tazlina River; thence down that river to the Copper. This route seems to have been started chiefly by prospectors before the snow disappeared in the spring of 1898, after which the marshy country over which it ran led to its disuse. That part of it down the Tazlina, however, is an Indian trail, and is said to be pretty fair and to continue westward down the Matanuska and Knik rivers to Cook Inlet. Long ago it was in use by the Russians in traveling from Cook Inlet to Copper River.

Previous maps have reported a good trail from Taral northward on both sides of the Copper. This is a mistake, for although portions of a trail are here and there met with, they are liable at any time to run out, usually extending but a short distance from the native villages. The survey party, in coming down the Copper to Taral, found it necessary to cut trail most of the way. From Taral southward on the east side of the Copper River there is a portage trail of about 4 miles, for foot only, to the lower end of Wood Canyon, from which point southward through the mountains there is no trail save that recently cut by prospectors at difficult points for towing up boats. An Indian trail is said to ascend the Chittena River from Taral to above the forks, but is not suitable for pack animals.

A proposed route from Valdes into the Copper River country starts up Lowe River Valley, which it would leave at Dutch Camp, and bearing off to the north would cross the headwaters of the Tonsina, and, descending Manker Creek Valley, strike the Klutena River and trail just below the lake. It runs over some unexplored country, but seems to be by far the most suitable of all for railroad and pack train purposes. At the head of the Tonsina a branch trail strikes off to Sawmill Camp just below Twelvemile Camp. Some engineering will be required on Lowe River to make the trail practicable for all-summer travel.

Another feasible route would be from Valdes up Lowe River across the divide (which is only 1,800 feet high), and down the Tasnuna River to the Copper, whence the transportation up the Copper would have to be by boat, preferably a light-draft steamer of special power.

POPULATION.

Prince William Sound natives.—The natives about Prince William Sound, probably several hundred in all, are known as Aleuts. They have long been under missionary influences, chiefly Russian. Their chief settlements or villages are Tatitlak, Nuchek, Chenega, Eyak, and Allaghanik. They trade with the whites and are often employed by them, chiefly in hunting, fishing, and boating. They are not a very healthy people, consumptive tendencies being common among them.

Prince William Sound whites.—About a dozen white men have married into the native tribes, and have become residents there, being engaged in trade or some other industry, such as blue-fox raising.

At Orca and Eyak are large salmon canneries, owned and operated by American companies during the summer months only. The labor employed here is mostly Chinese, imported from San Francisco for each season only. Orca is also a United States post-office, with monthly mails.

Copper River natives.—The Copper River natives are distinct from the Aleut tribes on the coast, and seem to be more closely allied to the North American Indians; their total number is probably less than 300. The country is apportioned off politically, each clan adhering closely to its own district in hunting and fishing. Until recently those best known to the whites were the Taral or Chittena natives, whose chief, Nicolai, has been mentioned by Lieutenant Allen, Lieutenant Schwatka, and Dr. Hayes. Nicolai, however, has now lost his influence among his people, who, with unanimous praise, refer to Hanegetta as the most wealthy, powerful, and capable leader of their tribe. The Tazlinas and Gakonas, constituting the Upper Copper River natives, are commonly known as the Kulchanes. They are said to number about 200, the Tazlinas about 125, and the Gakonas about 70. The Tazlinas occupy the country from the Copper River westward along the Tazlina River and Lake to Knik River. The country from above Lake Klutena down the Copper to near Taral is occupied by the "Stick" natives, headed by the sturdy chief, Stiphan. (Pl. XXV.)

The Copper River natives on the whole seem to be honest. Though poor, they are hospitable and obliging people, and on several occasions last summer they saved the lives and property of whites who had gone astray.

Prospectors and explorers.—Owing probably very largely to the liberal advertisement of passage to the Copper River region by transportation companies, many prospectors and adventurers bound for the Klondike or to indefinite destinations in Alaska were led, in the season of 1898, to try their fortunes in the Copper River country. Many hoped at the same time to proceed by way of the prospective all-American route into the gold districts of the Upper Yukon.

The influx began in February and continued until late in June, during which time it is estimated that more than 4,000 people and their outfits landed at Valdes, the great gateway to the Copper. Of these, more than 3,000 are supposed to have entered the Copper River Basin over the summit of the Valdes Glacier. In the meantime several hundred prospectors landed at Orca and attempted to ascend the Copper River from its mouth, but very few of them reached Taral and the Chittena.

The exodus began early in May and continued until late in October, many returning over the glacier to Valdes afoot and many down the Copper by boat. Probably 300 remained in the country, mostly at Copper Center, during the winter of 1898–99, and a score or so at Valdes, on the coast. Among those in the interior numerous cases of scurvy, some of which were serious, are reported to have occurred.

The letter mail taken from Valdes into the Copper River during the three months of August, September, and October numbered more than 4,200. Applications for the establishment of an official post-office at Valdes and at Copper Center are now on the files of the Postmaster-General.

CLIMATE.

Prince William Sound.—The climate at Prince William Sound is mild, with a high average percentage of cloudiness, very heavy precipitation, and great barometric range.

Spring, midsummer, and a part of the fall are rainy and foggy. The annual snowfall is from 7 to 10 feet. Some fierce blasts are said to occur in winter.

During the summer of 1898 the weather at Valdes was as follows:

From April 24 to May 1: Continuous heavy snowfall, with some thawing; little or no wind.

May: Generally rainy, foggy, and mild.

June 1 to about July 10: Fine weather, generally bright and sunny; middays warm, but not hot; temperature generally comfortable to cool; little or no fog.

July 10 to August 10: Generally rainy and foggy.

Valdes Summit.—The Summit is almost constantly enveloped in storm and fog, with precipitation nearly always in the solid state.

Copper River district.—The change of climate experienced in a few hours' travel of 7 or 8 miles from the bleak, frigid, and stormy summit down into the Copper River Basin in August is remarkable. Here the slopes are clothed with moss, timber, variegated flowers, grasses, and berries, while the clear, bright skies rival the halcyon summer days of the Upper Yukon or the rainless districts of western United States.

According to the reports of prospectors, the summer months are bright and warm, with midday often hot; night frost may occur at any time, but is very rare in June, July, and early August. The streams begin to freeze late in October and snow to fall a few weeks later; the annual snowfall is from 2 to 4 feet. The winter seems to be much the same as on the Upper Yukon, though not quite so cold; but it is a storm-ridden country, swept by fierce blasts, descending from the interior to the coast.

ANIMAL LIFE.

Fish.—In the lakelets in the Copper River country several species of handsome lake trout occur, but the fish most relied upon for subsistence by the natives is the salmon, notably the king salmon, which normally ascends the Copper and its tributaries in great numbers annually. Large quantities had already been dried by the prospectors on Lake Klutena early in August, and the fish was still running late in September between Taral and Copper Center.

Quadrupeds.—There is large game in the Copper Basin, several species of bear, caribou, and some moose. In the mountains toward the coast Rocky Mountain sheep were shot by prospectors, and wolf are also said to occur. Beaver are present on most of the tributaries and lakelets. Red and gray squirrel, though usually of small size, are abundant throughout the timber. No rabbits were seen by us, though they were long ago reported by Allen; porcupine are common. A species of field mouse was seen, and a third-grown or dwarf frog.

Birds.—The eagle, black crow, hawk, goose, duck, ptarmigan, grouse, sea gull, sandpiper, snowbird, American robin, brown thrush, oriole, blackbird, woodpecker, and many other migratory species of birds were seen.

Insects.—During the months of May, June, and July the mosquito is a veritable pest. Sand flies and gnats also occur later in the season. Flies, grasshoppers, beetles, butterflies, moths, and several species of *Neuroptera* were seen on the mountain slopes at the foot of Lake Klutena late in August.

VEGETATION.

Prince William Sound.—About Prince William Sound the chief timber is spruce, sometimes called Sitka spruce, with some yellow cedar, cottonwood, willow, and alder. The poplar is usually confined to the flats in the mouths of the valleys and inlets, where some good grass also occurs. The timber line is about 2,000 feet, above which only moss and dwarf shrubbery grow. All the hardier garden vegetables were successfully grown in Valdes during the last summer.

Copper River district.—In the Copper River district the country is comparatively well, though not densely, timbered. Spruce is the dominant and most valuable tree, and has a good, tall growth; hemlock, aspen, balm of Gilead, birch, poplar, alder, and willow are also present. The timber line scarcely reaches to 2,000 feet. Though the surface is normally clothed with a dense growth of moss, large areas of good grass also occur. The grasses represent half a dozen or more species, some of which resemble the silvertop, redtop, and bluejoint of the Western States. They are of a rank, succulent growth, and often 3 or more feet high, excellent for grazing and seemingly good for hay purposes. Wild flowers, many species of which are identical with those found in the States, occur in great abundance. In luxuriance of growth the wild roses along the Copper greatly surpass anything ever seen by the writer in the States. The ripened hips of the rose are much used by the natives as food, and in the absence of fruit diet the members of the party also partook of them with much relish. In many localities wild red currants occur in great abundance, also great quantities of the moss berry, or ground cranberry; and the black currant, gooseberry, blueberry, huckleberry, red salmon berry, red raspberry, cranberry, and a kind of viburnum, or high-bush light-red cranberry, are also found. From early June to the close of the season of 1898 all the ordinary garden vegetables were successfully grown at Copper Center by Mr. Jacob Sittel, a gardener from Portland, Oregon.

EARLIER DISCOVERIES AND EXPLORATIONS.

Prince William Sound.—The southern coast of Alaska was first discovered by Bering and Cherikoff (Russian) in 1741, in which year, on July 20, Bering anchored at Kayak Island, off the mouth of the Copper River, and about 100 miles east of Prince William Sound, from whence he beheld and named Mount St. Elias. The discovery of Prince William Sound itself, however, and much of the adjacent mainland coast was first made by the English, through Captain Cook, in May, 1778. He named Cape Suckling, Controller Bay, Kayak Island, Cape Hinchinbrook, Snug Corner Cove, Montague Island, and applied the name of Prince William Sound to the entire inlet. These names are all in use now. The sound was further explored by Lieutenant Fidalgo under the Spanish in 1790. Fidalgo named the bays or ports of Gravina, Valdes, and others. Again, in May, 1794, the English, through Vancouver, made further surveys, naming Port Wells, Port Fidalgo, Hawkins Island, and other places.

Copper River.—In 1779 Caudra (Spanish) correctly surmised the location of the mouth of the Copper and expressed in his journal the conviction that a large river must enter the sea between Kayak and Nuchek islands. In 1783 Nagaieff (Russian) discovered and ascended the Copper for a short distance. In 1794 Purtoff made a passage to the second mouth of the Copper from the west side. In 1796 an expedition under Samoyloff to the Copper River was cut off by natives.[1] In 1798 Lastochkin visited the Copper River with great caution.[2] In 1803 Bazanoff explored the Copper River for a short distance.[3] In 1819 Klimoffsky attempted to explore the Copper River.[4] By 1816 two attempts had been made to explore the headwaters of the Copper but in both instances the leaders were killed by the natives.[5] In 1843 two parties of the Russian-American Company explored the Sushitna and Copper rivers to extend trade with the natives.[6] In the same year Zagoskin started to explore the Copper River, but was impeded by

[1] Alaska and its Resources, by Dr. W. H. Dall, p. 317.
[2] Op. cit., p. 318.
[3] Op. cit., p. 321.
[4] Op. cit., p. 331.
[5] Bancroft's History of Alaska, p. 525.
[6] Ibid., p. 526.

the natives. In 1848 Serebrenikoff, to whose researches our knowledge of the course of the river for a long time was due, ascended the Copper, but was killed by the natives for his misconduct.[1] At the mouth of the Chittena a single Russian remained for a few years and traded with the natives.[2] In 1882 C. G. Holt ascended the Copper as far as Taral.[3] In 1884 Capt. (then Lieut.) W. R. Abercrombie, of the United States Army, ascended the Copper as far as Miles Glacier.[4] Also in 1884 John Bremner, a miner, ascended the Copper as far as Taral and wintered there with the natives until the spring of 1885, when he accompanied Allen.[5] During the spring and summer of 1885 Lieut. H. T. Allen, of the United States Army, made a creditable reconnoissance trip by boat and portage up the Copper from its mouth, leaving its basin northward by way of Suslota Pass. He added considerable to our knowledge of the Copper River country and its people.[6] In 1891 Dr. C. W. Hayes and Lieutenant Schwatka, in exploring overland from Fort Selkirk to the coast, crossed the divide between the White and Copper rivers through Scolia Pass and descended the Nizzena or north branch of the Chittena, the Chittena, and thence the Copper to its mouth.[7] The topographic map about Scolia Pass and the Upper Chittena, by Dr. Hayes, is the only one ever made of that district, and is of value. It shows a rugged, mountainous country with many local glaciers. The vegetation on the south side of the pass is said to rival that of the coast in luxuriance of growth. The Nizzena for 7 miles above the forks flow through a canyon with rocky walls from 300 to 500 feet high.[8]

On the Lower Copper, at Miles Glacier, the river tumbles over a band of huge morainal bowlders and is impassable for boats, necessitating a portage of sometimes a couple of miles across moraine and glacier.[9] A short distance below Miles Glacier is the head of the delta, which reaches 30 miles southward to the line of bars or keys at the edge of deep water. During the summer of 1898 the Copper River delta was surveyed by a party from the United States Coast and Geodetic Survey in charge of Mr. Ritter.

GEOGRAPHY.

Prince William Sound and the Copper River district, taken as a whole, lies at the head of the Gulf of Alaska, where, roughly considered, it forms an inverted keystone of the great arch or crescent of the

1 Alaska and its Resources, by Dr. W. H. Dall, pp. 272, 343.
2 Op. cit., p. 272.
3 Lieut. H. T. Allen's report, p. 223.
4 W. R. Abercrombie's unpublished report on the Copper River Expedition, No. 2, of 1898.
5 Lieut. H. T. Allen's Report, p. 23.
6 Allen's Reconnoissance in Alaska, 1885.
7 An expedition through the Yukon district, by C. W. Hayes, Nat. Geog. Mag., Vol. II, p. 124, May 15, 1892.
8 Op. cit., p. 125.
9 Op. cit., p. 126.

coast line. Its area is about 55,000 square miles. It is comprised roughly between the sixtieth and sixty-third parallels of north latitude and the one hundred and forty-second and one hundred and forty-ninth meridians in west longitude. Its outline is that of a quadrilateral, or roughly truncated isosceles triangle, the base coinciding with the sixtieth parallel.

It is bounded on the north and on the northeast by the basin of the Yukon, here represented by the Upper Tanana district, on the east by the Upper White River district, and on the northeast by the St. Elias Mountains; on the south it is bounded by that part of the North Pacific Ocean known as the Gulf of Alaska, and on the west, beginning at the north, by the Sushitna River district and the Kenai Peninsula.

From near Mount St. Elias a broad belt of snow-capped mountains 5,000 feet high concentrically follows the crescent of the coast line westward and southwestward to Kenai Peninsula, where the mountains descend into the sea. In the northeastern part of the district the local but somewhat noted group of mountains, of which Mount Wrangell is the highest peak, rises to a height of more than 17,000 feet.

The drainage of the district, which is separated from that of the Yukon on the north by the Alaska Mountains, is all southward directly to the coast. The master stream is the Copper River, which flows southward through the district. It breaks through the Chugatch Range in a long, mountainous canyon, and soon after debouches over its large mud-flat delta into the sea. It can not be ascended by boat, on account of the impassable rapids which occur about 30 miles above its mouth. Above these rapids the river is navigable, but the current is swift.

TOPOGRAPHY AND DRAINAGE.

COAST OUTLINE.

The southern coast of Alaska lies in the form of a great crescent extending from about latitude 54° N. and longitude 130° W., at Dixon's entrance and the southern end of the Alexander Archipelago, or "panhandle" of Alaska, westward to the Kadiak Archipelago in latitude 57° N. and longitude 154° W. (map 18). The concavity is to the south and embraces the large body of water or embayment of the North Pacific Ocean commonly known as the Gulf of Alaska, so named by the United States Coast and Geodetic Survey.

Excepting at the middle or northern part of the crescent the outline of the coast is very irregular, being variously, often deeply, indented by sounds, bays, straits, fiords, and inlets of unequal extent, and fringed by numerous outlying islands.

MOUNTAINS.

ST. ELIAS CHAIN.

Near the head of Lynn Canal the western mainland range of the Cordilleran system, which south of here, as the Coast Range, fronts the sea to the southwest, does not continue to closely follow the curvature of the coast to the westward, but follows the projection of its own previous course more directly northward. It soon passes inland, something like a tangent to the crescentic Alaska coast, and proceeding northward it is supposed to merge in the southeastern part of the great Yukon Plateau toward the White River district. Its place on the coast is now taken by a new mountain system, the St. Elias Chain. This chain concentrically follows the crescent of the coast line around to the southwestward to the point where it passes beneath the sea, at the southern end of Kenai Peninsula and Kadiak Archipelago. It is doubtless the uplift of these mountains which has determined the shape and configuration of the coast line.

This chain consists of a broad, elevated, mountainous belt, above whose general land mass many disconnected ridges and peaks rise to a considerable height; the highest of these are Mounts St. Elias and Logan, each more than 18,000 feet high, near the middle of the coast-line crescent and the inner end of the "panhandle" of Alaska. Mount St. Elias is principally American, and marks the international boundary corner on the one hundred and forty-first meridian. To the southeast the partial submergence of the St. Elias Chain forms the great Alexander Archipelago, through which the inland steamer route, well known to Alaskan tourists, threads its way for 500 or more miles. To its continuation, still farther southward, has been applied the name Vancouver Range.

West of Mount St. Elias the St. Elias Chain soon bifurcates into two divergent ranges, which are separated at first by the valley of the Chittena, farther westward by the Copper River Basin and finally, on the west, by Cook Inlet and the Sushitna River Basin. Of these two ranges, the southern one, following the crescent of the coast line westward and southwestward around the head of Prince William Sound and down Kenai Peninsula, where it becomes submerged, is known as the Chugatch Mountains, a native term already in use by Petroff. To that portion of this range on Kenai Peninsula the name of Kenai Mountains has been applied. The other divergent range bears off to the northwestward, where, passing around the head of the Copper and Sushitna river basins parallel with the crescent of the coast line and the Chugatch Mountains and also with the great valley of the Yukon on the north, it is known as the Alaskan Range. Beyond the Sushitna the general alignment of this range is continued southwestward along the west side of Cook Inlet, first by the Tordrillo Mountains, next by the Chigmit Mountains, and, finally, on the Alaska Peninsula by the Aleutian Mountains. To this system of mountains belongs a great many volcanic peaks and craters, some of which are still active. In the Alaska Mountains, northwest of the Sushitna Basin, occur some of the highest peaks of the North American continent, culminating in Mount McKinley, more than 20,000 feet above sea level. Also belonging to these mountains on the east, after leaving the St. Elias Chain, is the Wrangell group, the highest of which, Mount Wrangell, rises to more than 17,000 feet above tide. North of the Copper River Basin the Alaska Mountains are interrupted by gaps, low and often broad, such as Mentasta and Suslota passes, the latter about 4,000 feet or less in elevation, and on the northeast by Scolai Pass, about 5,000 feet high.

CHUGATCH MOUNTAINS.

These mountains comprise the southern divergent range, which continues westward from the St. Elias Chain around the head of Prince William Sound, and southwestward through the Kenai Peninsula to its terminus—the Kadiak Archipelago—on the extreme southwest.

Where crossed, and best observed by the writer, between Prince William Sound on the south and the Copper River Basin on the north, the Chugatch Mountains form a somewhat plateaulike belt about 80 miles broad, whose general land mass rises to a height of from 5,000 to 6,000 feet above sea level. Its surface, which for the most part slopes gently coastward, as if slightly tilted to the south, is rugged, being considerably dissected and freely studded with nunataks, sharp, jagged peaks, turrets, and broken or discontinuous sawtooth ridges interspersed with local glaciers and névé (Pl. XXII, *A*). This type of topography, largely due to the character and attitude of the rocks, which almost everywhere are steeply upturned or stand on edge, continues eastward toward the Mount St. Elias district and westward toward the Sushitna Basin. The ridges, nunataks, and peaks may rise to a height of 2,000 feet, rarely more, above the waste of glaciers and névé through which they break. The amphitheaters or cirques, which are common at the base of many peaks and ridges, constitute a modification of the normal type of topography, brought about through the agency of ice or local glaciers at points where the topography and atmospheric conditions have favored the accumulation of snow and ice.

Between Prince William Sound and the Copper River Basin these mountains differ from most other mountain ranges, in the fact that they descend rather abruptly along the coast on the south and into the Copper River Basin on the north and northwest.

The edges of the range on both the coastal and inland sides are etched by generally short deep valleys or canyons and gulches, which carry off the drainage. The canyon of the Copper River alone cuts through the range. Here the range extends northward about 100 miles from the coast to Taral and the mouth of the Chittena, the most southern edge of the Copper River Basin, which lies back of the range. On the west side of the Copper the range continues some 20 miles farther north to the Tonsina and is very rugged. The next lowest known gap through this great coastal barrier into the Copper River Basin, besides the canyon of the Copper, is the summit of Valdes Glacier, where the divide is still 4,800 feet above tide.

In the region of Prince William Sound the southern edge of the range has gone down, giving to this district the topography of a submerged coast, with the many deep inlets, fiords, and bays denoting the lower reaches of former subaerial valleys, while the outlying islands represent the crests of mountainous ridges whose bases are now under water. From below Orca northward toward Valdes the relief of the country may almost be defined as a mild form of the bad-land type of topography, ranging from rather rounded, low, and somewhat dome-shaped hills to steep or almost abrupt-faced mountains from 2,000 to 4,000 feet in height, which often terminate in sharp peaks. These steep slopes are especially characteristic of the inner portions of the bays and inlets which almost everywhere deeply indent the coast. Farther northward the topography becomes of a much rougher and more exclusively mountainous and jagged character, soon passing into that of the Chugatch Range already described.

East of Prince William Sound, in the vicinity of the mouth of the Copper River, the mountains as seen when approached from the sea have the appearance of one vast rugged snow-peaked range, covered with perpetual snow and ice fields, with innumerable glaciers creeping down its steep, barren sides and filling its deep-cut canyons. The seaward face of the range breaks off quite abruptly.

The Copper River breaks through the range about 30 miles from the coast, and soon after, through a flat marshy country, debouches over its large delta into the sea.

Of the coastal belt of country extending from the mouth of the Copper eastward to Mount St. Elias and Yakutat Bay, and lying between the foot of the mountains and the coast, but little in detail is known except that it is a narrow, gently seaward-sloping tableland, backed by foothills in places, generally well timbered, and traversed by numerous shallow streams arising from glaciers and névé. Some large areas are occupied by ice sheets of the Piedmont Glacier type,[1] of which the most important are the Bering and Malaspina glaciers. From Yakutat Bay to Prince William Sound the coast is inhospitable, and consequently but little visited.

[1] For the Piedmont Glacier, see Russell, Nat. Geog. Mag., Vol. III, May 29, 1891, p. 105.

WRANGELL MOUNTAINS.

The Wrangell group is a large lobelike spur of the eastern or St. Elias end of the Alaskan Range, near the base or divergence of the latter from the St. Elias Chain. It lies for the most part within the upper part of the Copper River Basin on the northeast, where it occupies the so-called "big bend" of the Copper. The Copper heads to the northeast of the group, where its course at first is northwest, but finally becomes southeast on the opposite side of the group, and by the time it reaches Taral and the mouth of the Chittena the river has more than three-fourths inclosed the mountains in its embrace.

These mountains occupy an area of about 4,500 square miles. The outline of the group is elliptical, with the major axis about 90 miles in length and trending northwest and southeast. The highest part of the land mass lies along the minor northeast-southwest axis, where, on the northeast, Mount Wrangell, the highest peak of the group, rises to a height of 17,500 feet, and Mount Tillman, on the southwest, to a height of 13,300 feet. From here the slope of the land mass is to the northwest, to Mount Sanford, at the end of the group, which rises to 14,000 feet, and southeast to Mount Blackburn, 12,500 feet high. Mount Drum, a somewhat prominent peak on the west to the southwest of Mount Sanford, is 13,700 feet high (Pl. XXVI, *A*). These peaks, which constitute the group, are, so far as known, all situated about the periphery of the elliptical outline; they are all enveloped in perpetual snow. Of the inner part of the ellipse little is known, as it has never been explored. Judging, however, from what has been seen of its edges wherever exposed between the peaks it is a mountainous waste of glaciers and névé.

So far as could be seen from our route down the Copper River, the Wrangell group is flanked on the west by one or two successively parallel ranges, which in places may pass into foothills, and these in turn come down to the gravel plateaus which skirt the rim of the Copper River Basin. In front of the region between Mounts Drum and Tillman was noted what seemed to be a bed rock plateau of no small extent, which may represent marine benching, or, more probably, a surface of effusive lava flows. Mount Drum (Pl. XXVI, *A*) has much the form of a large volcanic cone or crater, with its southern part torn away. Mount Tillman is gently rounded and elongated, with its longer axis extending northwest and southeast, and Mount Blackburn, the most southeasterly of the group, rises to a height of 12,500 feet. Its longer axis coincides in direction with that of Tillman. As the frontal range on the west cuts off the view of the lower portion of this mountain, only the portion above snow line was seen. Its crest line, seemingly sharp, is comparatively even, and descends, with some sway, toward the south. Its northwest end, which broadens rapidly with descent, is very steep, apparently not ascendable, and is deeply dissected by sharp ridges and V-shaped gullies or canyons. The southwestern slope is not so steep. Here it is doubly amphitheatrical, being composed in the main of one large amphitheater comprising two smaller; of these latter the northern is the larger; both are filled with snow. A good view of the upper part of Blackburn may be had from almost any of the heights of the Copper River about the mouth of the Chittena and for some distance farther north along the Copper.

AGE OF THE MOUNTAINS.

The St. Elias Chain, according to Russell, is geologically very young. Its topography, which in the region of Mount St. Elias is often largely constructional, consisting of huge faulted blocks and scarps but little eroded, denotes extreme youth, especially compared to the older and more eroded Coast Range to the southeast.

The rocks in the St. Elias Mountains, according to Russell, contain fossil forms of Pliocene and Pleistocene species still living in the adjacent waters, which makes the mountains of Pleistocene age; and since the Wrangell Mountains seem to have partaken of the same St. Elias uplift, they would also seem to be of this same age. They, however may consist of eruptive rocks extruded at an earlier date than the time of the uplift or later.

The topography of the Chugatch Mountains, though they probably belong to the St. Elias uplift, can hardly be said to be as young as that described by Russell for the Mount St. Elias region.

PRINCE WILLIAM SOUND.

Prince William Sound (see map 19) is the large bay at the head of the Gulf of Alaska. It lies in north latitude 160° to 161° and longitude 146° to 149° W. It is bounded on the north and northeast by the mainland or Chugatch Mountains, on the west by Kenai Peninsula, and on the south by numerous islands, of which the principal are Knights, Montague, Latouche, and Nuchek. Its submerged mountainous topography has already been indicated. The numerous deep indentations of the coast line on the north, with the outlying islands, present natural harbor facilities of the highest class for even the largest ocean vessels. The most marked of these inlets are Port Fidalgo and Port Valdes, each about 3 or 4 miles wide by about 30 miles in length. On the northwest, Port Wells is also prominent.

The interior of the sound forms a basin almost entirely landlocked, being sheltered from the south by the islands of Nuchek and Montague. Nevertheless, it is often subject to furious gales and squalls, which sweep down from the mountains without warning.

The main entrance is from the southeast, between Nuchek or Hinchinbrook Island on the northeast and Sukuluk or Montague Island on the southwest. It is known locally as the Neenoork or Chugatch entrance, but is called Meiklejohn entrance on the accompanying map (map 19). Through it the tidal currents play back and forth with considerable velocity. In the northeast part of the sound the topography trends nearly east and west, with the strike and trend of the rocks and the axis of the Chugatch Range to the north. This feature is specially marked by the elongated form of the islands, the trend of the peninsulas, mountainous capes, and deep inlets, the heads of which latter—Cordova Bay and Ports Gravina, Fidalgo, and Valdes—extend far to the eastward.

In the southwestern part of the sound, as shown by the large islands in that region, the trend of the topography becomes more north and south, conforming with the neighboring Coast Range crescent, here represented by the Kenai Mountains.

CORDOVA BAY.

This is the first large inlet to the right upon entering the sound from the southeast. It is about 3 miles in width and 30 miles in length. Its lower reaches are protected from the sea on the southeast by Hawkins Island, the north end of which extends into the bay. From the immediate shores of the bay, especially near its head, the mountains rise steeply to a height of several thousand feet. Orca, the site of the Pacific Steam Whaling Company's salmon cannery and a United States post office, is located on the southeastern shore, about 10 miles from the head of the bay, between the tide in front and the steep mountains in the rear. It is couched in the narrow mouth and partly on the fan cone delta of a small gulch whose waters descend the steep mountains with constant roar.

At about 5 miles below Orca an old valley cuts through the Cape Whitshed ridge of mountains, which lie between Cordova Bay and the open country at the mouth of the Copper on the east. By short portage and boat this old valley connects the Cordova Bay and Copper River traffic. It is occupied by two small so-called rivers—the Odiak and the Eyak. The Odiak, which opens westward into Cordova Bay, is little more than a tidal inlet about a mile in extent. On the low divide at its head are located Eyak, the village of the Eyak natives, and the so-called Eyak salmon cannery belonging to the Alaska Packing Association.

The divide, which is low and flat, rises to scarcely 25 feet above tide and is about 1½ miles wide; it seems to be purely constructional, the deposits which form it probably being laid down mostly by tidal action accompanied by recent slight crustal elevation. East of the divide occurs a small lake about 5 miles in diameter, whose outlet on the east forms the Eyak River. This river flows about 2 miles eastward through the mountains to the open country on the east, where it empties into a western slough of the Sherman Glacier stream which runs southward to the coast.

PORT FIDALGO.

The longest inlet on the sound is Port Fidalgo. It is more than 30 miles in length. Near its head occur narrows through which the tide rushes at ebb and flow. The shore is mountainous throughout, some of the mountains rising to a height of 4,000 feet, into a region of perpetual snow and glaciers, especially on the north and east (Pl. XXIII). Two mountain streams of considerable size and apparently of glacial origin enter the inlet near the head—one from the north and one from the east. They have both done much toward silting up the head of the inlet, and flow over extensive deltoid deposits of gravel and mud flats at their mouths, especially at low tide.

PORT VALDES.

Of all the inlets of the sound, Port Valdes, by reason of the gateway it seems to form from the coast into the Copper River country, is commercially by far the most important. It lies at the extreme head of the sound, and has an inland extent of about 30 miles. Its trend is at first nearly northward, but its upper half lies in an east-and-west direction. It makes a great elbow or right angle at about its middle. Just before this its shores gradually contract, forming the Valdes or Stanton narrows, about a mile in width, through which the tide plays with considerable force at ebb and flow. Above the narrows the inlet is inclosed by mountains, which almost everywhere rise steeply from the shore to a height of about 5,000 feet (Pls. XXVI, *B*, and XXVII, *A*), those on the north side being much the steeper. This is probably due to the steep northerly dip of the rock, which seems to have directed the intensity of the downcutting of the river, which formerly occupied the older valley, to the north side, by the traveling of the stream down the dip of rocks. The drainage entering Port Valdes is a good instance of that in neighboring inlets throughout the mountainous district about Prince William Sound. Here it is usually through V-shaped gulches, canyons, or small canyonlike valleys, normally with steeply sloping or precipitous walls and bottoms of torrential gradient, so that even the smaller streams are, during the period of spring and early summer, converted into impassable torrents. These canyons and valleys usually head up in névés and cirques, the latter generally occupied by local glaciers whose melting is the main source of many of the streams. The most prominent valleys opening into Port Valdes are those of Valdes Glacier, Lowe River, and Canyon Creek. The two former discharge into the head of Port Valdes, which they have silted up for a distance of 5 or 6 miles with a delta deposit 1,000 feet or more in thickness. The town of Valdes stands upon its frontal or seaward edge (maps 20 and 21).

The submerged frontal slope of the delta lies at a very steep angle, 11° or more, where, at low tide, large ocean vessels safely moor in deep water and discharge their cargo by derrick onto dry land. At about a mile out from shore the depth of water is 150 fathoms, beyond which it has not been sounded. This, combined with the shelter of the surrounding mountains, affords natural harbor facilities of the highest order. The steep frontal slope of the delta and the shore line configuration here is probably due to the fact that construction is constantly going on, and may be aided by the fact that the dominant wind is from the west; also the absence of ocean swell and its attendant beach action may be a factor. The average normal tide here has a vertical range of about 13 feet. At low tide the beach across the head of the inlet exposes a belt of mud flats from one-half to three-quarters of a mile in width, composed of fine blue mud or rock flour, presumably of glacial origin. The highest tide experienced at Valdes is about 18 feet.

Although Lowe River contributes much toward the silting up of the head of the inlet, the head of the delta is very distinctly at the foot of Valdes Glacier, whence most of the material has been derived. From the areal front of the delta at tide water to the head of the delta at the foot of Valdes Glacier, a distance of about 5 miles, the total rise is about 200 feet. The slope is extremely uniform and gentle until it reaches a point within three-quarters of a mile of the glacier, where some increase occurs, as the material becomes more coarse and bowldery. In a few localities quite near the glacier, especially on the west, some terminal moraine still lies intact, with hummocks rising some 60 or 80 feet above the adjacent kettles.

From the head of the delta as a center the radial streams discharged from beneath the foot of the glacier swing pendulum-like back and forth over the delta on their way to tide water, changing their courses often within a few days from next the base of the mountains on the north around to the base of those on the east.

The subglacial streams (Pl. XXVII, *B*) which issue from beneath the glacier, usually but two in number, in their course to tide water may unite or each break up into numberless distributaries, but usually during summer there is one main stream so swift and deep as to be impassable for man or horse. It is locally called Glacier River.

VALDES GLACIER VALLEY.

This valley, now occupied by Valdes Glacier, is about 25 or more miles in length and about 2 miles in average width. It is a canyon-like valley, with steep rock-walled mountains rising to a height of

5,000 feet above sea level, or usually several thousand feet above the surface edges of the glacier. It seems to head about 5 miles northwest of Valdes Summit in a rugged mountainous waste of névé and glaciers. Here there seems to be a low pass, about 5,000 feet in elevation, leading apparently either into the head of Canyon Creek Glacier Valley, which finally opens into Port Valdes at the bend near the narrows, or northwestward into the Matanuska Valley. At the foot of the Summit (map 20) the surface of the glacier lies at an elevation of about 3,800 feet, but as there are no criteria for determining the thickness of the glacier the depth to which erosion of the valley has progressed is not known. It is probable, however, that at this point it has been cut down to less than 2,000 feet above tide level. It is the largest drainage way opening into Port Valdes, which it enters at the head of the inlet on the northeast. Next to the canyon of the Copper River it is the largest transverse incision found in the Chugatch Mountains. It trends about south, or more precisely a little east of south, directly across the strike of the rocks. It differs markedly in this respect from nearly all the main inlets about Prince William Sound, most of which are old strike valleys. Its drainage is fed by numerous tributaries, mostly in the form of branch valley glaciers, perched or hanging glaciers, on both the west and the east, and some of the latter, doubtless beyond the divide, connect with the Copper River drainage on the eastern side.

LOWE RIVER.

This is the principal stream draining the rugged mountainous country immediately east of Port Valdes. Its most distant waters are derived from Baird Glacier[1] to the northeast of the divide between Lowe and Tasnuna rivers, about 25 miles east of Valdes. This divide, which is wide or open, has an elevation of about 1,800 feet. It represents a sag in the axis of the mountainous belt sloping gently southward to the sea. On the north, as is usual in these rocks, the mountains rise up rather abruptly 5,000 or more feet above tide, while on the south the rise is gradual, but continues up to above snow line (Pl. XXVIII, *A*).

A few miles west of the divide Lowe River soon receives tributaries from the north, and especially from the south, whence they are fed by valley glaciers (Pl. XXVIII, *A*). At about 4 miles from the divide the river enters Heiden Canyon, which is very narrow, sharply V-shaped, and from 500 to 600 feet deep, with the bed-rock walls often precipitous. In this canyon the river, receiving tributaries from both right and left, continues as a torrential mountain stream, with deafening roar, for about 6 miles due westward, to where it emerges into Dutch Camp

[1] So named in memory of Baird, the prospector, who, in the spring of 1898, lost his life exploring on this glacier.

Basin. Here the valley expands into an open area of a mile or two in width and about 4 miles in length. The elevation of the basin is about 650 feet above tide. It is inclosed on the north and west by steep mountains 5,000 feet high, through a gap of which on the north, called Thompsons Pass, a probable trail and possible railroad route may be found to lead northward into the basin of the Copper. In the upper reaches of Dutch Camp Basin occur gravel deposits several hundred feet in thickness, into which, at vertical intervals of about 100 feet, terraces have been cut. The deposits are of a nature to suggest probable former occupation of the basin by a much larger body of water than now flows through it. The topography is such that the damming up of Keystone Canyon by a landslide may easily have converted the basin into a small lake, in which the gravels were hastily deposited and which again disappeared as soon as the dam was removed by erosion. Here in the basin the river receives several large contributions, especially that of the stream from the Hogback Glacier on the north. At the foot of Dutch Camp Basin the river is deflected somewhat southward by the southern foot of Hogback Mountain, and plunges into Keystone Canyon, a narrow, more or less precipitous walled gorge about 800 feet deep and 3½ miles long. Upon emerging from this canyon the river enters an open gravel-bottomed valley a few miles in width, in which it continues, with comparatively steep gradient, in a course a little north of west, for about 12 miles to tide water, which it finally enters over a mud flat delta at the head of Port Valdes on the southeast. Only the lower reaches of the river are navigable by small boats. According to reports of resident white men at Valdes, the river at lowest tide tumbles over a bed-rock bench, with a fall of some 8 or 9 feet, into the inlet. Keystone Canyon, so far as known, is passable during the sledding period of winter and early spring only when not occupied by water.

CANYON CREEK GLACIER VALLEY.

This short drainageway opens into Port Valdes at the bend or elbow, and drains the country on the northwest. This, like the valley of Valdes Glacier, is occupied by a glacier of medium size, which comes down to tide and gives off many small icebergs. It is the only tidal glacier seen by the writer during the season. The foot of the glacier is about half a mile across, throughout which distance it is being broken off by the tide. The vertical front is about 200 feet high, from the upper edge of which the ice surface soon slopes at a steep angle to 500 or 600 feet above tide. Just below the front of the glacier the valley is contracted by a broad foothill ridge descending from the west. In front of this, partly inclosed by a hook spit on the east, is a small bay several miles in extent. Back of the front the valley soon expands, attaining a width of about 2 miles; but this it retains only a short distance, as 3 or 4 miles back from the shore it again is seen to be contracted to a mere canyon by the mountains out of which, from the northeast, the glacier issues in séracs or cascade topography. The trend of the valley is about south across the strike. The above statement of drainage for Valdes Inlet applies in general almost equally well to the inland or northwestern slopes of the mountains and the northwestern part of Copper River Basin down to the point where the drainage leaves the mountains and enters the terrane of the Copper River Plateau. It applies also on the east down to the line where the drainage descending the western slopes of the Mount Wrangell group enters the plateau terrane in that region.

COPPER RIVER BASIN.

The Copper River Basin, as already indicated, lies back of the Coast Range or Chugatch Mountains, in the northwestward opening of the fork formed by the two divergent ranges from the St. Elias Chain. Its drainage is accordingly separated from that of the Yukon or adjacent Tanana and White rivers on the north and northeast by the Alaskan Range, and from the coastal drainage on the south and southwest by the Coast Range or Chugatch Mountains. The northwestern edge of the basin is not well defined. Here the bed rock disappears beneath the vast tundra plateau, which has an elevation of some 2,800 or 2,900 feet above tide water, and forms the divide or poorly defined watershed between the Copper on the east and that of the Sushitna on the west. This tundra extends from the north base of the Chugatch Mountains in the vicinity of Lake Tazlina northeastward to the region of Mentasta Pass in the Alaskan Mountains on the north. It is the lowest of any part of the basin rim that is not directed coastward or formed by bed rock mountain barriers.

The outline of the basin, roughly considered, is crudely circular, or perhaps more nearly that of a short ellipse. The trend is from northwest to southeast, about parallel with that of the Wrangell Mountains. The longer axis of the basin, from Mentasta Pass to the head of Wood Canyon, is about 140 miles; the transverse diameter from southwest to northeast is somewhat less.

COPPER RIVER PLATEAU.

The topography within the Copper River Basin is greatly in contrast with that already described for the surrounding mountainous regions. Here the interior of the basin is occupied by an extensive plateau. This plateau is composed of a geologically recent terrane of silts and gravels deposited within the basin to such a thickness—probably a thousand feet or more in maximum—as to cover over in most cases all trace of bed rock topography. Its edges rest up against the slopes of the Chugatch Mountains on the south and southwest and against the slopes of the Wrangell Mountains on the east. It extends from the head of Wood Canyon northward apparently to at least near Mentasta

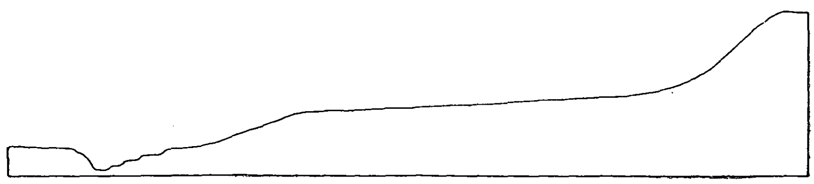

FIG. 16.—Profile from foot of Mount Drum to west of Copper River on Copper River Plateau.

Pass, while on the northwest it seems to merge into or be continuous with the tundra plateau, already referred to, which forms the low flat divide between the drainage of the Copper on its southeast and that of the Sushitna and Tanana waters on the northwest. The plateau in general slopes gently southeastward, or downstream with the drainage, while from its edges at the foothills of the mountains, both on the east and west sides of the basin, its slope is westward and eastward towards the master stream, the Copper, which flows through the middle of the basin in a southeasterly direction.

Near the middle of the basin, just west of Copper Center and the mouth of the Klutena, the plateau has an elevation of about 1,500 feet above tide, while at the foot of Lake Klutena, about 30 miles distant, its surface slopes up to about 1,700 feet. Above this elevation the basin in some localities at least is skirted by one or more terraces of considerable prominence. They are conspicuous in front of the Wrangell Mountains, northeast of the Copper, and along the foothills of the Chugatch Mountains southeast of the Klutena River (map 21). Here, in the vicinity of Mount Durelle, as ascertained by level, the highest terrace lies at an elevation of about 2,750 feet. This elevation accords well with that of remnants of similar deposits found elsewhere, notably up the Klutena Valley above the lake, and up Salmon Creek Valley northwest of Lake Lilly (fig. 17, p. 386). Whether these higher marginal terraces are a part of and in direct continuation, or vice versa, with the Copper River Plateau extending across the basin was not ascertained. The indications seem to be that they are nearly if not quite contemporaneous.

Within the basin of the Copper the surface of the plateau is a nearly level moss and timber covered area, dotted by many lakelets and swamps, especially in the poorly drained interstream areas back from the rivers. Down into the plateau the Copper River and its tributaries have incised themselves to a depth of from 500 to 800 feet. Here, in narrow V-shaped canyons between the steep bluffs formed by the silts and gravels (Pl. XXVIII, *B*) which compose the plateau terrane, this river system now flows as a superimposed drainage.

The drainage is very young; this is shown by the large swampy inter-stream areas of the plateau which as yet have been scarcely touched by erosion. Downcutting of the streams has been exceedingly rapid and is still very vigorously going on. The Copper River itself has an average velocity of about 8 miles an hour, while most of the tributaries are so swift as to be scarcely navigable by any kind of craft. All the streams are heavily loaded with sediment. Since the bed-rock bottom of the basin has apparently nowhere been reached by the Copper in its course through the middle part of the basin, it seems probable that

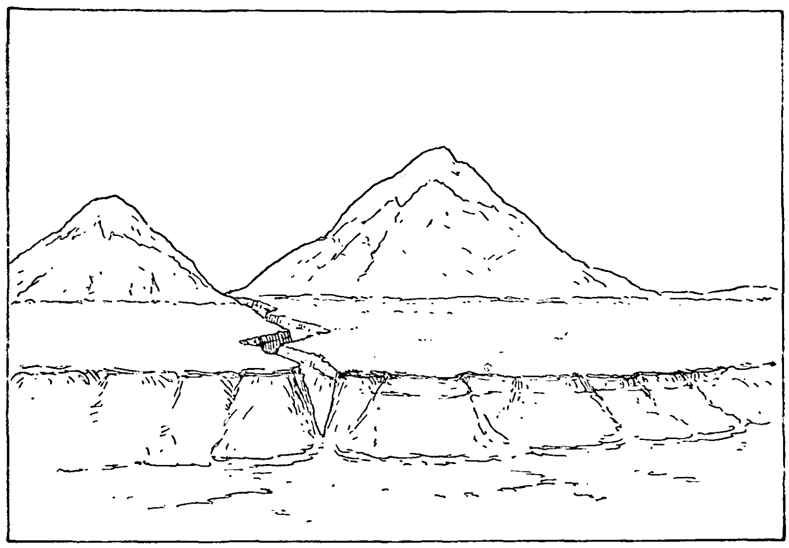

FIG. 17.—Remnants of Copper River Plateau, with recently cut canyon at head of Salmon Creek Valley.

the plateau terrane may exceed a thousand feet in thickness. Southward toward the Chittena and Wood Canyon the thickness seems to diminish, owing chiefly to the fact that it nears the rim of the basin here, and apparently to the contraction of the basin in this direction and the combined erosion of which the terrane has here suffered from the Copper and Chittena. Here, just below the mouth of the Chittena at Taral and the head of Wood Canyon, the plateau terrane ends. No trace of it was found below the canyon, which is a narrow rock-walled gorge several miles in length. From this it is inferred that at this point must have been a barrier which prevented the extension of the terrane farther southward at the time of its deposition.

COPPER RIVER.

The Copper is probably the largest river on the southern coast of Alaska. Its length is more than 300 miles; its general course is about south; not directly, however, for, as seen on the map, it lies in the form of a great inverted hook, with its headwaters or source representing the point, and its concavity, which incloses the Mount Wrangell group, directed southeastward. The region about the extreme headwaters of the river still remains to be explored. So far as known, however, the source lies northeast of the Wrangell Mountains, probably in glaciers on the eastern slope of Mount Wrangell itself. Following the general curve of the hook the first 80 miles of its course is in a northwesterly direction. Here, in the next 60 miles, it rounds the bight of the hook, or "big bend," about the northwest end of the Wrangell Mountains; thence its course for the next 80 miles is southeastward to the mouth of the Chittena, its largest tributary. From here its general course is about due south to the sea, with two about equal bends, one to the west at the mouth of the Teikell, and one to the east at Miles Glacier. These bends also are respectively about equidistant from the mouth of the Chittena and the coast.

At what point the headwaters of the Copper enter the plateau terrane in the upper part of the basin has not yet been definitely determined. It seems, however, to be well up toward the source, to the north if not northeast of the Wrangell Mountains.

The main tributaries received by the Copper on its right, principally from the west, commencing at the north, are the Slana, Chestochina, Gakona, Tazlina, Klutena, and Tonsina, all of which lie within the basin back of the mountains, and form a part of the superimposed drainage of the Copper River Plateau. Most of them head in the mountains and attain an average length of about 50 miles; their course is usually very direct and about at right angles to the Copper. Continuing southward through the mountains on the same side of the river, the principal streams are the Konsina, Cleave Creek, and the Tasnuna.

On the left, or east, the principal drainage, which is largely derived from glaciers of the Wrangell Mountains, commencing at the north, consists of Bowlder Creek, Dry Creek, Davis Creek, Sanford River, Klawasena Creek, Knetena and Tatena rivers, Chetastena Creek, and Cheshnena, Blackburn, Katselena, and Chittena rivers, all of which enter the river within the basin, and, with the possible exception of the Chittena, also form a part of the superimposed drainage of the Copper River Plateau.

For some distance up from its mouth the north bank of the Chittena is formed by the terrane of the Copper River Plateau. Its south shore, however, is the bed-rock slope of the mountains, all trace of the plateau terrane having been stripped off. The above tributaries on the east side of the Copper, like their fellows on the west, are very direct in course, and flow at nearly right angles to the Copper. Their length, however, so far as known, is somewhat less than the tributaries on the west. Continuing southward from Taral through the mountains, the only tributaries of any size on the east are Dewey Creek, opposite the Konsina, and Bremner River, opposite the Tasnuna. Considerable drainage probably also enters the river in the region of Miles Glacier.

The tributaries flowing through the plateau terrane within the basin are nearly all torrential streams. Since the Klutena forms a fair example it will now be described somewhat in detail, with a view to affording a somewhat clearer idea of the drainage of the Upper Copper as a whole.

KLUTENA RIVER.

The source of the Klutena River is the Klutena Glacier, in the Chugatch Mountains, which starts on the eastern slopes of Valdes Summit and receives several large branch glaciers from both right and left, in its rather steep descent of 5 or 6 miles into the deep canyon valley of the Klutena. Here, at an elevation of about 2,000 feet above sea, the glacier abruptly terminates in a steep slope several hundred feet high. Here several subglacial streams, with usually one main one debouching through arched tunnels from the foot of the glacier, flow, or rather tumble, together over the rough terminal moraine gravels, and form the head of the Klutena River. From this point the general course of the river is northeastward to the Copper, some 60 miles distant. For the first 4 miles of this course it continues in a very narrow canyonlike portion of valley, with steep, rocky, mountain slopes on either side rising to a height of 5,000 feet above tide, the elevation of the mountainous land mass in the Chugatch Plateau. The width of the valley floor, which is gravel covered, is about a mile; its gradient for about 4 miles is about 60 feet per mile down to Twelvemile Camp. During normal stages the river, which may not exceed 100 yards in width and 3 or 4 feet in depth, oscillates from side to side of the valley, as the accumulation of morainal débris and gravel may lead to a shifting of the channel. Only during the higher stages of the river, at times of maximum thaw and rain, does it extend as a continuous sheet entirely across the valley.

Even at its normal stages the velocity and force of the current is so great that it can be forded by man or horse only with the greatest difficulty. On the northwestern side of this section of the valley occur a couple of bed-rock benches belonging to a much older age of erosion, which will be deferred for subsequent treatment.

At Twelvemile Camp the mountains on the northwest disappear and the width of the valley is almost doubled by its union with a similar valley, that of Stephens Creek, coming in from the west. This creek is about as large as the Klutena itself and very nearly as swift. It also heads in glaciers much the same as the Klutena, which probably connect with or at least arise from the same névé extending northward from the Summit and head of Valdes Glacier.

On the northern side of Stephens Creek Valley the mountains rise steeply to a height of more than 5,000 feet. On the south the topography is less steep, with several perched or hanging glaciers, some of considerable size, on the upper north slopes of the interstream mountainous ridge which descends to the east. This spur or ridge ends somewhat abruptly at Twelvemile Camp, as already indicated, though its alignment is continued northeastward a mile or two down the valley by prominent outliers several hundred feet high.

At about 3 miles below Twelvemile Camp, just below Sawmill Camp and the confluence of Stephens Creek and the Klutena River, another tributary, known as Sawmill Creek, is received from the southeast. It also is said to head in a glacier some 10 or more miles up from the river. Its valley is comparatively open and is said to form an easy trail or route to the headwaters of the Tonsina and Konsina rivers. At about the confluence and Sawmill Camp the steep sides of the valley are diminished somewhat by foothills, which begin here and continue for some 15 miles northward to within a few miles of the head of Lake Klutena, where, by gradual widening from the confluence, the valley floor attains a width of about 3 miles. The foothills are more prominent on the north side of the valley, where they form a belt a mile or more in width and are often very rugged, extending well up into the mountains. From the confluence to the head of the lake the main channel of the river follows the south side of the valley and enters the lake through many narrow mouths over a delta of considerable size on the southeast at Twentyfourmile Camp.

From the southwest another glacial mountain stream—Hallet River—about the size of Stephens Creek or the Klutena above the confluence, flows into the head of the lake. Within a few miles of the lake Hallet Valley is contracted into a narrow canyon or mere gorge cut in the floor of a much broader and older valley. This, so far as observed, seems to characterize the valley throughout a considerable portion of its extent. Its confluence with that of the Klutena gives to the valley of the latter, at the head of the lake, a total width of about 5 miles, the actual width of the lake here being about 4 miles.

Lake Klutena is merely an elongated depression in the valley of the Klutena River, for the valley is continuous, without any marked contraction or interruption of any sort. The length of the lake is a little less than 30 miles. Its average width is about 4 miles, with a maximum of about 5 miles across its middle part at the elbow. It is on the whole shallow, its maximum depth probably not much exceeding 200 feet. The south or upper half lies nearly north and south, but at about the middle point of its length it makes a big bend of almost a right angle, beyond which the lower half lies in an almost east and westerly direction.

The lake contracts at its foot or lower end, where, at the base of the mountains, it is confined by the edge of the terrane of the Copper River Plateau, through which an outlet for it has been cut by the Klutena River northeastward to the Copper. If this terrane could be removed at this point we should be pretty sure to find the Klutena Valley opening out through a broad bed-rock mouth into the Copper River basin.

The lake was formerly very much larger and deeper than now, as is shown by the series of gravel terraces which skirt its shores and rest up against the foothills to a height of several hundred feet or more above the present level of the lake. These terraces are most marked on the west side of the upper half of the lake, where they extend back about a mile from the shore. The higher of these terraces seem to accord in level with the remnants of terraces observed at Twelvemile Camp, on the south side of the river, at the base of Camp Mountain, and may represent identical deposits in the same body of water; but the connection is no longer continuous, or at least could not be traced down the valley, as the valley at the time was often filled with dense smoke arising from forest fires.

The width of the valley above the lake and the flatness of its gravel and silt floor in this section strongly suggests that the lake may formerly have extended nearly if not quite to Twelvemile Camp. If so, the 10 or 12 miles of deposits between Twelvemile Camp and the present head of the lake represent lake filling. This lake filling is still very rapidly going on at the head of the lake by the vast quantity of detritus brought in by the Klutena and Hallet rivers. This, together with the downcutting at the outlet at its foot, is causing a rapid diminution of the lake in size and volume. This is shown by the recently formed small terraces or beach deposits of gravel and silts but a few feet above its present surface, and which, for several years at least, seem to have rested intact above the reach of the water, which is now forming similar deposits at a lower level.

It has been indicated that the lake owes its present existence to the confinement of its waters at the lower end by the edge of the Copper River Plateau. This, however, does not explain its origin, for if the lake owes its existence to recent deposits thrown across the mouth of the valley at its foot, as seems to be the case, there must be some reason why these deposits did not extend up the valley and fill the concavity or basin now occupied by the lake. Why this did not take place seems to be due to the fact that the basin at the time was probably occupied by ice in the form of a long valley glacier, just as the valley of Valdes Glacier is occupied by its glacier at the present time. It probably extended from Valdes Summit to the present foot of the lake, for the mountain slopes throughout this extent bear evidence of ice action up to a height of several thousand feet.

Accordingly, about the lower reaches of the glacier, probably aided much by material furnished from its own terminal moraine, deposition and upbuilding took place at a rapid rate, extending considerably, probably several hundred feet, above the floor of the valley occupied by the bottom of the glacier at the time. Upon the recession of the glacier or melting away of the ice back of this deposition, or dam, due probably to change in climatic conditions, its place in the valley, now converted into an elongated concavity or basin, became filled with water and occupied by the lake much as it is to-day. This class of geologic work is going on at the present time. The bottom of Valdes Glacier, for instance, at its lower end is seen to be considerably, perhaps several hundred feet, below the areal surface of its terminal moraine and head of its delta, which stretch like a great dam across the mouth of the valley. Obviously, upon a pronounced recession of the glacier or the melting away of the ice here, the concavity or basin which it now occupies in the rear of the dam would become converted into a lake, much the same as the present Lake Klutena.

The bed rock topography about the most of Lake Klutena may be characterized as steeply mountainous. From the terraces skirting the lake the slopes ascend rapidly to the level of the mountainous land mass or Chugatch Plateau, 5,000 feet in elevation. The edges of this plateau here are etched in double fashion, bearing record of two distinct periods of erosion. This etching consists, first, of remnants of somewhat broad and apparently old valleys opening into that of the Klutena at an elevation of about 2,700 feet, or about 1,000 feet above the level of the lake; and, secondly, down into the floors of these old side valleys the present drainage has entrenched itself in the form of sharp V-shaped canyons and gulches to a depth of many hundred feet, as seen in fig. 17. The floors of the side valleys slope gently toward that of the Klutena, while the present drainage in the canyons and gulches is of the most torrential gradient. Opening into the Klutena Valley, at the elbow of the lake on the northwest, is a somewhat prominent broad, flat valley—that of Salmon Creek. It is about 3 miles in width and probably 12 or 15 miles in length. It heads in a low divide to the northeast of Lake Lilly, whence its general trend is about south, with some curve to the westward near its midlength. Its lower reaches are bordered on either side by mountains much the same as the Klutena. Toward its head, however, these mountains descend into foothills, which soon disappear in the Copper River Plateau.

The low divide at the head of this valley separates the drainage of the Klutena from that of the Tazlina on the north. It is probably purely constructional, for Salmon Creek, the stream which flows from Lake Lilly into Lake Klutena, is but a small stream meandering sluggishly over the broad bottom of the valley. As its size is not at all commensurate with the valley which it occupies this would seem to denote that other forces than Salmon Creek must have operated in forming this valley. The divide, so far as could be ascertained, does not rise more than about 200 feet above the level of Lake Klutena.

At about midway between Cranberry Marsh and the foot of the lake another valley of considerable size—Ottoway Valley—opens into the lake on the north. Through Lake Klutena the average velocity of the current is about half a mile an hour. Near the foot of the lake Mahlo River, a stream of considerable size which heads well up in the mountains to the south, is received from the southeast. At the foot of the lake Klutena River, which forms the outlet, is very rapid, and immediately enters the plateau terrane of the Copper River Basin, into which its channel sinks deeper and deeper, finally to a depth of more than 500 feet before it discharges its waters into the Copper River at Copper Center, about 28 miles distant. The total fall of the river from the foot of the lake to the Copper River is about 620 feet, making more than 22 feet per mile. The velocity of the stream will probably average nearly 14 miles an hour. A boat load of provisions, amounting to about three-quarters of a ton, was run from the foot of the lake to Copper Center in about two hours. The roughest and most rapid portion of the current seems to lie between Amys Landing, about 6 miles below the foot of the lake, and Copper Center, throughout which distance, for about 20 miles, the river is a continuous line of whitecaps rushing at the bottom of its narrow bluff-bordered canyon. The roughness is largely due to huge bowlders lying in various attitudes and places in the bed of the stream. The fierceness of these waters is shown by the wrecking of hundreds of craft, which, during the summer of 1898, in the hands of prospectors and experienced as well as inexperienced boatmen, attempted to descend the river.

Between the foot of the lake and Copper Center the only tributary of any considerable size received by the Klutena is Manker Creek, on the southeast, about 3 miles below the lake. This creek is of considerable length; it heads well back in the mountains to the south, whence its course is nearly north. The valley, which is of moderate gradient and open, is said to be traversed by an easy trail, suitable for pack train, leading from the Klutena to the headwaters of the Tonsina, where some gold placers are now being worked.

What has been said of the Klutena River applies almost equally well, with certain minor exceptions, to most of the other tributaries of the Copper received back of the Coast Range.

TAZLINA RIVER.

The Tazlina, next north of the Klutena, is very similar. It heads back in the mountains, at the edge of which, like the Klutena, it flows through a lake—Lake Tazlina or Pleveznie—about 25 miles long, then rushes, in a rough bowldery-bedded canyon, through the Copper River Plateau, some 30 or more miles distant, to the Copper, which it enters at 9 miles north of Copper Center and the mouth of the Klutena.

TONSINA RIVER.

Also the Tonsina, next to the foot of the Chugatch Mountains on the south, heads in glaciers in the mountains, flows through a lake near the edge of the plateau, and thence through the plateau to the Copper. It seems to have two main forks, one coming in from the northwestward, the other from the southwestward.

The Tonsina furnishes a good instance of the manner in which the deltas of these tributaries usually crowd the Copper River to the opposite side of its valley. The gradient of the tributaries is considerably steeper than that of the Copper, consequently the velocity and carrying power is also much greater, and, since they flow in narrow canyons or valleys in the unconsolidated plateau terrane, which yields detritus without limit, the carrying power is usually taxed to its utmost, so that the amount of detritus and sediment brought down is often enormous, considering the size of the streams. As soon as the velocity is diminished, when the much more quiet waters of the Copper are reached, much of the sediment is dropped in the mouth of the tributary, resulting in the construction of deltas, which soon extend far out into the channel of the Copper and finally crowd the master stream several miles or so out of its ordinary course, to the opposite side of the valley, where it is not rarely compelled to add anew to its channel by undercutting and transporting away large sections of the plateau terrane from 500 to 600 feet high. Here the Tonsina, for example, has formed a delta about 3 miles wide. It is threaded by numerous sloughs and channels. The front of the delta, only partially shown on maps 20 and 21, now occupies and extends entirely across what was formerly the normal channel of the Copper, which stream it has so crowded to the opposite or northeast side of the valley that it has formed a marked curve in the several miles of bluff which it has undercut at that point in its efforts to pass around the front of the delta. No sooner has the delta been passed than the river immediately resumes its normal position in the middle of the valley. Even the deltas of the smaller tributaries, descending with very steep gradient from the Wrangell Mountains, are very effective in completely forcing the Copper River to the opposite side of the valley.

CHESTOCHINA RIVER.

The Chestochina enters the Copper at the outside of its big bend on the northwest. It is among the largest of the upper tributaries of the Copper, and by some has been called the northwest branch or fork of the Copper. Its source lies well to the northwest in the southern foothills of the Alaskan Range, where it is formed by the confluence of about half a dozen vigorous mountain streams, some of which are reported to head in glaciers well up in the mountains.

On its way to the Copper the river has intrenched itself in a narrow bluff-walled canyon several hundred feet deep into the Copper River Plateau. Here it flows at a rate of about 10 miles an hour. The stream bed is very rough and bowldery. The nature of the plateau country on either side is largely that of a timber-covered marsh dotted by ponds and occasional lakelets. In its lower reaches the river widens considerably and is beset by a great number of islands and sand bars. It finally flows over a large delta and empties into the Copper through a great many channels, of which the most southerly is about 3 miles south of the main channel.

CHITTENA RIVER.

The Chittena is probably the largest tributary of the Copper, which it enters on the east at about a mile above Taral and the head of Wood Canyon. It lies in the rugged, mountainous topography in the angle formed by the Chugatch and Alaskan ranges at the point of their divergence from the St. Elias Chain. At about 50 miles from the Copper the Chittena divides into two main forks—north and south. The north fork, known as the Nizzena, heads in the south lobe of Russell Glacier, which occupies Scolai Pass, the lowest gap in the divide between the Copper and White rivers on the north. Its elevation, according to Dr. Hayes, is about 5,000 feet. For the first 15 miles of its course the Nizzena flows westward through a narrow canyonlike valley, and then southward for about 20 miles, soon receiving in its upper course contributions from numerous large glaciers, both right and left; thence, upon leaving the mountains, it flows about 30 miles westward, or nearly westward, to its confluence with the south fork or the Chittestone. For the last 7 miles above the confluence its course is in a narrow, rock-walled canyon from 400 to 500 feet deep, in the lower end of which the walls, according to Dr. Hayes,[1] rise vertically to a height of 2,000 or 3,000 feet. From its confluence with the Chittestone the river, from here on known as the Chittena, continues its course about 50 miles farther westward to the Copper. From about 30 miles above the confluence of the forks to the Copper, a distance of about 80 miles, the Nizzena and Chittena flow in a rather broad, open

[1] An expedition through the Yukon district, by Charles Willard Hayes: Nat. Geog. Mag., Vol. II, pp. 117–162.

valley, bordered by gravel bluffs, about a mile apart, rising from 200 to 400 feet high from the edges of the flood plain.[1] These bluffs probably represent an eastward continuation of the Copper River Plateau.

The lower reaches of the Chittena contain numerous small islands or gravel bars. Its mouth, where it enters the Copper, is about 1½ miles in width. Its north bank at the mouth is formed by the dissected south edge of the Copper River Plateau, but the south bank is bed-rock topography, which ascends steeply into the rugged mountains back of Taral. Though the current is swift, the stream can be ascended for a considerable distance by boat.

BREMNER RIVER.

Proceeding southward from the Chittena through the mountains, the only tributary of any considerable size received by the Copper on the east is the Bremner, about 45 miles downstream. The rest of the

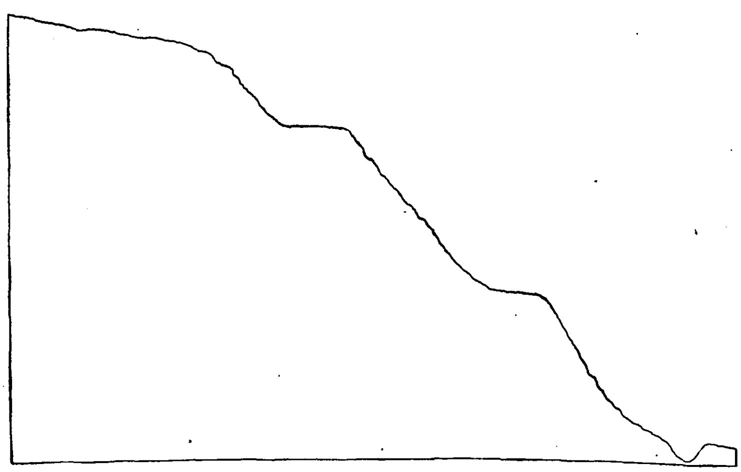

FIG. 18.—Old bed-rock benching at mouth of Bremner River Valley, north side.

drainage from these rugged glacial mountains is discharged into the Copper through comparatively short, deeply cut, mountainous canyons, or rather gulches, of which Dewey Creek (Pl. XXIX), opposite the Konsina, is an example.

The Bremner enters the Copper on the east, opposite the mouth of the Tasnuna. The valley at the mouth is several miles in width, open and flat, much like that of the Tasnuna, denoting a tributary of probably considerable size. Upstream it seems soon to contract and drain a considerable area of the rugged, snow-capped, mountainous country lying well to the eastward—at least 20 miles or more—from the Copper. Fig. 18 shows profile of bed-rock benching at its mouth.

[1] Hayes, op. cit., p. 136.

TEIKELL RIVER.

This is the first tributary of any considerable size entering the Copper below Wood Canyon from the west. Its source lies in the heart of the unexplored mountainous area in the Chugatch Range. It enters the valley of the Copper about 25 miles below Wood Canyon through a rugged canyon of moderate size.

KONSINA RIVER.

The Konsina, or Tsaina, is the next river below the Teikell. It is about 30 miles below Taral and about 15 miles above the Tasnuna. It also heads far to the westward, in the unexplored snow-capped, mountainous area of the Coast Range lying between Valdes Glacier and the Copper. The upper part of the valley may be found to be more hospitable, but the lower 15 or 20 miles is very rugged, being freely dissected by numerous almost impassable canyons and ridges and bordered by snow-capped mountains about 5,000 feet high. The river enters the valley of the Copper through a succession of short gorge-like canyons; thence by numerous distributary streams it descends over its large delta, several miles in radius, to the Copper River itself, which here, also, the delta has crowded to the eastern side of the valley. The Konsina in its lower reaches above the delta strongly resembles Fortymile Creek of the Yukon, though it is not so navigable as Fortymile. The stream normally consists of slightly widened stretches, from 80 to several hundred yards long, of comparatively smooth water, connected by riffles or rapids of usually less extent.

In the mouth of the valley, on its south side, occurs what seems to be a rather prominent bed-rock benching at an elevation of about 2,300 feet, or 1,500 feet above the present bed of the Copper.

CLEAVE CREEK.

This is merely a gulchlike valley, about 7 miles in length, which heads in the unexplored country between the Konsina and the Tasnuna. It is about a mile or more wide at its mouth, where lies a prominent delta. The gradient of the valley is steep, and the floor covered by a thick sheet of coarse gravel, over which a moderate-sized torrential stream—Cleave Creek—scarcely fordable by man, rushes down to the Copper. The head of the valley is occupied by the foot or lobe of a glacier (Pl. XXX) which is a good representative of the type found in the head of many valleys throughout this country. This glacier, with the cascades of numerous hanging or perched glaciers on the upper slopes of the surrounding mountains, forms the creek.

TASNUNA RIVER.

The Tasnuna is probably the largest tributary of the Lower Copper. It drains a considerable area of the hitherto but little known country lying between Port Valdes and the Copper. It heads on the east side of the Tasnuna and Lowe River divide, about midway between Port Valdes and the Copper, or about 24 miles west of the latter. It enters the Copper about 55 miles from the coast opposite the Bremner. The divide, which is low and open, has an elevation of about 1,800 feet and is bordered by snow-capped mountains on both the north and the south. The rise on the north is steep, but on the south it is gradual (Pl. XXVIII). It represents merely a sway in the belt of mountains sloping southward to the coast between Prince William Sound on the west and the Copper River on the east. The trend of the valley is nearly east along the strike, as is also that of the Konsina, Cleave Creek, and the Bremner. At its mouth it has a width of about 4 miles and is open (maps 20 and 21). Upstream, however, it gradually narrows until just above Woodworth Glacier,[1] about 20 miles from the Copper, it contracts into a canyonlike valley (Pl. XXXI), which continues to within a couple of miles of the divide, and at the upper end of which it becomes contracted into an impassable gorge but 3 or 4 feet in width and a couple of hundred feet deep, through which the stream rushes in a heap of foam (Pl. XXIV).

The upper part of the present channel of the Tasnuna, like that of Lowe River on the western side of the divide, seems to be cut in the floor of a much older valley. This old valley floor is represented largely by remnants in the form of bed-rock benches, often lipped or slightly ridged along the front edge or border, back of which frequently is found a sluggish minor drainage, with ponds and beaver dams. The benches may rise from 100 to several hundred feet above the present channel of the Tasnuna. On the north side of the valley the mountains are practically continuous or unbroken, and rise rather steeply from the edge of the valley flat to the general level of the land mass, which is here about 4,500 feet and is studded with snow peaks. On the south side of the valley the topography is still more rugged, the mountains are not quite so high, however, and have their slopes deeply dissected into canyons, gulches, and ridges, and broken through by two local glaciers—Schwan and Woodworth—each several miles in width, which descend into the valley (maps 20 and 21 and Pls. XXXII, XXXIII, *A*, and XXIII, *B*). So far as observed these glaciers seem to be 10 or more miles in length. They trend northeastward. Their waters contribute largely to the volume of the Tasnuna River, which, in fact, is largely a glacial stream, its headwaters being derived from numerous hanging or perched and small valley glaciers in the mountainous topography along the upper reaches of the valley.

The lower 5 or 6 miles of the valley is a dead-level mud flat, which at high water is apparently overflooded, but at normal stages is dotted

[1] This glacier has been named in honor of Mr. J. B. Woodworth, of Harvard University, whose observations and writings have contributed much to our knowledge of glaciology.

by lagoons and ponds and traversed by sloughs. It is usually impassable on account of the softness of the blue mud or glacial rock flour and quicksands of which it is composed. The flats extend from the Copper to the lower edge of the gravel delta of Schwan Glacier, which extends entirely across the valley. The terminal moraine and gravel deltas of both Schwan and Woodworth glaciers have crowded the river to the extreme north side of the valley. Between these deltas occurs a short interval of mud flats traversed by sloughs. The outlying terminal moraines in front of the glacier have, to some extent, locally modified the topography. It consists of sinks and hummocks, or mounds of huge bowlders and morainic material, often resting upon outliers of ice 100 feet or more in thickness, and supporting a dense growth of alder.

As soon as the river has passed the delta of Schwan Glacier it meanders southeastward across the mud flats to the extreme south side of the valley, where it continues on to the Copper. The lower 4 or 5 miles of the river here is about 300 feet wide and from 5 to 10 feet deep,[1] with a velocity of about 2½ miles an hour. The river could probably be ascended by a small steamboat to near the upper edge of the mud flats, a distance of at least 5 miles. Above this the current becomes more swift, with occasional gravel ripples, but can be ascended with a small rowboat to considerably above Woodworth Glacier, a distance of nearly 20 miles from the Copper, where the stream becomes quite torrential.

PAIRING OFF OF THE TRIBUTARIES.

The tendency to pairing off of the tributaries of the Copper in its course through the mountains, one of each pair lying topographically on the immediately opposite side of the valley of the master stream, would seem to denote a weakness or softness in the rock along the strike line in those localities. Examples are the Teikell River and White Creek, the Konsina River and Dewey Creek, and the Tasnuna and Bremner rivers. There are some indications that the valley of the Bremner may be a synclinal; closer observation, however, will be necessary before any definite statement can be made.

From Copper Center and the mouth of the Klutena, near the middle of the basin, out to the Coast Range the Copper flows southeastward through the plateau terrane to the edge of the basin at the mouth of the Chittena and head of Wood Canyon. The course throughout this section of the river is moderately direct. The river lies in the bottom of its new valley, which it has cut from 500 to 600 feet deep into the plateau. The width of the bottom of the valley is from about 1 to 2 miles. Over it, often in many channels separated by numerous small islands and gravel bars, the Copper meanders from side to side, largely

[1] These observations were made in October, when the river was 8 feet below high water mark.

as the deltas of the tributaries may locally determine. Portions of the valley, however, are occupied by timber flats of limited extent. From the edges of the valley flats to the surface of the plateau the rise is sometimes by a succession of well-marked terraces, often reaching back a considerable distance from the river, or, it may be, by a single bold overlooking bluff 600 feet high.

At a few miles above the mouth of the Chittena the Copper, which hitherto has maintained a width of nearly 2 miles, leaves the plateau terrane and, gradually contracting at Taral, enters Wood Canyon and the mountains. Wood Canyon consists of a narrow rock-walled gorge about 3 miles long and from about one-twentieth to one-tenth of a mile in width, where the river traverses a narrow zone of hard rock. The walls rise to a height of 500 or 600 feet along its immediate sides, but are not always precipitous. Below Wood Canyon the Copper soon enters a zone of softer rocks, in which its channel is somewhat less contracted and in which it continues 60 miles southward, through the rugged Coast Range it has just entered, in a narrow canyonlike valley, with rugged walls rising steeply to a height of from 3,000 to 5,000 feet, while the stream at its bottom meanders from side to side over a flood plain of coarse gravel. The walls are practically continuous, with merely local interruptions only where the valleys of the few lateral tributaries open into the Copper. From the relations of the rocks at the head of Wood Canyon some slight inferences have been drawn suggesting that the valley of the Copper may lie on a fault line cutting transversely throughout the Coast Range.

Where the Copper breaks through the range, about 30 miles from the coast, it is flanked on the east by Miles Glacier and on the west by Childs Glacier. Here occur the rapids, forming an insurmountable barrier to any kind of upstream navigation except canoes. The rapids are caused by deposits of the north lateral moraine of Miles Glacier, which upon the retreat of the glacier remained as a huge dam across the channel, over which the river now tumbles, forming the impassable rapids. On its upper side the dam has spread the river out into a shallow lake of considerable size.

Above these rapids the Copper, though swift in places, is navigable and could probably be ascended to the upper reaches of its big bend, northwest of the Wrangell Mountains, by river steamers of moderate size and special power—sufficient to overcome a current of 9 miles an hour. The same seems to be true of the lower reaches of the Chittena River.

From Miles Glacier for a short distance southward to the head of the delta the current of the Copper is swift and follows many channels, which frequently change their depth and course. From its head the delta, which for the most part consists of broad, level meadows or marshy flats, a few sand dunes, and at low tide extensive mud flats, reaches 30 miles southward to the line of bars or keys at the edge of deep water on the coast. According to the latest determinations by the United States Coast and Geodetic Survey, the astronomic position of the middle point of the lower or south frontal aerial edge of the delta lies in latitude 60° 20′ N., and longitude 145° 5′ W.

From the head of the delta to where the river leaves the meadows or marshy flats and spreads out over the mud flats it flows nearly south, is about 5 miles wide, and here also it consists of many changeable channels varying in depth from 5 to 20 feet, depending upon the stage of the river.[1]

Soon after the river enters the delta several tributaries or branches are given off, which flow in a southwest and westerly direction through the delta. The first or westernmost is known as Alaganik Slough, the native village of Alaganik being situated on it. As it is the most extensively traveled, it is often called the main branch of the Copper. It is a tidal stream, the tide being felt as far as Alaganik, where it amounts to several feet. At the lower end of the flats the average tide during the summer season is about 10 feet. From where the stream breaks into the flats to where it leaves them is about 15 miles. The average width of the stream between these points varies from one-half to 1 mile. Its navigation is greatly facilitated by the tide, which at its flood gives rise to an easterly current, while ebb tide changes it to a westerly direction.

The area at the mouth of the Copper, which at low tide becomes continuous mud flats, amounts to 250 square miles. Seaward these mud flats merge into sand reefs, and farther out into submerged bars which extend far out to sea. The body of water between the mud flats and the ocean reefs is navigable for boats drawing from 3 to 4 feet of water, and in places for these at high tide only.

In conclusion, the drainage system of the Copper is young and vigorous. Downcutting is everywhere going on at a very rapid rate. The river is striving to adjust its new drainage basin back of the Coast Range, which for some time after the uplift until the downcutting of Wood Canyon seems to have found an outlet elsewhere, probably to the northwest. The most active period of work is spring and early summer—from late April to August, from the time the ice on the river breaks up until the melting season of snow and glaciers on the mountains has passed its zenith.

PHYSIOGRAPHY.

With an outline of the foregoing topographic description of the country in mind, a brief statement of its physiography will here be attempted. The physiographic history of the region properly begins

[1] Much of what follows concerning the Copper River delta is from unpublished information kindly furnished by the United States Coast and Geodetic Survey.

with its elevation or emergence above sea level, for by far the greater part of the country is covered by sediments deposited in the sea. At what time, geologically speaking, this elevation began, can only be approximated, owing to our lack of knowledge of the age of the rocks. It must, however, have been after the youngest rocks which enter into the composition of the mountain ranges were laid down—after the deposition of the Orca and Valdes series, probably post-Cretaceous, and possibly as late as Miocene time. The axial lines of maximum uplift, as shown by the Chugatch Mountains on the coast and the Alaskan Range on the north, were largely concentrically parallel with the present coast line of the head of the Gulf of Alaska and Prince William Sound. Whether the uplift of these two ranges was probably synchronous the observations of the writer have hardly been extensive enough to affirm. Since the younger rocks, the Orca and Valdes series, are not known to occur in the Alaskan Mountains on the north side of the Copper River Basin, but the range here seems to be composed of an older class of rocks, which extend northward into the great Yukon Plateau, it seems that the uplift of the Alaskan Range in this section may have antedated that of the Coast Range, and since nearly all field observations made were on the Coast Range, to it the following remarks will be largely confined.

The aspect of the topography in the general land mass of the Chugatch or Coast Range, as has been indicated, is that of a somewhat eroded plateaulike belt, with its surface studded by peaks and ridges, but not generally deeply dissected except on its edges. This suggests that soon after emergence from the sea the land mass of the range may have undergone erosion during a somewhat prolonged stage of comparative rest at an elevation but little above sea level. Soon after this, judging from bed rock floors of some of the old valleys and the bed rock benches which line the sides of others, there occurred a somewhat rapid and pronounced elevation of about 2,000 feet. Examples of the old bed rock valleys are the upper reaches of Lowe and Tasnuna rivers and the Konsina River. The benching occurs on the headwaters of the Klutena, and on the Copper from the vicinity of Wood Canyon northward for 20 miles or more beyond the mouth of the Chittena, where now, in a somewhat dissected state, it forms the foothills of the mountains on the west. Some also occurs at the mouth of the Bremner Valley (fig. 17). This pronounced elevation seems to have been followed by a somewhat prolonged period of relative rest, during which the drainage became comparatively well adjusted, the streams finally wandering to and fro in the somewhat broadened bottoms of their bed rock valleys. The general level of the somewhat broad benching along the Copper, opposite and above the mouth of the Chittena, belongs to this pause. This benching is roughly continuous with that in vicinity of Wood Canyon. Its elevation is about 1,000 feet above the river at that point. It may denote a former outlet of the Copper River southward to the sea, or possibly a broad channel of the sea extending up the Sushitna and Copper River valleys, completely encircling as a large island the great block of the Chugatch Mountains, now lying between Prince William Sound and the Copper River Basin. In such event the bench cutting along the west side of the Copper opposite the Chittena would be largely marine. However long that pause may have been, it was followed by another elevation of limited extent along the axis of the Chugatch Range. It was probably sufficient, however, to form a barrier at Wood Canyon between the present basin of the Copper and the sea on the south; but it probably left the basin of the Copper continuous with that of the Sushitna on the north.

This great crescentic depression between the Alaskan Range on the northwest and the Chugatch on the southeast was probably occupied by an arm of the sea which opened out into the ocean through the broad valley of Cook Inlet, west of Kenai Peninsula. This supposition is strengthened by the continuation of the gravel deposits from the basin of the Sushitna over the present low divide, and their apparent connection with the Copper River silts and gravels in the Copper River Basin. During and subsequent to this change in elevation the Pleistocene Copper River silts and gravels, and similar, if not the same deposits, continued to the westward and were laid down in this arm of the sea, the materials of which they were composed being derived by erosion from the surrounding mountains, much of it probably from the moraines of local glaciers, for the old landmarks of these glaciers show unmistakably that ice action was far more vigorous at that time than at present. This accounts for the gravels in certain localities often partaking more of the nature of ground moraine than true water-laid deposits, especially along the margin of the formation near the base of the mountains, while farther within the basin they consist largely of evenly stratified fine silts. Some of the surrounding glaciers seem to have discharged into the water body at the time, whose moraine-laden bergs best explain the pockets of till and coarse gravel dumped here and there among the water-laid fine silts near the middle of the basin. While this deposition was going on the elevation of the continental land mass was probably more or less continuous, with occasional slight pauses here and there now marked by the terraces of Pleistocene gravels which skirt the sides of the basin at successive levels.

During this same period the drainage along the eastern slope of the mountains west of the Copper, opposite and above the Chittena, seems to have been directed northward directly opposite to the present course of the Copper. Along the western edge of the benching and through the foothills it cut a deep north and south gorge or canyon (map 21) in the bed rock, now occupied by a succession of lakelets and pools. The drainage of the northern portion of this canyon still flows sluggishly northward till it finds an outlet eastward to the Copper.

While the above elevation and Pleistocene deposition was going on, or toward its close, a change took place in the relative elevation of the region about Taral on the south, with reference to that now forming the low divide between the basin of the Copper and that of the Sushitna on the northwest. Elevation of the country in general was probably more or less continuous, but on the northwest it seems to have exceeded that on the south to such an extent that the present low divide on the northwest was probably raised above sea level, the Copper River basin being cut off from the sea on the west, and converted into a temporarily inland lake. With continued relative increase in elevation on the northwest, amounting as it were to a tilt of the basin to the south, the drainage of the lake and basin was soon forced to find an outlet southward down the supposed old valley of the Copper through the Coast Range. Now began vigorously the downcutting of the barrier on the south, which finally resulted in the formation of the present gorge known as Wood Canyon.

This rapid downcutting with a probable further increase in the tilt of the basin as elevation went on, soon, geologically speaking, drained the basin of its lake, and the Pleistocene Copper River silts and gravels which were deposited in the basin while occupied by the arm of the sea and subsequently by the lake, now became the Copper River Plateau, on whose surface the present superimposed drainage of the Copper back of the Coast Range was quickly inaugurated.

Already before the basin was drained of its lake, as elevation went on, sharply V-shaped canyons and gulches were being incised into the bed-rock floors of the old valleys in the surrounding mountains. These are still being rapidly cut down as the superimposed drainage in the Copper River Plateau deepens.

Much of the physiographic history of the Copper River district is probably contemporaneous with or belongs to the St. Elias uplift, judging from the monoclinal structure in the Coast Range, which traverses the district where the rocks all dip steeply northward, the thrust or force of uplift seeming to have come from the south or coastal direction. Since, however, the Orca rocks, which are apparently younger than the Valdes series, seem to occupy the lower horizon, the possibility of an overturn should be kept in mind in the future study of the region.

In the northeast part of the basin, in the district of the Wrangell Mountains, where the rocks seem to be largely igneous, volcanic activity seems to have played a very important part in the physiographic development. The rocks seem to consist largely of flows of rhyolitic lavas, to some extent at least, and were probably poured out during the earlier stages of the uplift of the Copper River district, or at least before Pleistocene time, as they seem to have contributed largely to the Pleistocene beds within the basin, and are probably a dominant factor in imparting to the silts their light color (see Pl. XXXV, *A*).

According to Bremner, Allen, and Hayes, Mount Wrangell was seen to emit smoke and vapor during the winter of 1884 and 1885, the summer of 1885, and in August, 1891. Many who beheld the mountain at a distance during the summer of 1898 likewise pronounced it to be sending up smoke and vapor. It also had this appearance when seen by the writer from within the basin of the Copper, late in August and in September. The mountain is designated by the Stick natives as the one which intermittently sends up puffs of smoke.

On the coast, crustal movements, as shown by bed-rock benching near tide level, have been going on in comparatively recent time. Fig. 19 is a sketch of the northwest point of Nuchek Island, showing marine benching at several successive stages in elevation of the land with reference to the sea. In 1794 Vancouver's expedition, under the English, reported to have found that during the past decade the waters

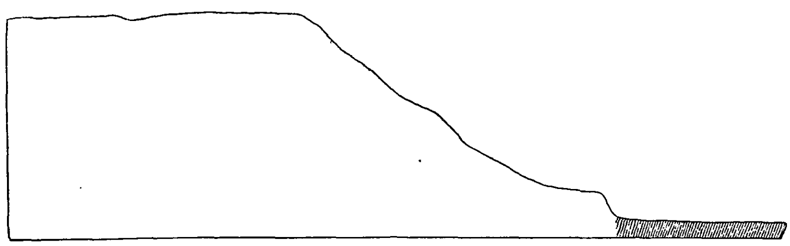

FIG. 19.—Marine benching, northwest shore of Nuchek Island.

of Prince William Sound had been rapidly encroaching on the shore line.[1] In 1891 Dr. Hayes, at the delta of the Copper, observed large spruce trees standing several feet below tide water, denoting a sinking of the land in this locality.[2] Discordance in level of the marine benching in vicinity of Galena Bay, as observed by the writer in 1898, show a sinking of the land in this locality.

GEOLOGY.

SEDIMENTARY ROCKS.

ORCA SERIES.[3]

Forming the north shore of Prince William Sound and its adjacent islands, beginning below Orca and extending northward and northwestward, the rocks are a sedimentary series consisting of thick-bedded brown and gray sandstones, black limestones, and arkoses, interlarded

[1] Bancroft's History of Alaska, p. 278.

[2] Nat. Geog. Mag., Vol. IV, p. 136.

[3] The rocks about Prince William Sound were observed in the field at such points only as it was found necessary to land in carrying on a triangulation from Orca to Valdes by boat early in May, while the snow lay 6 feet deep on the level.

with usually thin layers of dark shale and slate, and occasionally some conglomerate. The general strike or trend is a little north of east, or about east and west. The dip is steeply north. The rocks are freely jointed, often intensely folded (see sketch, fig. 20), and minutely faulted and somewhat altered, especially the shale and slate. They are traversed by three or more sets of cleavages, of which the most prominent has a southward dip almost at right angles to the bedding. The cleavage planes are often followed by quartz and calcite veinlets. The minute faulting seems to have taken place subsequent to the veining.

Character of the rocks.—The conglomerate, so far as observed, occurs sparingly in beds but a few feet in thickness. The pebbles consist largely of gray quartzite and some quartz, generally rolled and waterworn. They rarely exceed 3 inches in diameter and will probably not average more than 1 inch. The cement, which is rather coarse, is largely siliceous or gritty and sometimes iron stained or ferruginous.

The sandstones, which usually weather brown on the surface, owing to oxidation of the iron ingredients, are often difficult to differentiate

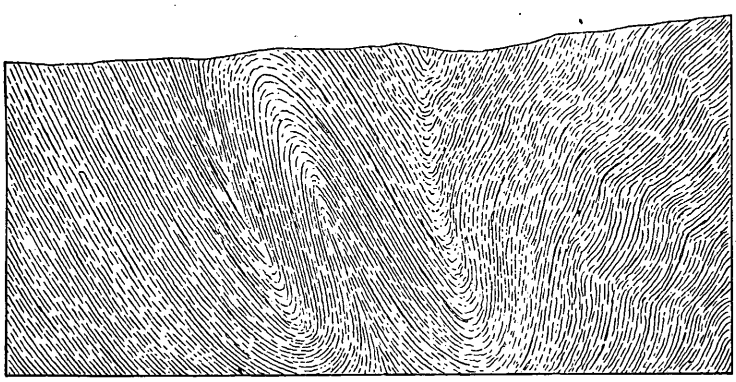

FIG. 20.—Folding in Orca rocks at Porcupine Point, Prince William Sound.

from the arkose rocks. They are usually thick bedded, occurring in layers of from 1 to 6 or more feet in thickness. They are sometimes quartzitic, resembling very much a true brown quartzite, but not normally so. Along shear zones and planes of movement they are brecciated and carry angular fragments of black kneaded slate. With this black slate, the rock in some localities appears brecciated or conglomeratic, but for want of opportunity its true nature could not be determined. In the hand specimen the sandstone is of a medium uniform grain, with the fresh surface usually dark gray in color. Under the microscope it seems to be composed mostly of quartz grains, some rolled, but more generally irregularly subangular and occasionally interlocking. In the cement, which is largely siliceous, occurs much argillaceous and foreign detrital matter.

The arkoses, which by some geologists would be called graywacke, constitute by far the larger portion of the Orca rocks. They consist of medium or fine grained rocks. On the fresh surface they are usually dark gray or dark blue in color. They are softer than the sandstone and not so quartzitic, though like them they are at times very largely made up of grains of quartz. They are sometimes slightly calcareous and occasionally carry small quartz or calcite veinlets and some iron pyrites. The term arkose is here used for these rocks, since under the microscope they are seen to be composed, besides the partially rolled and subangular quartz grains, of feldspar detritus, especially plagioclase, which is sometimes abundant, with occasionally fragmentary grains of augite and some decomposition products belonging to the hornblende group.

The limestone representative of the series as exposed at Yellow-Cedar Bay, on the north of Hawkins Island, consists of layers varying from 1 to 2 feet or more in thickness. It is compact or dense in texture, and dark blue or black in color. The shales and slates, which for the most part are the ordinary clay slate, are also dark and usually very fine grained, and may in cases graduate to the arkose beds, but are usually distinctly interlarded as thin layers or beds between the arkose and sandstones. In the dynamic movements to which the series has been subjected the shale and slate have suffered most.

Origin of the Orca rocks.—Since the arkoses form by far the larger part of the series, it may be inferred from what has just been stated concerning mineralogic constituents of the arkoses, that the material which now composes the Orca rocks was largely derived by erosion from some parent igneous rock, probably diabase or possibly augite-diorite.

Probable age of the Orca rocks.—The following is the report of Mr. F. H. Knowlton, of the United States Geological Survey, on the fragmentary plant remains found in the Orca rocks, and submitted for examination:

No. 3. Northeast shore Hawkins Island. Two specimens. These specimens appear to represent portions of the cone of a *Glyptostrobus* or possibly a *Sequoia*. The form of the cone can not be made out, as the only portions remaining are a number of the scales. If the appearance is not deceptive, these fragments are quite like certain Upper Cretaceous or Lower Tertiary forms, but are too indefinite to be of much value.

No. 20. Gravina Point, west shore of Prince William Sound. These are very small fragments covered with remains of fragments of plants, the nature of which can not be made out.

No. 24. Johnsons Point, north coast Hinchinbrook Island, Prince William Sound. The specimen is covered with a disconnected mass of fragments that have very little character. There is, however, one piece that has somewhat the appearance of a branch of a conifer. It has or appears to have three leaves attached to a branchlet, and is not unlike *Sequoia* or *Taxodium*. It is too imperfect to be of any value in determining age.

All that can be gathered from the above is the possibility or slight probability of the rocks being Upper Cretaceous or Lower Tertiary, as indicated by Mr. Knowlton in No. 3.

Correlation of the Orca rocks.[1]—The Orca rocks in some respects seem to strongly resemble the rocks described by Professor Russell as the Yakutat series in the St. Elias district,[2] and may be a continuation of the same along the coast. The Yakutat system, however, as determined by Russell, is supposed to be much younger than the probable age of the Orca rocks. Hayes supposes the Orca series to be Mesozoic or younger.[3] It is of interest in this connection to note that in the coastal plateau between Icy Bay and Controller Bay similar rocks have been found and briefly described by Mr. Spurr in his report in this volume.

Owing to the upturned, folded, and contorted attitude of the Orca rocks, any statement as to their thickness would necessarily be purely

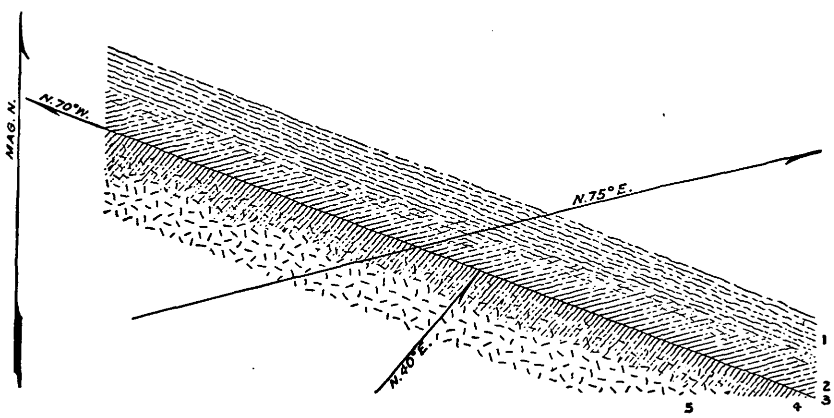

FIG. 21.—Contact of diabase with slate, Bligh Island, north shore: 1, slate; 2, hornstone; 3, contact; 4, altered diabase; 5, diabase.

hypothetical. Judging, however, from their extent northward to Port Fidalgo, the thickness is probably at least several miles.

Dike rocks in the Orca series.—Judging from contact pebbles found along the beach and at the mouths of some of the canyons, the Orca rocks are occasionally cut by diabase and granitoid or aplite dikes. On the north shore of Bligh Island a typical medium-grained iron-gray diabase meets the darker slate. The slate along the contact has been altered to hornstone, and the diabase also considerably changed (see fig. 21). Under the microscope the diabase is found to be a typical diabase with ophitic structure, and is composed of augite and plagioclase feldspar, with some of the augite in places altered to hornblende

[1] See table of hypothetical correlations, opposite p. 413.

[2] An expedition to Mount St. Elias, Alaska, by Israel C. Russell: Nat. Geog. Mag., Vol. III, p. 167.

[3] An expedition through the Yukon district, by Charles Willard Hayes: Nat. Geog. Mag., Vol. IV, p. 142.

and some serpentinized; also in the head of Gladhaugh Bay a diabase dike apparently of considerable thickness occurs. Its feldspar was determined by Mr. Spurr to be labradorite.

VALDES SERIES.

As previously indicated, the Orca rocks extend northward to the vicinity of Fidalgo Bay. From this point and Copper Mountain, proceeding northward, the rocks become more highly metamorphosed and consist of bluish-gray and dark quartzites, arkoses, and quartz-schists, interbedded with generally thin beds of dark-blue or black slate, shale, mica-schist (sometimes slightly graphitic), nodular mica-schist, and occasionally some stretched conglomerate. These rocks may be a direct continuation of the Orca rocks, more highly metamorphosed and altered as they pass toward the axis of the mountain range, but for the present, on account of their difference from the Orca rocks in lithologic character, they have been given another name and are here called the Valdes series, from the fact that they are best exposed about Port Valdes. The strike and dip of these rocks, well shown in Port Valdes, is the same as in the Orca rocks. The series extends northward over the range and down into the Copper River Basin, and eastward across the Copper from below the Tasnuna up near the foot of Wood Canyon below Taral. The rocks show much the same faulting, folding, and cleavage as the Orca rocks. They are frequently traversed or threaded by quartz veinlets, with some stringers (fig. 22), and occasionally by veins a foot or more in thickness.

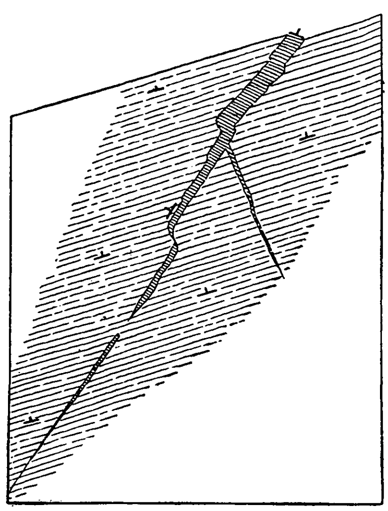

FIG. 22.—Quartz vein in Valdes schists at Port Valdes, showing faulting and pinching.

Character of the Valdes rocks.—The quartzites and quartz-schists are medium grained and under the microscope show a pronounced schistose structure; and some biotite and muscovite are usually developed, and the quartz often gives a wavy extinction. The mica in the mica-schists is usually biotite, sometimes forming an almost typical biotite-schist. The nodular mica-schist, found principally in the head of Port Fidalgo, consists of nodules of quartz around which are bent overlapping foils of biotite which chiefly constitute the rock. The pebbles in the stretched conglomerate so far as observed are largely quartzite. The arkoses differ from those of the Orca rocks only in the fact that they are somewhat more altered, exhibit a schistose structure, and contain some mica, which is here apparently a metamorphic product.

Probable age of the Valdes rocks.—Plant remains, consisting, according to Mr. F. H. Knowlton, of bark or stems, were collected from the schists at Point Lowe, in the southwest part of Port Valdes, but unfortunately were without character and too greatly altered for determination.

Correlation of the Valdes rocks.—The lithologic resemblance of the Valdes rocks, however, both in the field and under the microscope, with those of the Sunrise series of Mr. Mendenhall, west of Prince William Sound, would suggest the possible reference of the rocks to the Devonian or Carboniferous age. As seen in the accompanying hypothetical table of correlations (p. 413), they also are supposed to be either Lower Tertiary or Cretaceous.

Thickness of the Valdes rocks.—Almost wherever observed between Port Fidalgo and Lake Klutena, a distance of about 50 miles, the strike or trend of the rocks is about east and west and the dip steeply north, but, with the possible unobserved plications that may have

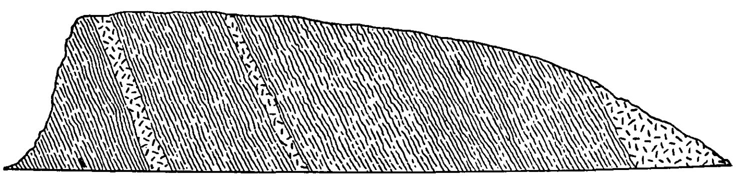

FIG. 23.—Aplite dikes in Valdes schists, Giant Rocks, Port Valdes.

taken place in mountain buildings, it can only be conjectured that the thickness of the rocks is probably very great.

Dike rocks in the Valdes series.—The Valdes rocks are also occasionally cut by granitic diorite or aplite dikes and some porphyry-diorite. A couple of these dikes are seen at Giant Rocks, in Port Valdes. (Pl. XXXIV, *B*, and fig. 23). Here they have the attitude of intrusives and lie parallel with the bedding of the sedimentaries. At the east edge of Valdes glacier, about 2 miles south of the summit, another large dike occurs. It trends northeastward, apparently cutting through the crest of the range, and reappears on the north side of the Klutena Valley near the foot of Klutena glacier. Here, also, portions of a half dozen or more light-colored dikes are exposed at various elevations in the surrounding slopes of the mountains. Several are also shown in the upper slopes of the mountains on both sides of Klutena Valley between Twelvemile Camp and the head of Lake Klutena. At the base of Mayer Peak, about 4 miles above the head of the lake, one is well exposed in the foothills at the edge of the valley flats. It has an east and westerly trend. Others were also observed in the mountains about Lake Klutena and north of Cranberry Marsh, on the east side of Salmon Creek Valley. The most prevalent of the aplitic dike rocks is normally light gray in hand specimen, with a tinge of green and with a slightly micaceous or silvery sheen. It is occasionally slightly porphyritic and is usually medium grained; often it is some schistose. Under the microscope it consists, essentially, of orthoclase in short, stout prisms, some plagioclase, quartz, and some green chloritoid mica, which latter gives to the rock its slightly greenish tinge. The dikes in the Klutena Valley are inferred, from mineralogic resemblance in the field and the hand specimen, to be the same as those found about Valdes. None of the Klutena specimens were studied under the microscope, as the collections were lost by accident on the Tonsina River.

KLUTENA SERIES.

The Valdes rocks, roughly speaking, extend northward to the region of Lake Klutena. Here they form the base of the mountains and are still exposed in the lower reaches of the gulches, but gradually give way to a different class of rocks, which already appear above Lake Klutena in the upper slopes of the mountains and extend into the foothills at the edge of the Copper River Plateau. These rocks, by reason of the locality in which they occur, are provisionally called the Klutena series. They form the most of the mountains about the lake and seem to overlie the Valdes rocks, which northward seem to pass beneath them. They consist of mica-schists, quartz-schists, sometimes cherty or jaspery in character, and crystalline limestone or marble. In the vicinity of Sunny Mountain and Mount Carter, north of the foot of the lake, the marble occurs in beds from 2 to 6 feet or more in thickness, interlarded in the mica- and quartz-schists. These rocks resemble in some respects the rocks of the Fortymile series in the Yukon district. In places they have been greatly folded, to such a degree that no definite strike can be determined. So far as observed, however, they seem to have, in a general way, an east-west trend and to dip steeply north.

Probable age and correlation of the Klutena series.—Judging from the lithologic resemblance above noted, the rocks, as indicated, may belong to the Fortymile series. If so, they are probably pre-Silurian sediments.

COPPER RIVER SILTS AND GRAVELS.

The Copper River silts and gravels form the plateau terrane of the Copper River Basin, already described under the heading Topography (Pls. XXVIII, *B* and XXXIV, *A*). They are composed, for the most part, of beds of fine-grained light-buff colored unconsolidated silts, with local deposits of sand and gravel and sometimes bowlders. The stratification is nearly or quite horizontal. This, with the fineness of the material and the areal extent of the beds over the basin, covering, probably, more than 2,000 square miles, leads to the view that they were most probably deposited in some large lake or branch of the sea. The beds are exposed in the form of bluffs and terraces all along the Copper River above Taral and on the tributaries of that section of the river, often rising steeply from the river to a height of 500 or 600 feet. Since the Copper, where it has cut deepest in the beds near the middle part of the basin, has, apparently, nowhere reached bed rock, it is inferred that the deposit probably exceeds 1,000 feet in maximum thickness. The beds are here called the Copper River silts, owing to the fact that throughout the middle of the basin the beds are very largely composed of silts only (Pl. XXXIV, *A*). Here the fineness of the material and the horizontal stratification leave no doubt as to the manner in which they were deposited. In other localities, however, notably in the northwest part of the basin, on the upper part of the Chestochina and elsewhere, it is inferred, from the description given by reliable prospectors, that the deposits may be largely of glacial nature. This is probably due to variation of condition at different localities at the time of contemporaneous deposition, some areas being near large local glaciers.

Geologically the beds seem to be very young. They nowhere show a tendency to consolidation, nor do they seem to carry any fossils other than recent shells, chiefly *Succinea chrysis*, occasionally found near the tops of the beds. These organisms now live along some of the streams in that district. The beds are therefore considered to be Pleistocene in age, and, as seen in the accompanying hypothetical table of correlation (p. 413), are correlated with similar deposits having a wide extent in the Yukon district and other parts of Alaska. The significant feature is that they are probably continuous from the Copper River Basin with those mapped by Mr. Mendenhall on the west, extending from Resurrection Bay to the Tanana River. They seem to form the low tundra divide which at present separates the drainage of the Copper from that of the Matanuska and Sushitna drainages on the west and from the Tanana on the northwest. The present elevation of this divide, as determined by Mr. Mendenhall, is about 2,800 or 2,900 feet. This elevation accords well with the highest of the terraces which skirt the rim of the Copper River Basin, and whose gravels are probably contemporaneous and identical with, or a part of, the same deposits. From the highest of these terraces the descent into the middle of the basin is by several other terraces, located at somewhat wide intervals. Near the middle of the basin the elevation of the beds is about 1,500 feet. Farther downstream, at the southern part of the basin, above Wood Canyon and opposite the mouth of the Chittena, they rise to about 1,300 feet. On the north side of the Chittena they seem to extend up that stream, forming its north bank for half a mile. This, however, may not be nearly the extent in that direction, for, as previously suggested, they may connect with similar deposits found by

Dr. Hayes, extending to above the forks of the Chittena. Below Wood Canyon no trace of the beds is found.[1]

Origin of the Copper River silts and gravels.—The beds are obviously composed of sediments derived by erosion from the surrounding mountains and deposited in a standing body of water of considerable extent. This body of water was either a large inland lake or probably an arm of the sea, with which it seems likely to have connected by way of the low divide on the northwest through the Matanuska and Sushitna River valleys and possibly with that of the Tanana. At that time the drainage of the Copper River basin probably passed out around the western end of the coast range into Cook Inlet instead of passing through the range by means of the Copper River Valley as to-day. This view finds support in the apparent continuation of the deposits as above indicated, and further by the absence of any trace of the beds below Wood Canyon. This latter point at the time of the deposition of the beds seems to have been a closed part of the rim of the basin. Wood Canyon had probably not then been cut down as it is to-day.

During the time of the deposition of the beds glacial activity in the surrounding mountainous regions seems to have been much greater than at present, for among the silts, often forming large pockets far within the basin, occur deposits of unassorted gravels and bowlders, some of which are unmistakably of glacial origin. The most plausible explanation for this local occurrence of these coarse foreign deposits in the evenly stratified silts is that the former were brought here by berg ice floating on the surface of the water and that they dropped light deposits of till of morainal dumps over which the deposition of the silts continued. The silts are finest in the interior or middle regions of the basin. Here in some localities in the middle of the basin the silts when wet form a mud or very uniform clay, in texture much like potter's clay. They become coarser and gravelly toward the edge of the deposit, in some localities extremely coarse and bowldery. It is probable that in most localities near mountains of any considerable height the material forming the deposits about the border is almost wholly of glacial origin and on the whole very coarse. The terraces represent different stages of the water level with reference to the surrounding land. If the body of water was an inland arm of the sea the elevation of the land mass which finally shut out the sea must have been very rapid.

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[1] For a more detailed topographic statement of the beds the reader is referred to the heading Copper River Plateau, p. 384.

Table of provisional correlations.

	Spurr: Yukon district, 1896.	Brooks: White River and Tanana district, 1898.	Mendenhall: Resurrection Bay to the Tanana River, 1898.	Spurr: Southwestern Alaska, 1898.	Eldridge: Sushitna Valley, Alaskan Range, and Cantwell River, 1898.	Schrader: Copper River district, 1898.
Pleistocene	Silts and gravels.	Silts and gravels.	Sands and gravels.	Silts, sands, and gravels.	Sands, gravels, and bowlder clays.	Silts and gravels.
Neocene	Twelvemile beds, Porcupine beds, Nulato sandstone, Palisades conglomerate.	Tok sandstone.		Tyonek beds, Hayes River beds, Nushagak beds.		
Eocene or Oligocene.	Kenai series.			Yentna beds.	Kenai series.	Orca series, Valdes series (?)
Cretaceous	Mission Creek series.		Matanuska series.	Tordrillo series, Holiknuk series, Kolmakof series, Oklune series.	Cantwell conglomerate (?)	Valdes series (?)
Jurassic				Naknek series, Skwentna series.		
Devonian and Carboniferous.	Tahkandit series.	Wellesley series, Nilkoka beds.	Sunrise series (?)	Tachatna series.	Cantwell conglomerate (?)	Valdes series (?)
Silurian	Rampart series.	Greenstone schists.	Greenstones (?)			
Pre-Silurian sediments.	Birch Creek schists, Fortymile series.	Tanana schists, Nasina series.	Tanana schists.		Sushitna schists.	Klutena series.
Archean	Basal granite.	Gneissic series.			Basal granite and gneissic series.	

IGNEOUS ROCKS.

COPPER MOUNTAIN GREENSTONE OR AMPHIBOLITE-SCHIST.

Exposed on the north shore of Prince William Sound, along the zone where the Orca rocks give way to the Valdes series, and trending nearly east and west, runs a mountainous backbone or ridge of green amphibolite-schist. It is a totally different rock from either the Orca or the Valdes series, both of which it seems to greatly exceed in age. On the sound it is best exposed to the east of Tatitlak, where it constitutes almost the entire mass of Copper Mountain (map 19), which rises steeply about 5,000 feet above the sea. Thence, as a somewhat prominent mountainous ridge, it extends eastward beyond Fidalgo Bay and across country toward the Copper River. In the Copper River Basin it forms the mountains of the Coast Range along the south side of the Tonsina Valley, and from here it continues southward without interruption to below Wood Canyon, and thence eastward for some distance. It probably also forms the frontal ranges which come down toward the Copper from the Mount Wrangell group on the southwest. At Copper Mountain the rock seems to be infolded along with both the Orca and the Valdes series. It agrees with those series in trend and dip. It accordingly seems to overlie the Orca rocks and to underlie the Valdes rocks. It should, however, be borne in mind that its present attitude and relations to these series has probably been brought about very largely by mountain-building forces. As has been indicated, the rock on the coast trends with the Orca and Valdes series. In the Copper River Basin, north of the Coast Range, between the Tonsina and Wood Canyon, where it has been best observed, the trend maintains this direction only in a very general way. Large areas of the rock sometimes occur in a nearly massive state. In some places there is a pronounced banding parallel with the schistosity. The rock again occurs on the south side of the range, in the vicinity of Heiden Canyon, and south of the divide at the head of Tasnuna and Lowe rivers. Judging from the quantity of large, angular bowlders and blocks of the rock occurring in the older terminal moraines of Schwan and Woodworth glaciers, it probably also forms most of the country rock about the heads of those glaciers to the south of the Tasnuna.

Character of the Copper Mountain greenstone or amphibolite-schist.—The rock in the field and in hand specimen varies from apple green to dull green or greenish gray in color. It is medium or fine grained. The schistosity is pronounced, usully showing on the surface a pronounced graining or fibrouslike structure. The surface is often smooth or glossy and talcose to the touch. The mineral, however, which at first was taken for talc, was found by Mr. Steiger, on chemical analysis, to belong to the amphibolite group. In driving a tunnel at Copper

Mountain the Alaska Commercial Company found the rock very hard to drill. It may be characterized as tough, or tenacious, rather than brittle. The freshly fractured surface, however, which is usually irregular or semiconchoidal, often appears dense and massive, especially when broken at right angles to the schistosity.

Under the microscope the rock is found to be composed essentially of plagioclase feldspar and hornblende or serpentine, with occasionally some partially altered augite, and often some quartz. The feldspar, which in certain cases has been determined to be albite, is usually greatly crushed, bent, and broken, giving, like the quartz, when present, a very wavy extinction. It is usually fresh, showing but little alteration in comparison with the other minerals, some of it so fresh as to suggest that it may be secondary. The hornblende, which seems to have been derived by process of uralitization from the augite, is pale green, generally very fibrous, often with actinolitic habit, and sometimes altered to serpentine. What remains of the augite is in small grains or minute masses, much broken down about the edges. Quartz does not occur in all slides. When present it occurs in grains or portions of crystals which have been greatly crushed and bent, and, like the feldspar, give a very wavy extinction, due to the destruction of the optical continuity by dynamic action to which the rock has been subjected. Occasionally a few small veinlets are met with which do not show such action and seem, therefore, to be of later origin. Small scales of mica, muscovite, and chlorite are sometimes present.

Origin of the Copper Mountain greenstone or amphibolite-schist.—A study of the rock in microscopic thin section seems to leave little doubt that the schist has been derived from a former igneous rock, apparently of diabasic nature, which has been so sheared and crushed by dynamic mountain-building forces as to convert it into the schist which we now find. This original igneous rock may have been of a lava-flow n: ture.

GRANITIC DIORITE.

Above Orca, about Sheep Bay and Gravina Point, the beach is sometimes for miles lined with granitic diorite bowlders, whose large size and numbers would seem to favor the occurrence of the parent bed rock near by. So far as seen from the distance, but not visited, it seems to form an area about the head of Sheep Bay, between that bay and Port Gravina on the northwest. At the head of Klutena River, just below the foot of the glacier forming some of the benches on the north side of the valley in this locality, occurs what seems to be a gray ferruginous rock or ironstone, probably of diabasic character.

GABBRO.

A rock which is probably a gabbro occurs about 8 miles below Lake Klutena, on the northwest side of Klutena River, where it forms a hill about 2 miles in diameter which rises about 1,100 feet above the river. Judging from the character of the topography and the large number of bowlders found in the Klutena River below this point, it is probable that other of the foothills are composed of the same rock.

RHYOLITE.

The rocks of the Mount Wrangell group have long been supposed to be volcanic, but, as they have never been visited by any scientists, nothing definite is known of them. Of two specimens received from Messrs. Cantwell and Mason, who in the summer of 1898 had penetrated to and collected them from the north crater of Mount Drum, one was pronounced by the writer, from macroscopic examination, to be a red rhyolite, and the other probably a gray andesite. Prospectors

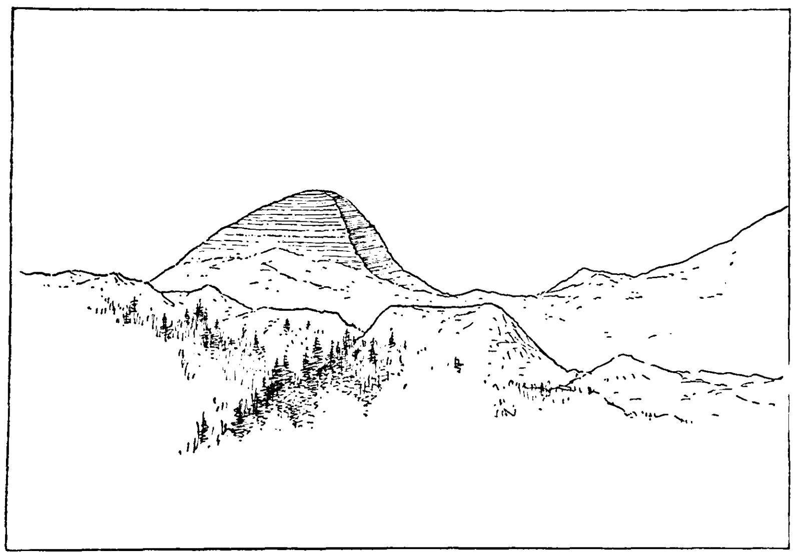

FIG. 24.—Wolff Peak, between Mounts Drum and Tillman, showing lava flows or stratification.

report the entire mass of Mount Drum, so far as seen, to be made up principally of this red rhyolite, and that it extends many hundred square miles northward around and beyond Mount Sanford. Large bowlders of this rock occur in the coarse gravels of the Klutena River, between Lake Klutena and Copper Center, where they were probably transported by floating ice and were probably derived from the Wrangell Mountains, since this rock is not known to occur on the southwest side of the Copper River Valley. There is, therefore, some probability that a large portion of at least the northern part of the Wrangell Mountains is composed of red rhyolitic lavas. They apparently constitute the prominent peak south of Mount Drum, now named Wolff Peak,[1] shown in fig. 24.

[1] Named from Prof. J. E. Wolff, of Harvard University.

MONZONITE.

Judging from the quantity of bowlders found in Taral Creek, which descends the mountains from the east of Taral and enters the Copper at that point, a rock, which under the microscope has been determined to be monzonite, probably occurs in considerable quantity in the mountains back of Taral. It is a medium or coarse grained rock, gray in color or speckled black and white, and is found, under the microscope, to consist essentially of plagioclase, feldspar, orthoclase, hornblende, biotite, and considerable epidote. The feldspars are usually fresh; the hornblende, which occurs in large quantity, is green, and the biotite brown.

OTHER IGNEOUS ROCKS.

Dike rocks, which occur in the sedimentary series, have been briefly described under the head of each series.

MINERAL RESOURCES.

COPPER.

About Prince William Sound it is common to find iron and copper sulphides disseminated almost everywhere throughout the country rock, but on some of the larger islands of the sound and at several localities on the shore of the mainland occur mineralized zones of considerable extent, some of which are of very promising economic value on account of the ores which they carry. The worth of the ores rests chiefly in their copper value, but in some of them gold and silver have also been assayed in good paying quantities. The deposits occur mostly in the northeast and southwest parts of the sound and trend in a general way with the topography of this part of the district.

Copper Mountain mine.—At Copper Mountain, near Tatitlak, in Landlocked Bay, where one of these deposits is being mined by the Alaska Commercial Company, the ore consists principally of copper pyrites and bornite. It is best exposed about 600 feet above sea level. The croppings were not accessible when visited by the writer in May, on account of the steep slope of the mountain. A considerable amount of ore, however, had rolled down to the base as talus, from which samples were collected. This talus is what first led to the discovery of the vein by Thurstonson and Jacobson in 1897. A tunnel is being driven a couple of hundred feet beneath the croppings by the company with the aim of diagonally crosscutting the vein or ledge. The croppings were subsequently made accessible and visited by Mr. Spurr in October, who found the deposit to occupy a shear zone in the Copper Mountain greenstone or amphibolite-schist. The main exposure is only about 8 by 10 feet in area. The ore, which is sometimes brecciated with country rock, consists of chalcopyrites, some bornite, marcasite, yellow iron pyrites, with some quartz and some specularite. It varies from fine to medium coarse grain. Of the two official assays made by the Alaska Commercial Company of ore brought down in the summer of 1898, one is reported to have shown 11.4 per cent copper and the other 12.5 per cent copper per ton.

On the northwest base of Copper Mountain, facing Copper Mountain Bay, a somewhat similar deposit occurs, known as the "Ripstein Ledge," which possibly belongs to the same shear zone as the Copper Mountain mine. Where undisturbed beneath the moss it is covered by a rusty-brown iron cap or eisenhut composed of oxidized iron, forming, along with some gritty material, a crusty cement. It also occurs in the green amphibolite-schist, which forms the foot wall on the south, while the hanging wall on the north seems to be a greenish quartzite, probably an altered phase of the schist. The ledge or vein is about 15 feet in thickness, and dips about 80° north, or is nearly vertical. It consists for the most part of soft light-grayish pyritiferous copper ore, usually fine grained, and which seems to contain much marcasite. There is also present a considerable amount of purple copper ore, with a considerable admixture of quartz. This deposit at the time of visit in May had been uncovered for a distance of about 30 feet. It descends nearly to tide level. Its value in copper hardly seems as yet to have been established. Of two samples collected by the writer and assayed by the chemical laboratory of the United States Geological Survey one yielded 0.1 ounce of gold per ton, and 0.35 ounce silver per ton, and the other 0.45 ounce silver per ton. This deposit is reported to have been discovered by Ripstein through the natives early in 1897.

Gladhaugh Bay mine.—Just above Tatitlak, in the head of Gladhaugh Bay, a vein or deposit about 300 feet in width, consisting mostly of iron and copper pyrites, is being worked by a Vancouver mining company. The contact of an igneous dike of olivine-diabase with the country rock here seems to have something to do with mineralization of the ore deposit. The country rock in which it occurs is a gray arkose of medium grain. The ore deposit or vein trends with the rock, or nearly east and west, and seems to dip steeply to the north. Much of the ledge is below high-tide level and is exposed at low tide only. The ore is associated in character with that already described, and consists largely of chalcopyrite and gray copper ore, with some bornite, producing the peacock variety; some epidote is also present. There is present an apparently large amount of white iron pyrites or marcasite. The ore is reported to assay $20 in gold and $10 in copper per ton. The rock here, which the miners and prospectors call porphyry, seems to be the olivine-diabase above alluded to. This deposit lies a little north of west from the Copper

Mountain mine, and about 4½ miles distant. The property was first staked by Gladhaugh in 1897. It was known, however, as early as 1895.

Bligh Island.—About due south of Gladhaugh Bay deposit, a few miles distant, on the north shore of Bligh Island, occurs a somewhat mineralized zone consisting of iron and copper pyrites with calcite veining. The country rock is dark slate or arkose. No development of any consequence has yet been done here, nor is the extent of mineralization known. Its occurrence is associated with contact metamorphism where diabase meets the slate. Some claims have been staked.

Latouche and Knight islands.—Other localities which are receiving considerable attention and are being developed are Latouche and Knight islands, especially Latouche. On this island, which lies in the southern part of the sound, the deposit of copper ore seems to be a phenomenally large one. The ore is mostly bornite and copper pyrites, with some quartz, and is of good grade, frequently running as high as 25 per cent in copper to the ton, with from $1 to $3 in gold and silver. The following assays of Latouche Island ore were made by the United States Geological Survey:

Marks.	Gold (ounces per ton).	Silver (ounces per ton).	Per cent copper.
Latouche Island, Bonanza claim, No. 93	Trace.	0.15	....
Latouche Island, Bonanza claim, No. 96	0.45	0.85	16.30
Latouche Island, Ripstein ledge, No. 140	None.	None.	25.37
Near Tyonek, No. 729	0.15	0.35	14.71

The sample 729 was furnished to Mr. Spurr by a prospector, who reports the ore to occur near Tyonek.

A certified copy of ten assays of the ore made by Price & Sons, assayers, of San Francisco, California, and furnished by Mr. Beatson, of Oakland, California, show an average of about $1.25 in gold and silver, and about 11 per cent copper per ton. Another sample, collected on Lewis Creek by Mr. Mahlo and assayed by C. E. Bogardus, of Seattle, yielded gold $0.20, silver $0.20, and copper 17.52 per cent per ton. The country rock seems to be chiefly black slate, with some conglomerate on the northwest, with greenstone—probably amphibolite-schist—on the southeast. The ledge trends northeast and southwest. The width of the vein, which is comparatively pure ore, varies from one hundred to several hundred feet. The croppings are known to extend through a distance of several miles, some rise to a height of several hundred feet above sea level. The large ownership of the claims, which include much of the richest ore, is known as the Bonanza group. Up to the close of 1898 but little work had been done on this ore deposit more than to stake a great many claims and uncover portions of the vein. The occurrence of the ore on Latouche Island was only recently discovered by squaw men through the Chenega natives. Some deposits are also said to occur on Knight Island and on the northeast shore of Kenai Peninsula.

From what has been said it may be inferred that the facilities of cheap transportation afforded by the ease of access for large ocean vessels and proper development of the ore deposits as mines, especially those of Latouche Island, will probably enable Prince William Sound, in the future, to produce considerable copper. Good copper ore, consisting chiefly of pyrities, is said to occur 20 miles back of Yakutat.

In the Copper River Basin.—Long before the Russian-American purchase, native copper was obtained from the Indians on the Atna or Copper River, being found occasionally in masses, some of which are reported to have weighed more than 30 pounds. It was used in trade with the Coast Indians. At present it is found in small amount in the possession of the Copper River natives. Its source is supposed to be the Chittena and Upper White River districts. In 1891 Schwatka and Hayes were taken to placer deposits containing small nuggets of native copper on the headwaters of the White River, which the natives on that side of the divide reported to be the source of their copper. Prospectors who ascended the Chittena in the summer of 1898 reported the prospects of copper good in that section and brought out some nuggets of the native metal from 2 to 3 inches in diameter. North of the Chittena the "Stick" natives reported the best source of copper to be up the tributaries coming down from the southwest base of the Mount Wrangell group, while the Taral and Chittena natives, so far as can be learned, are probably familiar with a considerable deposit of the metal or its ore up the Chittestone, or southeast fork of the Chittena, each tribe being best acquainted with that in its own districts. Judging from the reports of prospectors, that on the Chittena seems to be largely associated with igneous rocks, which are presumably volcanic. A few specimens of chrysocolla and some malachite from below the forks of the Chittena were seen by the writer.

Native copper was among the first metals reported from the Cassiar district, where it was in use among the natives and was reported by them to have been obtained from the head of the Copper River. Bremner, the prospector, in wintering at Taral in 1884–85, reports that Indians returning from the headwaters of the Chittena gave him a piece of copper an inch thick, with rock, presumably gangue, attached to each side of it, and that they reported the deposit from whence it came to be a very large one.

According to Petroff, repeated attempts were made by the early Russians, and later by Americans, to locate the source of the copper, which always resulted in failure.

During the summer of 1898, a 4-ounce nugget of the native metal is said to have been found by prospectors on the Klutena River. Indications of copper in the form of ore veins occurring in mica-schist and slate are also reported by prospectors on the Chestochina River near its headwaters. Copper ore with pyrites is also reported to occur about 20 miles back of Yakutat.

In conclusion, the copper ore about Prince William Sound occurs for the most part in schists and metamorphic slates, where it sometimes occupies shear zones, but it seems to be more particularly associated with igneous dike rocks, chiefly diabases.

GOLD.

Gold-bearing quartz.—The quartz found in the country rock usually occurs in discontinuous stringers or veinlets (Pl. XXXV and fig. 22), and not normally in large quantities, though some veins nearly 2 feet in thickness were observed in the Valdes rocks. Nothing as yet has been done toward quartz mining. Assays of quartz samples collected from the stringers at several points in the Orca and Valdes rocks show it to carry gold which is probably the source of the placer or fine gold found disseminated in the gravels throughout the country. So far as the observations of the writer extend the country can hardly be considered promising for gold-quartz mining. One assay, however, collected by the writer from Wilson Point, in Prince William Sound, yielded 1.25 ounces of gold and 3 ounces of silver, or a total money value of about $27 to the ton. The vein is about 3 feet in thickness. It is an aggregate stringer vein, being made up of a great many parallel quartz stringers or veinlets trending with the bedding of the rock. It is apparently a shear zone deposit. Its dip is nearly vertical. No idea of its linear extent was formed, as it soon passed beneath the deep covering of moss and snow; it seems, however, to warrant further investigation and probably development.

According to Mr. Mendenhall the aplitic dikes which cut the rocks about the head of Cook Inlet have also been found by assay to carry gold, these being possibly somewhat similar to the aplite dikes of the Fortymile district in the Yukon country.

Placers.—About the most of Prince William Sound and in the Copper River country gold placer digging is yet in its early stages. The considerable prospecting, however, which has been done seems to indicate that the country, as a whole, is not very promising in this line, although fine or flour gold occurs almost everywhere, in both the gravels on the coast and in the Copper River district.

Several years ago gravels at the mouth of Mineral Creek, which flows into Port Valdes, are reported to have yielded fair pay to several pioneers who worked them. Some work was also done on the south side of the sound in Solomon Basin, with similar results; and recently in Canyon Creek Bay some coarse gold has been sluiced. Claims are staked off at various localities, some in the terminal moraine gravels at the foot of Valdes Glacier. Some coarse gold has also been panned from the gravels in Dutch Camp Basin.

In the Copper River country the thick deposit of gravels and lake beds, which, during most of the summer, carry considerable water, is a great impediment to effectual prospecting. According to seemingly reliable prospectors, good coarse gold was found last summer on a branch of the Slana River near the headwaters of the Copper, and on Quartz Creek, one of the upper tributaries of the Tonsina, where many claims are reported staked and some men are wintering. Much fine and some small coarse gold was panned by the survey party where it crossed the Tonsina, about 5 miles above its mouth. Latest reports from Mr. Charles Brown, United States quartermaster, now at Valdes, accredits men with working on Manker Creek and Mahlo River, both tributaries to the Klutena; also on some of the headwaters of the Teikell. The presence of gold has also been reported on the Gakona, on the Chestochina, and on the headwaters of the Tazlina. Above Lake Pleveznie fine or flour gold is obtainable almost everywhere, even in the surface soil, sands, and silts of the Copper River Plateau.

COAL.

So far as seen by the writer, the formations met with seem to be barren of coal and lignite. It may be mentioned, however, that on the upper Gakona River some prospectors report the occurrence of coal in workable quantities in schist and slate.

SLATE.

At some localities in the Valdes rocks on the sound, the slates are so thoroughly cleaved as to make apparently a very good article for roofing or other commercial purposes. They often break into large, handsome thin sheets, as for example, about the mouth of Port Fidalgo and Landlocked bay, near Copper Mountain.

BUILDING STONE.

In both the Orca and Valdes rocks there is an abundance of gray and reddish sandstone or arkose, suitable for foundations and all rougher building purposes. In some localities it is rather freely jointed, but not to such a degree as to prevent obtaining blocks suitable for heavy bridge purposes.

CLAY.

Much of the ash-colored clay silts forming the lake bed bluffs along the Copper River is of so fine and uniform a texture and possesses apparently the pliability and workable properties of potter's clay to such a degree as to suggest that in more accessible districts it would probably be of considerable economic value.

PETROLEUM.

Petroleum[1] in considerable quantity, as well as lignite, have been reported to occur about Copper River Delta.[2]

MINERAL WATER.

A pint of mineral water collected from a saline spring on the Copper River, 12 miles above the mouth of the Tazlina was examined by Mr. H. N. Stokes and found to be "very rich in sodium, calcium, and magnesium, and to contain a large quantity of ferrous iron and some carbonic acid, but no sulphates or sulphides."

On Prince William Sound the native village of Tatitlak, which formerly stood at the head of Gladhaugh Bay, was some years ago moved to its present site, near Copper Mountain, on account of the unwholesome mineral properties contained in the water, which the natives, after prolonged illness and some loss in numbers, found to be injurious to the health of their people. Here the injurious ingredients seem to be sulphides of iron, copper, and possibly some lead.

The presence of iron, finely disseminated in the sedimentary rocks, especially throughout the Valdes series, is shown both on the coast and in the Copper River Basin by the effect of fire upon the gravels. Wherever the gravels have been heated by timber or camp fires they have been changed from their normally gray to a pronounced red color, denoting a change in the iron from the ferrous to the ferric state. In the northwest part of the Copper River Basin, at the heads of the tributaries in the foothills of the Alaskan Mountains, iron is reported by prospectors to occur in quantities promising economic value. So far as known, however, no specimens have been brought out to the coast.

In the northern part of Prince William Sound, Galena Bay is supposed to be named from the occurrence of galena on its shores. If present at all, however, the ore is probably in very small amount. Near the head of Port Valdes, in a narrow mineralized shear zone of quartz and crushed slate, a few crystals of galena were found, along with some copper and iron pyrites and calcite.

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[1] Bancroft's History of Alaska, Vol. XXXIII, p. 695.
[2] See Spurr's report in this volume, pp. 31-264.

A RECONNAISSANCE IN THE TANANA AND WHITE RIVER BASINS, ALASKA, IN 1898

BY

ALFRED HULSE BROOKS

CONTENTS.

ILLUSTRATIONS.

A RECONNAISSANCE IN THE WHITE AND TANANA RIVER BASINS, ALASKA, IN 1898.[1]

By Alfred Hulse Brooks.

INTRODUCTION.

The following report is based on field work done in the summer of 1898, while a member of a party of which Mr. William J. Peters, topographer, was in charge. The purpose of our expedition was to make a reconnaissance of the Lower White River and of as much of the Tanana River as the limited time would permit. Besides the topographer and the geologist, there were four camp hands in the party—Charles Ray, H. B. Baker, L. D. Gardiner, and A. R. Airs—all of whom rendered faithful and efficient services throughout the trip.

I wish to acknowledge my great indebtedness to Mr. Peters for giving me every opportunity for pursuing my investigations which circumstances would allow, and to Dr. C. Willard Hayes, Mr. Walter C. Mendenhall, and Mr. J. Edward Spurr for the valuable suggestions and criticisms which their familiarity with adjacent regions have enabled them to give.

ITINERARY.

Our party, with the three other expeditions of the Geological Survey, embarked at Seattle on the U. S. gunboat *Wheeling* on the 5th of April, and after a delightful voyage amid the grand scenery of the inland passage was landed at Skagway on the 11th of April. The many courtesies extended to us by the commander and officers of the *Wheeling* added much to our enjoyment of this part of our journey.

Since the wagon road to the foot of the White Pass from Skagway was finished, in the spring of 1898, this route into the interior has become a strong competitor of the better-known Dyea trail. At the time of our visit Skagway was an enterprising town of several thousand inhabitants, and since then the completion of the narrow-gauge railway across the White Pass, which was then being surveyed, has made

[1] A brief summary of the results of our investigations, entitled "Report of the White River-Tanana expedition," by W. J. Peters and Alfred H. Brooks, was published in Maps and Descriptions of Routes of Exploration in Alaska in 1898, United States Geological Survey, 1899.

Skagway probably the most important commercial center of the Territory. Our party and Mr. Barnard's crossed the White Pass on the snow about the middle of April and made their way to Bennett City, at the head of Lake Bennett, in British Columbia. Our outfit, including canoes and five months' provisions, was hauled to the foot of the pass by wagons and then transferred to sleds, taken to the top of the pass, and finally carried the rest of the distance by dog teams and pack animals. Bennett City is below the point where the confluent streams of prospectors from the two passes unite, and nearly the whole traffic into the interior by the Lewes River route passes through this place. It sprang into existence suddenly, like so many other camps on the main routes of Alaskan travel, but it is assured of a more permanent existence than many of these, because it is the head of steamboat navigation on the lakes, and because it probably will be the terminus of the White Pass Railway.

During the several days spent at Bennett City I was enabled to make a trip to the top of Chilkoot Pass. The summit presented a very animated scene, for here, as at White Pass, the Canadian custom-house is situated. Nearly every square foot of the narrow saddle across which the trail leads was piled high with boxes and bags, and to these the wire-rope tramway and an almost unbroken line of staggering men, each with a heavy load, was constantly adding. It was a strange picture; the tents of the officials, half buried in the snow, over which waved the British flag; the continuous procession of panting, wearied men; the crimson uniform of the Canadian police, contrasting strongly with the snow-clad, rugged mountain slopes glittering in the sun in every direction. The Chilkoot Pass will continue to be a competitor with the railway for freight transportation into the interior. Several tramways now carry freight across the summit, delivering it at Crater Lake, and from there a wagon road is said to be under construction to Bennett City.

From Bennett City we continued our journey across the ice to Marsh Lake, where the spring thaw, making the ice unsafe for travel, necessitated a delay of several weeks. I was able to utilize this time in making some excursions in the neighborhood, one of which took me across a divide, little known, between the upper end of Atlin Lake and the Teslin (Hootalinqua) River.[1] This divide is only about 600 feet above Marsh Lake and offers a good route for railway or pack-horse trail from Marsh Lake to the Teslin.

The ice did not begin to break up until toward the end of May, and it was not until the 27th that we made the start in our canoes. After two days of somewhat perilous navigation among the ice floes, and after

[1] The name Hootalinqua for this river is in universal use by the thousands who passed through this region in the past two years, and I fear that it will be impossible to supplant it by the correct Indian name Teslin.

making several portages, we reached clear water at the lower end of Marsh Lake. The following day we reached Miles Canyon and were portaged around it and the adjacent White Horse Rapids. Under present conditions this is easily and quickly accomplished by means of one of the tramways. Miles Canyon can be run in a good boat or canoe by anyone skilled in handling boats in rapid water. The White Horse Rapids, too, are not as dangerous as they are often represented, for of the thousands of boats that were run through them during the past season, including several steamers, there have probably not been over half a dozen accidents which resulted in the loss of life. They should, however, never be run unless the boat be steered by one of the local pilots who make it their business. This year the first boats went through the rapids the last week in April. Our party reached Lake Lebarge June 1, and found that the ice had just broken up and that the large ice floes still made navigation somewhat perilous. Below Lake Lebarge the Lewes River offers no serious difficulties for boating. Properly handled a boat can run the Five Finger Rapids without danger, while the barrier rock forming the Rink Rapids a few miles below extends only about halfway across the river, giving comparatively smooth water along the right bank. Last summer both of these rapids were ascended by steamers a number of times; but in the case of the Five Finger Rapids it was found necessary to resort to the use of a hawser and windlass.

Our party reached Selkirk on June 4, and here a short stop was made, with a view to obtaining information from the Indians in regard to the White and Tanana River regions. Our success was very moderate and the results not very encouraging. We were assured that it would be impossible to ascend the White River in boats, and the portage to the Tanana was estimated all the way from 20 to 100 miles. We found it impossible to secure the services of a guide through this little-known region, and the current stories of the warlike nature of the Tanana Indians were recounted to us with many picturesque additions. With this information we were forced to content ourselves, and continuing our journey we reached the mouth of the White River on June 5. At this point Mr. E. C. Barnard and his topographic party left us to continue their journey to the Fortymile district. They reached Dawson a day or two later and were among the first arrivals of the season from the Upper Lewes.

On June 8 our party, now reduced to six, made the start up White River. Our three months' provisions and equipment were divided among three canoes, making about 900 pounds to each. The ascent of the river proved feasible, though exceedingly difficult. The methods employed in taking our canoes up against the swift current were lining, poling, and frequently wading and dragging the canoes. We were much hampered by the many quicksands which occur along the river, and which sometimes almost threatened to make further progress impossible. Considerable time was also lost in repairing our canoes, for in spite of our best efforts they were often injured by being swept against snags by the swift current. These were often difficult enough to avoid when they could be seen, but when buried in the opaque, muddy waters they proved exceedingly treacherous. After passing the first big bend of the White, we made a side trip to the top of what we called Moosehorn Mountain. This trip was accomplished in about three days, with our packs upon our backs. From the top of the mountain we gained our first view into the Tanana Valley and were able to obtain some idea as to what would probably be our best route. After this two more stops were made for the purpose of ascending Caribou Mountain and Mount Baker. Above the mouth of the Klotassin River the valley soon begins to broaden out, and we here obtained our first view of the snow-clad peaks of the St. Elias Range.

As we ascended the river the constant increase in the rapidity of the current made our progress slower and much more difficult. At one time we were threatened with the loss of a third of our outfit by the capsizing of one of our canoes. Fortunately, this contingency had been provided for by lashing the heavier articles to the canoe and incasing the provisions in more or less waterproof bags, so that they floated. During the first weeks in July we had much drizzling rain and often cold winds from the snow-clad mountains, which, with the continuous wading and the occasional unexpected duckings, made the work very trying. While on the White River the killing of two moose gave us a welcome change of diet.

Finally, on July 10, we reached the mouth of Snag River, and continuing up that stream were relieved to leave White River behind us. The Snag River, though it had a swift current, proved easier to ascend than the White, for the hard bottom made poling possible, and in about two weeks we made some 50 miles. To our great delight we found that Mirror Creek, a tributary of the Tanana, had its source in the broad flat through which Snag River flows. After some investigation we selected our route for portaging and cut a trail through from one stream to the other, a distance of about 5 miles. Our portage trail lay through a flat, swampy area, and the transportation of our canoes and supplies proved no easy task, though far easier than we had expected, and it was accomplished in three days. We then started on our downstream trip. Our easy progress down the clear waters of Mirror Creek contrasted strongly with our struggle against the swift, muddy current of the White and its tributary. The only obstacles were the frequent log jams through which we had to cut our way or, where this was not feasible, make a portage. After a journey of some 60 miles we reached the Tanana River and found it here to be a stream of considerable size.

We now had one month's provisions left and about 600 or 700 miles of more or less unknown river to traverse. Many tales of the cataracts and canyons on the Tanana River had been told us, but we found them utterly without foundation. For several miles below the point where we reached the river there are a series of small rapids, and in one of these our canoe was injured on a snag, requiring a delay of several hours for repairs. Below this, to where the Fortymile trail comes in, the current is seldom more than 3 or 4 miles an hour, and frequently it was scarcely noticeable, the river being practically a series of lakes.

At the Fortymile trail we met a party of prospectors who had come over from Copper River, and these were the first human beings we had seen in two months. Here also we saw the first Indians, and they proved to be anything but warlike. From this point to below Bates Rapids there is much swift water on the river, but nothing that can not be easily run in a good canoe or rowboat. We found that we could do much geologic and topographic work and still make 30 to 50 miles a day, because the swift current bore us along very rapidly. Below the Bates Rapids the current was from 3 to 5 miles and our progress correspondingly slower. Along this part of the river we saw many Indians who were catching salmon for their winter supply. We met several parties of prospectors, and about 100 miles from the mouth we met a steamer, the second one which has ever made the attempt to ascend the Tanana. We reached Weare, at the mouth, just as had been planned, on the 1st of September, with our provisions entirely exhausted. From there we continued down the Yukon by river steamer to St. Michael, and thence returned to Seattle.

PREVIOUS EXPLORATIONS.

WHITE RIVER.

The mouth of the White River was discovered in 1850 by Mr. Robert Campbell,[1] an officer of the Hudson Bay Company, who gave it the name because of its milky white color. The Indians are said to call the river the Yukokon,[2] while according to Lieutenant Allen the Tanana Indians give it the name of Nasina, and the coast Indians are said to have still another name for it. The first recorded exploration of the White River was made on the ice in 1872 by Mr. Arthur Harper, one of the pioneer traders of the Yukon.[3] Harper ascended the river for about 50 miles, and in a second trip is said to have crossed one of the divides to the Tanana. The lower part of the White River

[1] Report on an exploration in the Yukon district, Northwest Territory and adjacent northern portions of British Columbia; by George M. Dawson: Geol. and Nat. Hist. Survey of Canada, Part B, Ann. Rep. 1887, p. 138B.

[2] Military Reconnaissance in Alaska, 1883, by Lieut. Frederick Schwatka, U. S. A.

[3] Exploratory survey of part of the Lewes, Tatonduc, Porcupine, Bell, Trout, Pelly, and Mackenzie rivers; William Ogilvie: Report to minister of the interior, Ottawa, 1890.

has been visited by several parties of prospectors, and one of these wintered some 50 miles above its mouth, but until 1891 no attempt had been made to reach its head waters, and the larger part of the White River Basin was entirely unknown.

The average Alaskan prospector takes no notes, seldom even compass bearings, and usually has very exaggerated ideas of distances. The result is that, though as a class they are indefatigable explorers, the information which they possess, even when it is available, is usually of a very indefinite character, and the amount which they have added to our geographic knowledge of the Territory is entirely disproportionate to the sacrifices of time and energy and often of human life which they have made.

The only definite published information of the White River Basin is contained in the report of Dr. C. Willard Hayes, of the United States Geological Survey.[1] Hayes's report is based on a trip made by him with Lieutenant Schwatka in 1891. The party crossed overland from Fort Selkirk, on the Yukon, to the White River, reaching the valley of the latter near where it is crossed by the international boundary. They then continued up the White to its source, and though they were deserted by all of their Indian packers the three white men of the party crossed Scolai Pass, and after reaching navigable waters on the Nizzena built a boat and continued down to the Copper River. Dr. Hayes's report and map are remarkably complete and accurate, considering the exceedingly trying conditions under which the field observations were made, and give much geologic and geographic information about a region which up to the time of its publication was practically unknown. Nearly every traveler who has passed the mouth of the White River has commented on its turbid waters and its swift current, but it is beyond the scope of this report to make further mention of them.

TANANA RIVER.

The Tanana River is one which has fortunately preserved its Indian name, which is said to signify the river of the mountains. Lieutenant Allen is authority for the statement that the Indians of the Upper Tanana call the river the Nabesna; but at the present time the latter name has fallen entirely into disuse.[2] The exact date on which white men first reached the mouth of the Tanana is not known. The Russians established a trading post at Nulato in 1838, and three years later Lieutenant Zagoskin, of the Russian navy, made the first survey of the Yukon up to that point. In the spring of 1843 he extended his reconnoissance survey 200 miles farther up the river, to Nowikakat,

[1] An expedition through the Yukon district: Nat. Geog. Mag., Vol. IV, pp. 117-162, May 15, 1892.

[2] For the sake of preserving this euphonious Indian name we have applied it on the map to the chief tributary of the Upper Tanana, for which we were unfortunately unable to find the true Indian name.

but made no attempt to go beyond, and, in fact, reported the Yukon unnavigable above this point. The employees of the Hudson Bay Company reached the Yukon from the Mackenzie and established Fort Yukon at the mouth of the Porcupine River in 1847. The region between the posts of the two rival fur-trading companies, one at Nulato and the other at Fort Yukon, continued to be debatable territory, and probably about 1860 the Russians extended their spring trading trips to Nuklukayet, at the mouth of the Tanana, and the Hudson Bay Company traders descended to the same point a little later.[1] It was not, however, until 1863 that the absolute identity of the Kwikpak, as the Russians called the lower portion of the Yukon, and the Yukon of the British traders was established. In that year a Russian creole named Ivan Simonson Lukeen ascended the river as far as Fort Yukon.

In 1866–67 Frank E. Ketcham and Michael Lebarge, of the Western Union Telegraph expedition, made two trips from the mouth of the river to Fort Yukon, and in 1868 Dr. William H. Dall, accompanied by Frank Whymper, also of the telegraph survey, made the first map of the lower river as far as Fort Yukon, and hence was the first to map the mouth of the Tanana.[2] A fuller account of this early exploration will be found in Dr. Dall's classic work on Alaska.

This portion of the Yukon was more accurately mapped by Charles W. Raymond, U. S. A., who in 1865 determined several points astronomically, and again by Lieut. Frederick Schwatka, U. S. A., in 1883.[3] In 1888, Messrs. J. E. McGrath and J. Henry Turner, of the United States Coast and Geodetic Survey, ascended the Yukon, while en route to determine the one hundred and forty-first meridian, and made corrections in the existing maps, which have been embodied in the latest publications of that bureau and form the basis for the best maps of the region.

For many years after the discovery of its mouth the Tanana remained entirely unknown to white men. It was mapped only from the accounts of it given by the natives who came to the Yukon to trade, and strangely enough this information was entirely at fault, for in the earlier maps it is usually represented as having a northerly trend and heading in the great bend of the Yukon. As is the case with the White River, the credit of the first exploration of the Tanana seems to belong to the trader Harper. Just when he made his first trip to this river is not known, but it was probably late in the seventies

[1] Nuklukayet was at that time an Indian village at the mouth of the Tanana; it was subsequently moved down the river a few miles, and the name has now fallen into disuse, the trading posts near this locality being called "Weare" and "Tanana."

[2] Alaska and Its Resources; William H. Dall, Boston, 1870, pp. 276–278. A partial account of this early exploration work is also given in Travel and Adventure in the Territory of Alaska, by Frederick Whymper, New York, 1869.

[3] Report of a reconnoissance of the Yukon River, Alaska Territory; Executive Document No. 12, Forty-second Congress, first session, Senate, 1871. Report of a military reconnoissance in Alaska; Executive Document No. 2, Forty-eighth Congress, second session, Senate.

that he, with one companion named Bates, crossed from Bell Isle, on the Yukon, to the Tanana, built a boat or raft, and floated down that stream to its mouth.[1] There may have been others who followed in Harper's footsteps, but of these we have no record, and up to 1885 this great river was practically unknown and unmapped.

In March, 1885, Lieut. Henry T. Allen, U. S. A., landed at the mouth of the Copper River with a small party, and making his way up that stream crossed the Suslota Pass, and after enduring great hardships reached the Tanana Valley at Tetling River early in June.[2] He continued his journey down the Tanana, in a moose-skin boat which he procured from the Indians. During this part of his journey the party was dependent entirely upon the country for food, and about the end of June they reached the Yukon in a half-starved condition. With indefatigable energy Allen extended his explorations up the Koyukuk River during the same summer. No man through his own individual explorations has added more to our knowledge of Alaska than has Lieutenant Allen, and his maps of three of the great rivers of the Territory, made some twelve years ago, have to the present time been the basis for all maps, while his report embraces practically all the definite existing information of the region visited by him. While on the Tanana Lieutenant Allen was unfortunately forced to travel very rapidly, and his notes and map of this part of the journey are not so complete or so detailed as those made of the Copper River. Since this exploration quite a number of prospecting parties have reached the Tanana and have in many cases floated down to its mouth, but they have added little or nothing to our knowledge of the river. Above the point reached by Lieutenant Allen the Tanana River was up to the past summer practically unexplored.

In 1896 J. E. Spurr, accompanied by H. B. Goodrich and F. C. Schrader, all of the United States Geological Survey, visited the Yukon gold district and studied in some detail the diggings on Fortymile River and on Birch and Mynook creeks. In his report Spurr published a geologic reconnoissance map which embraces the Tanana region and which is based on the geological notes of Hayes and Allen, together with some information furnished him by prospectors.[3] This sketch of the previous exploratory work in the region would not be complete without some reference to the investigations of the Canadian geological survey. While none of the members of the survey have visited the region embraced in this report, their work in adjacent areas has thrown much light on the broader geologic and physiographic

[1] Schwatka makes reference to this trip in the reports cited above; also in Along Alaska's Great River, by Frederick Schwatka, New York, 1885, p. 301.

[2] A Report of an Expedition to the Copper, Tanana, and Koyukuk Rivers in the Territory of Alaska, in the year 1885, by Lieut. Henry T. Allen.

[3] Geology of the Yukon gold district, by Josiah Edward Spurr, with an introductory chapter on the history and conditions of the district to 1897, by Harold Beach Goodrich: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 87 et seq.

problems. Notable among these is the work of the director, Dr. George M. Dawson, and of Mr. R. G. McConnell. The results of Mr. J. B. Tyrrell's investigations to the east of White River have unfortunately not been published.[1]

ROUTES AND MEANS OF TRANSPORTATION.[2]

In the past the few prospectors who penetrated this region limited their journeys chiefly to the larger waterways. In the open season they followed these in boats, or more often in downstream trips on rafts, and in the winter traversed their frozen surfaces with dog teams. The Indians also use cumbersome rafts for navigating the rivers, which they construct very ingeniously without the use of tools. When they are unprovided with axes, they use drift timber or burn off dead trees, and fasten them together with withes. They also construct well-shaped birch-bark canoes, which are decked over in the kayak fashion and are usually only large enough for one or two persons. These are propelled by a single paddle, with which they alternate from one side of the canoe to the other at every second stroke. Canoes of a similar pattern are also covered with moose skin in lieu of birch bark, and these are sometimes made much larger. In going up shallow streams in their small canoes the Indians make use of two short poling sticks, one in either hand. In this manner they are able to make fairly rapid progress against a 4 or 5 mile current. The swifter parts of the river are seldom navigated by the Indians, and then only in downstream trips, the return being made by portage. The Indian canoes are very frail craft and are easily injured on rocks and snags, and this is probably the reason they have such a fear of swift water and why their statements in regard to the danger of rapids are almost always overdrawn. In winter the Indians make long journeys with their dog teams, and this is undoubtedly the best time to travel in the

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[1] In addition to the publications cited the following will be found to contain information of general interest in regard to the region:

On the late physiographical geology of the Rocky Mountain region and Canada, with special references to the changes in elevation and to the history of the glacial period; G. M. Dawson: Trans. Royal Soc. Canada, 1890, Vol. VIII.

Report on an exploration in the Yukon and Mackenzie basins, Northwest Territory; by R. G. McConnell: Ann. Rept. Geol. Nat. Hist. Survey of Canada, Part D, Vol. IV, 1888–89.

The Klondike Official Guide; prepared by William Ogilvie, dominion land surveyor and explorer, published by authority of the department of the interior of the Dominion of Canada, 1898.

Notes on surface geology of Alaska; I. C. Russell: Bull. Geol. Soc. America, Vol. I, 1890, pp. 99–162.

The Yukon district; C. Willard Hayes: Jour. School Geog., Vol. I, Oct., 1897, No. 8, pp. 236–241.

The country of the Klondike; Russell L. Dunn: Mining and Scientific Press, San Francisco, Vol. LXXVII; No. 1998, Oct. 2; No. 1999, Oct. 29; No. 2000, Nov. 5, 1898.

"Die geologischen Verhältnisse der Goldlagerstätten des Klondikegebietes;" by Dr. Otto Nordenskjöld: Zeitschrift für praktische Geologie, March, 1899, pp. 71–83.

Glacial phenomena in the Canadian-Yukon district; by J. B. Tyrrell: Bull. Geol. Soc. America, Vol. X, pp. 193–198, April, 1899.

[2] The more feasible routes which are here described are approximately indicated on the accompanying map of Alaska (map 22). It should be borne in mind that but very few of these routes follow trails, though most of them have been more or less traveled.

region. The trip up the Tanana from the mouth and across to the mouth of Fortymile Creek is said to have been made by white men in one month with the use of dog teams.

Pack animals can be used to good advantage in many parts of both the White and the Tanana river basins. Mr. Tyrrell reached the mouth of the Nisling with a pack train from Chilkat Inlet, and several similarly equipped expeditions from the northwest have crossed the Tanana en route to the Yukon. Horses have also been used on the trail from Circle City to the Tanana. Pasturage for animals can be found from about the middle of June to the middle of September. Grass is especially abundant in the flats of the Upper Tanana and White rivers. The development of the region would be greatly accelerated by the introduction of steamers on the navigable waters and by the more extended use of pack trains.

WHITE RIVER.

The navigation of the White River as a whole by steamers is entirely impracticable. It is possible, however, that a light-draft steamer might reach the mouth of Ladue Creek if it were equipped with a very powerful engine. The experience of our party last summer shows that it is possible to ascend the White with light boats as far as the mouth of Snag River at least; but it is very doubtful whether this route will recommend itself to prospectors. The dragging of the loaded canoes against such a swift current is exceedingly laborious and time robbing. In the winter the White can be ascended with sleds, as has been done by several expeditions. It is said that the White, on account of its swift current, remains open a month later in the fall and breaks a month earlier in the spring than the Upper Yukon.

Overland routes to the White River.—Probably the best route to the White River is by pack train from Chilkat Inlet, on Lynn Canal. This route leads over the Dalton trail to Aishihik Lake and then crosses the divide, which is not high, to the Nisling River, and continues down that stream to its junction with the White. This was the route followed by Mr. Tyrrell with a pack train, and he informs me that there are no serious difficulties. The distance is something less than 300 miles.

An old Indian trail has been reported which extends from Lynn Canal, following near the base of the St. Elias Range, and reaches the White near its head by a valley of the Koidern River. This trail is said to have been used by the coast Indians in their trading journeys which they made into the White and Tanana river basins.

Another route which has been suggested crosses from Yakutat Bay to the Kaskar Worlch River, a western branch of the Alsek, and, following up the stream, crosses the divide to the White River waters.

As this proposed route lies in high mountain ranges, it is probable that the rivers have very swift currents. The route of the Schwatka-Hayes expedition from Fort Selkirk to the Nisling is entirely feasible for pack animals. The distance from Fort Selkirk to the White at the mouth of the Nisling is less than 100 miles.

The route from Copper River over the Scolai Pass is not likely to recommend itself to prospectors because of the difficulty of ascending the Chittena River and its tributary, the Nizzena. The Lower White can be reached from Sixtymile River by crossing the divide and descending Ladue Creek. Ladue Creek in the lower 20 miles of its course probably has a comparative slow current.

TANANA RIVER.

The Tanana River has been repeatedly descended from the point where the Fortymile trail reaches it to its mouth, and small boats have probably been brought up the river to this point, though of this we have no definite information. In any event it is entirely feasible to reach the Fortymile trail from the mouth of the Tanana with a row-boat, but it would be a long and wearisome task. In the part of the river which we mapped there are no dangerous rapids. In the central portion of the Tanana there are many small rapids, but they are formed of gravel bars and driftwood, and there are no barrier reefs such as are found on the Lewes. On the long stretch of swift water known as the Bates Rapids a boat must be handled carefully, and close attention must be given to avoid the many snags, but by so doing there remains only a very small element of danger. Attention has already been drawn to the fact that the Tanana Indians navigate most of the river with their frail canoes and on their crudely-built rafts. There are no serious difficulties in ascending the Tanana by steamer to where the river broadens out above the mouth of the Cantwell, a distance of about 170 miles. From this point to where the Fortymile and Mentasta trail crosses, the river can only be ascended by a steamer which is especially adapted to the purpose. Such a steamer should be capable of making progress against an 8-mile current and should have facilities for warping where it was necessary. In this section of the river there are usually many channels, and by carefully picking the route much of the swifter water can be avoided. A steamer in going upstream should always have a small boat ahead to pick out the best channel. A slough some 30 miles in length, which is suitable for a steamboat, is said to extend along the north bank from below the mouth of the Chena River to the Salchaket. At the time of our journey last summer we met a steamer about 100 miles above the mouth, and I am informed that this steamer reached the mouth of the Chena River and ascended that stream. This is the second steamer which has navigated the Tanana.

From the Fortymile trail to Gardner Creek the current is usually very moderate, and a flat-bottomed steam launch drawing not over 18 inches of water could easily navigate this stretch of the river. The Goodpaster and Volkmar, and probably the Chena, as well as the Toclat, could probably be ascended for some distance by a small flat-bottomed steamer.

Overland routes to the Tanana.—The broad valleys of the Snag and Mirror rivers form good routes of communication between the White and the Upper Tanana. Indian portage trails are said to exist from both Ladue Creek and Katrina River to Tanana waters; these routes probably reach the main river by Scottie and Gardner creeks. The best-known trail to the Tanana is the one crossing from Fortymile Creek. This route leaves the north fork of Fortymile at the Ketchumstock Indian village, which is said to be at the head of small boat navigation; from the Ketchumstock Indian village to the Indian settlement on Lake Mansfield a good trail is said to exist, and thence, in a distance of about 8 miles, the trail reaches the Tanana about half way between the Tok and Robertson rivers. The distance from water navigable by small boats on Fortymile River to the Tanana has been estimated at 50 miles. Last summer pack horses were used in a trail from Circle City to the Tanana, a route probably not over 200 miles in length, which reaches the Tanana between the mouths of Silokh and Salchaket rivers.

In the summer of 1898 the Copper River Basin drew much attention, as offering a possible all-American route to the placer diggings on the Yukon. A discussion of this region by Mr. Schrader will be found elsewhere in this volume, and I shall confine myself to a few brief notes on the Tanana end of this route. A crossing from the Copper River to the Tanana can be made by the Suslota Pass, probably about 4,000 feet, or by the Mentasta Pass, which is somewhat lower. In crossing the Suslota Pass the trail reaches the Tok River, and the prospectors usually raft down that stream to the Tanana. Lake Mentasta drains into Salina River, and can be easily reached in small boats, for the current of the Salina is very moderate. From Lake Mentasta a low, broad pass separates the Tanana and Copper river waters, the distance being said to be about 20 miles. Another route which has been used by at least one party of prospectors crosses from the Chestochina River, a tributary of the Copper, to Robertson River, and thence down that stream. This route will hardly recommend itself, for, though the portage is only about 10 miles, the swift current of the Robertson River renders navigation somewhat precarious. The routes from Cook Inlet to the Tanana have been the subject of investigation by Mr. Mendenhall and Mr. Eldridge. The military expedition which was in charge of Captain Glenn, and to which Mr. Mendenhall was attached, reached the Tanana at the mouth of Delta River. Mr. Mendenhall informs me that the distance by trail from

Knik Arm to Cook Inlet is over 300 miles, and can be traversed with a pack train. Mr. Eldridge's party did not actually reach the Tanana, but crossed the divide and followed the headwaters of the Cantwell for some distance, which they reported as a very swift river, navigable only with great difficulty. The Lower Tanana Indians are said to have a route which ascends the Toclat River and thence by portage trail crosses to the waters of the Kuskokwim. It is rumored that this trail was used some by traders in the early history of Alaska; but this rumor has never been verified, and the region is one which is entirely unexplored.

At the mouth of the Tanana are two settlements close together. The Alaska Commercial Company calls its post Tanana, while the North American Trading and Transportation Company have named their station Weare. A post-office now exists at one of these posts, and a United States land office is to be located here. Weare can be reached from St. Michael by steamer in about two weeks, and from Dawson in three or four days by steamer.

Table of approximate distances.

	Miles.
WHITE RIVER.	
Mouth of White River to Snag River	85
Mouth of Snag River to portage to Mirror Creek	66
Portage	5
Mouth of White River to Dawson	100
TANANA RIVER.	
Mouth of Tanana to Circle City trail	231
Circle City trail to Mentasta-Fortymile trail	179
Mentasta-Fortymile trail to mouth of Mirror Creek	150
Mouth of Mirror Creek to portage to Snag River	60
Portage	5
Mouth of Tanana to mouth of Yukon	650

GENERAL GEOGRAPHIC FEATURES.

The region to be embraced in this description lies for the most part between the one hundred and fortieth and the one hundred and fifty-second meridians, and is approximately bounded on the south by the sixty-second and on the north by the sixty-fifth degree of latitude. It is a part of the great Yukon drainage basin, which occupies a large irregular area in the interior of Alaska and in the adjacent portions of British Northwest Territory and British Columbia. Roughly outlined, the Yukon Basin is bounded on the east and northeast by the northern extension of the Rocky Mountains, while to the north the almost unexplored Davidson and De Long ranges mark the divide between the Yukon and the Arctic coast drainage. To the south the Coast Range, the St. Elias Range, and the Alaskan Range separate the Yukon and

Pacific waters. To the southeast the basin is not limited by any dominant mountain chain, and the tributaries of the Yukon and the opposing headwaters of the Liard and Stikine rivers interlock irregularly. While these may be considered the general limits of the basin, the actual line of watershed is a very irregular one. Along the southern margin the divide is thrown inland by the Stikine and Taku rivers, whose sources lie north of the Coast Range and within the interior plateau. The Alsek River, flowing into the Pacific, rises to the north of the St. Elias Range, while the Delta and Cantwell rivers, belonging to the Yukon Basin, head to the south of the great Alaskan Range. Again, on the east the Liard River rises near a tributary of the Yukon and traverses the entire Rocky Mountain Range before it joins the Mackenzie; and similarly a tributary of the Peel River, which belongs to the Mackenzie Basin, rises within a hundred miles of the Yukon, and hence to the west of the Rocky Mountain Range.

An examination of a map of Alaska will show a crescentlike bend of the coast line along the Gulf of Alaska, and a study of the dominant mountain chains will show that they, too, experience this marked change in direction, which amounts almost to a right angle. The Rocky Mountains, which limit the Yukon Basin on the northeast, extend in a northwest direction to near the Arctic coast, and then make an abrupt westerly turn and continue parallel to that coast.[1] The Alaskan Range, which limits the basin on the south, makes a similar bend in about latitude 63°. As if in conformity with the periphery of its basin, the Yukon, too, when it touches the Arctic circle, makes a right-angle bend to the southwest.

The portion of the basin which is the subject of this article is drained by the White and Tanana rivers, which are among the most important tributaries of the Yukon. The White River rises in the northern range of the St. Elias Chain, and flowing in a general northerly direction, reaches the Yukon some 1,400 miles above its mouth. The source of the Tanana has never been explored, but it is believed to rise near the head of the White. Its general course is north and northwest, and its junction with the Yukon is some 650 miles above the mouth of the latter river. The district here to be discussed is roughly blocked out by the White River on the east, by the Nutzotin and Alaskan mountains on the south, by the Yukon on the west, and by the Tanana Hills, the Ketchumstock Hills, and the Yukon River on the north.

The field observations were chiefly confined to a narrow belt lying adjacent to the White and Tanana rivers. Only those who are familiar from personal experience with the present conditions of exploring such a region can understand why scientific observations must be more or less fragmentary. The explorer must of necessity expend a large part

[1] So far as I know, this correlation of the mountains north of the Yukon and the Rocky Mountains was first suggested by Dr. Hayes in The Yukon District: Jour. of School Geog., Vol. I, 1897, No. 8, p. 37.

of his energies and time in overcoming the physical obstacles to his progress, and geologic investigations, except of the most hasty kind, can be made only at such times as conditions of traveling permit. These facts the reader should bear in mind when he feels like criticising the author for leaving so many important questions unsettled.

TOPOGRAPHY AND DRAINAGE.

A brief discussion of the general geographic features of the Yukon Basin has already been given, and I will here confine myself chiefly to the area embraced in the accompanying map 23. Our topographic work was chiefly confined to such parts of the region as could be mapped from our route of travel, for our limited time enabled us to make but very few excursions away from the river.

The general features of the mountain ranges limiting the basin on the south are known through the report of Hayes, who crossed the Scolai Pass; by Allen's map, who crossed the Suslota Pass from Copper River; and through the work of Mendenhall, who reached the Tanana from the south by the valley of Delta River, as well as by investigation of Eldridge and Muldrow, who penetrated the Alaskan Range from the south along the valley of the Upper Cantwell. The reports of Messrs. Mendenhall and Eldridge will be found in another part of this volume. It is plain that this is rather meager evidence for discussion of the features of a mountainous region some 400 miles in length. The watersheds between the Yukon and Tanana, except for the maps of the gold districts prepared by Spurr, had been up to last summer entirely unmapped. The Fortymile quadrangle, surveyed by Mr. E. C. Barnard during the past summer, is a valuable contribution to our knowledge of the topography of this district.

MOUNTAIN RANGES.

While traversing the broad flat of the White River Valley we could see far to the south a snow range of cragged peaks whose summits towered above a near foothill range. These mountains are part of the great chain to which the name St. Elias Range has been given.[1] Dr. Hayes describes the St. Elias Range as follows:

> Like the southern coast range, it is a broad, level belt, with numerous peaks and short ridges, probably the highest being along its southern border, culminating in Mount St. Elias. Westward from this peak the range is separated into two divergent ranges by the valley of the Chittena River; the one continued to the northwest contains the high volcanic peaks of the Wrangell group.[2]

[1] In a recent publication Mr. J. B. Tyrrell has suggested the name Chilkat Range for these mountains. He gives no reason for supplanting the old name by one which has already been used to designate a river and a pass. Bull. Geol. Soc. America, Vol. X, 1899, p. 193.

[2] Nat. Geog. Mag., Vol. IV, p. 129.

On reaching the Tanana Valley another range to the south was visible to us, which proved to be much nearer. The position and altitude of several peaks of these mountains was determined by Mr. Peters, and a prominent one among them, having an elevation somewhat over 10,000 feet, was called Mount Allen.[1] These snow-clad mountains, which seem to be distinct from the St. Elias chain, we have called the Nutzotin Mountains.[2] I was unable to determine the relation of the Nutzotin to the St. Elias Range. It would seem that the source of the White River must lie beyond the Nutzotin Mountains, but Dr. Hayes makes no mention of high mountains to the north, though he may not have been in a position to see them. If this be a distinct range it breaks down before it reaches the valley of the White. These snow-covered mountains continued to the west to about the gap of Nabesna River, beyond which they were not seen, for a broad depression exists between these mountains and the most easterly peaks of the Alaskan Range. It is across this broad depression that the Mentasta and Suslota trails from Copper River to the Tanana lead.

Beyond this break Mount Kimball was the first peak of the Alaskan Range whose position was determined. An examination of the map will show that the extension of the Nutzotin Mountains would carry them far to the south of the Alaskan Range, and they would seem, therefore, to bear a somewhat similar relation to the Alaskan Range that the St. Elias Range does to the Nutzotin Mountains. Mount Kimball lies but 15 miles from the Tanana Valley, but to the west the Alaskan Range rapidly recedes from the river, and beyond Mount Hayes[3] the range makes a sharp bend to the southwest. The continuity of the Alaskan Range is interrupted by the valleys of two rivers tributary to the Tanana which head to the south of the range. The Delta, the more easterly one of these, has a comparatively narrow valley, but the gap of Cantwell River marks a decided break in the range.

From the foregoing it will be clear that south of the White and Tanana river basins there are several mountain groups separated by more or less broad depressions. These mountains can all undoubtedly be regarded as belonging to the same chain, but it is still unsettled whether they are parts of the same range isolated by the broad erosion gaps, or whether they belong to different periods of uplifts. They all have the sharp peaks and rugged outline of young topography. That portion of the St. Elias Range which borders the Pacific coast, as determined by Russell, had its origin in a post-Tertiary uplift; but it is probable that the northern portions of the chain are older. We have no facts to determine the age of the Nutzotin Mountains

[1] Named in honor of Lieut. Henry T. Allen.

[2] This mountain range is, unfortunately, not represented on the accompanying topographic map (map 23), because the map had to be cut down to make it fit into this report.

[3] This is a prominent peak of the Alaskan Range, having an elevation of about 14,500 feet, and was named in honor of Dr. C. Willard Hayes.

except that in their general outlines they resemble the adjacent ranges and seem to belong to about the same geographic cycle. The Alaskan Mountains, as well as the Nutzotin, are broken by broad gaps which, as will be shown, probably represent the same level of erosion as the interior plateau. Their formation must, therefore, have considerably antedated the elevation of the interior plateau, and yet their relief suggests immature topography.

YUKON PLATEAU.

To the north of the snow-covered mountain ranges which have been described is an abrupt change in the aspect of the country. A rolling upland, deeply dissected by many river and stream valleys and diversified by scattering mountain masses and isolated peaks which rise above the general level, stretches toward the Yukon. The moss-covered plateau remnants contrast strongly with the rugged mountain slopes to the south. This dissected plateau was first described by Dr. Dawson in British Columbia, and later was traced by Hayes northwestward into Alaska. I quote as follows from Dr. Hayes's description of this feature:

> An appropriate and convenient name for this great upland is the Yukon Plateau. Its general altitude at the divide between the Taku, the Liard, and the southern branches of the Yukon is about 5,000 feet. So far as known it retains this elevation along its southern margin at the base of the Coast and St. Elias ranges, but slopes gradually northward and westward to less than 3,000 feet near the axis of the basin. Thence it rises again, but less rapidly, northward to the base of the Rocky Mountain Range. Only in a general way can this highland be regarded as a plateau, for when considered in detail much of its surface is extremely rough and broken. The larger streams have sunk their channels from 1,000 to 3,000 feet below the general plateau level, and most of them have opened out rather broad valleys wherever they have encountered soft rocks. The smaller streams in their lower courses flow in narrow, V-shaped gorges, while their head branches often occupy high, broad valleys, which indicate an old lowland formed near the former level of the ocean. A recent uplift has given the streams new vigor, and thus the valleys are in part old and in part young.[1]

I first noted this old upland on the Lower White River, where several mountains whose summits mark the old plateau surface were ascended. As these mountain tops are entirely above timber line, with the clear atmosphere which usually obtains in the interior region of Alaska, a splendid view was obtained, only interrupted in some directions by smoke of forest fires. To the northwest of these peaks, whose elevations average about 4,800 feet, were seen innumerable broad, flat summits, all standing at about the same elevation. The most striking feature of the scene was the even sky line. To the northeast the plain was not so striking, for in many cases it was marked by broad spurs of mountains whose summits proper were

[1] Jour. School Geog., Vol. I, p. 239.

above the general level. As a study in base-leveling the region visible from the mountain tops of the Lower White can hardly be excelled. The horizontal plain, superimposed on the contorted rocks of the Nasina series, impresses one strongly with the fact that this is a level of erosion. The summits which mark the peneplain are sometimes half a mile or more in extent. This is illustrated by the photograph of the summit of Moosehorn Mountain, Pl. XXXVI, *B*.

From Mount Chisana an excellent view of the peneplain was also obtained. The general level to the north was only here and there interrupted by isolated mountain masses and peaks. This mountain, which is made up of contorted crystalline schists, possesses the same flat-topped character as those previously described, but its elevation is some 1,500 feet lower, showing an inclination of the plain of about 20 feet to the mile. In the Fortymile district the plateau probably stands at an elevation of 3,500 to 3,800 feet, and has approximately the same height in the Birch Creek district. The Mentasta Pass is reported to be a broad, flat depression having an elevation of about 3,500 feet, while the flat divide between the Sushitna and Cantwell rivers is less than 3,000 feet.[1]

There is not now sufficient data for the discussion of these interesting topographic features, but I am impressed with the fact that these points mark the same level of erosion, modified by more or less subsequent deformation. Goodrich[2] has shown that there have been recent warpings in the Fortymile and Birch Creek districts, and Spurr[3] noted the deformation of the Yukon silts, which I have also observed on the Lewes River. It is possible that the warping of the peneplain is a manifestation of these same crustal movements.

Near the Yukon and Tanana divide are a series of mountains forming a broken chain, whose summits are far above the plateau level. Prominent among these is Sixtymile Butte, whose conelike summit rises about 1,500 feet above the upland surface. This and the Ketchumstock Hills and probably the Tanana Hills and other isolated peaks, are remnants of the older land mass, which for some cause was not reduced during the planation, and now rise as monadnocks above the peneplain.

WHITE RIVER.

The White River rises in the northern lobe of the Russell Glacier, which comes down from the St. Elias Mountains and flows east for about 40 miles nearly parallel with the range, and receives from it numerous tributaries. In its upper course it has a broad, gravel-floored valley some 10 miles in width, which gradually narrows down

[1] See topographic map of the Sushitna-Cantwell River basins, by Robert Muldrow, topographer, United States Geological Survey.

[2] Recent warpings as shown by drainage peculiarities, Harold Beach Goodrich, in Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, 1896-97, Part III, p. 276.

[3] Op. cit., p. 213.

and assumes a canyonlike character. The narrow valley continues for a distance of 20 miles, and then the river debouches on a broad valley lowland. This second basin has a length of over 75 miles, an extreme width of 50 miles, while its floor is also composed of river gravels. It embraces not only the White River Valley and some of the confluent streams, but is extended through to the Tanana by broad, flat valleys, while to the east it is continued by the valley of the Nisling River. Here and there the comparatively even plain of the lowland is interrupted by knobs, hills, and mountainous masses, which rise rather abruptly. In two instances the White has cut canyons through spurs of the valley walls. One of these, described by Hayes,[1] is a few miles above the mouth of the Nisling, and the second is just below the mouth of the Snag River. Hayes has suggested that this is a case of superimposed drainage due to the occupation of the valley by ice.

Some 10 miles below the mouth of Snag River the flats end abruptly and the White enters a narrower valley. In this part of its course the valley bottom is some 1,300 feet below the plateau surface. Terraces are found on both sides as far as the mouth of the Klotassin, below which they are replaced by steep, granite bluffs. The Klotassin, which at its mouth is some hundred yards wide, is a clear-water stream flowing in a broad, flat-bottomed valley. Between the Klotassin and the Katrina rivers the White River Valley is rather contracted, with abruptly rising walls, while below the Katrina it gradually widens out and continues in this form to its junction with the Yukon. The valleys of both the Katrina River and Ladue Creek are broad and flat and they are both clear-water streams. At the junction with the White the Yukon makes a right-angled bend to the northeast, so that the axis of the White River Valley is extended by the Yukon below its mouth. Steep bluffs rise rather abruptly some 1,400 feet above the river on the Yukon opposite the mouth of the White. The junction of the two rivers is in British Northwest Territory, some hundred miles above Dawson, and the total length of the White is about 200 miles.

Throughout its course the White is a turbid, swiftly-flowing stream, and it is shallow, with numerous channels, and is studded with constantly shifting sand bars and islands. It has all of the characteristics of an overloaded stream. No current determinations were made on the White River, but rough estimates show currents of from 5 to 10 miles an hour.

TANANA RIVER.

The source of the Tanana River has never been explored, but is supposed to be near that of the White. It leaves the Nutzotin Mountains through a narrow valley and debouches on the broad valley low-

[1] Nat. Geog. Mag., Vol. IV, p. 134.

land of the Upper Tanana, which has already been referred to as extending through from the White. After leaving the mountains the Tanana flows northeast, traversing the gravel-floored lowland until it reaches the north side of the valley and there bends abruptly to the northwest. The valleys of Gardner and Scottie creeks, as well as of Mirror Creek, have flat gravel-filled bottoms and are practically continuations of flats of the main river. The size of these valleys is entirely disproportionate to the streams which now occupy them.

The broad lowland ends near the mouth of the Tetling, where the valley is contracted to about 7 miles. West of Mount Chisana the Tanana Valley is formed by a series of connecting basins, possessing outlines of parallelograms. These will be described below and their origin ascribed to structural lines. This basinlike character is more or less well marked to about the mouth of the Silokh River, where the recession of the south wall of the valley produces another lowland, some 30 miles wide, and which continues to broaden out to the west. Something of the same basinlike character is preserved in this part of the valley by the succession of reentrant angles in the northern escarpment.

Where the Tanana leaves the mountains, near its headwaters, the peaks on either side of the gorge rise over 4,000 feet above the river level. The summit of Mount Chisana, a part of the old plateau surface, is some 1,500 feet above the river, and the top of the escarpments which form the southern valley wall of the Middle Tanana are believed to have about the same amount of relief, though the elevations were unfortunately not determined and the contouring on the accompanying topographic map was made purely from estimated elevations. The ridges which bound the Tanana on the north near its mouth stand not over 300 or 400 feet above the water.

The northern tributaries of the Tanana are all slow, sluggish streams flowing in broad valleys and have considerable depth of water. They are as a rule clear or only slightly turbid, carry little sediment, and have no deltas at their mouths. The southern tributaries having their sources in the high mountains are all shallow, turbid, swift-flowing streams, usually with large deltas. The formation of these deltas is probably the chief cause for the position of the main river close to the north wall of its valley, though this may have been aided by warping.

The Nabesna River is the most important tributary of the Upper Tanana and nearly equals it in size. Like the Tanana, it leaves the mountains through a narrow valley, and on reaching the lowland continues its course to the northeast until it joins the main river. The Tetling is a river of secondary importance, draining a group of small lakes which lie within the valley. These lakes probably owe their origin to the damming of the former course of the Tetling by the delta deposits of the Nabesna. Its old course is marked by a series of small lakes which may be seen on the topographic map. The Tok River is of comparatively small size, and in its character is the exception among the rivers from the south. Rising as it does in the depression between the Nutzotin and Alaskan mountains, it is not fed to any extent by glacial streams or streams from the snow mountains and therefore has clear water. The Robertson and Johnson rivers are both swiftly flowing, shallow, turbid streams, and the waters have a slight greenish tinge. These rivers leave the mountains through narrow valleys, and both have broad deltas and glacial sand bluffs at their mouths. The Goodpaster and Volkmar rivers flow in broad valleys and are sluggish streams. The Volkmar is said to have its source in a rather rugged mountain region. The Delta River is much like the Robertson and Johnson in its general character, except that its valley is somewhat broader. The Mahutzu and Silokh rivers[1] are similar in character to the Delta, but are considerably smaller.

The Salchaket and Chena rivers[2] were not visited by our party, but they both have broad, flat valleys. The Nilkoka River and Baker Creek have the characteristics of the other rivers of the north side of the valley. The Cantwell[3] has turbid waters and many sand bars, but in its long journey across the valley it has lost something of its swift character. The Toclat[4] is a deep, muddy stream, and in its lower course has a comparatively moderate current. It has never been explored, so of its upper course we have no information.

From where the Tanana leaves the mountains until it reaches the north side of the broad valley at its first great bend it is a shallow, swift-flowing stream, comparable in every way to the White River. Below this point, to the contraction of the valley near where the Fortymile trail reaches it, the Tanana has a very slow current and a very tortuous course; in many places it consists of little but a chain of ox-bow lakes. A few short riffles occur in this part of the river, but usually the current does not exceed 2 or 3 miles in all. Below this sluggish part of the Tanana, to a point some 10 miles above the Cantwell River, the current is usually very swift. Several rapids are marked on the map, none of which, however, are due to rock barriers. In the region of Bates Rapids the river has spread out until it is several miles in width and has innumerable channels, sand bars, and islands. Below the Cantwell River to the mouth the Tanana is usually confined to one or two channels and has a current of from 3 to 5 miles an hour.

[1] It was one of these rivers which was called Delta Creek by Lieutenant Allen, but as we have been unable to establish the identity of his stream, we thought it best to give them new names.

[2] These are said to be the Indian names of the rivers.

[3] The Indian name for this river is said to be Anana.

[4] According to Lieutenant Allen, Toclat signified dishwater in the Indian language.

PHYSIOGRAPHIC DEVELOPMENT.

A study of the detailed physiography of the region must be deferred to some future time when our knowledge of the topography is more complete. A few broad generalizations can, however, be made on the present basis of facts. The topography has been described as a dissected plateau stretching northward from a rugged mountain mass which is separable into three distinct ranges—the St. Elias, the Nutzotin, and the Alaskan—the extension of whose axes would overlap rather than coincide. It has been shown that we have not now sufficient data to determine the age of uplift of these mountain masses, nor do we know whether they were produced by synchronous movements of the earth's crust. Attention has been called to the form of these mountain ranges, which suggests immature topography. The broad gaps which interrupt the continuity of the Alaskan and the Nutzotin mountains are believed to be of synchronous origin with the erosion level represented by the plateau, and therefore the uplift of the ranges must considerably antedate the formation of the peneplain. It has been noted that the plateau is deeply dissected and interrupted by broad gravel-filled valleys, and that in many parts of the region isolated mountain masses and ridges rise to considerable elevation above the upland surface. The larger waterways flow through series of broad basins which are connected by contracted portions of the river valleys.

In studying the physiographic development of a region it is necessary to have some datum plane with which to compare the subsequent elevations or depressions, and, fortunately, in the Yukon district the surface of the plateau affords such a plane. In the following consideration of the region an attempt will be made to study the evolution of the present topography during the development of this plane and subsequent to it. This rolling upland, marked by the remnants of the old plateau and probably also by the broad gaps in the mountains to the south, has been described, and is unquestionably a plane of erosion, and hence a peneplain. At a time when the region stood at a much lower elevation than it does now, the amount of this depression being approximately measured by the present relief of the plateau, the erosive forces reduced the land mass to a gently rolling plane which sloped gradually toward the sea. A suggestion of the minimum amount of this erosion is given by the monadnocks or unreduced areas which here and there interrupt the plateau surface. The Ketchumstock Hills and Sixtymile Butte rise over 1,500 feet above the peneplain, while numerous other peaks rise above the plain, but have low relief. Whether the survival of these masses during the planation of the adjacent areas is due to the fact that they are formed of rocks having a greater resistance to erosion or whether they owe their present relief to their positions between drainage courses during the period of base-leveling has not yet been determined. The plane has a gentle slope to the northwest, as will be seen by a comparison of its elevation in British Columbia and in the Birch Creek district, and has broad undulations, which, as has been explained, are probably due to warping.

My own investigations throw no light on the age of the peneplain, and I will therefore not enter into a discussion of this subject. Dr. Dawson, who has made a closer study than anyone else of the physiography of the region lying to the south in British Northwest Territory and British Columbia, assigns it to the Eocene age.[1] Spurr described the interior plateau and considered that it was formed during Neocene age.[2] He regards the Nulato sandstone, which Dr. Dall has proved is of Neocene age, as a marine littoral deposit synchronous with the erosion which formed the plateau.

This period of erosion was one of relative stability, during which no orographic movement of any consequence took place. It was followed by an uplift which revived the activity of the drainage system. The peneplain shows some evidence of having been warped, and it is probable, therefore, that this uplift was a differential one. We have considerable evidence that the uplift was both gradual and intermittent, for on both the White and the Tanana I observed rock benches on the valley slopes which undoubtedly mark the former position of the river beds, and on the Upper Tanana I also noted a local baselevel some 600 feet below the plateau surface, which I was able to trace for some 60 miles. It is probable that when the detailed topography of the region has been studied it will be found that there are a number of these features which probably represent periods of comparative stability, and hence interruptions in orographic movement. I do not wish to imply that these topographic features can only be formed at base-level, for it is manifest that barriers in a river system may cause the formation of purely local base-level, which are not necessarily concomitant with interruptions in the orographic movement. I have ascribed these features to interruptions in the uplift because of their wide distribution in the Yukon Basin, both within and without the area under discussion. We have no accurate means of determining the amount of the uplift, and we know only that it must have been much greater than the present relief of the peneplain. The flat-bottomed valleys which now stand in some cases 2,000 feet below the plateau surface are the result of the silting up of much deeper-cut valleys. A downward extension of the present valley slopes would give depths of three times the present relief and may be considered a rough measure of the amount of the elevation.

The drainage during this cycle offers many interesting problems,

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[1] On the late physiographic geology of the Rocky Mountain region in Canada, with special references to changes in elevation and to the history of the Glacial period; by George M. Dawson: Trans. Royal Soc., Canada, Vol. VIII, sec. 4, 1890.

[2] Geology of the Yukon gold district, pp. 259-260.

but our present knowledge is inadequate to point to more than a few general conclusions. The Lower Tanana valley as far as Goodpaster River must have had very much its present outline, with, of course, greater depth. It was occupied by a river which had its more important sources in the broad valleys of the Volkmar and Goodpaster rivers. An examination of the topographic map will show that in this part of the Tanana all the tributaries make a downstream bend before they join the main river. In the Upper White and Tanana regions the drainage conditions must have been very different from what they are now. The contracted valley of the Middle Tanana is a comparatively new cutting, and it is probable that this drainage, including Johnson and Robertson rivers, flowed to the southeast. In this part of the basin the tributary rivers all make an upstream bend before joining the main river, indicating a reversal of the drainage system. This old river valley must have included the immense flat which now forms a part of the Upper Tanana and White River valleys. This old Tanana-White River, as I will call it, could not have escaped by the Upper White, for above the flat the White flows through a comparatively young gorge, and the valley of the Lower White below the Klotassin is also a recent incision and shows no evidence of having been a part of this old drainage system. The only possible outlet for the Tanana-White was therefore to the southeast, and the weight of evidence seems to point to the broad, flat valley of the Nisling. In a recent publication Mr. J. B. Tyrrell has described an old valley which is now occupied by the Chilkat River, entering into Lynn Canal and by a part of the Alsek River. In describing it he says:

> This range (St. Elias) is bounded on the south and southwest by the Pacific Ocean, toward the north and northeast by the great Chilkat-Alsek Valley, which extends inland from the western arm of Lynn Canal, following more or less closely the line of contact of the granite to the northeast and the schists and limestones to the southwest. * * * The bottom of the valley is almost flat, and the sides rise in gentle willow-covered slopes for 2,000 feet or more to the foot of the ungraded rocky peaks on either hand.[1]

From a personal conversation with Mr. Tyrrell I gained the impression that he traced this depression through to the White River by the valley of the Nisling. While this evidence is only fragmentary, it may be at least accepted as a working hypothesis that the Tanana-White River once drained into Lynn Canal.[2]

The Klotassin was probably tributary to the Tanana-White River, for it is connected with the flat by a broad stretch of the White River Valley, which offers a rather strong contrast with the narrow gorge below the mouth of the Klotassin. Plate XXXVI, *A* shows a view

[1] Glacial phenomena in the Yukon district: Bull. Geol. Soc. America, Vol. X, 1899, pp. 194-5.

[2] Since the above was written some further field investigations in this region have modified my views somewhat. I think it more likely that the water of the old White-Tanana River found its way to the sea by the Alsek Valley and did not drain into Lynn Canal.

up this part of the White River Valley from a point a few miles above the mouth of the Klotassin.

The drainage of the Lower White during this cycle is an unsolved problem, but it probably followed the present valley below the mouth of Ladue Creek. The basin of the Upper White is connected with a river flowing to the west by a broad, low gap, and this valley has usually been considered a part of the Tanana drainage.[1] Mr. Peters's determination of the position of the Nutzotin Mountains makes it possible that this is the valley of the Copper River. It will remain for future investigation to determine where the drainage of the basin of the Upper White River went at this time. It may have gone westward through this broad depression mentioned by Hayes, or it may have drained eastward through the valley of an unnamed stream joining the White about 20 miles southwest of the Koidern.

On the southeastern coast the same orographic movement is probably represented by the deep-cut valleys, whose subsequent drowning produced the fiorded coast of this part of Alaska. The region remained long enough in the elevated position for the streams to cut rather broad valleys, and then a period of subsidence began. The destructive actions of the rivers ceased, and they became agencies of construction. Instead of cutting down their valley floors, the gradients having been decreased, the sediments contributed by side streams were built into flood plains. The depression probably continued until the sea invaded the lower courses of the larger valleys, and this part of the country was diversified by estuaries, as is the case now along the southeastern coast of Alaska. In these estuaries and their confluent streams accumulated the detrital matter which was contributed by the processes of erosion. Just how far the sea actually penetrated along these deep-cut valleys it is impossible to state, but it is quite probable that the accumulation of sediments about kept pace, in a measure, with the depression, and that the major part of the deposits are of fluvial origin.

The only glacial deposits in the White River Valley were associated with the silts and gravels which were part of the deposits laid down during this period of depression, and within the district I found no evidence of general glaciation, such as has been noted elsewhere in the Yukon Basin by Dawson, McConnell, Russell, and Hayes. Hayes, in his study of the Upper White River, has shown that the front of the Cordilleran ice sheet extended northward to about the mouth of the Donjek, and hence it is outside of the area under discussion. The White River Valley itself, however, was at one time occupied by a glacier of considerable size, and this was probably contemporaneous with the maximum extension of the Cordilleran ice sheet. About 5 miles above the mouth of the Klotassin, on the west bank of the White, a river cut has exposed a good section of glacial till overlain by silts.

[1] Expedition through the Yukon district, C. W. Hayes: Nat. Geog. Mag., Vol. IV, p. 130.

The till has an exposed thickness of 50 feet, and consists of bowlder clay, sand, and gravel, with bowlders sometimes 2 feet in diameter. This deposit has as a rule no regular arrangement, but in places shows a rude stratification. Overlying the till is some 50 feet of fine silt containing Pleistocene fossils, and above this silt a few inches of volcanic tufa, and then higher terraces. This is the only locality in the region where I found any subglacial material. A few miles above this exposure erratic granite blocks of considerable size were found strewn over the valley slopes, some 200 feet above the river. From these facts it is evident that a glacier once occupied the White River Valley, and that probably its northern limit was near the mouth of the Klotassin, as is shown on the geologic map (map 25). No terminal moraine was found, but the stratified silts and gravel deposits below this point frequently contained large bowlders, which must have reached their present position by floating ice.

From our route of travel along the Tanana River we observed a number of glaciers in the mountains to the south. We had no opportunity of visiting these, and in fact were unable to locate them accurately. The most easterly of these lies in the Nutzotin Mountains, and apparently drains into the Nabesna River. On Mount Kimball and on Mount Hayes we saw a number of glaciers, and also several which were tributary to the Delta. As in the White River Valley, there is no evidence of general glaciation on the Tanana, but a number of its tributary valleys in the south show signs of having been occupied by ice. The first of these which was studied is the Robertson River, at whose mouth stratified sand and silt bluffs rise some 200 feet above the water (see Pl. XXXVII *A*). The presence of large bowlders in these fine deposits bear evidence that they were probably laid down not far from an ice front. At the mouth of Johnson River a similar deposit of fluvioglacial material was found.

The moraine at the mouth of Delta River has already been described, but in order to make this part of my paper complete I will briefly recapitulate. This moraine was first seen about 15 miles below the delta of the river and was traced as far as the Silokh River, a distance of about 20 miles (see Pl. XXXVII, *B*). It has contributed some large bowlders to the Tanana, and the river where it skirts the margin of the moraine consists of a series of small rapids. From an elevated point on the valley slope six different morainic ridges were observed, having a rough parallelism and extending part way across the broad valley of the Delta River.

Whether these glacial deposits of the Tanana Valley are to be regarded as contemporaneous with the advance of the White River glacier has not yet been definitely determined, but they are probably of somewhat later age and are not a part of the Cordilleran ice sheet, but represent rather a recent extension of the existing glaciers. This opinion is also held by Mr. Mendenhall, whose route of travel lay along the Delta River Valley. These glaciers which occupied the Tanana and confluent valleys are comparable to the Piedmont type, of which we have so many excellent examples on the southeastern coast of Alaska. It is of course highly probable that the glaciation of both the White and the tributaries of the Tanana is homotaxial with the maximum extension of the Cordilleran ice sheet. Mr. Tyrrell,[1] in the region studied by him between the Lynn Canal and the White River, described somewhat similar conditions to those prevailing in the White and Tanana Basin. According to his statements, during the ice advance the valleys were occupied by glaciers, while the sides above a certain line bear no evidence of ice action.

It will be seen from this description of the glacial phenomena that they play a comparatively unimportant part in the physiographic development of the region. The glacial action, however, had the effect of contributing a large amount of fine sediments, and probably also helped to bring about certain changes of drainage which will be discussed below.

On the upper Tanana and White are found terraces, sometimes 200 feet above the rivers, which represent the latest deposits laid down during the period of depression. These terraces are usually formed of fine silts and sands, with occasional nests of bowlders. They are largely formed of extraglacial wash, and from the fineness of the material would indicate depositions in quiet waters. On the White River fresh-water Pleistocene fossils were found in the silts overlying the glacial till. These deposits may represent estuaries of landlocked basins, or, as Mr. Tyrrell has suggested, ice-dammed lakes. The coarse, stratified gravels which are occasionally found in them probably represent delta deposits of streams tributary to the quiet waters in which they were laid down.

On the lower White and Tanana fine sediments are also found in terraces, and on the Tanana, below the mouth of the delta, these terraces rise sometimes 200 feet above the river, while on the White, near their southern limit at Ladue Creek, they are not over 300 feet thick. These fine sediments may be remotely glacial, but are not so evidently extraglacial wash as those described nearer the headwaters of the rivers. Those of the Lower Tanana are coextensive with the silts of the Yukon, and they must have been laid down in still waters for the most part, and are probably estuary deposits or fluvial sediments of large sluggish rivers. I can see no evidence that the broad valley of the Lower Tanana and the Yukon was ever occupied by a lake, and am forced to the conclusion that during the deposition of these sediments the region stood at a lower elevation. A measure

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[1] Op. cit., p. 195.

of the amount of this depression is given by the relief of the terraces above the present valley bottom. The fine sediments of the Lower White may represent lake deposits, but of this there is no direct evidence. The silts and gravels of the Yukon district, of which these are a part, have been described by Dawson, Russell, Spurr, and Tyrrell, and they have advanced various theories in regard to their origin which will be found in the publications already cited.

Having indicated in a rough way the important features of the old drainage system of the White and Tanana River basins, it still remains to summarize the development of the present water courses. The region, as has been shown, was drained by three important rivers, namely, the old Tanana, the old White, and the Tanana-White. The old Tanana toward the close of the period of depression probably had as its chief source the headwaters of what is now Goodpaster River, and the divide between it and the Tanana-White River lay probably between the present Gerstle and Johnson rivers and extended northeastward to the Ketchumstock Mountains. The base-level of this river was probably near at hand, for the deposits in the valley of the Lower Tanana indicate sluggish or quiet water conditions, which would have practically the same effect as actual base-level.

The source of the old White River probably corresponded in a general way with the present valley of Ladue Creek, or possibly of Katrina River. The watershed between it and the drainage basin of the Tanana-White River must have been near a line extending eastward from Caribou Mountain. This old White was a part of the Yukon, and the latter river probably occupied its present valley down to the flats. The flats of the Yukon, like those of the Lower Tanana, at this time represented the base-level toward which the Yukon and its tributary the White were cutting. Just how far up Yukon Valley this sluggish water then extended is not known, but in any event the old White, like the old Tanana, had its base-level near at hand. The Tanana-White River was much the larger of the three, and carried the major portion of the drainage and emptied it into what is now Lynn Canal, on the southeast coast. From its watershed with the old Tanana it probably had a distance of 300 miles to traverse before it reached the sea, while the divide between it and the old White must have been over 200 miles from its mouth. If the lower course of its valley was occupied by the sea, the distance would be less, but in any event the old Tanana and the old White had the advantage in pushing back the divides, and were therefore able to cut through the watersheds and to rob the larger river of a part of its drainage. There was, however, another factor which has been only indirectly referred to. We know that the peneplain is tilted to the northwest, and it is quite possible that this took place at a time when it would be a decisive factor in the drainage readjustment. Such a northwest tilt would retard the action of rivers flowing against it and accelerate those flowing into it.

We find, then, that of the two systems of rivers the two smaller ones, flowing northwest, had the advantage of position and grade over the larger one, flowing to the southeast. The pushing back of the divide between the old Tanana and the Tanana-White robbed the latter of its upper course, and eventually caused a reversal of the drainage. This robbery probably took place near the present Gerstle River. The old White tapped the Tanana-White between the Katrina and Klotassin, and eventually extended its conquest to the main river.

This change of drainage was perhaps accelerated by the advance of the ice across the course of the Tanana-White River Valley. On the accompanying geologic map (map 25), the limit of the White River glacier is indicated. A glacier in such a position would completely dam the Tanana-White River, which then, as has been stated, flowed southeastward, probably through the present valley of the Nisling. Such being the case, the drainage is quite likely to have found its way to the northwestward into the old Tanana and hastened the cutting down of the divide between the old Tanana and the Tanana-White. There may have been other glaciers along the lower course of the Tanana-White, in the present valleys of the Nisling and the upper Alsek, which also helped to bring about the reversal of the drainage.

It is interesting to note that this White River glacier might also dam the Klotassin, which was then tributary to the Tanana-White, and, by turning its waters across the divide into the old White River, aid the process of this second diversion of drainage. I offer these considerations in regard to effect on the drainage of White River glacier as mere suggestions, for as yet we have not sufficient facts to furnish definite proof. The weakness of the theory lies in the fact that it can not be established that the ice advance took place before the drainage readjustment.

A reference to the structural map (fig. 26) will snow that both the old Tanana and the old White were following structural lines during this robbing. On the Tanana between the Gerstle and the Johnson rivers, where the robbing probably took place, the main river follows the zones of shearing, as will be shown in the description of the structural lines. Similarly the White for some distance above the mouth of the Katrina, which is believed to have been the scene of the river piracy, also follows the direction of the major structure of the gneisses. Whether this gave the pirating streams any advantage over the Tanana-White can not yet be definitely answered. It will be seen, then, that the old Tanana and the old White rivers had the advantage of position, grade, and possibly structure features in their fight for supremacy with the larger river, and that they were possibly also aided by the interruptions to drainage caused by the presence of the ice. The barrier between the Upper and Lower Tanana River at the constricted portion of the valley which marks the position of the old divide has not yet been entirely removed. The river is here still actively cutting and consists of a series of small rapids, while above this swift water the river is sluggish and retains something of its ponded condition.

There are many minor problems of stream adjustment which have not yet been solved. A reference has been made to the small canyons of the White River formed by the river cutting through projecting spurs of the valley walls. Several similar topographic features, but of lesser magnitude, were found on the Tanana. These, as will be shown, are regarded as results of superposition, probably during the advance of the ice.

GEOLOGY.

GNEISSIC SERIES.

This series is a complex one, which it was impossible to unravel during a hurried reconnaissance trip, but it is believed to embrace the oldest rocks of the district. On the accompanying geologic map (map 24) the outline of this formation is indicated, as far as my observations of last summer determined it. It includes mica-schists, gneisses, gneissoid granites, and also massive granitic rocks, as well as altered basic rocks. In general, it may be said that the predominating rocks are granites or such as have been derived from granites by dynamic metamorphism. Every type intermediate between the quartz-mica-schists and an entirely unaltered granite was observed. As the younger clastic beds also contain considerable masses of intrusive granite which have often been more or less sheared, it was found in many instances difficult to differentiate the older gneissic series and the younger rocks, and hence the boundaries represented on the map can be considered only approximately accurate. The differentiation is further complicated by the presence of large masses of igneous rock, which have been intruded near the contact of the older and younger series in some of the localities. In the schistose phases of the gneisses quartz veins are found which are sometimes mineralized.

LITHOLOGIC NOTES.[1]

Biotite-granite.—A rock whose mineralogical composition would class it as a biotite-granite predominates in the series. It varies considerably in texture, being sometimes fine grained, but more often coarse. When fresh it has a gray color and is speckled with small plates of biotite. When weathered, as it is most frequently, it has a

[1] I am unable to include any petrographic descriptions, for as yet I have only had time to give the rocks a very hasty microscopic examination.

yellow or reddish color and the biotite is often chloritized. In thin section the structure, when not effaced by deformation, is seen to be granular hypidimorphic. Mineralogically, it consists essentially of quartz, orthoclase, albite, sometimes oligoclase and biotite, often with some hornblende. Epidote and rutile are not uncommon constituents, and in the weathered phases muscovite, a chloritic mineral, and kaolin are common.

Hornblende-biotite-granite.—This differs from the biotite-granite only in having a greater proportion of amphibole, which so far as determined is hornblende.

Hornblende-granite.—In this phase of the granite the dark silicate is almost entirely hornblende, though biotite is sometimes present as an accessory mineral.

Porphyritic granite.—All three of these varieties of granite have porphyritic phases. In these the phenocrysts are usually the feldspars, both of the orthoclase and plagioclase varieties. Some very coarse phases of this porphyritic granite, in which the phenocrysts of pink feldspar are an inch or more in diameter, were observed at several localities.

Basic segregations.—Basic segregations are not uncommon in all of these granites. On microscopic examination they are found to consist of segregations of the more basic minerals of the rock. Thus in the hornblende-granite a dark bleb was found to consist essentially of plagioclase and hornblende.

Gneissoid granites.—As has already been stated, a large proportion of these granites has been more or less altered by deformation. These have the same texture and mineralogic composition as the massive granite, but the structure is more or less modified by deformation. An examination of the gneissoid granites under the microscope usually shows the quartz to be cataclastic and the feldspar deformed, while the minerals all have a more or less parallel arrangement. In at least two instances a study of the thin section showed that the gneissoid structure was a primary one. In these the minerals were all more or less elongated and arranged parallel, but the rock showed no evidence of having suffered deformation. The quartz and feldspar gave clear extinctions, just as they would in a massive granite. From these facts the conclusion is inevitable that the parallel structure of the gneiss was coincident with the cooling of the rock magma and the crystallization of the minerals in their present forms. This primary gneissoid granite is, however, the exception, for ordinarily these rocks show every evidence of having suffered deformation, and the original structure has been entirely effaced.

Augen-gneiss.—The augen-gneiss is a product of a more extreme phase of deformation of the granites above described. It varies considerably in texture, being sometimes fine and sometimes exceedingly coarse grained. In the coarser varieties the augen sometimes reach an inch in their longer axes. When fresh, this rock has a gray color, but is more often found weathered, and the iron oxide gives it a reddish or yellow stain. The augen are lenticular in outline, and about them the biotite is arranged parallel to their peripheries. In the more compact varieties the rock is entirely made up of interlocking augen separated only by films of biotite and chloritic minerals.

Mineralogically, the augen-gneisses are identical with the granites from which they have been derived and show the same variations in composition. The chief constituents are quartz, orthoclase, plagioclase, usually albite, sometimes oligoclase, and biotite or hornblende, or both. Chloritic minerals are not infrequently present as secondary products, and the same is true of muscovite. When examined under a microscope there are found to be three more or less distinct phases of the augen. The augen most commonly consist of single feldspar individuals, usually orthoclase, but when the deformation has gone far enough these are often accompanied by augen consisting of intergrowths of quartz. These are secondary quartz masses which in thin sections appear as fine mosaic intergrowths. A third variety of the augen is only found in the most extreme phases of deformation, and this is made up of small lenticular masses of the rock itself which have been isolated by the shearing action. If this process be continued long enough, the rock eventually passes into a quartz-mica-schist. All of the types between an augen-gneiss and a quartz-mica-schist were observed in the field.

Gneisses and crystalline schists.—The gneisses and crystalline schists are hardly worthy of special mention, as they simply represent more highly altered phases of the gneissoid granite and have already been referred to. The gneisses consist essentially of elongated quartz and feldspar grains, all of which are cataclastic, together with occasionally some biotite or hornblende, but more frequently only secondary chloritic minerals. Other secondary minerals which are frequently present are garnet, muscovite, and epidote. The mica-schist is essentially the same rock, except that in it the feldspar is secondary or is entirely absent. This rock consists largely of quartz and muscovite, which are chiefly secondary. It is usually of a silvery-gray color and is finely laminated and often intensely plicated. Like the gneisses, the schists frequently contain some garnet.

Basic igneous rocks and derived schists.—Under this heading are grouped some rocks which are closely associated with the granites and gneisses, but are of a more basic character. The meager collections made of these last summer would hardly warrant subdividing this group, and in general it may be said to include rocks of a dioritic character. The feldspars are represented by rather acid plagioclases and sometimes by orthoclase. Quartz is almost always present as a secondary constituent and sometimes as a primary one. The prevailing dark silicates are hornblende and biotite, and these are very frequently in part or entirely replaced by secondary minerals. Apatite and magnetite are common accessories, while epidote, zoisite, and calcite are common secondary minerals. At a few localities some schists derived from a more basic rock were found. These contained pyroxene, basic plagioclase, and are believed to have been derived from a gabbro.

In general it may be said that the basic rocks of this series have suffered more deformation than the granites, for they are very seldom found massive. The rocks of this group may be classed as metadiorite, metaquartz-diorite, and metagabbro, all more or less gneissoid; and as probable alteration products are found amphibole-schists, quartz-hornblende-schists, chlorite-schists, and epidote and zoisite-schists.

Relations of the gneissoid igneous rocks.—I was unable to determine the relative age of the gneissoid rocks, but it seems probable that during the deformation of the original complex, which must have consisted of both basic and acid rocks, and in part subsequent to it, granitic and some dioritic rocks were intruded.

Younger igneous rocks.—Within the gneissic belt there are several types of igneous rocks which are entirely massive, and must have been intruded or extruded, as the case may be, subsequent to the deformation of the series. These do not occupy sufficient areas to allow of their differentiation on the accompanying geologic map.

Aplite-granite.[1]—This is a massive rock, which when fresh is of an almost pure white color. It is usually medium grained, but is occasionally coarse enough to be called pegmatite. The typical aplite-granite of the region is composed of white feldspar with bluish vitreous quartz. The potash feldspar is orthoclase, sometimes microcline, and with it occurs considerable albite. The thin sections of this rock which were examined showed a typical granite structure. It is entirely massive, but in a few instances a distinct parallelism of the mineral was noted, which was undoubtedly an original structure.

Typically this is a quartz-feldspar rock, but often a little accessory muscovite is present, and it sometimes passes into a muscovite-granite. Apatite is a common accessory mineral, and in some specimens considerable tourmaline was noted. One phase of this rock is scantily sprinkled with small plates of biotite. This aplite-granite has a wide distribution in the White River and Tanana basins, and rocks of a somewhat similar character have been described by Spurr in the Fortymile and Birch Creek districts.[2] I found them cutting not only the gneisses, but also rocks of younger age, as will be described hereafter. They are usually intruded as small dikes parallel to the foliation and bedding planes, but are occasionally found cutting the structural planes.

[1] Aplite is here used purely in a mineralogic and not in a structural sense.
[2] Geology of the Yukon gold district: Eighteenth Ann. Rept. U. S. Geol. Survey, Part III, pp. 229–231.

Effusive rocks.—On the Tanana, a few miles below the mouth of the Tok River, some porphyritic rocks were found associated with the gneissoid granite. These are entirely massive and seem to be effusive, though the evidence of this was not conclusive. A hasty examination of a few exposures showed two types of rocks—first, one of a rhyolitic nature, and, second, one of a trachytic character. The rhyolite, or the metarhyolite as it might more properly be called, is of a gray color, and the hand specimen showed small phenocrysts of a feldspathic mineral in an aphanitic groundmass. When studied in thin section the phenocrysts of the metatrachyte were found to be orthoclase and albite, with a few of quartz. The groundmass of the rock is much decomposed, but seems to have been originally consisted chiefly of a microcrystalline intergrowth of feldspar.

DISTRIBUTION AND STRUCTURE OF GNEISSIC SERIES.

Distribution.—The rocks of the gneissic series were first noted on the White River just above the mouth of Ladue Creek, and from this point to the flats above, the White River cuts entirely across the belt occupied by this formation. I found rocks of a similar lithologic character in the Tanana below the mouth of the Nabesna, and regard these as the westward extension of the same belt. I was able to trace the series down the Tanana to about the mouth of Delta River. These facts of distribution are indicated on the accompanying geologic map (map 24). How far the gneissic series extends to the north of the Tanana I have no means of determining, but from information furnished me by prospectors think it must at least reach the Fortymile divide. To the south the limit of the gneisses is probably within the Tanana Valley, for Mr. Mendenhall informs me that he found no rocks of this character in the section exposed on Delta River.

On the Lower White River the gneisses and mica-schists, with gneissoid basic rocks, predominate up to within a few miles of the Klotassin River. From this point to the flats the belt is made up largely of a rather uniform gneissoid biotite-granite. On the Tanana the series was first recognized at Mount Chisana, where it was represented by a finely-laminated quartz-mica-schist and a mica-gneiss containing some feldspar. Below this point on the Tanana the area of this series is largely occupied by various kinds of granite. A very common type is the coarse augen-gneiss, which has already been described and which, with the more massive granites, forms the bold, picturesque bluffs which are so characteristic of this part of the Tanana.

Structure.—On the Lower White the gneisses strike in a northwesterly-southeasterly direction and have a cross structure nearly at right angles to this. The dip of the foliation is variable, but is usually low. On the Tanana there are two structures of equal value, one striking about east and west and the other a little west of north. These structural features will be considered below. The dip of the foliation is usually to the east and the angle of the dip variable.

AGE OF GNEISSIC SERIES.

As will be shown hereafter, definite proof of the basal nature of this gneissoid series is still wanting. There is, however, strong evidence that the metamorphosed clastic series which lie adjacent to the gneisses are younger, and that the gneisses should be regarded as basal. This would make it the equivalent of Spurr's basal granite and probably the same as the Archean granites mentioned by Hayes.[1] Spurr[2] has suggested a correlation of this basal series with the granites described by Dawson[3] on the Pelly and Dease rivers.

NASINA SERIES.

This series, which was found on the Lower White River, is made up largely of clastic rocks, with some intrusive sheets and dikes. It consists essentially of quartz-schists and white crystalline limestone, with some slates. It is probable that the quartz-schists and white limestones belong to distinctive horizons, but as their mutual relations were not determined it had been thought best to group them together. Quartz veins are numerous in this formation, and they are often more or less mineralized. The distribution of these rocks is shown on the general geologic map (map 24) and also on the special geologic map (map 25).

LITHOLOGIC NOTES.

Quartz-schist.—This is a gray schistose quartzose rock which in thin section is found to consist essentially of a mosaic intergrowth of quartz with some metamorphic minerals. The quartz grains are elongated and give wavy extinctions. A preliminary examination showed fine plates of biotite, chloritic minerals, epidote, cordierite, some carbonaceous matter, etc. The schist is often finely laminated.

Amphibole-schist.—This is a dark-green schistose rock which is often finely laminated. In thin section it is found to consist essentially of a pale-green actinolite, with irregular quartz grains which are sometimes in the form of mosaics. Magnetite is quite plentiful and zoisite and titanite are sometimes found.

Chloritic schist.—This is a soft, green, schistose rock closely related to the amphibole-schist. It consists almost entirely of chloritic minerals, both chlorites and chloratoids having been observed. Alterations of the amphibole-schist into this rock were noted in the field.

[1] Nat. Geog. Mag., Vol. IV, p. 138.
[2] Op. cit., p. 138.
[3] Ann. Rep. Geol. Nat. Hist. Survey Canada, Vol. III, Part I, 1889, p. 35B.

Quartz-actinolite-zoisite-schist.—This is a variety of amphibole-schist in which other minerals are important constituents of the rock. It consists essentially of actinolite, small lenticular quartz grains, zoisite prisms, and some magnetite.

Sheared granite.—This granite has a well-marked foliation, and its original structure has been almost entirely defaced. It now consists essentially of elongated grains of quartz-feldspar, apparently chiefly orthoclase, with secondary epidote and chloritic minerals. The sheared granites, as well as the amphibole- and chlorite-schists, are all altered igneous rocks which have been intruded parallel to the bedding planes. They are rarely found cutting the lamination. A development of metamorphic minerals has in some instances taken place along the contact zones of these intrusive sheets, but this metamorphic effect is very local.

Porphyritic biotite-hornblende-granite.—This rock is found as a small stock on the Lower White River. It is bounded on one side by the gneisses and on the other by the gneissic series. Its location is shown on the general geologic map (map 24), and on the special geologic map (map 25). In its lithologic character it is identical with those of similar type previously described as occurring in the gneissic series.

White crystalline limestone and slate.—The limestone is a pure white rock made up of an intergrowth of calcite with a little chlorite, and with it are found seams and thin beds of blue clay slate. The only exposures of the white limestone which I had opportunity to examine were located on the right bank of the White, about 12 miles above its mouth. At this point a cliff some 40 feet high rises from the water and is composed of white limestone and slate, the strike being N. 60° W. and the dip 25° N.

Quartz-sericite-schist.—This is a finely laminated schistose rock made up chiefly of fine quartz grains, stringers of chloritic minerals, and epidote. This and the quartz-sericite-schist were found in large exposures at the mouth of Ladue Creek. They lie near the gneisses, and should therefore represent the base of the Nasina series.

Effusive rocks.—On the north side of the White River Valley, about 15 miles from the mouth, are found considerable exposures of a gray porphyritic rock which is believed to be effusive. Except for an east and west jointing this rock is entirely massive. Angular and subangular fragments of a rock of similar character are irregularly scattered through it, and it is deeply weathered. Phenocrysts of an oligoclase or an andesine feldspar, with a groundmass composed chiefly of feldspar, go to make up the rock. A few phenocrysts of a pyroxene mineral considerably altered were also observed. This rock should probably be classed as an andesite, though further study of fresher material will be necessary to determine it definitely.

DISTRIBUTION AND STRUCTURE OF NASINA SERIES.

The Nasina series was identified only on the Lower White River and extend up to about the mouth of Ladue Creek. The bold bluffs which form the north side of the Yukon, opposite the mouth of the White River, are formed of the metamorphic schists of this series. At these bluffs the schists strike about north and south and dip to the east, while on the White River, a few miles above, the strike is nearly east and west and the dip on the two opposite sides of the valley is north. All of these dips are low, usually varying from 20° to 30°. Above the first big bend the series is found on the north bank as far as Ladue Creek, while the south wall of the valley is formed by a porphyritic biotite-granite having more or less of a secondary gneissoid structure, which may belong to the older series, but is believed to be intrusive in the sediments. The dips of the sedimentary beds are away from this stock of granite and suggest that the intrusion of the igneous mass may have produced a low dome.

The relation of the Nasina and the gneissic series can only be deduced from general evidence, for they were not found in contact. The gneisses are believed to be older, because they have suffered a much higher degree of metamorphism than the clastic rocks, for, while the sedimentaries have been rendered schistose, this deformation is not comparable in magnitude to that which the gneisses have suffered. There is also a marked change in strike in passing from one series to the other.

CORRELATION OF NASINA SERIES.

A discussion of the probable relative age of the Nasina series and the Tanana schists will be found elsewhere. In his report on the Yukon gold districts Spurr described a series of quartz-schists with some intrusives overlain by white crystalline limestone, also containing igneous intrusions. The older of these two series, made up of quartz-schists, overlies and is younger than the basal granite, and these Spurr has called the Birch Creek schists, and the succeeding white limestones he has named the Fortymile series. These two series have a general lithologic and stratigraphic similarity with the Nasina series. I have given the rocks studied by me a new name, because I was unable to differentiate two horizons as Spurr has done, and because long-distant correlations of unfossiliferous beds, which are based purely on lithologic similarity, seem of doubtful value. It remains for future work to determine by actual tracing in the field whether these horizons are identical, and if so the older name will have priority.

TANANA SCHISTS.

This formation includes for the most part only fine-grained argillaceous and calcareous rocks, all more or less altered, and which, as the name implies, can all be grouped together as schists. These schists have a wide distribution on the Tanana, if the correlation which I have made be correct. While it is by no means certain that all of these schists belong to one horizon, it is quite probable that they belong to the same general series, and hence I have grouped them together. Their distribution is shown on the accompanying geologic maps. Mineralized veins are quite common in these rocks.

LITHOLOGIC NOTES.

Micaceous and graphitic schists.—The micaceous and graphitic schists are the dominant types of the series, and are essentially argillaceous rocks which contain a varying amount of carbonaceous matter. They show considerable variation, due both to difference of original composition and to differences of degrees of metamorphism. As a rule they are finely foliated, often intensely plicated, and are blue and black in color. Under the microscope they are seen to be composed largely of sericite and quartz grains, often with more or less graphite. These schists find their typical development on the Tanana below the mouth of the Mahutzu. Here they are found exposed as bold bluffs along the river, and are often seamed with quartz and quartz-calcite veins.

Calcareous schists.—These are predominatingly calcareous, yet are hardly pure enough to be classed as limestones. They are gray in color and often finely banded. In thin section they show abundant calcite, with much clastic material; the clastic grains are both rounded and angular, and are made up of quartz, orthoclase, and plagioclase. This calcareous schist was first found on the Tanana, near the mouth of Scottie Creek, where it is interbedded with phyllites. In thin section it shows much clastic feldspathic material. The same rock is again found near the mouth of the Mahutzu, and here it also carried much clastic feldspathic material cemented by calcite. The presence of so much feldspathic matter suggests that these may be basal members of the series which derive their material from the gneisses.

Granite.—In only one locality was granite found in place cutting the schists. This is a small dike but 2 feet wide, intersecting the quartz-biotite-schist near the mouth of the Silokh River. This granite is a medium-grained light-colored rock, made up for the most part of a micrograpophyric intergrowth of quartz and orthoclase; some plagioclase and biotite are also present.

At several other localities granite débris was found intimately associated with the Tanana schists, and there are undoubtedly numerous granite intrusions in this series. Between the Mahutzu and Salchaket rivers, on the Tanana, several large masses of gneissoid porphyritic granite are found in the schists, but these are believed to be infolded masses of the gneissoid series and not intrusives, and are so represented on the map (map 24).

DISTRIBUTION, STRUCTURE, AND CORRELATION OF TANANA SCHISTS.

An examination of the geologic map will show that the Tanana schists are found in three separate areas in the district. The most easterly of these lies between the White and Nabesna rivers. The general strike is here about northwest and southeast and the dip usually steep to the north, and the schists in this belt are chiefly calcareous.

The second area of Tanana schists lies between the Mahutzu and Nilkoka rivers, and here they are composed essentially of micaceous and graphitic rocks. At the eastern margin of this belt the strikes are east and west, while west of the Chena River they are northeast and southwest. The dips are steep and generally to the north and west.

The rocks which make up Bean Ridge form the third belt of the Tanana schists. From Baker Creek to within a few miles of Harpers Bend the river skirts a bold bluff composed of graphitic and micaceous schists of this series.

The strike is about northeast and southwest and the dip usually steep to the northwest.

The Tanana schists are a distinctive horizon from the adjacent gneisses. Since they are much less metamorphosed than the gneisses they are believed to be younger, and probably overlie them unconformably. The presence of detrital minerals identical with those of the gneisses in the Tanana schists lends additional weight to this hypothesis. If this series, then, immediately overlies the gneisses, they have a stratigraphic position corresponding to the Nasina rocks, and future investigations will quite probably show them to be the equivalent of some member of that series. The greenstone schist series, which is closely associated with this formation, is unconformably overlain by the Upper Paleozoic conglomerates of the Wellesley formation. Reasons have already been given for believing that the Nasina series is the equivalent of the Birch Creek and Fortymile series, and if this be true the same line of reasoning would make the Tanana schists of about the same age as these beds described by Spurr. Mr. Mendenhall informs me that rocks of lithologic composition identical with the Tanana schists make up the main mass of the Alaskan Range where he traversed it along the valley of Delta River. He has accepted my nomenclature in his publication and called these rocks the Tanana schists.

GREENSTONE SCHISTS.

These rocks occur in two lenticular-shaped areas in the Upper Tanana Basin (see maps 24 and 25). They are for the most part of igneous origin and seem to have been intruded close to the contact of the Tanana schists and the older gneissic series. The contact between the larger mass of greenstones and the sedimentary rocks is not found, but small dikes of basic character lithologically identical with the greenstones were found in the Tanana schists at various localities. Dikes of the same general character were also found in the gneisses. They are uncomformably overlain by the Wellesley formation, as will be described below. In some respects these rocks are similar to Spurr's Rampart series.

LITHOLOGIC NOTES.

The gabbro type of greenstone.—This is a dark-green granular rock originally composed essentially of a basic plagioclase and pyroxene, with some magnetite and titanite. This type is frequently found altered to actinolite-, zoisite-, epidote-, or chloritic schist.

The dioritic type of greenstone.—In this greenstone the plagioclase is usually oligoclase and the darker silicate an amphibole. The original rock, as far as could be determined, seemed to have a granular structure.

The tuffaceous type of greenstone.—This rock has a well-marked parallel structure, and under the microscope the constituents do not show evidence of having suffered much dynamic metamorphism. The mineral constituents are fragmentary and have the appearance of being of clastic origin. It consists essentially of feldspar (orthoclase and oligoclase), hornblende, biotite, and some quartz. The feldspars and quartz are often in lenticular grains.

Chloritic, actinolite-, epidote-, and zoisite-schists.—The more or less massive greenstones are found to have their secondary phases, which are grouped under this head. This change is in part a surface weathering, but more largely a deep-seated alteration which accompanies the dynamic disturbances of the entire series. As these secondary schists are all derived from the rocks already described, it would not be advisable to give detailed descriptions of them here.

WELLESLEY FORMATION.

This formation can be roughly divided into two parts, the lower consisting of a coarse massive conglomerate interlarded with a few beds of clay slate, while the upper part consists almost entirely of clay slate. It was first found outcropping on the isolated hills and ridges of the White River flat, and was traced across into the Tanana

Valley. Some dikes were observed cutting the slate, but these are of secondary importance, and the series consists essentially of sedimentary rocks. The best evidence goes to show that the minimum thickness of the Wellesley formation is between 1,000 and 2,000 feet, but no exact measurements were obtained. The clay slates contain some quartz veins which are occasionally mineralized.

LITHOLOGIC NOTES.

Conglomerate.—The conglomerate is very massive, and seems to have been but little affected by the deformation which has locally considerably altered the associated slates. The pebbles of the conglomerate vary in size from a fraction of an inch to 18 inches in diameter. The cement is siliceous and ferruginous, giving a reddish color after weathering. The pebbles are very largely identical with the more massive phases of the greenstone schist series. It is a striking fact that while the pebbles have been very largely derived from the greenstones they are for the most part massive. The deformation, therefore, which has altered the greenstones must have taken place since the deposition of the conglomerate, and seems to have affected the conglomerate itself comparatively little. Massive quartzite pebbles whose derivation is unknown were also found in the conglomerate.

Clay slates.—This is a blue clay slate having usually an even fracture, and frequently containing a considerable percentage of carbonaceous matter. Locally the slate is altered to a phyllite containing considerable sericite. This is especially noticeable along the lines of faulting found in the Mirror River Valley. The slate is found in thin beds in the conglomerate, and, as has been stated, forms the upper part of the formation. The slates where altered frequently contain quartz veins.

Granite.—One dike of granite was found in the clay slate on the west bank of the Tanana, opposite the mouth of Mirror Creek. The dike is not over 30 feet wide, and near the contact considerable biotite is developed in the slate. The granite is gray in color and medium-grained, and in thin section is found to have a typical granite structure. It is massive, and consists essentially of orthoclase, quartz, albite, biotite, hornblende, and contains some tourmaline and secondary chlorite.

Metarhyolite.—A small dike of porphyritic rock was found cutting the slate about a mile west of the camp marked "July 19" on the topographic map. It was impossible to obtain fresh material from this dike, but it seemed to be an altered rhyolitic rock.

STRUCTURE AND CORRELATION OF WELLESLEY FORMATION.

The Wellesley formation overlies the greenstone schists unconformably. Its strikes are approximately northwest and southeast, and it occurs as a series of closed folds, which are more or less faulted and are overturned to the west. Its general distribution is shown on the special geologic map (map 25). Along the northern margin of the mass considerable faulting has taken place, and it dips directly toward the greenstone. The section on map 25 is a generalized one, as the details could not be shown on the scale.

In the Snag River Valley, about 1 mile west of camp marked "July 19," a few fossils were found in a slate bed occurring in the massive conglomerate. These fossils were referred to Mr. Charles Schuchert, of the United States National Museum, and he reports as follows:

The most abundant species present is a small nucula having the general appearance of *Nucula neda* Hall and Whitfield, and *N. corbuliformis* Hall, of the Middle Devonian. On the other hand, since nuculas are generally present in faunas of the Devonian and Carboniferous, it is at present impossible to say to which of these two systems the fossils in question belong. That the age of this nucula can not be younger than the Carboniferous is proven by the fact that associated with them is a fragment of a thoracic segment (a pleura) of a trilobite. Nuculoid genera are known throughout the geologic column, beginning with the Ordivician system, but the aspect of the Tanana species is more that of late than early Paleozoic times.

A closely coiled *Bellerophon* is also present, but since the only specimen is very small and shows no surface ornamentation, it has no particular stratigraphic value.

Mr. Schuchert's determination therefore shows the formation to be of Devonian or Carboniferous age. In a general way it may be regarded as the equivalent of Spurr's Tahkandit series.

NILKOKA BEDS.

The rocks included in this formation are exposed on the Lower Tanana, between the Nilkoka River and Baker Creek, where they form conspicuous bluffs along the river bank. They include fine quartz conglomerate and sandstones, with red and green clay slates. The slates and sandstones could not be differentiated into two horizons, but in general the upper part of the formation seemed more argillaceous and the lower part more arenaceous. The whole series is closely folded, but shows little evidence of metamorphism. The unaltered condition of the slates contrasts strongly with the graphitic Tanana schists which were found on both sides of the belt. A few quartz veins occur cutting the sandstone, but none were observed in the slate.

The Nilkoka formation is undoubtedly younger than the Tanana schists and probably overlies them unconformably. No fossils were found in the rocks, and hence there is little clue to their age. In a broad way I am inclined to correlate them with the Wellesley formation and consider them probably of Paleozoic age. Their stratigraphic position with an older formation on either side would go to show that the general structure was synclinal. The strikes, as well as the dips, are variable, but the general trend of the series is NE. and SW.

TOK SANDSTONE.

A few miles below the mouth of the Tok River several exposures of a soft yellow sandstone were found. This sandstone, though of small areal distribution, has been given a special name because it is probably younger than any of the formations already described. It has a yellowish color, is friable, and is thinly bedded. Beds of fine feldspathic conglomerate of no great thickness are found in it. The sandstone itself showed a thickness of something over 50 feet at one locality.

Several basic dikes of considerable size were found cutting the sandstone at right angles to the bedding, and these were usually deeply weathered. A microscopic examination of one of the dikes showed it to be an olivine diabase. The strike of these beds is about E. and W., and the dip, which is rolling, not over 5° or 10°. This strike

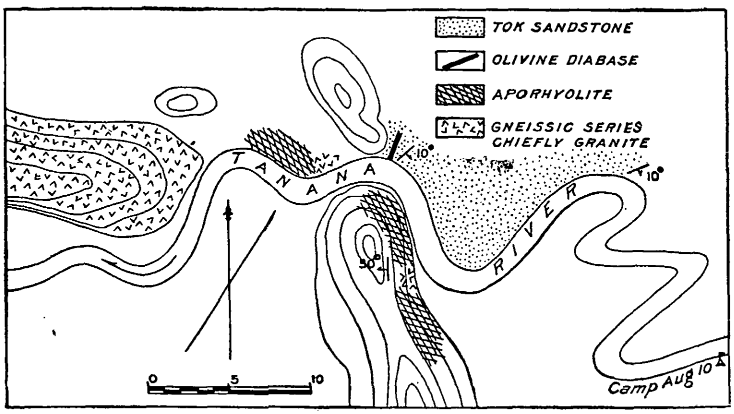

FIG. 25.—Sketch map showing distribution of Tok sandstone.

is entirely at variance with that of the gneisses which are near at hand. These general facts of the distribution of the sandstone and adjacent rocks are represented in fig. 25.

Fragmental plant remains were found in the Tok sandstone, but unfortunately are not well enough preserved to give any clue as to the age of the beds. From their slight deformation and unaltered appearance I am inclined to regard them as post-Paleozoic and most likely of Tertiary age.

PLEISTOCENE DEPOSITS.

The Pleistocene history of the region is a rather complex one and must go hand in hand with the consideration of the physiography, so that this matter has been taken up under a previous heading. My purpose here is to describe the Pleistocene beds simply as part of the stratigraphical column and not to consider their origin except so far as it determines their classification.

The Pleistocene deposits have a wider distribution than any other formation of the region. The silt terraces of the Lower White, the glacial till, lacustrine silt, and sand and gravel terraces of the Middle White are all of this age. On the upper Tanana I found sand and gravel terraces, and on the lower river fine sand bluffs, which must all be classed as Pleistocene. The morainic material of the Delta Valley and the widely-distributed volcanic tuff are also of this age. Finally, the gravels in which the old river valleys of both basins are in part buried are important members of this formation, and the present river gravels must also be classed with the Pleistocene.

The old river gravels.—The origin of the basins and broad, flat-bottomed valleys of the Tanana and White River has been discussed in a previous chapter. In brief, however, at a period not long distant, when the region stood at considerably higher elevation, wide valleys were eroded, and, depression following, they were filled by sediments, probably chiefly fluvial gravels. Of the character of these oldest Pleistocene deposits—for as such they must be regarded—we have no information, for they are not exposed.

Glacial till.—A discussion of the glacial phenomena of the region has been given, and only the deposits themselves will here be considered. About 5 miles above the mouth of the Klotassin, on the west bank of the White, a river-cutting has exposed a good section of glacial till overlain by silts. The till has an exposed thickness of 50 feet and consists of bowlder clay, sand, and gravel, with bowlders sometimes 2 feet in diameter. This deposit has as a rule no regular arrangement, but in places shows a rude stratification. Overlying the till is some 50 feet of fine silt containing Pleistocene fossils, and above this silt a few inches of volcanic tuff, as will be described hereafter. This is the only locality where I found any subglacial material.

Glacial moraines.—About 15 miles below the Delta the Tanana is hemmed in on the south by an old glacial moraine, which it skirts as far as the mouth of the Siloh River. This morainal ridge, so far as I was able to determine it, is even crested, symmetrical, and is composed of sands and gravels. It is about 200 feet in height, and was traced for some 20 miles. The Mahutzu River has cut its channel completely through the ridge, while the Silokh flows around its western end. From a hill slope opposite the mouth of the Mahutzu a good view of the Lower Delta was obtained. With the aid of my field glasses I was able to count six different ridges extending part way across the valley of the Delta River. These ridges all had a general parallelism and are believed to be morainic.

Silt and gravel terraces.—The silts and gravels of the region are more widely distributed than any of the other formations. Fine micaceous silt deposits, some 30 feet thick, occur on the Lower White, and were traced up as far as the first big bend of the river above Ladue Creek.

Pl. XXXVIII is a reproduction of a photograph of a silt bluff at the mouth of Moosehorn Creek on the White River. Above the mouth of the Klotassin terraces of sand, gravel, and silts are found on both sides of the valley, the highest being some 200 feet above the water. On the Tanana also the terraces of silt and sand are prominent features of the topography of the river valley and are found at various levels. On the White River Pleistocene fresh-water fossils were found in the silts overlying the till.

Volcanic tuff.—On the Lower Pelly and Lewes rivers and on the Upper White a volcanic tuff has a wide distribution as a surface deposit. This ash has been noted by Schwatka, McConnell, and Russell, and has been specially studied by Dawson[1] and Hayes.[2] The distribution of this deposit, so far as it was then known, was represented by Hayes on a map which accompanied his paper, and he estimated the area over which the tuff was distributed to be over 52,000 square miles. The greatest thickness observed by him was between 75 and 100 feet, and this occurred on the western bank of the Klutlan River.

I first found this ash on the White River, a few miles above the mouth of the Klotassin, where a bed a few inches thick, overlain by 6 inches of soil, occurs on top of the silt terrace. On the Snag River I found a thickness of 3 feet exposed on the river bank, and here succeeded by a foot or more of soil. It was here cross bedded, and was evidently a stream-laid deposit. On Mirror Creek I observed it again, and the bed was somewhat thinner. It was traced down the Tanana, with a constantly decreasing thickness, nearly to the mouth of the Tok River.

The material is a finely comminuted white ash, which seems to be made up entirely of volcanic glass. The coarsest grains observed by me were found on the Snag River, and varied from 0.5 to 1 mm. in diameter. The grains decrease in size toward the limits of the area, and near the periphery the tuff is made up of fine white powder. Hayes has suggested that this tuff has its origin in an explosive eruption from a volcanic peak situated in the northern part of the St. Elias Mountains, near the source of the Klutlan Glacier.

Modern river gravels and alluvium.—Both the White and Tanana rivers, as well as many of their tributaries, fed as they are by glacial streams and streams from snow-clad mountains, are overloaded with sediments and are rapidly building up their flood plains. The character of the stream deposits varies according to the current of the river and the source of the detrital matter. In that part of the White River which was traversed by our party the flood plain included coarse gravels as well as sand and fine alluvium. The fine material is derived in part from the glacial streams and in part from the silt terraces which the

[1] Explorations in the Yukon district: Geol. Nat. Hist. Survey, Canada, Part B, 1887.
[2] Op. cit., p. 147.

river is constantly undercutting. The frozen banks when exposed to the fierce rays of the arctic midsummer sun are thawing and continually caving in. Dr. Hayes has suggested that the volcanic ash is an important source of the finer sediments of the White River.[1]

The Snag is the only muddy tributary of the White which we saw, and it is probably fed by glaciers in the Nutzotin Mountains. All the rivers having steep gradients which flow through timbered areas carry large quantities of driftwood. This wood finds its way into the streams by the undercutting of the banks and by the thawing, which, as has been stated, takes place when the soil is laid bare. The Snag River was so named because of the inordinate quantity of driftwood found along its course. The floating trees and roots frequently form log jams, through which we had to cut channels for our canoes or around which we were forced to make portages. In a number of places I observed old dams which had been formed by driftwood and accumulation of sediments, and which sometimes had evidently caused temporary lakes of considerable size.

The flood plain of the Tanana as far as the mouth of Scottie Creek we found to be similar in character to that of the White. Below this creek to Cathedral Rapids gravels were seldom found, and the flood plain consisted chiefly of alluvium. In this part of the river the Nabesna is the only tributary which has its source in high mountains. This river contributes very little coarse material, for it deposits this in the long stretch across the flat Tanana Valley before reaching the main river. From Cathedral Rapids to where the Tanana narrows down above the Cantwell the river deposits are usually very coarse. All of the southern tributaries of any size are overlaid glacial streams and bear coarse detrital matter to the main river. The glacial moraine of Delta River is also a source of coarse gravels, and the undercutting of the glacial silt terraces frequently contribute large bowlders. In this part of the river driftwood is very abundant, and the countless snags will always be an element of danger to navigation.

From the Cantwell River to the mouth of the Tanana the flood plain is made up of alluvium almost to the exclusion of gravels and sands. The character of the streams tributary to the Tanana and White has been referred to under the heading of drainage. In general it may be said that the confluent streams of the Lower White and those entering the Tanana from the north are sluggish, while the southern tributaries of the Tanana are swift flowing. I need hardly add that the flood plains of the sluggish tributaries are built up of fine sediments, while coarse deposits characterize the streams having steep gradients.

Soils and ground ice.—I have, of course, not sufficient data for any detailed discussion of the soils. The region as a whole not having been glaciated, the soils are of immediate derivation from the under-

[1] Nat. Geog. Mag., Vol. IV, p. 150.

lying rocks, and their composition depends on the character of these. Where exposures were obtained the soil was found to be not over a foot or 18 inches deep. It contains, as a rule, considerable vegetable material derived from the dense growth of moss, which, except in some tracts of meadow land, nearly everywhere covers the surface of the country.

The ground ice of Alaska, as well as of other northern regions, has been frequently described. As far as my information goes its thickness has never been determined, for nowhere have excavations been made which pierced it. Test pits in Alaska have been reported 30 and 40 feet in depth which did not reach below the ice. My observations in the White-Tanana district are that the thawing during the summer seldom extends more than 1 or 2 feet below the surface, and in newly cut river banks I have seen 20 feet of frozen soil. The dense mantle of moss protects the frozen soil from the sun's rays, and the thawing action is therefore limited to shallow surface zones. The moss cover is usually wet and has been compared to a sponge, a comparison which will appeal to those who have been forced to travel across such moss-covered areas. This vegetable growth reduces the power of erosion of surface waters, and, as Professor Russell[1] has suggested, seems to retard the decomposition of the rocks. He has also called attention to the fact that the disintegration of the rock in Alaska is very marked, and assigns it to the great variation in temperature. The mountain slopes which we had occasion to traverse were all covered with a very heavy talus. The smaller valleys and ravines are frequently in part filled with large angular bowlders, among which, far below the surface, the water courses find their way. These bowlders on the hilly slopes and in the ravines are usually covered by a carpet of moss, and such areas afford only very treacherous footing.

SUMMARY OF STRATIGRAPHIC AND STRUCTURAL GEOLOGY.

In the foregoing I have attempted to describe the various formations of the region, their lithologic character and structural relations, and to suggest such correlations as our limited knowledge of the geology of Alaska would permit. For the sake of emphasizing the more important facts I will here give a brief recapitulation.

The gneissic series, which is believed to include the oldest rocks, is exposed in a belt running northwest and southeast, crossing the Lower White and extending to the mouth of the Delta and Tanana Rivers. This basal series is composed of a complex of gneisses of igneous origin, both of an acid and a basic character, together with many intrusives which are sometimes massive but more often schistose. The

[1] Professor Russell has given a detailed discussion of this subject in his publication entitled The surface geology of Alaska: Bull. Geol. Soc. America, Vol. I, 1890, pp. 129-137.

belt is flanked on either side by younger clastics, and is, in fact, a central crystalline core of an anticlinal uplift which is overturned to the west. These relations are shown in the section on map 25. The complex contains no recognizable clastic material and can therefore probably be safely referred to the Archæan. It probably suffered considerable deformation previous to the deposition of the sedimentary beds. To the west these gneisses have been traced as far as the mouth of Delta River, below which point the younger schistose series outcrop. As the strikes are here swinging to the southwest the extension of the basal series should be found to the southwest of the Tanana. The gneisses have not been traced east of the White River, but it is quite possible that the granites of the Pelly River described by Dr. Dawson are along the same line of uplift. To the north the limit of the gneisses has not been determined but must lie near the Yukon and Tanana watershed. As Mr. Mendenhall saw nothing of this series in his section on Delta River, it is believed that the boundary of the formation lies in or close to the Tanana Valley.

To the north of the gneisses on the White are a group of rocks which are called the Nasina series. They consist essentially of quartz-schists, with numerous acid and basic intrusives, and of a white crystalline limestone. Their relation to the gneisses can only be inferred from the relative amount of metamorphism, for the contact was not found. The gneisses, as has been stated, are excessively sheared, while the Nasina series shows no evidence of having suffered extreme deformation. These sediments are therefore regarded as younger than the gneisses, which they are believed to overlie unconformably. The strike of these beds is variable, being about north and south on the Yukon and swinging around until they are nearly east and west near the contact with the gneisses. The dips are low to the north and east. I identified this series only on the Lower White, but some hasty observations convince me that it extends up the Yukon for some distance toward Fort Selkirk. To the west they are probably coextensive with the older sediments in the Fortymile district described by Spurr.

On the Tanana occurs a series of schists adjacent to the gneisses which has been called the Tanana schists. It includes a series of calcareous, argillaceous, and graphitic schists, with a few intrusions, and occurs in two areas on the Tanana adjacent to the gneisses. On the Upper Tanana a narrow belt of this rock lies to the south of the gneissic area and has a northwest-southeast strike. On the lower river the Tanana schists lie to the northwest of the gneisses, and the strike is northeast and southwest. The contact relation, as in the case of the Nasina series, was not determined, but the clastics are believed to be younger than the gneisses. The upper belt of the Tanana schists has not been followed to the east, but in its western extension, according to Mr. Mendenhall, it broadens out and forms the main mass of the Alaskan Mountains. On the Lower Tanana these rocks are probably continued to the northeast by one of the sedimentary series in the Birch Creek district described by Spurr. The southwestern extension of this belt would carry it into the metamorphic rocks found at Gold Mountain, on the Yukon below the mouth of the Tanana. In a broad way I am inclined to correlate the Nasina series with the Tanana schists. I think it quite likely that when the region has been studied in more detail the Nasina series will be found to include the Tanana schists.

The greenstone schist is considered the next formation in point of age, and was found in two areas in the Upper Tanana. I have been unable to reach a satisfactory conclusion in regard to the origin of this formation, for while it is largely composed of rocks which seem to have a deep-seated igneous origin, it also includes rocks which upon microscopic examination have a decidedly tuffaceous appearance. It is clear, however, that it is in part at least intrusive, and that as a whole it is younger than the Tanana schists. A hasty petrographic study has led to subdividing these rocks into dioritic, gabbroic, and tuffaceous phases. Mr. Mendenhall informs me that he found a greenstone area lying to the south of the Tanana schists near the headwaters of Delta River. These greenstones are intrusives for the most part, with possibly some extrusives. Spurr's Rampart series resembles the greenstone schists, but is largely made up of extrusive and tuffaceous material.

The Wellesley formation, which is of Devonian or Carboniferous age, comprises a heavy, coarse conglomerate, with some slate beds probably 1,000 to 1,500 feet in thickness, succeeded by several hundred feet of clay slate. It occurs in a series of overturned closed folds, striking east and west in a belt south of Mirror Creek. The pebbles of the conglomerate are derived for the most part from the greenstones and mark an erosional interval. The heavily bedded conglomerate itself has been little affected by folding, but the slate is considerably deformed, and shows the development of secondary minerals and jointing. A few dikes of an acid character occur in this formation.

We have no basis for any extension of the Wellesley formation east or west of the area indicated on the map. At the upper end of Marsh Lake, however, I had opportunity for studying a part of the Paleozoic series, consisting of conglomerates and slates which bear a strong lithologic resemblance to the Wellesley formation. As no fossils were found in the Marsh Lake beds there is hardly an adequate basis for correlation, and I simply note these facts. Hayes[1] makes mention of some coarse arkoses and conglomerates and associated schists occurring between Fort Selkirk and the White River. Future stratigraphic

[1] Op. cit., p. 139.

and paleontologic investigation will quite likely show that the Wellesley formation is the equivalent of the whole or of a part of Spurr's Tahkandit series.

The Nilkoka beds consist of sandstones and slates closely folded, but little altered. It occupies what is believed to be a synclinorium flanked on either side by the older Tanana schists. The axis runs about northeast and southwest. The series is believed to be Paleozoic and is tentatively correlated with the Wellesley formation.

A small area of fine, soft sandstone, very slightly folded, was found on the Tanana near the mouth of the Tok River. This is believed to be of Tertiary age. The Pleistocene includes the old river gravels, glacial deposits, the silts and gravels of the terraces, the modern fluvial deposits, and the volcanic ash.

If a geologic map of this central portion of the Yukon Basin lying adjacent to the Yukon River were prepared, a great divergence of strikes would be noted between the rocks of the lower river and those of the upper river above the flats. Professor Russell[1] was the first to call attention to this and to the corresponding bend of the ridges and mountain chains parallel to this structure. He states that at the international boundary the strike averages east and west, while below the mouth of the Porcupine it is northeast and southwest.

In the White and Tanana river basins a similar variation of the major strike line was observed, modified by minor structures. In the gneisses and adjacent schists on the White River the dominant structure is northwest and southeast, with a minor structure making an angle of 60° to 90° with this direction. Near the western limits of the region on the Tanana a northeast-and-southwest system of folding predominates in the schists, while a zone or shearing runs about northwest and southeast. The facts which I wish to emphasize are that the strike or major structure near the White River is nearly parallel to the shear zone or minor structure of the western part of the region, and vice versa; the direction of the axes of the folds near the mouth of the Tanana is approximately parallel to the shear zones in the gneisses on the White River. In the intermediate region there is no dominant structural line, but both systems of deformation are equally represented by the foliation of the gneisses. The rocks of this portion of the belt being chiefly homogenous igneous rocks, their deformation by two stresses would be less complex than if the folding was modified by bedding planes and variations in lithologic character. In this belt the strikes are variable, yet, broadly speaking, they can be resolved into two lines of deformation.

While we were contouring the region of the Middle Tanana I was much impressed by the escarpments whose angles and reentrant angles give a succession of elbowlike forms to the valley walls (see map

[1] Surface geology of Alaska; I. C. Russell: Bull. Geol. Soc. America, Vol. I, 1890, p. 108.

23). As the mapping progressed, it was found that these escarpments had a more or less regular arrangement. An examination of the topographic map will show that the river which follows the north wall of the valley closely emphasizes this feature, and that this portion of the Tanana Valley is in fact a chain of parallelograms which the river enters at one angle and leaves at the one diagonally opposite. A study of the geology developed the fact that in all cases the strike of the foliation was parallel to the sides of the parallelograms, and that it changed abruptly in passing from the side of one parallelogram to the other. I also observed that the shearing was always much intensified at the apices of the triangles, that is in the transition zone. It seems, therefore, that this peculiar form of the valley was brought about because erosion followed the structural lines, these being the directions of least resistance. It is possible that the escarpments have been emphasized by subsequent faulting along the old planes of shearing, but of this we have no evidence.

I have made this digression to describe the topographic feature because of its close relation to the deformation of the region. These

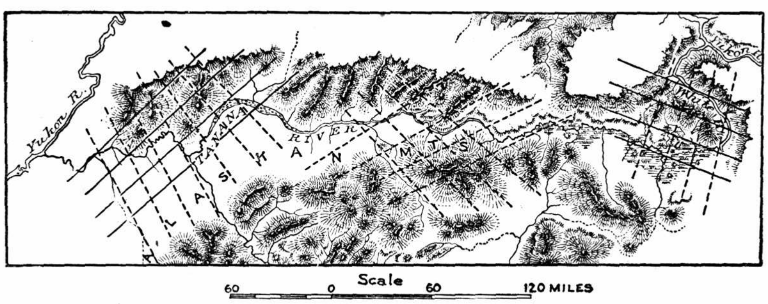

FIG 26.—Diagrammatic generalization of structure lines in the Tanana and White river basins.

shear-zones I regard as the resultants of the two forces acting from different directions, which produced the deformation of the region. These structural features are illustrated in the accompanying map, fig. 26. In this the major structures are indicated by a black line and the minor structures by a broken black line; the two zones of shearing in the central portion of the belt are shown by broken lines.

From the foregoing description it will be clear that there is no structure which dominates throughout the belt, but that the major structure in the east becomes the minor structure in the west, and vice versa. I conclude, therefore, that the deformation was caused by two synchronous thrusts coming from different directions. Near the apex of the angle made by the two dominant structural lines the resultants of the two synchronous thrusts produced the two zones of shearing, both equally well marked.

The region has not yet been studied in sufficient detail to differentiate closely the various periods of dynamic disturbance. It is extremely probable that the Archæan complex suffered deformation previous to the deposition of the sedimentary beds found overlying. It is certain that after the deposition of the Tanana schists and the Nasina series a crustal movement of considerable magnitude took place, and that during this dynamic disturbance the dominant structural features which have been described were outlined, though the subsequent deformation probably followed the same structural lines. This disturbance was probably accompanied by the injection of the larger masses of igneous rocks, including both the granites of the basal complex and the greenstone series. These disturbances were followed by a period of quiescence, during which the Wellesley series and probably the Nilkoka beds were deposited, and then a third period of dynamic disturbance was inaugurated which uplifted and deformed these beds. This crustal movement can be assigned to a post-Paleozoic and to a pre-Tertiary age. The last deformation manifest in the region is that which slightly folded the Tok sandstone, believed to be of Tertiary age. The elevations and depressions of the region during Pleistocene times have been referred to in a previous chapter.

The oldest igneous rocks of the region are the gneisses of the Archean. These, when studied carefully, are found to be altered granitic and dioritic rocks. The first great intrusion is represented by the granite masses found in the gneissic complex and also in the adjacent older sediments. These were followed by the basic rocks of the greenstone schist series, of dioritic and gabbroic types, and possibly in part extrusive. The next intrusion was the aplitic granite, which is one of the most widely distributed of the igneous rocks and occurs chiefly in small dikes. In post-Paleozoic times the extrusion of the andesitic and rhyolitic rocks took place, small areas of which were found at several localities. A still later intrusion is represented by the extremely basic dikes which cut the Tok sandstone, while the most recent volcanic rock is the tuff, whose wide distribution has already been referred to.

CORRELATION.

The accompanying table has been prepared with the cooperation of Mr. Spurr and Mr. Mendenhall, with the view to representing graphically the probable equivalency between the various horizons which have been studied in adjacent areas. This table must, in our present state of knowledge, be regarded as largely hypothetical, and will be undoubtedly subjected to changes as the investigation of the region is continued.

The correlation of the gneisses with Spurr's basal granite is based on lithologic similarity and on the fact that both series are believed to bear similar relations to the overlying sediments. The Wellesley series and the Tahkandit series are both of Carboniferous or Devonian age, as determined by paleontologic evidence. The metamorphic rocks occurring between the Wellesley series and the basal complex are undoubtedly the equivalents of the horizons represented in Spurr's column in the same position, but no detailed correlation can be made. The Tok sandstone is placed in the Tertiary tentatively only, for there is no direct evidence for its correlation. The correlation of the Pleistocene silts and gravels hardly needs any special notice. The correlations with Mr. Mendenhall are based almost wholly on lithologic grounds. The Tanana schists are believed to be continuous between the two areas. There is strong reason for believing that the Sunrise series is pre-Cretaceous, and hence it is tentatively put at the top of the Paleozoic column.

Table of hypothetical correlations.

	Spurr: Yukon district, 1896.	Brooks: White and Tanana River districts, 1898.	Mendenhall: Resurrection Bay to the Tanana River, 1898.
Pleistocene	Silts and gravels	Silts and gravels	Sands and gravels.
Miocene	Twelvemile beds, Porcupine beds, Nulato sandstone, Palisade conglomerate.	Tok sandstone (?)	
Eocene	Kenai series.		
Cretaceous	Mission Creek series.		Matanuska series.
Devonian and Carboniferous.	Tahkandit series	Wellesley series, Nilkoka beds (?)	Sunrise series.
Silurian	Rampart series	Greenstone schists (?)	Greenstones.
Pre-Silurian sediments.	Birch Creek schists, Fortymile series.	Tanana schists, Nasina series.	Tanana schists.
Archæan	Basal granite	Gneissic series.	

RESOURCES, AGRICULTURE, AND CLIMATE.

GOLD.

The White and Tanana river basins were long ago reported as gold-bearing, but up to the summer of 1898 we have no authentic information that workable placers have ever been found. In the Tenth Census Report I find this statement, which is rather remarkable in the light of our present knowledge of the Yukon Basin: "Prospectors have been at work for many years on its [Yukon] upper courses, but only on the Tanana have traces of gold been found in sufficient quantities to pay a laborer's wages during the brief summer season."[1]

[1] Report of Population and Resources of Alaska, by Ivan Petroff: Vol. III, Tenth Census, 1880.

Like other inaccessible parts of the Territory, the Upper Tanana Basin has at various times figured as a veritable Eldorado. These stories found credence chiefly because the region was almost entirely unknown, and thus their authors were not hampered by any basis of facts.

As far as our information goes there were last summer no gold deposits being worked in either the White or the Tanana river basins. About a year ago there was a stampede to the Lower White to stake quartz claims, and there is also a story current that two years ago a prospector took out several thousand dollars on Delta River, but this we were unable to verify. The results of our own investigations, limited as they were to one line of travel, with only occasional opportunities to visit side streams and with the pannings confined almost wholly to river bars, can not be conclusive as to the presence or absence of workable gold deposits.

The Lower White River has been more or less visited by prospectors, but the Tanana may be considered almost a virgin field, for though many prospectors have made hurried trips through the basin, little or no thorough work has been done. In the years gone by these parties have usually reached the Tanana, when their provisions were about exhausted, and they were forced to build rafts or boats and make a hurried trip to the mouth of the river, doing but little prospecting except along the river bars. Late last summer several parties reached the Tanana prepared to spend the winter; and it is only by such means that the work of prospecting in this almost inaccessible region can be successfully carried out.

Quartz veins in the older series.—In the descriptions of the rocks of the region reference has been made to the presence of quartz in the gneisses and the two oldest series of metamorphosed clastics. In the gneissic series the quartz veins are limited to the sheared and schistose phases whose foliation planes afford opportunities for the injection of the quartz-bearing solutions. On the Middle Tanana, where the two shear zones are equally developed, the quartz veins are found in both systems. In the quartz schists and associated rocks of the Nasina series of the Lower White the quartz veins reach a great development; they are found intruded parallel to the foliation, and very seldom cut across it. I noted in this series a close relationship between the quartz and the coarse pegmatite veins, and at a number of localities was able to trace transitions from one to the other. A similar transition has been noted by Spurr in the Birch Creek and Fortymile districts.[1] The quartz veins are most abundant in the Tanana schists, whose finely fissile condition gave abundant opportunity for the penetration of the mineral-bearing solutions. The veins are more widely disseminated in the Tanana schists than in any of the other formations. The green-

[1] Geology of the Yukon gold district, p. 298.

stone schists show very few quartz veins, for in many cases the rocks are too massive to afford any line of weakness along which the solutions could have penetrated.

In his study of the Yukon gold district, Spurr noted two ages of quartz veins, the older of which are more or less sheared and the younger are massive. In the Tanana and White river basins I have been unable to differentiate the quartz veins into two periods of intrusion, though I have observed both sheared and unsheared veins. These seem to rather grade into each other, and their injection was probably concomitant with the deformation and was one of the results of the dynamic disturbances. The intrusion of these quartz veins of the older series I think took place probably during and after the crustal movement which resulted in the folding of the Nasina and Tanana schists.

Some large quartz veins were observed in the region, but typically the quartz occurs in small, disseminated, nonpersistent veins. These

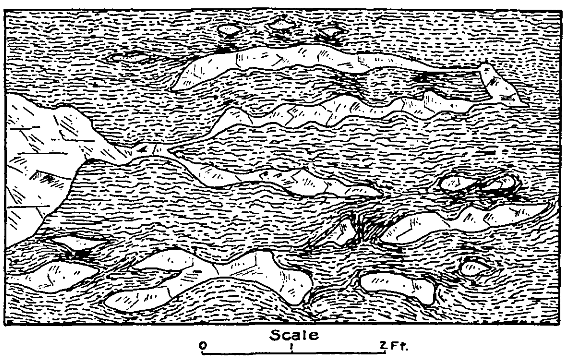

FIG. 27.—Quartz-calcite veins in mica-schist.

veins follow lines of foliation and frequently expand and contract, giving a series of connected irregular lenses. Fig. 3 is a reproduction of a sketch made on the Lower Tanana, showing the distribution of the quartz veins in the Tanana schists and the relation of the foliation to the intruded vein. In this locality the veins contained a great deal of calcite as well as quartz. It will be observed that in this sketch the foliation of the schists, as a rule, runs parallel to the peripheries of the quartz masses, but that in some cases it is cut by the quartz vein.

These veins are very largely composed of barren white vitreous quartz, but not infrequently contain other minerals; calcite is a very commom constituent of the veins in some parts of the region. On the Lower Tanana I observed many veins composed of a coarse intergrowth of quartz and calcite, in which the calcite individuals sometimes measured 3 or 4 inches in their longer dimensions and often showed more or less of a idiomorphic development. The quartz of these veins is vitreous and occurs in small irregular masses between the calcite crystals. In its structure the rock very much resembles a pegmatitic intergrowth of quartz and fieldspar. These veins grade into pure quartz veins containing no calcite.

Among other mineral constituents of the quartz veins I observed copper and iron pyrite and galena. The mineralization of the quartz veins is not limited to any one part of the region, but evidences of it were found at numerous widely separated localities. I found no vein of the quartz which contained free gold visible to the naked eye, but assays of several specimens showed the presence of traces of both gold and silver. The following table shows the result of these analyses:

Assays of specimens from Tanana River basin.

[By Prof. Charles E. Munroe.]

Specimen No.	Locality.	Gold, ounces.	Silver per ton.
175	Quartz from river gravel, Tanana River, near mouth of Scottie Creek	None.	0.05
178	Vein quartz from Tanana schists, exposures near mouth of Scottie Creek	Trace.	.10
180	....do	None.	.10
182	....do	None.	.10
187	Vein quartz from Tanana schists 10 miles below Gardner Creek	None.	.10
200	Vein quartz from gneissic series, Mount Chisana.	None.	.05
207	Vein quartz from river gravel near mouth of Tok River, Tanana	0.05	.95
306	Vein quartz from Tanana schists near mouth of Silokh River	Trace.	.20
311	Vein quartz from gneissic series near mouth of Silokh River	0.05	.25
336	Vein quartz from Tanana schists 20 miles below the mouth of Chena River	Trace.	.10

NOTE.—Five other specimens carried neither gold nor silver.

Mineralized shear zones in the older metamorphic series.—Spurr has described in considerable detail the mineralized shear zones of the region studied by him. In the region under consideration shear zones are frequent, but the injected matter is usually barren quartz, with sometimes some calcite. At two localities, however, gold was observed in a shear zone. Near the mouth of Scottie Creek, on the Tanana, is an exposure of impure limestone schist and mica-schist. The rock has been much deformed, and quartz veins are numerous. The mineral-bearing solutions have been injected in a zone of shearing some 30 feet wide, in which lie numerous mineralized quartz veins.

Copper and iron pyrite were observed, and probably some galena. In a specimen of the calcareous schist taken from close to the shear zone, but not forming part of it, I found some grains of gold which had evidently been brought in by the penetrating solution. The gold occurs in the unaltered rock and was not associated with any extraneous matter.

At another locality, about 15 miles below the mouth of the Robertson River, on the north side of the Tanana, a mineralized shear zone was found in the granite. This zone was not over 10 feet wide, and the granite along it had been brecciated rather than deformed. In this zone pyrite was observed and a few fine particles of gold. An assay of another specimen from this shear zone by Professor Munroe gave a trace of gold and 0.15 of an ounce of silver per ton.

Mineral veins in the younger rocks.—While the Wellesley formation and the Nilkoka beds as a rule carry but little vein quartz, yet this does not hold true throughout. The upper part of the Wellesley formation has been described as a series of clay slates. Along the Mirror Creek Valley considerable faulting and some intense folding of these slates has taken place, and they are locally altered to phyllites. Quartz veins here are quite abundant, and are often more or less mineralized. An analysis of such a quartz vein showed a trace of gold and 0.15 ounce of silver to the ton.[1] In the sandstones of the Nilkoka beds some mineralized quartz veins were found and assayed a trace of gold and 0.25 ounce of silver to the ton.

Placer gold.—In the introduction to this chapter I have referred to the rumors of valuable placer finds on the Tanana which I have been unable to verify. Colors of gold have a wide distribution in the river gravels, but in our hasty trip we were unable to make investigations which would determine the presence or absence of coarse gold.

The colors of gold found in the river gravels may sometimes be of rather remote derivation. Many of the old gravel terraces, and probably some of the glacial deposits, contain small quantities of gold, and when these are dissected the gold finds its way into the river bars, where it is concentrated in the usual way. As the terraces often bear no direct relation to the present drainage, it is evident that the presence of such gold can not be regarded as a safe criterion of the presence of gold in the region drained by the river. The finding of colors is, of course, a favorable sign but one which should be interpreted with caution.

The investigations have led to a few general conclusions in regard to the distribution of gold derived from a study of the colors in the river bars and also of the presence of gold in the bed rock. On the Lower White River colors were not only found in the main river bars, where they may have been of remote derivation, but also in side

[1] By Prof. Charles E. Munroe.

streams, which goes to prove that the bed rock must be gold bearing. On the Upper Tanana we found no colors until after passing below the area of the Tanana schists represented on the geologic map near the mouth of Scottie Creek. As the quartz veins of these schists were found to contain traces of gold, they were probably the source of this gold. Our journey did not take us up the Tanana beyond the mouth of Mirror Creek, but I am inclined to believe that this region is occupied by younger clastics and is not likely to prove gold bearing. From Gardner Creek to the first rapids on the Tanana the current is too sluggish to carry gold, and I found no colors in the few gravel bars which occur in this part of the river. From the first rapids to the Cantwell the river bars usually show colors. Below the Cantwell the main river is too sluggish to carry gold. The tributaries of the Tanana from the north are all too sluggish to be gold bearing, while those from the south, notably Robertson, Johnson, Delta, Silokh, and Mahatzu, gave good colors, in some cases there being fifteen or twenty to the pan.

Summary.—In this description of the gold resources an attempt has been made to state the bare facts, clearly shorn of all speculations and wild rumors. We have seen that traces of gold have been found throughout the region examined by our party, and that the conditions for its occurrence are in many respects favorable; also that the little prospecting which has been done up to the present time has been too hurried and too superficial to be regarded as a fair test of the region. Our best information leads us to believe that the same horizons which carry the gold to the Fortymile and Birch Creek districts are represented in the White and Tanana River basins. I believe, therefore, in spite of the adverse results which have been obtained so far, which are purely negative, that the White and Tanana River basins still offer a favorable field for the intelligent prospector. I am inclined to think that the upper basins of these rivers are occupied chiefly by the younger non-gold-bearing rocks. I should advise prospectors to carefully investigate the small tributary streams of the Lower White and of the Tanana from Mirror Creek to the mouth. The headwaters of the streams lying to the north of the Tanana ought to offer favorable returns, situated as they are opposite the headwaters of Fortymile and Birch Creek streams, which are more or less gold bearing.

COPPER.

There have long been traditions of copper deposits on the White and the Tanana as well as on the Copper River. In 1891 Dr. Hayes was taken by White River Indians to the deposits from which they obtained their copper, which proved to be placer, and which are located on Kletsan Creek, near the head of the White. The largest nuggets of this placer deposit are said to have weighed several ounces. Dr. Hayes was also shown some azurite by the natives of the Yukon which he was told came from the White River region.[1] There are fairly well authenticated stories of the finding of copper ores on the Tanana, but in our trip of last summer we were unable to verify these statements by any personal observations.

COAL.

Both bituminous and lignitic coal has been reported from the Tanana, and some of the seams are said to have a thickness of 30 feet. This coal is, from our best information, on some of the tributaries of the Tanana, but its exact location has not been published. My own investigations throw no light on this matter beyond establishing the occurrence of both Carboniferous and Tertiary rocks, for our time was too limited to allow of explorations of any of the tributary streams of the Tanana.

TIMBER.

Among the earliest mentions of the Tanana River we find statements in regard to the large trees which were found among the driftwood at its mouth. While the timber will never have any value for export, it is, according to the standards of the interior of Alaska, of excellent quality. Both on the Tanana and on the White trees 18 inches to 2 feet in diameter can be found at numerous localities. The timber line varies somewhat according to local conditions, but stands approximately at 3,400 feet. The spruce is the most abundant tree, in addition to which are found white birch, aspen, cottonwood, alder, and several varieties of willow. Much timber is annually destroyed by fires, which are due not only to the carelessness of the prospectors, but are also in part chargeable to the Indians.

GAME.

On the White River and in parts of the Tanana Basin large game is still plentiful, but is likely to decrease very rapidly now that the Indians are armed with modern repeating rifles. Though we spent no time hunting, our party killed four moose and one caribou during our three months' trip. The large animals of the region include moose, caribou, several varieties of bear, wolves, wolverine, together with mountain goats and sheep in the higher altitudes. Wild fowl are still very abundant, and breed extensively on the Upper Tanana. The salmon run on the Tanana reaches the swift water above the mouth of the Cantwell, and on the White the salmon probably ascend the Klotassin.

[1] Expedition through the Yukon district, pp. 144-145.

AGRICULTURE.

The agricultural possibilities of the Yukon Basin have been fully discussed by Drs. Dall and Dawson, and by Mr. Ogilvie, in reports which have already been cited. The conclusions reached by these gentlemen are applicable to the Tanana Basin. Should the mineral wealth of the region attract a population, certain vegetables and the hardier grains would undoubtedly be raised to supply the demand. Many of the lower benches and terraces of the Tanana offer good ground for cultivation.

CLIMATE.

The annual precipitation of the upper parts of the Yukon Basin is very low compared with the coast region. The summers are short, dry, and hot, while the winters are long and cold, but with no great snowfall. These general climatic features apply equally to the White and Tanana River basins. The upper basin of the Tanana has a drier climate than the lower river valley, which feels somewhat the effect of the moisture-laden winds which sweep up the broad Yukon Valley from the Bering Sea. The following table gives a summary of Mr. Peters's meteorologic observations:

Temperature.

	Minimum.	Maximum.	Rainy days.
	Degrees.	*Degrees.*	*Degrees.*
June	42	70	3
July	42	75	10
August	41	63	8

INHABITANTS.

INDIANS.

The Indians of the White and Tanana river basins, like most of those of the interior of Alaska, are of Athabascan stock. The White River Indians are confined chiefly to its southeastern tributaries, and we saw only the smoke of their camp fires in the distance. The only habitations that we saw on the White were a deserted fishing station near the mouth of the Klotassin and an old hut at the mouth of the Snag River, as well as a few winter camps.

The Tanana natives are divisable into two geographic groups, which are rather widely separated. The more easterly group includes the Indian settlements in the vicinity of Fortymile and Mentasta Pass trail. These have a small settlement on Lake Mansfield, about 8 miles from the Tanana, and several more on the lakes which are drained by the Tetling River. The chief of the Mansfield village is named Jonathan, and is an honest, reliable fellow. These Upper Tanana Indians have easy communication with the Copper River Indians through the two passes, and with the Ketchumstock Indians and the Yukon by the trail which has been described. They are comparatively isolated from the Indians of the lower river by the swift water which intervenes. As the salmon runs do not extend up as far as their settlements, these are situated away from the muddy Tanana waters, on the side streams and lakes where grayling or Arctic trout and other small fish abound. They depend for their food supply on these small fish, as well as on moose and caribou. Several Indian houses are found on and near the Tanana between the Goodpaster and the Salchakat and constitute a subgroup of the Upper Tanana Indians. They have communication with the Yukon through the broad flat valleys of the northern tributaries of the Tanana. At the mouth of the Volkmar there are two substantial cabins which are supplied with many of the products of civilization.

The most thickly settled part of the region is along the sluggish portions of the Lower Tanana. The largest villages are at the mouth of the Cantwell and Toclat rivers, and each of these consists of a number of good cabins. In the intervening region there are a number of isolated houses and fishing stations, which are marked on the accompanying map. One of the chief sources of food supply of these Lower Tanana Indians is the salmon, which run up the river probably to about the camp marked "August 26." The Indian settlements are chiefly on the main river, for the sake of this food supply. At the time we passed down the river the Indians were largely occupied in catching and curing salmon.

Their chief line of communication is by the river to the Yukon, and probably also to the Kuskokwim by the Toclat River. They also have more or less intercourse with the Indians of the Sushitna, the traveling between the two basins being done chiefly in the winter. In former years the visits to Cook Inlet must have been infrequent, for Ivan Petroff makes special note of the arrival of two Tanana Indians on Cook Inlet in 1865. Petroff states that the oldest man of the Coast Indians remembered only two previous visits by the interior Indians to the inlet.[1]

These two main groups of the Tanana Indians have probably existed for a long time, and the division was conditioned by the physical features of the country. The upper and lower basins of the Tanana Valley are well-defined geographic provinces which have a different origin, as has been shown in the study of the physiography. The region of the rapids which separate the lower valley from the upper basin has already been discussed, and this barrier has affected the natives by shutting out

[1] Bureau of Ethnology, 1st Ann. Rept., p. 492, 1879–80.

the salmon as a food supply and by preventing in a measure easy communication with the lower river. The Upper Tanana Indians obtained their first knowledge of the outside world by the products of civilization which they obtained through the Coast Indians of Lynn Canal. This barter was carried on by the old water routes, which formerly carried this drainage into Lynn Canal. They are closely connected to the Copper River by the broad gaps which break the range to the south, which is one of the results of the period of erosion which formed the peneplain. The White River Indians live in the same province and are influenced by somewhat the same geographic features. When the Hudson Bay Company established their posts on the Upper Yukon, these Indians were enabled to communicate with it by trails which cross the old peneplain, and they were not separated by any mountain barriers.

The Lower Tanana Indians first came in contact with white men on the Yukon, which they could easily reach by their great waterway. At the mouth of the Tanana, they bartered with the Russians and Hudson Bay Company traders, who make trips to this point every spring.

The Tanana Indians have always been reported as being hostile to white men, but this report seems to be without any valid foundation, because, so far as we have been able to learn, they have always received the whites who have visited their country both kindly and hospitably. The only crime which has been recorded against them is the murder of Mrs. Bean, to which reference is made below. From best accounts this was undoubtedly a cold-blooded, premeditated murder, and the intention seems to have been to kill the whole family. There may have been, however, extenuating circumstances of which we know nothing, for the trader himself is reported to have been a man without scruples, and the murderers may have taken this method of revenge for some real or fancied wrong. In any event it is not fair to make this one crime of twenty years ago a basis for an estimate of the character of all of the Tanana Indians. The missionaries who had to deal with them report them as being both kindly and intelligent.

Physically they average rather better than the Indians of the Yukon, and they have long been known for their skill in certain crude handicraft. Bows and arrows still find limited use among them for shooting wild fowl, but most of them are armed with repeating rifles. In their clothing they have not yet discarded the moose and caribou skins, although they are in part supplied with more civilized garb. Their only articles for barter are the furs, and when the fur-bearing animals are gone it is difficult to see how they will be able to supply themselves with ammunition, tea, etc., which they have now come to regard as necessities. In their hunting and trapping excursions they wander all over the basin of the Upper Tanana, but have no permanent habitations above the mouth of the Naberna. These long hunting trips are usually made in winter on the ice. Certain diseases seem to be quite prevalent among them, and the population is probably decreasing. We were led to believe this both from the large number of graves which we saw and also from the large number of deserted houses. In the region traveled by us old trails, blazes, and camps gave strong evidence that the region had been once more thickly populated. Among the Indians of the lower river bronchial troubles are rather prevalent, and in 1882 a Tanana Indian reported to the governor of Alaska that his people were dying of an epidemic.[1]

Our observations were too limited to enable us to form an opinion of the number of Indians on the Tanana, but I am inclined to think that there are less than 400. Lieutenant Allen's estimate, made in 1885, was between 550 and 600; he may, however, have overestimated the population of the upper river, which he did not visit.[2] In the Tenth Census report the Indian population of the Tanana is placed at between 700 and 800.[3] The younger Indians of the Tanana mostly speak a little English, which they have learned at the trading posts and mission stations on the Yukon.

WHITES.

Up to the summer of 1898 the Tanana and White river basins contained no permanent white inhabitants. Some twenty years ago a trader by the name of Bean attempted to establish a trading post on the Lower Tanana, near Harpers Bend. After the murder of the trader's wife by the Indians the project was abandoned and has never been repeated. During the past summer probably about a hundred prospectors visited different portions of the Tanana Basin, and there were possibly a few in the White River region. Of these probably two-thirds left the region again in the fall, while the remainder made preparations to spend the winter. Most of them confined their explorations to the Tanana and its tributaries west of the Fortymile trail, but several are said to have pushed on toward the head waters of the river, and some are reported to have returned with good copper ores.

DEVELOPMENT.

To those who are familiar with the development of a new mining region it will be clear that the Yukon district as a whole has only just reached the point when systematic exploration for its mineral wealth and the exploitation of the same can be carried on on a scientific and economic basis. It is known that the gold-bearing rocks have a wide distribution, and in spite of the large influx of population during the

[1] Report of Governor of Alaska, 1887, p. 47.
[2] Reconnoisance in Alaska; Lieut. Henry T. Allen, 1885, p. 137.
[3] Alaska: Its Population and Resources; Tenth Census, Vol. VIII, p. 161.

past two years, there are still many virgin fields for the prospector. Of the thousands of men who have entered the Yukon Basin in the years 1896 and 1897 but a small proportion had any conception of the difficulties ahead of them, and still less had any previous training which fitted them for the work they had so rashly undertaken. Hundreds toiled over the Coast Range passes and made the mad dash into the interior toward the Eldorado which their fancies had painted, and soon realizing their disappointment continued down the Yukon to its mouth, without hardly having been out of sight of its banks. Thousands of others clustered about the settlements near the gold districts, ready to take part in any stampede toward a reported new find, no matter how unfounded or ridiculous the rumor might be. It was men like these who staked creeks from their mouths to the head waters, in which no trace of gold had ever been found, and who, when their money or provisions gave out, made their way out of the country as best they could, ready to affirm that, so far as new discoveries were concerned, Alaska was entirely exhausted.

Alaska is eminently not the place for the haphazard or untrained prospector. In the long run only those who have the intelligence, training, and patience to study the conditions of the occurrence of gold can hope to succeed in this district, where time is too valuable to allow of the happy-go-lucky methods which have been successful in other gold regions where the climatic conditions were more favorable. This, while it applies to the entire Yukon district, can not be too strongly emphasized for the more inaccessible portions like the White and Tanana river basins.

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