DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
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# THE GEOLOGY AND MINERAL RESOURCES OF A PORTION OF THE COPPER RIVER DISTRICT, ALASKA

BY

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1901

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# GEOLOGY AND MINERAL RESOURCES OF A PORTION OF THE COPPER RIVER DISTRICT, ALASKA.

By F. C. Schrader and A. C. Spencer.

## INTRODUCTION.

The field work on which the following report is based was done during the latter part of the summer and in the fall of 1900 by a party consisting of F. C. Schrader and Arthur C. Spencer, geologists, T. G. Gerdine and D. C. Witherspoon, topographers, and eight other men, embracing packers, cooks, axmen, and camp hands. Late in the fall several additional men were employed as crew on the steamboat in charge of Captain McPherson and the sloop in charge of Lewis Tortensen, in completing the work about Prince William Sound.

During the seasons of 1898 and 1899 the favorable reports and samples of copper ore brought out by prospectors who had penetrated the rugged and little-explored Mount Wrangell region, in the eastern part of the Copper River Basin, led to a concentration of attention upon this region, and in response to urgent requests for a public survey and a much-needed geological and topographic map, funds were appropriated by Congress during the spring of 1900. The principal object of the work, therefore, as set forth in the letter of instructions to the party, was a survey of the Chitina copper district of the Copper River region, with the view of determining as nearly as possible the extent and character of the copper deposits of the district, ascertaining the number, character, and distribution of the copper-bearing formations, and gathering all possible information with reference to the genetic conditions of deposits of copper, the amount and quality of the ores, and all other questions having a geological or economic bearing.

The expedition was in charge of Mr. Schrader, who first visited the Copper Basin in 1898 with a party detailed by Captain Abercrombie to investigate the availability of Tasnuna River as a route to the interior, while Mr. Gerdine had the direction of the topographic work.

In making the topographic surveys it was the object to obtain data for completing a map of as large an area as possible, including the region in which the copper ores were found and the general drainage basin of Chitina River. Such a map has been drawn, and its geographic position has been determined by means of triangulation and stadia methods around a circuit of about 400 miles, from Valdes to the Chitina country and thence down Copper River to its mouth, where connection was made with the work of the United States Coast and Geodetic Survey. From Copper River to Knowles Head, in Prince William Sound, the Coast Survey had completed its triangulation. At the latter point the line was taken up and closed with the starting point. In assembling the topographic data in the office, Mr. Gerdine has had the collaboration of Mr. Witherspoon.

The geological observations were necessarily confined to the vicinity of the routes traveled, and while far from complete, they are sufficient to reveal the main geological features of the region traversed. The compilation of the geological notes and the drawing of the geological map has been the joint work of the two authors, but the form of the report and the manner of presentation of the data has fallen upon the junior author, because Mr. Schrader was obliged to devote much of his time while in the office to the perfection of plans for explorations in northern Alaska, and left for the field in February.

For assistance rendered and for open-handed hospitality and many courtesies the members of the expedition are indebted to Captain Abercrombie and other officers of the Army at Valdes, to Mr. R. F. McClellan and his associates of the Chitina Mining and Exploration Company, to many prospectors met upon the trail, and to the settlers in Prince William Sound. Thanks are also due to Mr. Shepherd, agent of the Pacific Steam Whaling Company at Orca, and to Messrs. J. J. Bannan and M. O. Gladhaugh, at Ellamar, for accommodations while waiting for the home-bound steamer.

The fossil determinations have been made by Dr. T. W. Stanton. The coal and oil analyses, together with mineral and rock tests, have been made in the chemical laboratory of the Survey, and the assays of gold, silver, and copper by E. E. Burlingame & Co., of Denver, Colo. Valuable assistance has been rendered by Mr. Waldemar Lindgren, of the Survey, in the determination of the principal rock types by means of the microscope.

In conclusion, thanks are due to the packers and other members of the party for constant efficiency under trying conditions.

## ITINERARY.

*Seattle to Valdes.*—The Copper River expedition of the United States Geological Survey left Seattle on the 5th day of June, 1900, on the steamer *Excelsior*, and arrived at Valdes on the 12th, landing with horses and provisions on the 13th. It was reported that much snow still remained on Thomson Pass, and it was found that it would be two weeks before it would be possible to cross with horses. Mr. Schrader therefore took the opportunity to go to Orca and Eyak and arrange for a steamboat to assist in the work planned for the autumn in Prince William Sound. Several days were consumed in arranging the outfit and repacking the provisions in such form that they could be transported by pack horses, after which the work of carrying everything up Lowe River was begun. Meantime Mr. Gerdine measured a base line on the beach near Valdes and started his triangulation. In view of the delay in getting into the interior, he decided to continue the triangulation down Port Valdes as far as practicable, and succeeded in carrying his work to Rocky Point, at the eastern side of the entrance to the inlet. Returning, he joined the main party on June 30 at Camp Comfort, about 12 miles from Valdes.

*Valdes to the Kotsina*[1] *trail.*—On July 3 the last of the provisions had been carried to the foot of the steep trail leading to Thomson Pass, and on this date Mr. Schrader returned. The next day the entire party went over the pass and camped at timber line, about a mile above Station No. 3 of the Army expedition. At the time of passage the snow was still from 3 to 4 feet deep over a portion of the flat-lying ground on the north side of the summit, and it was all that the horses could do to make their way across the soft snow. However, there were no accidents, and all of the materials were brought across within the next few days. Meantime opportunity was afforded to study the glaciers, and, to a limited extent, the geology of the neighboring region.

From Station No. 3 the trail was very open and for the most part good as far as the head of Kanata River. A few geological observations were made—enough to indicate the general structural uniformity of the region—and notes were made upon the physiography and past glaciation. Good bridges were found over the Tiekel and over Stuart Creek.

The first serious difficulties encountered were in the headwaters of Kanata River, where it was necessary to ford the stream, which is a swift mountain torrent. However, this was accomplished in safety, as was also the crossing of Fall Creek and Ernestine Creek. Beyond the head of Kanata River the trail became difficult, owing to the swampy nature of the broad, low divide at the head of the South Fork of the Tonsina. Here progress was necessarily slow, and the work

[1] Most of the names of drainage features in the Copper River region are of native origin, and in the various reports on explorations of the region these names have been spelled in a variety of ways. By most writers all rules of phonography have been avoided, while others have used, unnecessarily, cumbersome spellings. Thus the main tributary of Copper River has been given as follows: Chittyna, Chittena, Chittenah, Chitena, and Chitina. The last spelling is here adopted because it is the simplest way of rendering the name as pronounced by the Indians who live at its junction with Copper River, which they know as Atna. In order to reach some uniformity in the spelling of various names having the same ending, the word Chitina has been taken as a type, and such names as Klutina and Chestochina spelled with an i instead of with an e.

was extremely trying to both horses and men. This part of the trail has since been abandoned for a drier route farther to the east. Before the party left Ernestine Creek it was decided to proceed as far as Copper River with a single load. All the remaining material was cached and a man was left in charge. By proceeding in this manner it was possible to move every morning, and in this way Copper River was reached on the 17th and a camp was established on the broad delta of the Tonsina, where there were several native huts and a good log cabin built by the Copper River Exploring Company. From this camp all of the materials which had been brought were ferried across the river in boats which the natives had procured from prospectors in 1898. While this was being accomplished Mr. Schrader took the opportunity to search for the rock specimens that he had lost in 1898 in attempting to cross Tonsina River about 8 miles above its mouth. Reports had reached Valdes that these specimens had been washed out upon the bank of the river and had been found by a native and left hanging in a tree near the stream. Unfortunately he was not successful in his quest. Mr. Spencer went, in company with two native boys, to the mouth of Chetaslina or Liebigstag River, where he crossed Copper River and ascended the Chetaslina a distance of 5 or 6 miles to determine the character of a lava flow which had been noted in looking across the basin from the west. By the time he had returned, on the 20th of June, the party was ready to continue its march.

The head packer with nine horses had returned to the Ernestine cache, leaving the main party to proceed with eleven horses. This, of course, necessitated doubling the trail. On the 24th everything had been brought up to the Kotsina trail, which is the route to the headwaters of the river of the same name, and has been followed by natives for many years.

*Kotsina River and Strelna Creek.*—At the Kotsina trail Mr. Schrader, with Mr. Witherspoon as topographer, left the main party to investigate the copper deposits in the Kotsina country, carrying the observations across from the head of Clear Creek to Fall Creek and from the head of Kluvesna into Surprise Creek, while the horses in each case were sent around by the valley trail. From Surprise Creek the party proceeded down the east side of the Kotsina to Rock Creek and down to Copper Creek, thence up Pass Creek and through the head of Rock Creek to the head of Strelna Creek, which flows into the Kuskulana, and down the Strelna to where it is crossed by the main trail at the base of the mountains and edge of the plateau.

*Kotsina trail to Chitina River.*—On the 24th the main party, in charge of Mr. Gerdine and accompanied by Mr. Spencer, proceeded along the main trail, and since, with the reduced number of horses, it was necessary to make three trips, sufficient time was afforded for a fairly good examination of the geology within the 5 or 6 miles of the route which, from the crossing of Kotsina River, lies along the base of the mountains. Kuskulana River was reached on June 29, and here several days were spent in observing the topographic and geological features of the region. In the meantime the pack train had returned from Ernestine Creek, and on August 5 the united party moved ahead, camping above timber line beyond the divide of Kuskulana River.

While camped in the vicinity of Lakina River several side trips were made to complete the triangulation and for geological observations. The pack train was sent by a new trail which had been cut by the McClellan party down the Lakina and around the base of the mountains to Kennicott River. A detached party, however, went over the old trail which crossed the mountain and reached the Kennicott Valley several miles above the foot of the glacier.

After crossing Kennicott River on the lower end of the glacier a camp was established on McCarthy Creek, about 4 miles above its mouth. The topographer and geologist made a side camp near Kennicott River and the geologist spent two days in studying the region east of the glacier. On the 24th a side camp was made upon the mountain side west of McCarthy Creek, and on this day Mr. Schrader reached the main camp, after an absence from the party of about three weeks. On the 26th the geologists and topographers with their assistants camped together at Nikolai City, a name which has been given to the camp of the McClellan party who were engaged in developing the Nikolai mine. Several of the most pleasant incidents of the summer campaign were connected with the interchange of courtesies between our party and the members of the McClellan party.

After bringing up all of the outfit to the McCarthy Creek camp, the packers chopped a trail through the woods to Nizina River, and here they were joined by the detached parties by the time they had brought up all of their loads. After obtaining a supply of provisions, Mr. Spencer went to the head of Nizina River, while Mr. Schrader and the topographers visited the high region lying between the Nizina and the main fork of the Chitina. In the meantime the supply train had forded the Nizina at a point about 12 miles above the mouth of Kennicott River.

All of the members of the expedition, with the exception of Mr. Witherspoon and one man who was with him, assembled near the forks of the Chitina on September 8. Here all hands were engaged in separating the provisions for the outgoing parties and in packing specimens and photographic films to send to Valdes by the returning pack train.

*Plans for returning to the coast.*—It was decided that Messrs. Schrader and Gerdine, with three men, should attempt to traverse the unexplored region between Chitina River and the sea, making their way up Tana River and across the glacier and ice fields at its head to the crest of the St. Elias Range and thence to the coast, arrangements having been made with the American Packing Association to have one of its steamboats meet the party in the vicinity of Cape Yaktag. The object of this trip was the collection of data concerning the geography and structural geology of the region and the investigation of the coal and oil fields of the Yaktag and Kayak districts. Messrs. Spencer and Witherspoon with two men and five horses were to make their way to Taral, the Indian village near the junction of Chitina and Copper rivers, over an Indian trail which had been reported by Mr. Edward Gates of the McClellan party, and thence were to descend Copper River in boats.

The outgoing party consisted of three men and nine horses, and was placed in charge of Mr. Edward Brown, the chief packer. Charles Rae was to leave the party at Chitina River to procure the provisions and boats which had been left there, and to meet the Spencer party at Taral.

On September 12 the two exploring parties crossed the Chitina, ferrying their outfits in a small canvas boat which had been carried all the way from Valdes in anticipation of such a necessity. This craft, though but 12 feet in length, proved of the greatest service, since it would have been a difficult and even dangerous task to have carried the materials over on a raft. By this time the horses had had sufficient experience with the swift glacial streams of the country to cross them without difficulty, even when it was necessary for them to swim a considerable distance.

On the evening of the 12th Mr. Witherspoon joined the Spencer party, after a difficult trip in the upper drainage of the Chitina, and on the 13th the party crossed Tana River, starting from the west side at about 9 a. m. On the same day the Schrader party, after assuring themselves of the safe passage of the other party across the river, took up their march along the east side of the Tana.

*Trip to Tana Glacier.*—The Schrader party started up the eastern bank of Tana River on the morning of September 13 and proceeded to a point approximately 25 miles above the mouth of the Tana and about 5 miles above the foot of Tana Glacier and timber line. Here the unexplored and deeply crevice-riven glacier, estimated to have a length of about 40 miles, mantled with a sheet of freshly fallen, loose snow several feet in thickness, and the beginning of a heavy snowstorm on the 17th which lasted several days, led to the conclusion that it would not be practicable to carry the work out across the glacier and the coast range to the sea so late in the season, especially when but eight days remained in which to do the work and catch the boat at Cape Yaktag. This detachment accordingly returned to a point near the mouth of the Tana and followed the trail of the Spencer party to Taral, whence, after making a rapid descent of Copper River to the coast and proceeding by way of Alaganik and Eyak, they arrived at Orca, October 9. From here, with the Pacific Steam Whaling Company's stern-wheel steamboat *Wild Cat*, a hasty reconnaissance trip and inspection of the copper deposits was made about a part of Prince William Sound, the route of which is shown by red lines on the map, Pl. V. On this trip, owing to rain, fog, heavy seas, and impairment of the boat's boiler, the work, especially the topographic, was much embarrassed.

*Tana River to Taral.*—The information concerning the Indian trail said to lie back in the mountains at considerable distance from Chitina River was very vague, so that no knowledge could be gained as to where it entered the mountains. Upon a consideration of the topography as seen from the forks of Chitina and Tana rivers it was thought probable that the trail would enter an eastward-sloping valley which was seen at a distance of 12 to 15 miles. Consequently the course was laid in this direction. On the previous day Mr. Witherspoon had seen smoke off to the south and had surmised that the natives from Taral had arrived on their annual autumnal hunt. Shortly after starting from the river a rifle shot was heard, which was answered by a volley, and Mr. Spencer went in search of the natives, hoping to gain information in regard to the trail. Their deserted camp of the previous evening was seen, but it was not until 2 o'clock that Chief Hanagita was found, quite as desirous of finding the white men as they were of finding him. He had seen Mr. Gerdine, and carried a note from him in which it was stated that the chief would be rewarded with food if he would find the Spencer party and direct it to the trail. He was therefore willing to take up the trail of the horses, and tramped 4 or 5 miles to overtake them. From Hanagita it was learned that the trail lay in a valley to the south of the one which had been picked out, and for this information he was given a small sack of corn meal and a few spoonfuls of tea.

This day and two others were consumed in reaching Chakina River, a distance of about 12 miles, since all of the country traversed was very wet, and for much of the distance it was necessary to chop a way through the timber. On the 16th Mr. Witherspoon made station upon a high mountain west of the Chakina, establishing a connection with the work which had been done to the east of Chitina River. Up to this time the trail had not been found, but it was discovered by diligent search, and on the 17th the party took up its march. Its progress was attended with considerable difficulty, both in keeping the trail and because of the swampy nature of the ground. Taral was reached on the 28th, triangulation and topographic sketching having been carried through the entire distance.

Camp had only just been made at Taral, about 3 o'clock in the afternoon of the 28th, when the natives called attention to several boats coming down the river. Two of these proved to be the ones left at Tonsina River, and contained the fifth man, with the provisions. The boats were manned by natives and had several families as passengers.

The next two days were spent by the geologist in studying the exposures along the lower part of Chitina River and endeavoring to locate the copper deposits which had been reported in the neighborhood of McCarthy's cabin. In this last quest he was not successful. The topographer busied himself in laying out a base line upon a level sand bar above Taral and in commencing a new triangulation.

On the 29th one of Schrader's men reached Taral with a message saying that they had been unable to cross the coast range because of heavy snowstorms and asking that a boat be procured for them. This was done, and on the 1st of October they overtook the Spencer party. Of the provisions which were to take them to the coast there were about five days' rations remaining, and it seemed that it would be almost necessary to make a common stock of all the provisions left. Fortunately, however, a sack of flour was obtained from a native, and this made it possible to carry on the survey down Copper River as originally planned.

*Taral to Orca.*—On the 2d of October, about 3 o'clock, the surveying party, which had been increased to six men, left Taral in two small boats, making two stations that afternoon. It was followed by the other party within a few hours, and passed early in the evening. The surveying party carried on its work from day to day, suffering minor delays from cloudy and rainy weather. The survey was carried on by triangulation when the weather and the character of the topography permitted, while at other times stadia methods were employed. On account of the small supply of provisions and the fear that the river might freeze before the party could get out it was impracticable to take more time than was absolutely required for continuing the survey. For these reasons the geological observations were confined to the immediate vicinity of the river. The party arrived at Alaganik on the evening of October 12, with provisions reduced to less than one day's rations. At this place supplies were obtained and the party remained for several days on account of stormy weather, it not being deemed advisable to venture into the open ocean until calm weather should ensue. This wait allowed of the examination of the gold properties which had been discovered in the vicinity of McKinley Lake, near Alaganik, and on the 15th the survey was carried to the mouth of Alaganik Slough and there connected with one of the monuments of the Coast and Geodetic Survey.

At Alaganik a sail boat was chartered to take the party to Orca, and on the 14th it made its way from the mouth of Copper River around Cape Whitshed, but got only as far as Eyak because of calm weather. Here the party arrived several hours after dark, having rowed the craft for a distance of several miles. The skipper, Mr. Axel Englund, entertained the party at his home, and it arrived at Orca on the following day, the 16th of October.

*Orca to Port Valdes and Seattle.*—At Orca the party found Mr. Louis Torstensen, who had come for it with his 30-foot sloop *Fox*, at the instance of Mr. Schrader. Leaving two men at Orca, Messrs Witherspoon, Spencer, Charles Rae, and the skipper sailed on the 19th to connect the most westerly station of the Coast and Geodetic Survey with the work which the topographers had carried out at Port Valdes in the summer. In order to do this signals had first to be placed along the coast for a distance of about 40 miles, from Knowles Head to Rocky Point, and afterwards these points were occupied as triangulation stations. Since there was danger of being becalmed, it was not considered safe to try to return to Orca, but to catch the outgoing steamer at Virgin Bay. It was therefore necessary to traverse the line of survey three times. Several attempts were made to cross Valdes Inlet, but at no time was the water sufficiently smooth to allow a landing on the north shore. It was therefore decided first to complete, if possible, all the work between Knowles Head and Rocky Point, and then to close the line by crossing the rough water in a native boat, or bidarka. This plan was finally followed, and on November 3 Mr. Witherspoon crossed the inlet with two native men and succeeded in closing the circuit of about 450 miles from Valdes to Copper and Chitina rivers, down the Copper to the ocean, and from the mouth of the Copper around to Valdes. Owing to the lateness of the season it would have been impossible to complete this line had it not been for the work of the Coast and Geodetic Survey between Copper River and Knowles Head.

November 3 and 4 were spent by the geologists in visiting the copper deposits of Landlocked Bay, and later, while waiting for the steamer, opportunity was afforded for studying the copper deposits at the Gladhaugh mine.

After waiting a week at Ellamar, a post-office which had recently been established at Virgin Bay, the steamer *Bertha* was sighted on November 11, and on this vessel the party embarked the same evening and proceeded to Orca, where Mr. Schrader and his party were found waiting. They all left at once and arrived at Seattle on the 21st, after an absence of nearly six months.

## TRAILS.

*Copper River route.*—The Copper River Valley has been a route of travel for the natives passing between the interior of the Copper River region and the coast for many years. It was traveled in 1885 by Lieutenant Allen, who ascended as far as Taral and wintered there before continuing his journey northward to Tanana, Yukon, and Koyukuk rivers. In 1884 Lieutenant, now Captain, Abercrombie ascended Copper River to the vicinity of Miles Glacier. In 1891 Dr. Hayes, of the U. S. Geological Survey, and Lieutenant Schwatka crossed Skolai Pass from White River and descended the Chitina and Copper to the ocean.

During the summer of 1898 an attempt was made by many prospectors to reach the interior by means of Copper River, but of the several hundred men who attempted to pull their outfits up the stream in boats there were only a very few who reached Taral, and these spent practically the entire summer in the effort. During the same season many who had built boats on Klutina and Upper Copper rivers descended the lower river in them, and all but a few reached the coast in safety.

In winter there are always high winds in the lower part of the river, against which it is almost impossible to make headway, and the difficulties encountered in ascending Copper River during the late winter before the breaking up of the ice, or later, when it is necessary to employ boats, make it impossible to suppose that it will ever become a practicable way of reaching the Copper Basin. It will, however, always be available for those who wish to move rapidly in getting out of the country, since the difficulties it presents for boating are not insurmountable, the principal one being a portage of about 3 miles at the rapids just above Miles Glacier.

*Valdes Glacier route.*—The main traveled route from the coast to the interior during the season of 1898 was the one leading from Valdes by way of Valdes Glacier to Klutina River and descending along that stream to Copper Center, at its mouth. From this point travel was comparatively easy in all directions. The full description of this route is copied from the report of a reconnaissance of the region made in 1898 by F. C. Schrader:[1]

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. 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

[1] A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898, by F. C. Schrader: Twentieth Ann. Rept. U. S. Geol. Survey, Part VII, 1900, p. 365.

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.

During the season of 1899 practically everyone who went from Valdes to the interior traveled by the glacier route. Those who went in over the snow early in 1900 also followed the same trail, but during the summers of 1898 and 1899 the explorations carried on under the auspices of the United States Army resulted in the discovery of a more practicable route for summer travel, and many returning to the coast in the autumn of 1899 employed the new trail, leading from the head of Tonsina River, by way of Kanata and Tiekel rivers and Ptarmigan Creek, to Thomson Pass, which lies between the Copper River drainage and Lowe River, flowing into Valdes Inlet. In the summer of 1900 this route became open with the disappearance of the snow upon Thomson Pass, late in the month of June. After that date several expeditions, including that of the Geological Survey, went into the interior by this route. It was also employed by the army pack train engaged in transporting supplies to the men who were extending the trail toward Copper River and Mentasta Pass.

*Tasnuna route.*—Somewhat to the east of Thomson Pass there is a low divide which has been named Marshall Pass. This lies between the north fork of Lowe River and the head of Tasnuna River, which joins the Lower Copper about midway in its course to Taral on the coast. The Tasnuna was explored by the Schrader party in 1898 and reported to be a feasible line of travel as far as Copper River, but from its mouth to Taral there is no real trail, and the river is passable only in winter or at low water, when boats may be cordelled by walking along the banks and river bars. The difficulties of building a trail along the sides of the canyon would be very great, and it is not probable that this route will be generally followed. However, for reaching the Bremner River region it is probably the easiest route at all times except during low water in October, when it is possible to travel with comparative ease between this region and the trading post at Alaganik, near the mouth of Copper River.

*The Military trail.*—During the seasons of 1898 and 1899 several expeditions, under the direction of Captain Abercrombie, were engaged in exploring for a feasible route between Valdes and the interior, with the intention of locating a trail to be built to Copper River and thence to the Tanana, by way of Mentasta Pass, with the idea of eventually extending it as far as Eagle City, on the Yukon, and thus affording an all-American route from the coast to the Yukon, and telegraphic communication both with the river settlements and with the military post at St. Michael. The result of these explorations was the discovery of Thomson Pass and the comparatively easy line of travel by way of

Lowe River, Tsina and Kanata rivers, and Mosquito Creek. It was first planned to carry the trail from the Kanata across the range northward to the valley of the Tonsina, but the present route is down Mosquito Creek in dry weather, or along a drier route passing somewhat farther east, by way of Kimball Pass, when the ground becomes soft. In either case Tonsina River is crossed several miles below the junction of Mosquito Creek, and thence the trail runs northward, crossing the plateau to Copper Center, at the mouth of the Klutina. In 1898 the trail was open as far as Dutch Flats, in the upper part of Lowe River, and during 1899 it was extended to Copper Center. From Valdes to the head of Kanata River the timber was chopped out to a width of 30 feet, and bridges were constructed over the principal streams. During the summer of 1900 work was continued and the trail was completed as far as Taslina River. Klutina River has been bridged, and ferries will be established across all of the principal tributaries between this and the Chestochina. Besides the actual construction of the trail a telegraphic line is proposed and has been completed between Valdes and a point on the Tsina River.

The establishment of the Military trail has been an important factor in making the Copper Basin available to prospectors and others desirous of investigating the resources of the region, and while at present portions of it would be considered as very bad by those who are not accustomed to traveling in such unfrequented regions as abound in the Territory of Alaska, without this trail transportation of supplies for prospectors and exploring parties would be well-nigh impossible. The greatest difficulties to be overcome are the swift and treacherous glacial streams and the soft, swampy ground which exists over much of the route; but with the destruction by forest fires of the timber along the line of the trail, and the construction of drains and such additional bridges as would naturally follow the continued use of the trail, constant improvement may be expected.

Late in the winter of 1900 many of those having interests in the interior transported their supplies by means of trail sleds drawn by horses over the Military route rather than by the shorter, though more difficult, glacier route, and it seems probable that the latter will eventually be abandoned in favor of the former.

*Tonsina trail.*—A good trail is reported from the vicinity of Tonsina Lake, along the northern bank of the river as far as the military bridge, and from here native trails are reported on both sides of the river, extending as far as Copper River. So far as known, the trail on the south side has not been followed by white men, but that along the north side of the river was opened in 1899, and forms a very easy line of travel from Tonsina bridge to Copper River, on the banks of which it comes out at a point about a mile below the mouth of Chetaslina River. From this place a native trail leads along the bluffs of the Copper to the delta of Tonsina River, but this has been abandoned by those who have had occasion to traverse the region, and a new trail has been cut through the woods somewhat back from the river. Either of these trails, however, is entirely practicable.

*Tonsina River to Taral.*—Crossing Tonsina River near its mouth, an old native trail is found on the south side, which may be followed without difficulty and which was chopped out for the greater part of its length by the Schrader party in 1898. About 8 miles below Tonsina River it enters a valley parallel with Copper River and lying back from it a short distance, and follows along its course as far as Oostina Creek, just above Taral. From this point a trail is reported leading from Copper River and crossing the range to the head of the Kanata, but no definite information concerning it is at hand.

From a point opposite Tonsina River there is a well-marked native trail which has been chopped out by prospectors in that part of its course where it lies in the timber. This trail extends to the mouth of the Chitina and is entirely practicable, although it becomes somewhat dangerous at high water, since in several places it follows the clay banks which rise steeply from the river. On one occasion a horse is reported to have slipped into the river and to have been lost. Crossing Chitina River, which is probably fordable at low water, a trail is found running to the village of Taral and thence for several miles down the river, following the bank of the canyon.

*Tonsina River to Copper Center.*—From Tonsina River at a point about 6 or 8 miles above its mouth the trail of the Schrader party may be followed to Copper Center, although the route is reported as a very difficult one. From the Indian settlement at the mouth of the Tonsina there is also an Indian trail leading northward. It may be followed without difficulty as far as the Indian huts opposite Chetaslina River, but above this it is reported as impassable for horses.

*Hanagita trail.*—From the Indian village of Taral, below the mouth of the Chitina, there is a well-traveled Indian trail leading back into the depression which has been named Hanagita Valley, and which runs parallel with the course of Chitina River and at a distance of 10 to 15 miles from it. This trail was traversed by surveying parties during the autumn of 1900. From Taral the trail has a general easterly course, passing over the mountains lying between the angle of Chitina and Copper rivers and reaching a pass at an elevation of about 3,000 feet, thence circling about the high mountain east of the lower end of Wood Canyon and coming out into a flat divide between the waters which drain into the Chitina and those having their rise in the Hanagita Valley and flowing to the Copper. After a sharp descent of about 1,500 feet from this divide to the creek bed, the steepest and most difficult portion of the whole trail has been passed, within a distance of 6 or 8 miles from Taral. From this point the trail has a practically straight course, and may be followed with ease across Tebay, Klu, and Chitina rivers, and thence to Tana River, which it reaches about 5 miles above its junction with the Chitina. The route is a comparatively open one, and the country traversed affords abundant forage for horses. Through the timbered portion of this region the natives have cut out the trees and bushes, so that the trail is well marked. Any difficulty found in following the usual lines of travel will be in swampy ground, where the natives are accustomed to pick their way and return to the course when the ground becomes harder.

In attempting to find this trail, which had been reported by prospectors, we were aided by directions given by Hanagita, the present chief of the Taral Indians, but the main traveled route was not discovered until Chakina River was reached. The intermediate ground between the Tana and the last-named river was traversed over an independent route. For any who should subsequently travel this trail it would probably be better to keep as nearly as possible to the line traveled by the natives.

At a point about 25 miles east of Taral a trail leads off toward the north, and is reported to connect with the trail crossing Chitina River about 7 miles above the mouth of the Nizina, and striking across to that river to join the trail which is known to follow the eastern bank of the Nizina as far as Nikolai House. This is the route known as the Nikolai trail, and is the one followed by Edward Gates in company with a native who guided him to the Nikolai mine in the summer of 1899.

By means of these two Indian trails the upper part of the Chitina drainage is easily reached from Taral, and should the route which is reported to exist from the head of Kanata River to Taral be discovered, it would be very easy to reach the southern side of the Chitina Basin with pack trains. Also, should it be desired to prospect or explore in the region south of the Hanagita Valley, a region drained by streams of considerable length, well timbered, and of comparatively easy access, this country could also be reached by means of the Hanagita trail. It is supposed that these streams running into Chitina River head against Bremner River.

*Kotsina trail.*—About 3 miles below the mouth of the Kotsina, on the east side of Copper River, there are some Indian huts, and here the Indian known as Bellum has his residence. From this place there is a trail running in a southeasterly direction to the Kotsina at a point where it comes out of the mountains, a distance of 9 miles from Copper River. From this point it extends up the Kotsina to the glaciers at its head, and branch trails run up the various tributaries of the river. One of these branches follows Rock Creek toward the south, and by a pass about 4,800 feet in height makes its way into the southern fork of Strelna Creek, from which place it may be followed to the main

Chitina trail, which crosses Strelna Creek a short distance below the point where it emerges from the high mountains.

*Trails to the Nikolai mine.*—The first route followed by pack trains between Tonsina River and the Nikolai mine was by way of the trail already described, down the east side of the Copper to the mouth of the Chitina and thence to McCarthy's cabin, about 8 miles above its mouth. At this point the trail left the river and, striking across country, reached Strelna Creek, which it followed nearly to where it emerges from the mountains. Here it joined the Strelna trail, which has been described in the preceding paragraph, and the main Chitina trail as now used.

During the summer of 1900 the prospecting party operating under the direction of Mr. R. F. McClellan turned their attention to shortening the trail between the Tonsina and the Nikolai mine. They chopped a way through the timber from a point opposite Tonsina River to a point on the Kotsina trail about 2½ miles from Copper River, and thence followed a direct route to the point on Strelna Creek where the old trail turns southeastward, crossing the Kotsina about 9 miles above its mouth. From Strelna Creek the route lies along the timbered plateau and in places follows an old Indian trail. Kuskulana River was originally crossed upon the lower end of the glacier, but during the summer of 1901 this route became impracticable owing to changes in the drainage of the glacier, and it became necessary to ford the river. The usual fording place is about 2½ miles below the end of the glacial stream, but the ford is constantly changing through shifting of the sand and gravel. The route from Copper River to the Kuskulana is a comparatively easy one; the difficulties which are encountered are those attendant upon soft ground, but by burning the timber along the route this feature will be very largely overcome.

After crossing the Kuskulana Glacier the trail ascends a somewhat difficult gulch to a pass at about 3,500 feet, and thence continues by a comparatively easy grade across Chokosna Creek to Lakina River. From this place there are two routes. The old one, leading across the range, reaches the valley of Kennicott River several miles above the foot of the glacier. It is a steep and difficult trail and is now abandoned in favor of a route which follows down the west side of the Lakina, which it crosses just before it leaves the mountains, and, ascending on the eastern side, follows the plateau around the base of the mountains, reaches Kennicott River just below the glacier, and crosses upon the foot of the moraine. From Kuskulana River to the Kennicott is perhaps the most difficult portion of the whole trail, since the ground is swampy throughout almost the whole distance, and after the thawing of the ground it becomes very difficult for horses to carry considerable loads over it.

From Kennicott River the trail leads up McCarthy Creek, which stream it crosses several times below the mouth of Nikolai Creek, coming in from the east. Following up this stream, it ascends to the Nikolai mine, which is located at an elevation of approximately 4,600 feet. It is possible to travel with horses eastward from the Nikolai mine across the divide into the drainage of Nizina River and to follow this river as far as the glacier. Also, doubtless, Chitistone River could be ascended for a considerable distance, probably to within a few miles of Skolai Pass, which is reported to be more easily reached from the Chitistone than from Skolai Creek, which joins the Nizina several miles higher up and above the foot of the glacier.

*Routes east of Nizina River.*—In order to reach Chitina and Tana rivers during the explorations of 1900, it was necessary to cut a trail from a point about 6 miles above the mouth of McCarthy Creek and across the intervening low mountains to Nizina River. While this was being done by the camp men, the geologists in charge, and the topographers made their way into the country lying between Nizina and Chitina rivers. No difficulty was found in traversing this region. There are native trails following the principal streams. From the Nizina the trail was carried to the Chitina at a point just above the junction with Tana River. Above this point the Chitina Valley was traversed for a distance of 15 miles, and with horses it would be possible to go a considerably greater distance. A trail was also opened along the eastern side of the Tana as far as the glacier at its head; and from the Tana, which was crossed about one-half mile above its mouth, a trail was cut to Chakina River and up the western fork of that stream until the native trail, which has been named for Chief Hanagita, was found.

*Millard trail.*—The Millard trail follows an old native route from a point on the Copper opposite the mouth of the Klutina up Klawasina River and thence along the base of Mount Drum, and, crossing Sanford River, reaches Slana River by a route lying at some distance from the Copper. Throughout this distance the trail is said to be well marked and comparatively easy for horses. The Millard trail is the shortest route from Copper Center to Slana River at Mentasta Pass.

*Chestochina trail.*—A route of travel which has been followed for several years runs along the western bank of Copper River from Copper Center to Slana River and thence to Mentasta Pass, affording an alternate route with the Millard route to the Tanana and Yukon regions. This trail has been considered more difficult than the Millard trail because of the size of the rivers which it has to cross; however, it has been deemed the most feasible route for the Military trail, and it is the purpose of those having the matter in charge to extend the trail as far as the middle fork of Chestochina River and ascend this stream for a considerable distance before turning to the right and reaching Mentasta Pass. The general line of travel for those who have explored the Upper Chestochina has been to the mouth of the river and thence along its left bank to the headwaters.

From the upper part of Chestochina River it is comparatively easy to reach the route which has been followed from Cook Inlet across the great Matanuska Plateau to the head of Delta River and thence to the Tanana.

Before the end of another season the construction of the Military trail will doubtless have been completed as far as Mentasta Pass, and much of the danger attendant upon crossing the swift glacial streams north of Klutina River will be avoided.

*Copper River to the Nabesna.*—The following description is taken from a report by Oscar Rohn:[1]

From Batzulnetas a good trail leads in a general southerly direction for a distance of about 10 miles, where it forks, leading by three different passes to the Nabesna River. These are all feasible for horse trails, and each is advantageous according to the point on the Nabesna that is to be reached. The western one, by way of Lake Tanada, was used by prospecting parties traveling with pack train during the season of 1899, and the central one was used as a sled route. The eastern one, however, is the most practicable and the easiest, particularly for reaching the trail from the Nabesna to the Tanana and White rivers. The western one, which was traveled by pack trains, is well marked up, but the others are difficult to follow and require guides.

The trail from the Nabesna to the Tanana leads to one of two passes. The northern one, the most direct and the one used by the natives, is not feasible for pack horses, while the one a little farther south is. This is the only part of the route that offers any difficulty whatever for railroading, but the difficulties are not such that they can not be readily overcome.

*Copper River to the Tanana.*—From Copper River there are several trails leading to the Tanana, and thence to the White River and Yukon regions. From the vicinity of the mouth of the Slana there are four routes across the mountain range; two of them lead to Mentasta Pass, as does also the proposed Army trail, while the others traverse the range in passes farther to the southeast, the first of which is known as Suslota Pass, while the second is as yet unnamed. All of these routes have been traversed by prospectors and are reported to offer no extraordinary obstacles to travel with pack trains.

## GEOGRAPHY.

The Prince William Sound and 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 coast line. It is limited, in a general way, by parallels 60° and 63° north and meridians 142° and 149° west. Its outline is quadrilateral, or roughly that of a truncated isosceles triangle, the base coinciding with the sixtieth parallel. Its area is about 55,000 square miles.

[1] A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: Twenty-first Ann. Rept. U. S. Geol. Survey, Part II, 1901, p. 417.

It is bounded on the north and on 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 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 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 to 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 Alaskan Mountains, is all southward, directly to the coast. The master stream is Copper River, which flows southward through the district. It breaks through the Chugach Range in a long, mountainous canyon, and soon after debouches over its large mud-flat delta into the sea.

## TOPOGRAPHY.

*Prince William Sound.*—To the body of water, with its islands, which is now known as Prince William Sound, the name "Chugach Gulf" was formerly applied. The term *sound* is not correctly applied to a body of water of this description, but rather to a strait of large size, and while *gulf* is preferable, since it indicates a large body of water lying within a curving coast line, the geographic term which best fits the conditions is *archipelago.* However, common usage can hardly be changed at this time, and the inner, island-studded portion of the Gulf of Alaska will continue to be known as Prince William Sound.

The number of islands comprised in the area is approximately fifty, and for the most part they rise abruptly from the water to a height which is usually between 1,000 and 2,000 feet, but in some cases their summits reach above 3,000 feet. The interior of Prince William Sound forms a basin that is almost entirely landlocked, being sheltered from the ocean on the south by Hawkins, Hinchinbrook, and Montague islands. The islands of the archipelago show a general linear arrangement, which is roughly parallel with the course of the peninsulas between the fiords which cut back from the more open water into the Chugach Mountains.

Montague, Hinchinbrook, and Hawkins islands cut off the waters of the sound from the open gulf, and, with Knight and Flemming islands, form the five principal land areas of the archipelago. Montague Island is approximately 45 miles long and has an average width of from 6 to

7 miles. Hinchinbrook alone, of the larger islands, has approximately equal dimensions of length and breadth, but it is divided by a medial valley into two linear parts having the same general trend as Montague and Hawkins islands. The latter has a length of about 18 miles and an average width of 4 miles. These three outer islands have a general northeasterly trend, and as they separate the waters of the sound from those of the open gulf, so the line of islands beginning with Latouche and running in a more northerly course to the mainland upon the western side of Port Valdes divides the waters of Port Wells, with the adjacent bays and inlets, from the outer portion of the sound. Flemming Island, lying west of Latouche, is not less than 18 miles in length and of irregular outline. Latouche Island is 14 miles long and about 3½ wide.

Islands of the second class, having their greatest dimension less than 10 miles and more than 5, are Green, Chenega, Stamie, Glacier, and Bligh.

The topography of the islands is diverse without being rugged; the mountain slopes and summits are rounded rather than sharp, and the coast lines are, as a rule, simple rather than complex, though they are more sinuous than is shown upon the very much generalized map which accompanies this report. The aspect of the islands, as of the adjacent mainland, is that of mountains which have suffered vigorous erosion by moving ice, and it is believed that all of the topographic features of Prince William Sound are principally the result of glacial molding.

Of the long waterways which indent the mainland, the principal are Cordova Bay, Port Gravina, Port Fidalgo, Port Valdes, Unakwik Bay, and Port Wells. Between these fiords there are long tongues of mountainous land or peninsulas which in many cases are connected with the mainland by very narrow necks. The mountains of these peninsulas reach an elevation of from 5,000 to 6,000 feet, and are often but little lower than the general elevation of the main Chugach Range, of which they are spurs.

*Copper River delta.*—Eastward from Prince William Sound the mountains of the mainland are bordered by a low area of mud flats having a width of from 5 to 15 miles. Across the eastern portion of this lowland flow Eyak and Sheridan rivers, the latter draining the glacier of the same name. Only a short distance from the mouth of Sheridan River is the westernmost slough of Copper River, the first of the many distributaries of the Copper which come to the ocean at intervals for a distance of over 50 miles along the coast. The lower course of the Copper seems once to have been a wide embayment reaching back into the Chugach Mountains, but this has been filled in by vast quantities of sediments brought down by the river, and the broad delta is the result of their deposition.

*Chugach Mountains.*—The Chugach Mountains occupy a belt, about 50 miles in width, lying between the coast in the region of Prince William Sound and Copper River and the interior basin of Copper and Chitina rivers. The name as here used applies to the western extension of the range, which culminates in Mount St. Elias and which is commonly designated the St. Elias Range. From its junction with the St. Elias Mountains the Chugach Range extends westward across Copper River and thence to the Prince William Sound region, where it connects with the Kenai Mountains, which have a more southerly trend in Kenai Peninsula. Still farther to the southwest the same general mountainous features reappear in Kadiak Island, opposite the shoreward end of Alaska Peninsula, at the mouth of Cook Inlet.

The Chugach Mountains, so far as they have been traversed, and in all probability throughout their extent, have been very deeply dissected by the development of a complicated drainage system, and while as a whole they have a general trend dependent upon geological structure, they are cut up by canyons into very irregular masses, in which there is at first sight but little orderly arrangement. However, a glance at the maps of the region shows an arrangement of the deep valleys which is also noticeable to one who travels across the range, namely, the principal streams have courses which lie either practically at right angles to or parallel with the general trend of the mountain range. Copper River, which is the most important stream of the region and which drains all but the very minor portion that finds an outlet into Prince William Sound, is an example of those rivers which have their general course across mountains. Its chief tributaries, such as Bremner and Chitina rivers on the east, and Tasnuna and Tiekel rivers on the west, join the main stream at right angles. In the case of the valley of Tasnuna River, the same course is extended in a comparatively straight line to the divide which separates it from Lowe River, and thence down Lowe River to Valdes Inlet.

The upper part of Copper River lies entirely to the north of the Chugach Mountains, but its course is in general at right angles to that of the lower canyon portion of the river, and the tributaries which drain into it from the Chugach Mountains have courses which are directly across the trend of the mountains. Along the Military trail from Valdes to Copper River this rectangular arrangement of the drainage system is very well exhibited. Passing in an easterly direction up Lowe River to Station No. 2 the trail turns northward until Dutch Camp Flat is reached, then eastward to the foot of the mountain below Thomson Pass; thence, crossing the range, it pursues a general northeasterly course down Ptarmigan Creek to Tsina River and up Kanata River to the head of the South Fork of the Tonsina. From the junction of Tsina and Kanata rivers, Tiekel River, which is formed by their united waters, has a course which is at right angles to that of the tributaries, and this direction is held as far as Copper River, which flows practically parallel with the line of the Military trail. At the head of Kanata River, Fall Creek and Ernestine Creek come in at right angles, and the valley of the latter lies directly in line with that of Mosquito Creek. Again, Tonsina River has the same northeasterly course as the Tsina and Kanata valleys, and joins the Upper Copper at right angles to its course.

The drainage of the Chugach Mountains that reaches Chitina River shows this same rectangular arrangement, which is a feature that doubtless exists throughout the whole of the Chugach Range.

Throughout the Chugach Mountains the interstream areas rise to a generally uniform height, reaching an average elevation of about 6,000 feet. Occasional peaks rise above this elevation, but in general the mountain summits would fall into a somewhat undulating plateau about 6,000 feet above the sea. In the discussion of the development of the topography of the region, which is given in another place, it will be shown that these mountains have probably originated by the dissection of such a plateau, which reached its present altitude by means of several uplifts from an original position near the level of the sea.

*Copper Basin.*—Copper River rises on the eastern side of Mount Wrangell and, assuming a northward course, which is maintained for about 40 miles, turns toward the southwest and continues for 50 miles, when it turns again and bears more to the east; then, continuing in this direction, it is joined by Chitina River at a distance of about 150 miles from its head. Finally, after having half encircled the great Wrangell group of mountains, the river turns toward the south and traverses the Chugach Range in a comparatively constricted valley, reaching the Pacific Ocean about 150 miles west of St. Elias. It is just below this southerly bend that the river is joined by the Chitina, the tributaries of which reach the glaciated divides of the Tanana and the White on the east and those of the coastal watershed in the region north and west of St. Elias. Chitina River and the upper course of the Copper lie in trenches that have been cut into Pleistocene deposits that form the floor of the broad topographic depression which may be called the Copper Basin.

The topography of the Copper Basin shows a marked contrast to that of the mountainous regions by which it is surrounded. It is a broad valley of slight relief, sloping with the course of Copper River from the Matanuska Plateau, at an elevation of about 3,000 feet, to Wood Canyon, where the river enters the mountains and where the elevation of the valley floor is approximately 1,200 feet. Into the bottom of this depression Copper River has cut a channel from 500 to 800 feet in depth, and from the banks of this canyon there is a general slope, with occasional steps of the nature of terraces, to the foothills of the mountains on either side.

The main tributaries which flow from the Chugach Mountains and join Copper River show similar broad features, their valleys sloping in the direction in which the streams flow, and their cross sections showing a general rise from the vicinity of the streams to the mountains on either side. The same conditions are found in the eastward extension of the Copper Basin along the lower course of Chitina River. The lower part of the Chitina Valley merges completely with the contiguous portion of the valley of Copper River, but about 10 miles above the mouth of the Chitina there is a low, mountainous mass, about 1,000 feet in height, constricting the valley of that river, and from this point to the mouth of Lakina River the valley is comparatively narrow. Here it opens out into a valley about 20 miles in width, showing the same general features as the main Copper Basin. Illustrations of these features are given in Pls. X, *A*, and XIII, *A*.

The Copper Basin is traversed at intervals by streams which have their rise in the adjacent mountains and flow in deep canyons to join the main river. The origin of these canyons seems to have been very recent, since in general the rather flat-lying regions between them are very poorly drained, as is shown by the large number of lakes throughout the basin. In some cases the lakes lie within a few feet of the canyon walls, but their streams have not been able to cut channels sufficiently deep to drain them. The presence of these topographic depressions, filled with standing water, in connection with the character of the deposits which make up the floor of the basin, is considered sufficient to show the glacial origin of the main topographic features of these broad interior valleys.

*Wrangell Mountains.*—Lying within the great bend of Copper River to the north of Chitina River and west of the Nizina, is a group of high mountains which have been called the Wrangell Mountains. The principal peaks are Mount Sanford and Mount Drum on the north, with Mount Wrangell forming the central peak, while on the south is Mount Blackburn. The elevation of the northern mountains is supposed to be between 12,000 and 13,000 feet. Mount Wrangell reaches 14,000 or 14,500 feet, while the elevation of Mount Blackburn has been determined with a fair degree of accuracy as 16,150 feet. Mount Drum seems to stand apart from the main mass of the mountainous group, while Mount Sanford is connected with Wrangell by a high range, and Wrangell is connected with Blackburn by tracts above 10,000 feet, and this high ground is continued to the vicinity of the pass between Nizina and Tanana rivers.

The origin of the Wrangell Mountains, as shown by their present excessive height when compared with the Chugach Mountains, is doubtless volcanic. In the region about the head of Nizina River there is a great thickness of volcanic rocks in all probability of Tertiary age, but the extent of these toward the center of the Wrangell region is not known. It is, however, certain that Mount Wrangell is composed of lava flows, the latest of which have been very recently erupted.

The mountain is even now a volcano in a quiescent stage, for large volumes of steam are continually rising from the crater, which may be distinctly discerned at the summit of the smooth, gently sloping cone. Actual eruptions, though none of great importance, have been reported by those who have visited the region.

Around the southern edge of Wrangell Mountains are high ridges of sedimentary rock rising to the same general level as the Chugach Mountains, across Chitina River, and forming foothills to the higher volcanic mountains adjacent.

The Wrangell region is drained on the south by Nizina, Kennicott, and Lakina rivers, whose waters join those of the Upper Chitina, while the western side is drained by Kuskulana, Kotsina, and Chetaslina rivers and Klawasina Creek, the first flowing into the Chitina, the others directly into the Copper. On the northwest and north the principal streams are Sanford River, from the region between Mounts Drum and Sanford, and Upper Copper River and Tanada Creek. All these rivers, as well as the Nabesna and Tanana, which have their rise on the eastern side of the mountains, originate in glaciers that flow from a practically continuous snow cap extending from Mount Wrangell to Mount Blackburn and the Nizina-Tanana divide.

*Skolai Mountains.*—The name Skolai Mountains is used as a convenient term for the high region between Chitina and White rivers, lying to the east of the Nizina-Tanana divide. This is a high, rugged region, the present features of which are due to the erosion of volcanic materials similar to those which form the eastern portion of the Wrangell Mountains. On their southern side the mountains present the same foothill characteristics as have been described to exist south of the Wrangell Range, and these foothills, rising to about 6,000 feet, are composed of the older sedimentary rocks and seem to correspond in origin with the Chugach Mountains. Little is known of this region except such general impressions as have been gained by distant views from the Upper Chitina and Nizina valleys.

*Topographic maps.*—Two topographic maps accompany this report. The first (Pl. II) is on the scale of 1:250000, with a contour interval of 200 feet. It is based on stadia measurements, instrumental triangulation, and sketching by the usual plane-table methods, executed by Mr. T. G. Gerdine, topographer, and Mr. D. C. Witherspoon, assistant topographer. This map shows the territory adjacent to the Military trail between Valdes and the Tonsina valleys, and also parts of the Copper and Chitina valleys and adjacent mountains.

The second map (Pl. III) represents the features of Prince William Sound. Its scale is 1:625000, with sketch contours. It has been compiled principally from data taken from the military map of Prince William Sound.

## GEOLOGY.

### OUTLINE OF GEOLOGICAL HISTORY.

The rocks of the region to which is here given the general designation the Copper River district are of widely varying types and comprise formations of great range in point of geological age. The oldest are metamorphic rocks, derived from sedimentary formations through the processes of mountain building, which have been active at various dates; and these, upon the basis of the relative degrees of alteration which they have undergone, are divided into three series, to which have been given the names Klutina, Valdes, and Orca. The last includes, besides strata of clastic origin, layers of basalt representing contemporaneous volcanic extrusions, and similar basalts of possibly the same general age are to be found in parts of the region where the series as a whole has not been recognized. The three metamorphic series have all been intruded by igneous rocks, very largely of a date later than that of the latest intense folding.

Subsequent to the metamorphism of the Orca series the region suffered very deep erosion, which was followed by sinking and the deposition of more sediments belonging to the latter part of Paleozoic and to Mesozoic time. Two divisions of these strata are recognized below a third which rests unconformably upon the upturned edges of the other two—the Chitistone[1] limestone, of Carboniferous age, overlain by the Triassic limestones and shales, and the Kennicott formation, of late Jurassic or early Cretaceous age.

After the deposition of the last of these two formations land conditions again prevailed, and during the early part of Tertiary time the region suffered very deep erosion; but before the land was completely reduced volcanic rocks were piled up in parts of the area, and possibly sedimentary rocks were also locally formed. The latter and much of the former have since, however, been removed by the processes of erosion. Also at some period subsequent to the deposition of the Kennicott formation these sedimentary strata were invaded by igneous rocks in the form of stocks and irregular intrusions.

Finally, after a period of sculpturing by water, the region was very deeply glaciated, and local deposits of débris were formed in the wide valleys produced by erosion, and this deposition was accompanied, as it has been followed, by outflows of andesitic lava from Mount Wrangell and possibly from other volcanoes in the region. In the Chugach Mountains and in Prince William Sound the ice was actively engaged in erosion.

[1] The names which are used for the unmetamorphosed sediments of the Copper River district are those proposed by Rohn in his report entitled, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: Twenty-first Ann. Rept. U. S. Geol. Survey, Part II, 1900, pp. 399–439. The Triassic series has not been called by the name proposed by Rohn, because it seems so complex that it will be eventually divided into several formations.

*Table of provisional correlation.*

| | Spurr: Yukon district, 1896.[1] | Brooks: Pyramid Harbor to Fortymile River, 1899.[2] | Brooks: White River and Tanana district, 1898.[3] | Mendenhall: Resurrection Bay to the Tanana River, 1898.[4] | Spurr: Southwestern Alaska, 1898.[5] | Eldridge: Sushitna Valley, Alaskan Range, and Cantwell River, 1898.[6] | Schrader and Spencer: Copper River district, 1900.[7] |
|---|---|---|---|---|---|---|---|
| Pleistocene | Silts and gravels. | Silts, sands, and gravels. Effusive rocks in part. | Silts and gravels. | Sands and gravels. | Silts, sands, and gravels. | Sands, gravels, and bowlder clays. | Silts, gravels, and bowlder clays. |
| Neocene | Twelvemile beds, Porcupine beds, Nulato sandstone, Palisades conglomerate. | Tok sandstone and effusive rocks in part (?). | Tok sandstone | | Tyonek beds, Hayes River beds, Nushagak beds. | | |
| Eocene or Oligocene | Kenai series. | | | | Yentna beds. | Kenai series. | |
| Cretaceous | Mission Creek series. | | | Matanuska series. | Tordrillo series, Holiknuk series, Kolmakof series, Oklune series. | Cantwell conglomerate (?). | Kennicott formation, Orca series (?). |
| Jurassic | | | | | Naknek series, Skwentna series. | | |
| Triassic | | | | | | | Triassic shales and limestones. |
| Carboniferous | | | | | | | Chitistone limestone. |
| Carboniferous and Devonian. | Tahkandit series. | Nutzotin series. | Wellesley series, Nilkoka beds (?). | Sunrise series (?). | Tachatna series. | Cantwell conglomerate (?). | Nikolai greenstone (?). |
| Silurian | Rampart series. | Greenstone schists (?), Kotlo series. | Greenstone schists (?). | Greenstones (?). | | | Valdes series (?). |
| Pre-Silurian sediments. | Birch Creek schists, Fortymile series. | | Tanana schists, Nasina series. | Tanana schists. | | Sushitna schists. | Klutina series (?). |
| Archean | Basal granite. | Gneissic series. | Gneissic series. | | | Basal granite and gneissic series. | |

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

[2] A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the upper White and Tanana rivers: Twenty-first Ann. Rept., Pt. II.

[3] A reconnaissance in the White and Tanana river basins, Alaska: Twentieth Ann. Rept., Pt. VII.

[4] A reconnaissance from Resurrection Bay to the Tanana River, Alaska: Twentieth Ann. Rept., Pt. VII.

[5] A reconnaissance in southwestern Alaska: Twentieth Ann. Rept., Pt. VII.

[6] A reconnaissance in the Sushitna Basin and adjacent territory, Alaska, 1898: Twentieth Ann. Rept., Pt. VII.

[7] See, also, a reconnaissance of the Chitina River and the Skolai Mountains, Alaska, by Oscar Rohn: Twenty-first Ann. Rept., Pt. II.

## GEOLOGICAL MAPS.

The information obtained concerning the distribution of the geological formations of the Copper River district has been represented on the accompanying geological maps (Pls. IV and V). The geological work was of a reconnaissance nature and was carried on side by side with the topographic field work. The boundaries between the different formations are consequently very much generalized, and certain of the features, as, for instance, the occurrence of complicated intrusions of porphyry, are represented in a diagrammatic rather than an accurate way. Areas in which the geology is entirely unknown have been left blank, but general knowledge is represented by notes printed in red.

Geological cross sections on the same scale as the map are introduced to illustrate the structure near either end of the region studied. In these profiles there is a vertical exaggeration of 3 to 1.

## KLUTINA SERIES.

The term Klutina series was applied by Schrader, in the first report on the Copper River region, to a series of schists and crystalline limestones occurring near Klutina Lake.[1] They were separated from the Valdes rocks by reason of the more intense metamorphism which they exhibit, but this has not been complete enough to destroy all traces of stratification, though in many places the rocks are intensely folded. During the last field season rocks exhibiting the same characteristics as the Klutina series were observed in a limited area between Chitina and Tana rivers, in such position that they appear to be surrounded by the Valdes rocks, as they are known to be in the vicinity of Klutina Lake. The correspondence with the Klutina series is suggested in a tentative way, since the excess of metamorphism over that shown by the neighboring Valdes series may be due to changes which have been brought about by the intrusion of a large number of granitic dikes, which are found cutting the schists in a very intricate manner. In its original description the Klutina series was provisionally correlated with the Fortymile series in the Yukon district, described by Spurr, and upon this basis, and because of their relations to the Valdes rocks, they are supposed to be of pre-Silurian age.

## VALDES SERIES.

*Character and occurrence.*—The rocks of the Valdes series have been characterized by Schrader[2] as a metamorphosed complex made up of bluish-gray and dark quartzites, arkoses, and quartz-schists interbedded with thin bands of dark-blue or black slate, shale, mica-schist, graphite-schist, and stretched conglomerate. It is a series which, on

[1] A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, 1900, p. 410.

[2] Ibid.

the whole, is of rather uniform composition, in which there are no lithologic differences sufficient for making any special divisions. In a large way it is homogeneous, rather than heterogeneous, since throughout its thickness there is a constant repetition of alternating thin bands of arkoses, sandstones, and shales in various stages of metamorphism. The series, in general, may be characterized as a schist, although it does not show the extreme metamorphism of many rocks for which this term has been used.

Previous to the work of last summer the Valdes series had been observed only in the vicinity of Valdes, along the Klutina route to the interior, and along Copper River from Taral to Tasnuna River, and thence to Valdes by way of Lowe River. The observations of last summer did not add materially to the information concerning this series, except in extending its known area and determining the persistence of its general features throughout the region between the ocean and the interior basin of Copper River; but from the data now available it becomes apparent that the rocks belonging to this series form practically the whole of the Chugach Mountains from the region of Mount St. Elias to Kenai Peninsula.

The Valdes series is undoubtedly of sedimentary origin and represents the result of the metamorphism of water-laid formations, which must have been originally piled up to a considerable thickness and distributed over a wide area. The sedimentary character of the rocks is seen in their composition and in the alternating strata of sandstone and shale. The sediments were carbonaceous and calcareous shales with bands of sandstone derived from igneous rocks and with some limestones of a rather impure nature. Their metamorphism has been the accompaniment of important deep-seated disturbances of the earth's crust, by which the strata have been folded and by which they have also been compressed and sheared. The alteration of the rocks has not been so complete that the schistose structure is independent of the original bedding of the strata, but the foliation is ordinarily found to be parallel with the stratification, although in the case of certain shaly members, especially where they occur between strata which are rather massive, the schistosity becomes transverse to the original structure. However, the character of the rocks is so seldom homogeneous that it is not possible to make out the stratigraphic variations and thus to ascertain the true attitude of the strata.

*Structure.*—The strike of the Valdes rocks has a general northeast-southwest trend throughout the region in which it has been observed. The direction of strike varies from N. 30° E. to N. 75° E., with still greater local differences. The average strike is perhaps in the neighborhood of N. 40° E. The dips are both southerly and northerly, but the latter seem to be of somewhat more frequent occurrence. The dips are usually rather steep, varying from 40° to 80°.

It has not been found feasible to make a careful study of the structure of the Valdes series along any line directly across its general structure, but from such observations as have been made it appears that the series has been very completely folded, and it is thought that the strata in the region between the coast and the interior have been duplicated several times. The lack of distinctive horizons makes it impossible to recognize the number of such duplications or to obtain more than a very general idea of their existence. For this reason it is impossible to give even a rough estimate of the thickness of the series.

*Age of Valdes series.*—The geological relations of the Valdes rocks are not sufficiently well known to warrant an unreserved statement regarding their absolute age, but in the upper part of the Chitina drainage rocks that are correlated, upon structural evidence, with known Triassic formations in the adjacent region, are found to overlie the Valdes rocks, and these Mesozoic strata are entirely unmetamorphosed. The Triassic is also underlain by a series of limestones of probable Carboniferous age, and these rest in turn upon a series of volcanic rocks. All three of these rock groups are apparently conformable and have suffered the same amount of disturbance, but have not been metamorphosed to any noticeable degree. From this relation it would appear that the Valdes series is much older than the pre-Carboniferous greenstone, since it was very thoroughly metamorphosed in the period between that of its deposition and that in which the greenstones were erupted. Along the foothills of the Blackburn region, also, rocks which probably belong to the Valdes series are intruded by granular rocks which have not been metamorphosed except very locally, and these have nowhere been found to penetrate to Carboniferous rocks. The presence of these unmetamorphosed igneous rocks is a further indication of the lapse of a long period of time between the formation of the Valdes series and the deposition of the unmetamorphosed sediments of the Wrangell region.

It is supposed that the Orca series, occurring in Prince William Sound, is younger than the Valdes series, and if its age can be assigned as Devonian it is probable, from the difference in degree of metamorphism affecting the second series, that the Valdes rocks are at least as old as the Silurian.[1]

*Correlation of Valdes series.*—The resemblance of the Valdes series to the Sunrise series, which has been described as occurring in the region of Cook Inlet, was suggested in a report published in 1900,[2] but the Orca series is known to occur in the islands of Prince William Sound adjacent to Kenai Peninsula, and it is possible that the Sunrise series may represent the Orca rather than the Valdes rocks. The correlation of the Valdes and Sunrise series must therefore be left in

[1] See the table of provisional correlation, p. 33.

[2] A reconnaissance from Resurrection Bay to Tana River, Alaska, in 1898, by W. C. Mendenhall: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, 1900, p. 305.

doubt. It seems probable that the equivalents of the Valdes rocks are represented in the region of Mount St. Elias, for they were found by the writers in the adjacent portions of the Chugach Range, and, from the description of the St. Elias schists by Russell,[1] these two series are known to have many of the same lithologic characters.

## ORCA SERIES.

*Description.*—The rocks of the Orca series consist of arkose sandstones, usually very massive, interbedded with occasional black limestones and with a considerable amount of black shale. Locally there are conglomerates and rather massive brown and gray sandstones. The conglomerates are composed very largely of gray quartzites, with quartz grains, which are usually well rounded. The pebbles sometimes reach a diameter of 3 inches, though they are seldom larger than 1 inch. The sandstones are sometimes siliceous and frequently calcareous or ferruginous, but by far the greater part of the sandstones are feldspathic. On a fresh surface they are usually dark blue or gray in color, but when exposed to the weather they assume a pepper-and-salt appearance, giving a general grayish effect. Dark-blue or black limestones have been observed within the series at Yellow Cedar Bay, on the north side of Hawkins Island, in layers from 1 to 2 feet in thickness.

Occurring with the sediments of the Orca series, and to all appearance interbedded with them, there are some important masses of diabase or basalt. It seems probable that the period during which the Orca series was deposited was one of volcanic activity and that sedimentation went on alternately with the extrusion of basaltic lavas. There is but little variation in the character of the basaltic greenstones, except such as has arisen through the metamorphism which they have undergone. Their appearance under the microscope indicates that they were originally basalts, and it is with these rocks that most of the copper deposits of the Sound region are associated. In some localities, notably in one on Latouche Island and in the prospects on Mill Run south of Orca, the rock has an amygdaloidal character and a general texture which gives it very much the appearance of the Nikolai greenstone, which is similarly associated with the copper deposits of the Wrangell district.

*Occurrence of Orca series.*—The rocks of the Orca series, with their associated basaltic greenstones, are known to occur on the islands of Prince William Archipelago. They have been recognized also on the mainland to the west of Columbia Bay, and it is probable that they occupy at least a portion of Kenai Peninsula, although it is not known that this region is not occupied by the Valdes series, and no comparison has been made which warrants a definite correlation of

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[1] Expedition to Mount St. Elias: Nat. Geog. Mag., Vol. III, 1891-92, pp. 167-175.

the Sunrise series of the Cook Inlet region with either the Valdes or the Orca series of the Prince William Sound region.

The rocks between Columbia Bay and Port Valdes belong to the Valdes series, and this series also occurs on the east side of Port Valdes, in the vicinity of Galena Bay, and sweeps across and forms the northern shore and the head of Port Fidalgo. South of these occurrences, as is represented on the map of Prince William Sound which accompanies this report, there is a zone occupied by a greenstone. To the south of this greenstone the Orca series occurs, and it may be suggested that the greenstone lies between the Valdes and the Orca series, although the field relations have not been well enough observed to give the suggestion more than a tentative value. It is probable that the Orca series might be truthfully represented as covering all of the region south of the general trend of the greenstone and forming the surface of all the islands of the archipelago. The eastern limits of the formation are not known, and while the sedimentary rocks have been observed at McKinley Lake, in the vicinity of Alaganik, it was not found possible to determine whether they belong to the Valdes or to the Orca series, though it seems probable that they belong to the latter.

It may be suggested that the Orca series is to be correlated with the black shales of Kadiak Island, which have been studied by Dall,[1] and it also seems probable that they may be correlated with rocks in the vicinity of Yakutat Bay, which Russell has described and to which he has given the name Yakutat formation.[2]

*Metamorphism and structure.*—The rocks of the Orca series have been generally folded and sheared, but the metamorphism which they have suffered is somewhat less than that which has affected the Valdes series. Schistose structures have been produced in the less massive portions, but nowhere has metamorphism proceeded sufficiently far to cause a formation of secondary minerals, such as hornblende, mica, and epidote. The schistose structure is, as a rule, strictly parallel with the bedding, though in the case of some of the homogeneous shales it is found to be transverse to the planes of stratification. Intimate plications of the thin-bedded shales are of frequent occurrence. The general structure exhibited by the series is that of very complex folding. The strike and dip vary greatly within short distances, and it is not possible as yet to determine any general trend of the rocks, though perhaps northwest-southeast strikes are somewhat more frequent than any other. The variation in strike and dip, with the steep dips of the strata, indicate that there is much duplication of the beds from place

[1] Report on coal and lignite of Alaska, by W. H. Dall: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, 1896, p. 871. The latest information in regard to the Kadiak shales points toward a Mesozoic age.

[2] An expedition to Mount St. Elias, Alaska, by Israel C. Russell: Nat. Geog. Mag., Vol. III, p. 142. These also now (1901) seem likely to prove Mesozoic.

to place, and make it probable that the apparent thickness of the strata is greatly in excess of the actual thickness.

Among the results of the dynamic action to which the rocks have been subjected are the frequent joints and minute faults which occur, especially in the shales and slates. These fractures and other openings along the cleavage are often filled in with veins of quartz and calcite.

*Age of Orca series.*—Concerning the age of the Orca series there is conflicting evidence. In 1898 Mr. Schrader found plant remains in the Orca rocks, and these were studied by Dr. F. H. Knowlton, of the United States Geological Survey. Specimens collected from Gravina Point and Johnstone Point were not found to be of value for determining age relations, and cones collected on the northeast shore of Hawkins Island, resembling certain Upper Cretaceous or Lower Tertiary forms, were said to be too indefinite to be of much value. Other plant remains were seen in Jackson Cove, on Glacier Island, during the fall of 1900, but no recognizable specimens could be collected.

In 1895 Dr. Dall collected some fossils from a black schistose series of rocks on Woody Island, near Kadiak. One of these was regarded by Prof. A. Hyatt as belonging to the genus *Posidonomya*, but it has since been referred by Prof. E. O. Ulrich to a new, though allied, genus. The suggestion was made that the rocks are Triassic or older.[1]

Professor Ulrich and Dr. Knowlton have recently examined certain organic remains which were collected by the Harriman expedition from the same black slates, and which also occur in slates in the vicinity of Yakutat that may be equivalent to the Orca series. These include the remains of algæ. After a careful study of all the material from all sources Professor Ulrich supposes the age of the Kadiak horizon to be probably Jurassic, which accords sufficiently well with their stratigraphic position.

In the absence of really distinctive organic remains, the main dependence for estimating the age of the Orca series must be placed upon general structural features. The Orca series is in general less metamorphosed than the Valdes rocks, and therefore is supposed to be considerably younger; and while the relations of the Orca rocks to the Carboniferous and Mesozoic series of the Copper River region are nowhere directly exhibited in the localities which have been visited by the writers, the relation of these rocks to the Valdes is conclusive evidence that the latter are much older than the Carboniferous; and since these sedimentary formations have not suffered such degree of metamorphism as the Orca rocks, it becomes permissible to suppose that the Orca series is intermediate in age between the Valdes series and the Kennicott formation, a view that is supported by the paleontological evidence which has been given.

[1] Report on coal and lignite of Alaska, by W. H. Dall: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, 1896, pp. 871, 907.

From the fragmental descriptions of the formations occurring on Alaska Peninsula adjacent to Kadiak Island it appears that the shales there resting unconformably upon the Woody Island series may ultimately afford evidence that will decide the question.

If an attempt should be made to apportion the metamorphic rocks comprising the Orca and Valdes series to the divisions of the geological time scale, it would appear that the former might belong in general to the Devonian era, in which case it would be correlated in part with the Tahkandit series of Spurr, and in this case the Valdes series would belong to the Silurian era and would be equivalent to the Rampart series of the same author.[1]

## UNDETERMINED ROCKS ON KOTSINA RIVER.

On either side of Kotsina River and extending from the edge of the andesite west of Long Glacier and the region about Clear Creek southward to Elliot Creek there is a series of rocks whose relations and age have not been determined. They are made up of sediments, including limestones, shales, and coarse conglomerates, with intercalated sheets or flows of basalt like the Nikolai greenstone. The pebbles of the conglomerate are composed of greenstone material.

The series shows a general dip toward the southwest, and in this regard it follows the structure of the Nikolai greenstone and the Chitistone limestone which occur farther up the river. The age of the series is unknown, but from the structure it would seem that it must be younger than the Chitistone, which appears to dip beneath it. Owing to its make-up, however, and the fact that it has been affected to a certain extent by metamorphism, it seems impossible to correlate it with the adjacent Triassic strata. If, however, it is older than the limestone, it may be representative of a series equivalent to the Orca rocks occurring in Prince William Sound. This suggestion is made in the most tentative way, since there is no evidence at hand for the determination of the stratigraphic position of the series. For this reason it has been represented on the map as unknown sediments.

In cross section C–D, Pl. IV, a fault is suggested to explain the relation of the rocks shown on the map in the region of Copper and Pass creeks. The existence of such a fault would also explain the occurrence of the unknown series in its observed relations, on the supposition that it belongs beneath the mass of the Nikolai greenstone.

## NIKOLAI GREENSTONE.

*Description.*—The term Nikolai greenstone is employed to designate a series of volcanic flows forming an important mass in the Wrangell district. The rock shows considerable variation from place to place, both laterally and vertically, in the separate flows, but it is

[1] See table of provisional correlations, by J. E. Spurr, in Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, p. 187; also this report, p. 33.

*A.* SHEARED GREENSTONE ON SOUTH SIDE OF KOTSINA RIVER, BELOW SURPRISE CREEK.

*B.* INTRUSIONS OF FINE-GRAINED PORPHYRY IN BLACK SHALE ON YOUNG CREEK.

always easily distinguishable from other rocks of the region. In color it is generally green, though sometimes it is of a reddish hue. In texture it varies from fine-grained, very densely crystalline, to rather coarse-grained porphyritic, and in many places it shows amygdaloidal characters. Under the microscope the rock is found to consist of feldspar and augite, with considerable quantities of two green minerals, which are found to be chlorite and serpentine. In rare instances grains of olivine are noted under such conditions that it seems certain that the serpentine had its origin in the alteration of the olivine. The structure is always that which is characteristic of diabase, where the laths of feldspar form a felt-like mesh with augite lying in the interstices. At times the rock is so fine grained that it becomes almost aphanitic, while at other times the crystals of feldspar have dimensions reaching several millimeters. When amygdaloidal, as it frequently is, the cavities are filled by chlorite or serpentine, either with or without chalcedonic quartz. Accessory magnetite is always present and frequently in considerable amounts; also in many cases metallic sulphides are present, though these are probably of secondary origin. Locally metallic copper occurs in grains or stringers, but always under such circumstances that it may be considered of secondary rather than primary origin. The composition and structure of the Nikolai greenstones show them to have been originally typical basalts. In their characters and in the mode of the occurrence of copper in them they are very closely related to certain of the greenstones of the Lake Superior copper region.

*Occurrence and distribution.*—The Nikolai greenstone occurs in many places in the Wrangell and Skolai mountains, and wherever seen is found to show the same relations to the sedimentary series of the region. The massive Carboniferous limestone, which is the lowest unmetamorphosed sedimentary formation of the district, lies directly upon the greenstone in such a way that it would seem as if it had been originally laid down upon the surface of the earlier volcanic flows. In this relation it is observed in the upper part of Kotsina River, where the greenstone passes beneath the Carboniferous limestone, dipping toward the southwest, and forms a large part of the mountain masses that are drained by the southern glaciers of the Kotsina Basin. From this region it connects directly with the occurrence in the mountains in the vicinity of Kuskulana Glacier, and, reappearing in the valley of the Lakina, is again found in the upper part of the Kennicott drainage, whence it may be traced (always bearing the same relation to the massive limestone) across McCarthy Creek and thence to the Nizina and the mountains to the east (see Pl. VIII, *B*). From the observations of Mr. Hayes and Mr. Brooks it is known that the same rock occurs at the headwaters of White and Tanana rivers.

While the top of the greenstone series is frequently exposed, the bottom has not been seen, so that the actual thickness of the series is not known. The greatest thickness that has been seen is probably in the upper part of the Kotsina, where it may be estimated very roughly at 4,000 feet.

*Structure of the greenstone.*—From the origin of the greenstone series, through the successive outflow of innumerable sheets of basalt, it is natural that the complex should show a bedded character comparable to stratification in sedimentary rocks, and in many places this structure is very well exhibited. The bedding in the volcanic series is always found to be in accord with the structure of the overlying water-laid formations.

Locally the greenstone shows a secondary structure due to shearing, as illustrated in Pl. VI, *A*, which is reproduced from a photograph taken below Surprise Creek on Kotsina River.

*Occurrence of copper in the greenstone.*—The copper deposits in the Wrangell district are, without exception, so far as seen, related to the Nikolai greenstone, since they occur either within its mass or within the sedimentary formations adjacent to the greenstone. From the relations observed it is evident that the volcanic rock is the source of the copper, which probably existed in it at the time of its eruption. In the deformation which the rocks have undergone fissures have been produced, cutting the greenstone and the overlying sediments, and along these fractures veins have been formed in many cases, and the metallic contents of the erupted rock have been concentrated by means of circulating waters and deposited along the fissures, both in the igneous rock and in the limestone that lies above it. In these cases where the ores have been deposited in the limestone they do not extend very far from the contact with the greenstone. The change from one rock to the other seems to have been favorable for the deposition of the copper minerals, and the contact has become the locus of valuable mineral deposits.

*Age of the greenstone.*—Concerning the actual age of the Nikolai series little can be said. They are older than the Carboniferous limestones which rest upon them, though probably not very much older, since there seems to have been no folding in the interval between the close of the volcanic outflows and the beginning of marine sedimentation. They are presumably later than the Valdes series, since the latter is very strongly metamorphosed, so that it can only be said that they belong to a period between that of the Valdes and that of the Carboniferous limestone. It seems likely that they may have been extruded during the deposition of the Orca series, at present preserved in Prince William Sound. Weight is added to this supposition by the occurrence at various horizons in the Orca series of intercalated basaltic rocks, which could well be the equivalent of the Nikolai series; so in the absence of definite knowledge it may be tentatively held that the greenstone belongs to the same period as the Orca series.

CRUMPLING IN THIN-BEDDED TRIASSIC LIMESTONE ON RIDGE EAST OF GILAHINA CREEK.

The evidence that the greenstone was formed previous to the Chitistone limestone is as follows: Wherever the two are in contact the limestone shows no metamorphism, such as usually results from the intrusion of a calcareous rock by an igneous mass; the pseudostratification in the greenstone is parallel with the bedding of the overlying limestone wherever observed, and the layers in the former are different in structure and general appearance. These facts, and the frequent occurrence of amygdaloidal phases in the greenstone and extremely marked variations in the coarseness of crystallization within short distances, are distinctly in favor of the origin of the greenstone by successive flows of basalt at a date preceding the deposition of the limestone. Furthermore, there are no dikes or irregular intrusions of the basalt which can be definitely shown to cut across the Carboniferous or Triassic strata, a condition which could hardly exist if the greenstone had been forced into the sedimentary rocks in the form of a long laccolith at a constant horizon.

This idea of the relations of the greenstone to the sediments with which it is associated is not entirely in accord with the observations of Hayes and Brooks, who report greenstones cutting the limestones and the overlying shales. The former[1] found fine-grained greenish amygdaloidal lavas both cutting and interbedded with the sedimentary rocks in the vicinity of Skolai Pass, where they are estimated to form as much as half the mass of the bedded rocks.

In the vicinity of Kletsan Creek, and elsewhere on White River and adjacent portions of the Tanana, Brooks[2] found amygdaloidal greenstones cutting the Carboniferous limestone and the overlying shales, as well as interbedded with the latter. It is with these greenstones, which have locally metamorphosed the limestone, that the copper deposits were found to be associated. The specimens of greenstone collected by Brooks are in every respect similar to the greenstones of the western side of the range.

From the distinct mode of occurrence in the two regions, and from the occurrence of a few thin flows of basalt in the Triassic rocks of the Chitina region, it appears that there were two periods during which basaltic rocks were erupted, one previous to the deposition of the Carboniferous limestone, and the other in the early part of the Triassic period of deposition. Of this latter basalt little evidence was seen in the Wrangell district, but in the north fork of Strelna Creek there are amygdaloidal greenstones in thin beds, apparently interstratified with the black shales, and in connection with them there are deposits of native copper.

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[1] An expedition through the Yukon district, by C. W. Hayes: Nat. Geog. Mag., Vol. IV, p. 140.

[2] A reconnaissance from Pyramid Harbor to Eagle City, Alaska: Twenty-first Ann. Rep. U. S. Geol. Survey, Part II, 1900, p. 381.

## CHITISTONE LIMESTONE.

*Description.*—The Chitistone formation is composed of very massive limestones, without any important intercalations of shale. When weathered it has a white or gray color, which makes it prominent in contrast with the greenstone upon which it lies, but when broken it is found to have a blue color, which is indicative of considerable carbonaceous material in its composition. In texture it is fine grained throughout. No fossils of sufficient worth for determination were found within the area studied.

*Occurrence and distribution.*—The massive Carboniferous limestone is one of the most prominent formations of the Wrangell region. It is found lying above the greenstone in the upper part of the Kotsina Basin, where it crosses the river at the mouth of Kluvesna Creek. Northeast of this place it has been traced as far as Long Glacier, which comes down from the slopes of Mount Wrangell, but beyond this glacier it is hidden by recent flows of andesite. Southeast of the Kotsina the limestone is found at various localities, which can not be connected upon the surface, since there are overlying unconformable deposits on the higher mountains, but the main outcrop may be traced toward the southeast to the divide between Rock Creek and the Kuskulana, and thence in the mountains which lie between Strelna Creek and Kuskulana River the formation is prominent. It is thought that the limestone may also occur on the southwestern slopes of the mountains beyond, where the Kuskulana comes out into the open basin of the Chitina Valley, but no observations have been made in this vicinity. At a point a mile or so above Trail Gulch, on the east side of Kuskulana River, the limestone appears, and, rising rapidly above the massive Nikolai greenstone, soon reaches the tops of the mountains lying south of Kuskulana Glacier. East of the first prominent creek on the south side of the eastern fork of Kuskulana Glacier observations have not been made, but from the distant view obtained of the upper part of the drainage it seems that the massive limestone is not present. Its absence must be explained through folding or faulting, the nature of which could not be ascertained. The limestone appears again on the east side of Lakina River above the lower end of the glacier, where it rises rapidly toward the northeast, and while probably it connects directly with the exposures on the west side of the Kennicott drainage, it has not been so represented on the map because of the lack of sufficient observations. On the east side of the mountains between Lakina and Kennicott glaciers the limestone is very well exposed and, dipping slightly toward the north, appears in the mountain between the first forks of the glacier, and again across the eastern fork about 7 miles above the foot of the glacier. From this place the massive stratum can be traced across McCarthy Creek to the head of

Nikolai Creek and to Nizina River. In the region between Kotsina River and the Lakina the general dip of the formation is southward, but from the Kennicott to the Nizina the structure is in the opposite direction, the dips varying from 20° to 60°. This structure is indicative of an anticlinal axis having a general northwest-southeast direction.

East of Nizina River the structure is more complex, and while the dips are not so steep the simple anticlinal structure gives place to a series of broad folds at times showing quaquaversal dips, so that erosion has revealed the underlying greenstone at various places both along the Nizina and on the tributaries which join it from the east. A view of the drainage basin of Skolai Creek shows the limestone rising gradually toward the White River divide, with the greenstone lying in the valleys. At the mouth of Chitistone River the limestone comes to the valley bottom on the north side, while on the south it is from 1,000 to 1,500 feet higher, and between the forks the greenstone reaches to the top of the mountain. From the lower side of the Chitistone the formation may be traced along the side of the mountain until the upper part of the creek which joins the Nizina at Nikolai House is reached, where the rocks are seen to be descending. The character of the contact between the limestone and the underlying volcanic series is illustrated in Pl. VIII, *B*, which also exhibits some of the structural features that have been mentioned.

Southward from the stream which joins the Nizina at Nikolai House the limestone is not found, and it seems necessary to suppose that its absence is due to a fault which follows the general course of this tributary. The mountains to the south are composed of black shales intruded by igneous dikes, and are supposed to belong to the Triassic series lying west of the Nizina. The same series is found south of the belt of greenstone without the occurrence of the limestone between, so that it seems probable that the supposed fault extends toward the west at least as far as Lakina River. The general line of the displacement has been represented on the geological map.

The limestone is known to extend to the east as far as the limits of the map, and its characteristic contact with the greenstone was made out by Mr. Witherspoon, the only one of the party who visited this region.

Along the base of the mountains north of Chitina River, above its junction with the Tana, limestones are exposed, which were observed only at a distance. It seems possible, from the general structural relations, that these limestones represent the Chitistone formation, and they are so shown on the map, although it is possible that they are calcareous beds developed in the Triassic shales.

In the geological investigations in the Wrangell district the limestones of the Carboniferous have been traced with practical continuity from Kotsina River on the west to Skolai Pass on the southeast.

Beyond the Nizina-White divide the same limestones have been reported by Dr. Hayes[1] and Mr. Brooks.[2]

*Thickness of Chitistone limestone.*—Studies of the Carboniferous and Triassic strata of the Wrangell district have not been sufficiently detailed to afford evidence as to where the line between these two formations should be drawn. Above the massive basal series of limestones there is a series of thin-bedded limestones with shaly partings, which is apparently in perfect conformity with the underlying beds and which passes by gradation into the black shales above. These black shales contain the fossils by means of which the Triassic age of the formation has been determined. The provisional and arbitrary line between the two formations has been placed at the top of the massive limestone series. The thickness of the Chitistone formation as thus defined is somewhat variable. Its maximum development is probably in the region of Nizina River, where it reaches a thickness of approximately 2,000 feet. In the Kotsina and Strelna region its thickness is somewhat less, but it can not be made out that there is any progressive thinning toward the west.

*Age of the limestone.*—No determinable fossils were secured from the Chitistone limestone during the study of last summer. The formation is, however, certainly to be correlated with similar massive limestones in the vicinity of Skolai Pass and on White River, as observed by Hayes and Brooks. In the latter region fossils were collected which show the limestone to be of Carboniferous age, and upon this determination rests the present knowledge of age relations.[3]

## TRIASSIC SERIES.

*Description.*—The rocks which have been included in the Triassic series comprise all the strata that lie above the Chitistone limestone and below the unconformable Kennicott formation of Jura-Cretaceous age. In the lower part, and resting conformably upon the Carboniferous limestone, is a series of thin-bedded limestones, in strata from a few inches to a foot or more in thickness, supported by thin partings of black shale. The thickness of this member is approximately 1,000 feet, and the limestone, so far as observed, did not contain fossil remains. Above the thin-bedded limestones, and sharply defined from them, are black shales containing occasional bands of impure limestone, locally affording fossils from which the age of the formation has been determined. The thickness of the upper member of the Triassic is very great, possibly more than 3,000 feet, but no opportunity was afforded for its direct measurement, since its occurrence as the surface

[1] An expedition through the Yukon district: Nat. Geog. Mag., May 15, 1892, Vol. IV, p. 140.

[2] A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the Upper White and Tanana rivers, by Alfred H. Brooks: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, 1900, p. 359.

[3] Loc. cit., p. 359.

*A*. HEAD OF NIKOLAI CREEK.

Base of Kennicott formation is shown in foreground and Chugach Mountains in background.

*B*. CONTACT OF NIKOLAI GREENSTONE AND CHITISTONE LIMESTONE.

West side of Nizina River, near Nikolai mine.

formation beneath strata lying unconformably upon it, together with the attitude which it has assumed as the result of folding and faulting, renders its relations complicated and obscure. A few thin flows of greenstone, similar to that of the Nikolai series, were observed here and there, interbedded with the black shales of the Triassic. The Triassic series may be easily recognized from its general homogeneous nature and the fine-grained character of its black Carbonaceous shales.

Locally the thin-bedded limestones are very intricately folded and contorted, a feature which is well shown in the ridge formed of Triassic rocks at the head of Gilahina Creek, and illustrated in Pl. VII.

*Occurrence and distribution.*—The Triassic rocks are found dipping toward the southwest in the Kotsina region, and may be traced in a continuous band southwestward to Kuskulana River and from the east side of that stream to Lakina River and thence to the Kennicott and Nizina. East of the Nizina they occur principally in the region south of the great fault which limits the Chitistone limestone, and in the region south of the Nizina the black shales reach across Chitina and Tana rivers and come in contact with rocks of the Valdes series. Their occurrence in the vicinity of Skolai Pass is reported by Hayes.

The Triassic rocks lie in a band a few miles in width between the outcrops of the Chitistone limestone and the older metamorphosed Valdes rocks, which, with their intruded masses, occupy the valley of the Chitina and the region of the Chugach Mountains. The structural relations by which these two formations come to be in contact are not understood. There is perhaps an overlap of the Triassic shales onto the Valdes rocks, or—equally possible—profound faulting by which the Carboniferous limestones have been cut out and the Triassic beds overthrust onto the Valdes series.

In the region south of the fault and east of Lakina River, and again east of this region as far as the mountains beyond the Nizina, the Triassic shales are very intricately included by dikes and sheets of porphyry.

*Fossils of Triassic series.*—Only two recognizable fossil forms have been determined in the material which was collected from the Triassic beds, but these are considered sufficient to fix definitely the age of the series. Dr. T. W. Stanton, of the Survey, reports the following forms of Upper Triassic age: *Monotis subcircularis* Gabb and *Daonella* like *D. lommeli* Wissmann.

## DISTURBANCES FOLLOWING DEPOSITION OF TRIASSIC.

The formations next younger than the Triassic shales in the Copper River region were deposited at the close of the Jurassic or the beginning of the Cretaceous—that is, at a time corresponding to the deposition of the Knoxville beds of the northwestern United States. These latter rocks are unconformable upon the Triassic and older formations, and previous to their formation the older rocks had been folded and raised above the sea and their upturned edges reduced by the process of erosion. The close of Triassic deposition in the western and southwestern portions of the continent has been very generally recognized as a period of mountain building and of geological revolution. It is supposed by Dawson that at this period the Vancouver and coast ranges of British Columbia were outlined, and that there was probably at the same time some corrugation along the line of the Rocky Mountains.[1] The result of this disturbance in the Wrangell district was the production of the broad folds which have been recognized from the attitude of the Nikolai greenstone and the overlying sediments. The period of erosion which followed the uplift and folding was a very long one, since the amount of rock removed must necessarily have been measured by several thousand feet.

The general trend of the folds in the Triassic and Carboniferous rocks is parallel with the structure of the adjacent Valdes series. This older structure is very uniform throughout the whole region from the coast to Copper River, and it is only natural that the recurrence of dynamic action in the region should have produced structures in accord with the lines of weakness that were developed at a very early date.

The Nikolai greenstone and the sedimentary formations which lie unconformably above it are at present found to be considerably jointed and cut by fissures, the latter frequently containing quartz veins with or without metalliferous deposits. It is probable that this fracturing of the rocks was produced during the post-Triassic disturbance, though it is reasonable to suppose that subsequent movements which must have accompanied the volcanic phenomena of the region may have caused additional fracturing and folding of the rocks.

It is believed that the eruptive phenomena of the Wrangell region may have begun during this period of disturbance, but there is no evidence to show that the intrusion of the Triassic shales occurred at this period rather than at a much later date, when, as is known, volcanic forces were very active.

## KENNICOTT FORMATION.

*Description.*—The strata which, on the evidence of fossils, have been assigned to the Upper Jurassic or Lower Cretaceous consist of a variable series of conglomerates, sandstones, limestones, and shales. The formation lies unconformably upon the upturned edges of the older rocks, resting at times upon the Nikolai greenstone, the Carboniferous limestone, and the shales of the Triassic. In places

[1] On the late physiographic geology of the Rocky Mountain region in Canada, with special reference to changes in elevation and to the history of the Glacial period, by George M. Dawson: Trans. Royal Soc. Canada, Vol. VIII, 1890, sec. 4, p. 6.

*A.* CASTLE MOUNTAIN.

Looking N. 60° W. from ridge between Gilahina Creek and Lakina River.

*B.* MOUNTAINS ON SOUTH SIDE OF KOTSINA RIVER, OPPOSITE SURPRISE CREEK it appears that these older formations were completely leveled by erosion previous to the deposition of the Kennicott formation, but elsewhere the relations, though obscure, are indicative of the probability that deposition took place in narrow, deep lagoons.

At the base of the formation there is usually a conglomerate or coarse sandstone composed of materials derived from the greenstone and from the limestones and shales, with an admixture of quartz sand. Above this there are alternations of green sandstone with black shales, and occasionally bands of limestone, in places containing considerable sand.

*Occurrence and distribution.*—The northernmost known occurrence of the Kennicott formation is at the head of Limestone Creek between Clear and Kluvesna creeks. Here the formation is in contact with the Carboniferous limestone and with the Triassic shales. South of this there is an outlier resting upon the shales, forming the top of a high peak between Clear Creek and Kluvesna Creek north of Kotsina River. South of the Kotsina the formation is found usually capping the highest ridges, where it rests upon the Triassic or locally upon the Carboniferous or the still older greenstone. From the ridge between Sheep and Copper creeks there is considerable cropping of the formation, which extends continuously to the divide between Rock and Strelna creeks, and again there is a considerable thickness in the high mountains at the head of the south fork of Strelna Creek.

As viewed from a distance the high ridge between the north fork of Kuskulana Glacier and the eastern drainage of the Kotsina appears to have a capping of sedimentary rock resting upon the greenstone, and though this region has not been visited it seems probable that the Kennicott formation may occur in these high peaks. To the east of Kuskulana Glacier it first appears in the bed of Trail Gulch, at an elevation of about 2,200 feet, and may be traced eastward for a distance of about 3 miles. In this locality the formation affords fossil remains. It does not appear again west of Lakina River, but to the east of that stream, in the drainage of Fohlin Creek, it attains considerable development, having a thickness which possibly reaches a thousand feet or more. In this locality and in the last it seems as if the formation was deposited in a submerged valley, the sides of which had considerable height above the level of the water.

East of Kennicott River the Kennicott formation occurs at the head of Nikolai Creek, where its general relations to the topography and to the Triassic formations are shown in Pl. VIII, *A*. The sloping strata in the middle of the photograph are the sandstones of the basal portion of the Kennicott formation, while the deep trenches cut through them into the underlying limestone and greenstone. The mountains in the distance are composed of Triassic shales, with igneous intrusions, which have protected the mountains from erosion.

Beyond the Nizina the formation is found capping the shale ridge between Young Creek and the Chitina.

*Age of Kennicott formation.*—The age of the Kennicott formation has been definitely determined by Dr. T. W. Stanton, who has studied its fossils and proved their general correspondence with the fossils of the Knoxville formation of northwestern United States. This places the formation in the doubtful series lying at the top of the Jurassic or at the base of the Cretaceous. The following forms have been recognized:

| | |
|---|---|
| Inoceramus eximius Eichwald? | Aucella pallasi Keyserling? |
| Belemnites sp. | Lytoceras sp. |
| Halobia occidentalis Whiteaves? | Hoplites sp. |
| Rhynchonella sp. | Olcostephanus? sp. |
| Pecten sp. | Gryphæa sp. |
| Avicula sp. | Sagenopteris sp. |

Concerning *Inoceramus eximius*, Dr. Stanton says:

This form is represented by a single specimen collected on Chitty Creek. It may be distinct from Eichwald's species originally described from Turkusitun Bay in Cook Inlet and referred by him to the Neocomian. Eichwald described three other species—*I. ambiguus*, *I. porrectus*, and *I. lucifer*—all belonging to one section of *Inoceramus*, from the same horizon in Alaska. The present shell does not agree perfectly with any of the figures, but it is most nearly like *I. eximius* and probably comes from the same formation. Similar forms occur both in the Jurassic and in the Cretaceous, but the evidence of the other fossils from this part of Alaska favors the reference of the Kennicott formation to the Jurassic.

Of the form referred with a question to *Halobia occidentalis*, Dr. Stanton says:

The specimens agree fairly well in sculpture and general appearance with some of the figures of Whiteaves's species from the Liard River, and may be identical with it. They are, however, somewhat suggestive of *Hinnites linæensis*, from the Jurassic (?) of Siberia.

*Sagenopteris* is a genus which occurs both in the Jurassic and in the Cretaceous, but the species is thought by Professor Ward, to whom it was shown, to be near a species occurring in the Jurassic of the Pacific coast.

Concerning the general relations of the fossils from the Kennicott formation, Dr. Stanton observes:

These fossils are all either Upper Jurrassic or Cretaceous, with a suggestion of a somewhat younger age for a few localities. In the present state of knowledge, and with these small collections, it is not practicable to determine whether they represent one horizon or several. In my opinion, they probably all belong to the Upper Jurassic, though subsequent work may show the contrary. The question is connected with the still unsolved problem of the exact boundary between the Jurassic and the Cretaceous in the Aucella-bearing beds of Russia, Siberia, and the Pacific coast region of North America. The *Aucella* occurring in the Copper River district appears to be referable to a Russian Jurassic species, but it is also quite similar to the Cretaceous form in the Lower Knoxville beds of California. The few other forms are mostly undescribed species of types that occur both in the Jurassic and in the Lower Cretaceous.

## POST-KENNICOTT DISTURBANCE AND EROSION.

After the deposition of the Kennicott formation the region seems to have been uplifted from its previous low position with reference to the sea and to have suffered a slight deformation, which gave rise in great part to the present slightly inclined attitude of the rocks that were deposited not long before its initiation. In respect to the amount of folding produced this uplift was of much less importance than the earlier disturbance which caused the folding of the Triassic and Carboniferous formations. It seems to have been a regional uplift without very much of the deformation which comes from lateral pressure.

The uplift which followed the deposition of early Cretaceous time seems to have been regional in its extent, and may be supposed to have affected all of the area between the present Wrangell Mountains and the coast and to have raised a large continent from the waters of the sea. The limits of the uplift can not be determined, but it was followed by a period of erosion during which the streams that developed upon the new land surface were able to reduce the land very nearly to sea level. The events of this period are more fully discussed in another place.[1]

Before the completion of this cycle of erosion a period of volcanic activity was commenced which very materially altered the character of the topography by the upbuilding of immense piles of lava and of volcanic tuffs.

## TERTIARY VOLCANIC SERIES.

*Description and occurrence.*—In the region about the head of Nizina River, extending westward to Mount Blackburn and eastward into the Skolai Mountains, there is a series of bedded volcanic rocks made up of andesites, rhyolites, and strata of pyroclastic origin. The main distribution of these rocks is in the region which was not penetrated during the explorations of 1900, but a sufficiently extended view of the upper basin of the Nizina was obtained to indicate the relations which the series bears to the older sedimentary and igneous rocks. The character of the materials is shown by the débris occurring upon Nizina Glacier. A single outlier, which is undoubtedly to be correlated with the series, lies north of the trail opposite the pass east of Kuskulana River. The general relations of the volcanic series in the Nizina region are shown in Pl. X, *B*.

Standing upon the high, shaly ridge between McCarthy Creek and Nizina River and looking toward the north and the east, one sees that the black Triassic shales, with the massive limestones of the Carboniferous beneath them and the greenstone still underlying, are folded in broad arches or domes, and that these structures have been eroded

[1] See page 64 et seq.

to a general uniform surface, and upon this surface a series of rocks has been nonconformably deposited. Assuming, as seems allowable, that these rocks were deposited in a nearly horizontal position, it is evident that there has been some deformation since they were laid down, as there is a general dip of the stratification toward the north, so that the series rising toward the south and east disappears where the underlying formations come up to form the tops of the range. Volcanic rocks, the description of which answers very well to that of this series, were mentioned by Rohn as occurring in the region at the head of the Nizina and the Tanana, also along the northern edge of the St. Elias Range; and an important volcanic series on Nabesna River has been described by Brooks.[1]

The rocks of the series are said to include rhyolitic, andesitic, and basaltic types. A similar series of volcanic rocks is known to occur along the northern front of the St. Elias Range.

*Thickness of volcanic series.*—No accurate determinations of the thickness of the volcanic series were possible, but from photographs showing its occurrence it is estimated that it can not be less than 3,000 feet in its maximum development.

The attitude of the series in the Nizina region is illustrated by Pl. X, *B*, which is a drawing based upon photographs. The point of view is the high shaly ridge west of Nizina River, and Nizina Glazier with its tributaries and the neighboring mountains are shown.

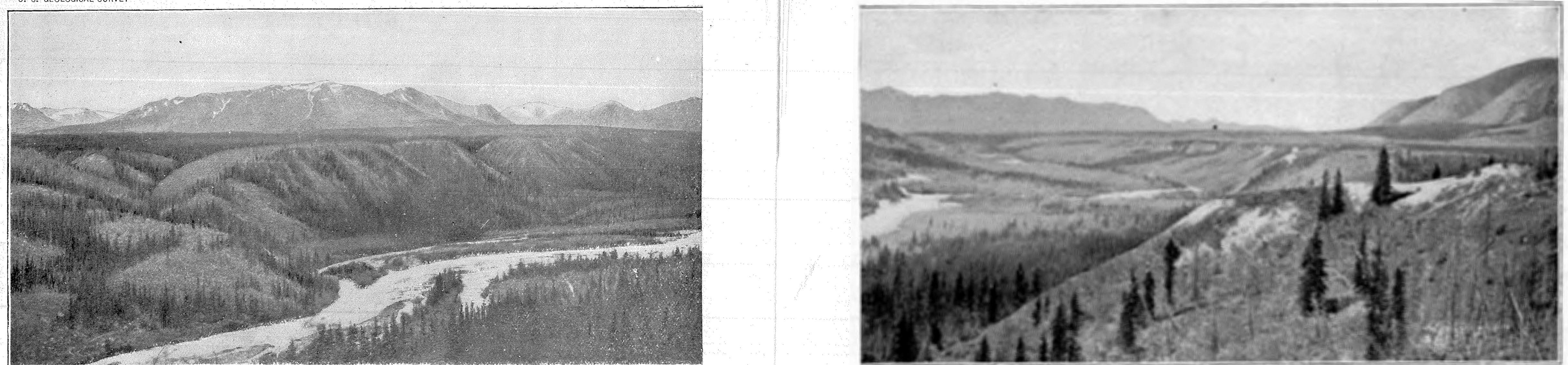
*Age of volcanic series.*—In the description of the topographic development of the Copper River region it will be shown that the land surface which was produced through the process of erosion previous to the formation of the volcanic series had its origin some time during the Tertiary, and with this conclusion as a basis it may be concluded that the age of the volcanic series is also Tertiary. There is, however, no criterion for determining the exact portion of the period to which its formation belongs, though it is doubtless later than the Eocene. Brooks shows that the volcanics of the St. Elias Range are probably of Tertiary age.[2]

## IGNEOUS ROCKS.

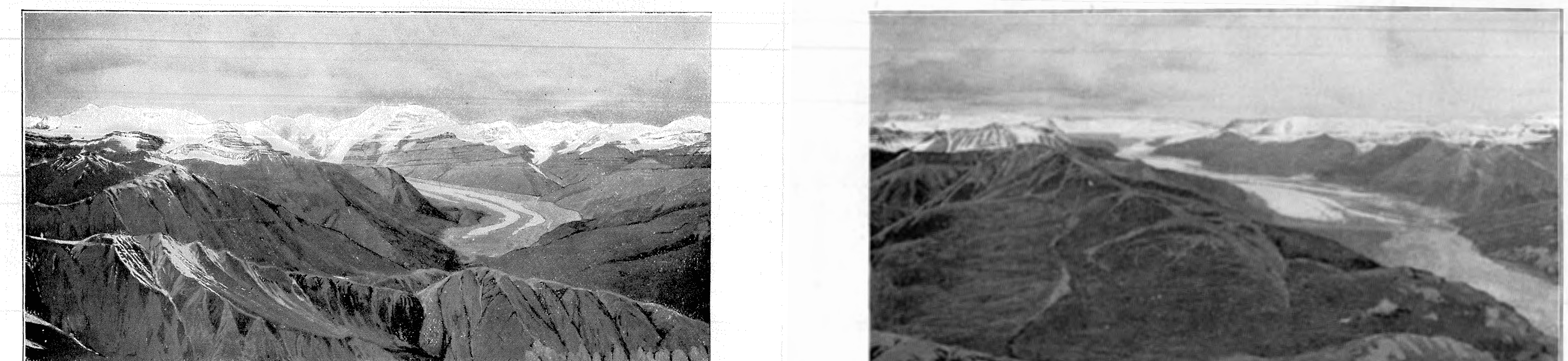
The igneous rocks of the Copper River district show a considerable variety of types, but since no exhaustive study has been made of them, only the most general descriptions can be given in this place. In the discussion which follows they will be grouped according to their occurrence in the larger geological divisions of the sedimentary rocks. Their representation on the geological map is in no sense detailed, since the various granular rocks are not distinguished by distinct colors but are

[1] A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the upper White and Tanana rivers, by A. H. Brooks: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, 1900, p. 362.

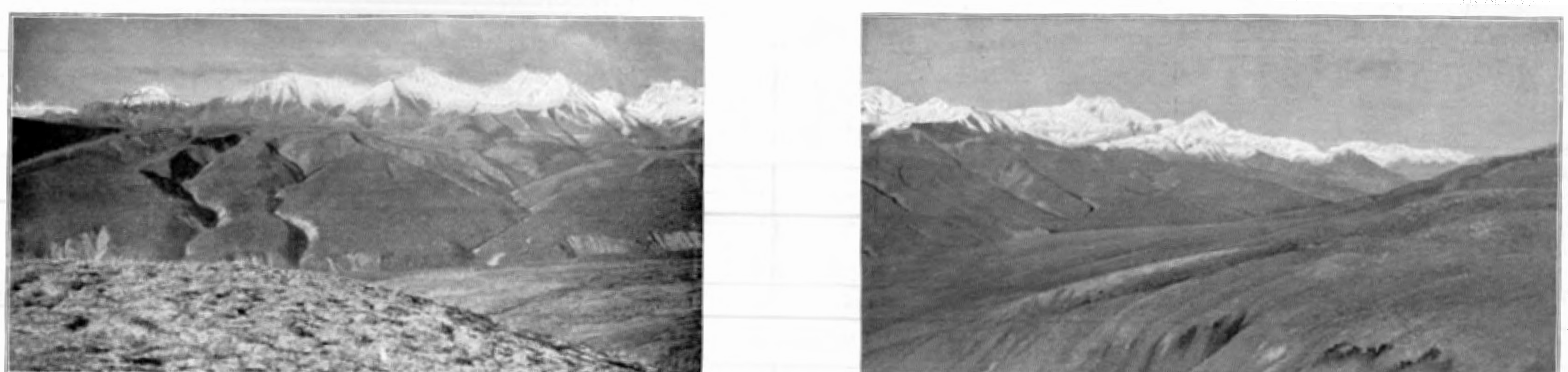
[2] Loc. cit., p. 363.



*A*. VALLEY OF TONSINA RIVER, LOOKING INTO CHUGACH RANGE, FROM RIVER BLUFF BELOW TONSINA BRIDGE.



*B*. NIZINA GLACIER FROM RIDGE AT HEAD OF NIKOLAI CREEK, SHOWING ALTITUDE OF THE TERTIARY VOLCANIC SERIES ABOVE THE OLDER SEDIMENTS.



*C*. MOUNTAINS EAST OF NIZINA RIVER, LOOKING N. 25° E. FROM RIDGE SOUTH OF YOUNG CREEK.

separated by initial letters. The intruded rocks of a porphyritic nature have been given a distinct color, and the same has been done for the andesites, though no attempt has been made to separate those of intrusive and of extrusive character.

*Intrusive rocks in Klutina series.*—The highly metamorphosed series of rocks which occurs between Tana and Chitina rivers, and which is supposed to correspond in age with the old rocks that occur near Klutina Lake, are cut in a most intricate manner by dikes and irregular beds of granite and granite-porphyry, but no detailed study of them has been made.

*Greenstone-schists.*—Probably the oldest intrusive rocks in the Copper River region, aside from those in the Klutina series, are the sheared greenstones seen in the Copper Mountain masses on Prince William Sound, and in the green schists which cross the Copper River at Wood Canyon. In the Copper Mountain rock local patches are found which retain the original character of the rock sufficiently to show that it was once a fine-grained diabase, but at Taral the original nature of the rock has been entirely destroyed. It is not certainly known that these rocks are actually of an intrusive nature, since in many cases rocks originally of similar character are evidently interbedded with stratified rocks in which they occur, and therefore have the nature of surface flows. However this may be, the rocks from which these schists have been derived are evidently older than the metamorphism of the Orca series, which is shown by their having been affected by similar changes in structure, brought about through crushing and shearing.

*Intrusive rocks in Valdes and Orca series.*—Massive granular rocks occur somewhat generally in the Valdes and occasionally in the Orca series, and as they are seldom found in a greatly metamorphosed condition they are supposed to have been introduced since the production of the magmas which affect the Valdes and Orca rocks. These igneous rocks are of considerable variety, when regarded from the standpoint of their mineralogical composition and structure, but for the purpose of the present geological discussion they may be grouped in three classes: The first consists of typical coarse-grained gabbro grading structurally into coarse diabase; the second is made up of rocks of types grouped about a more or less typical granite; the third class is diorite. The gabbros of the first class are coarse-grained rocks, made up of broad, irregular grains of augite, with some greenish-brown hornblende intercrystallized with feldspar, which is labradorite or bytownite. Magnetite is also present in considerable amount as an accessory constituent. Variations of structure are frequent, by which the ordinarily granular rock passes into an ophitic phase in which the augite is sharply defined against the well-individualized laths of feldspar.

Gabbros of the ordinary type have been observed along the base of the foothills in the vicinity of Kotsina River, and a large mass of them forms the mountains between Lakina and Chitina rivers. They are to be found at various points along the Hanagita trail, and also show considerable development in the lower part of the Chitina Valley, where they have been found to carry veins of copper. In Prince William Sound gabbro having an ophitic structure was observed on Glacier Island.

Locally the massive gabbros occurring in the Valdes rocks are jointed, and in some cases they have been sheared into a greenstone-schist which is indistinguishable from the greenstone-schists that are elsewhere known to have been derived from basalts or diabase. Schistose character, however, is not commonly observed, and its production in the massive rock must be considered as of later origin than the foliated structure of the older sedimentary rocks. Copper-bearing veins are known to occur in gabbro from float material found upon Kuskulana Glacier, but have not been observed in place.

Rocks of the granite class have been observed at several points. They are characterized by the occurrence of brown biotite with orthoclase and plagioclase in varying amounts. In some specimens the plagioclase is in excess, while in others the orthoclase seems to be principally feldspar. Besides the orthoclase a portion of the unstriated feldspar frequently appears to be anorthite, and the plagioclase often has the characteristic of oligoclase. The presence of these minerals is indicative of a large amount of soda in the composition of the rocks, and to test the inference, gained from their study under the microscope the following analyses were made by Mr. George Steiger in the chemical laboratory of the Survey: Analysis No. 1 is of a specimen collected on Glacier Island; No. 2 is from the moraine of Miles Glacier, and is similar to the granite occurring on Point Nowell and to the specimens collected from bowlders in the drift of Tana River.

*Analyses of granites from Glacier Island and the moraine of Miles Glacier.*

| | No. 1. | No. 2. |
|---|---|---|
| $SiO_2$ | .......... | 66.51 |
| CaO | 2.54 | 4.58 |
| $Na_2O$ | 9.19 | 2.82 |
| $K_2O$ | .22 | 1.69 |

The only occurrence of diorite which has been noted in the metamorphic rocks is on Glacier Island, where it is found in contact with diabase, but the extent of its distribution has not been made out. The rock is granular and of medium coarseness. It consists of andesine, with small grains and prisms of uralite, between which there are

*A.* JOINTED ANDESITE LYING UPON TILL.

South of Kotsina trail, about 5 miles east of Copper River.

*B.* HANAGITA VALLEY, LOOKING DOWN SOUTH FORK OF TEBAY RIVER.

Showing character of erosion in deep glacial deposits.

aggregates of quartz with possibly a small amount of orthoclase. The rock may be called a quartz-diorite.

Throughout the Chugach Mountains the Valdes rocks are occasionally cut by small dikes of a light-colored, fine-grained rock, which is usually very much altered from its fresh condition. In the specimens which have suffered the least change the rock is found to be made up of unstriated feldspar showing the zonal growth, with a smaller amount of uralite and mica in narrow crystals, and with a dense, stony groundmass of indeterminable character. The feldspar of the phenocrysts is probably albite and the rock is a rather unusual type, but further discussion of its characteristics must be deferred until a more complete petrographic study has been made.

When seen in place the white rock of the dikes contrast sharply with the darker schists and arkose sandstones of the Valdes series. Occurrences of such dikes are known on the rocky islands near the head of Port Valdes, along the Military trail near Keystone Canyon, and along Copper River above the mouth of the Tonsina. Its more general distribution is known from the observance of bowlders in the stream gravels of the rivers that drain the Chugach Mountains.

*Granular rocks in the unmetamorphosed sediments.*—The intruded rocks which occur in the unmetamorphosed sediments of the Wrangell region also consist of gabbros, granites, and dioritic rocks, and in addition there is a large cross-cutting mass of andesite which forms Castle Mountain. The rocks are, however, quite distinct in petrographic character from the rocks of similar names which have already been described.

The gabbro in the Mount Wrangell district is confined, so far as known, to three small areas: One in the Kotsina region between Long Glacier and Kluvesna Glacier, another at the head of Nugget Creek north of Kuskulana River, and the third just above the forks of Strelna Creek. The rocks of these three localities belong to the same type, but show minor variations. The gabbro occurring in the vicinity of Long Glacier is a coarse-grained rock, consisting of a very basic plagioclase, probably bytownite, and augite in large irregular grains. With the augite there is a small amount of brown hornblende, which is probably original. Magnetite occurs in large grains. In the gabbro of Strelna Creek there is some interstitial micropegmatite, which is probably of secondary origin.

A rock which is similar to these gabbros, but which has in addition to the minerals which they contain a considerable amount of brown mica, was noted in the vicinity of the crossing of the main Chitina and the Kotsina trails. Here, in the walls of the canyon, there is a coarse-grained granular rock made up of andesite, diallage, hypersthene, and a considerable amount of dark-brown biotite. The relations of this rock are rather unusual, since it is a granular rock cutting glacial gravels.

The only granite which has been noted in the Wrangell Mountains is located somewhere in the drainage of the second Kotsina Glacier. Its presence is known only from a specimen collected from the moraine. It is a fine-grained rock composed of biotite with some plagioclase.

On the north side of the main tributary of Kotsina River, near Surprise Creek, there is a mass of diorite which varies considerably in character from place to place. In some parts the rock is practically granular, while elsewhere it becomes porphyritic. It is composed essentially of abundant thick prisms of plagioclase, which is probably andesine, while between these prisms there is a sort of groundmass composed of orthoclase and quartz. Biotite and hornblende occur in irregular grains and imperfect prisms. The rock is related to granodiorite, but may be called a quartz-diorite.

A porphyritic phase of diorite occurs along the west side of Kuskulana Glacier, below the forks, though this mass has not been represented on the map. The broad dike which is represented as crossing the mountain mass between the forks of Kuskulana Glacier is supposed to have the same character.

*Porphyries in the unmetamorphosed sediments.*—Besides the granular or nearly granular rocks already considered, there is a considerable variety of porphyritic rocks occurring in dikes and irregular masses in the black shales of the Triassic formation and in the shales and sandstones of the Kennicott series. These rocks are rather generally distributed from the vicinity of Kuskulana River eastward as far as our observations extended. They are well shown in the shale series on either side of Kennicott River, and it is to the resistance which the intruded rocks have presented to erosion that the mountains of this vicinity owe their preservation. Some less important occurrences are observed in the valley of Young Creek and as far toward the south as Chitina River. Pl. VI, *B*, is illustrative of dikes of fine-grained porphyry cutting the black shale in the walls of Young Creek.

On the map the intricate intrusion of the shales is represented in a diagrammatic way to indicate the character of the intrusions rather than the actual occurrence of the cross-cutting beds.

The porphyries of the class here under consideration are always much altered, so much so, indeed, that it is very difficult to determine their exact nature, but it may be seen that they are all not identical, though they are probably closely related throughout. They are mostly diorite or quartz-diorite-porphyries, judging from the aggregates of altered minerals which now make up their mass. They vary in grain from cryptocrystalline to porphyritic with stony groundmass.

These porphyries are, in part at least, later than the Kennicott formation, of Jura-Cretaceous age, for they are found cutting this series in the region between Lakina and Kennicott rivers, and dikes of porphyry cut the bedded volcanic series east of Kuskulana River, and in the Nizina region there are masses of unknown character cutting across the volcanic series. It appears that in general the intruded rocks have been injected at comparatively recent dates, although there are no data for determining the priority of one or the other of the different types of rock. It may be that the porphyries were intruded during the period of folding which preceded the deposition that took place in Jura-Cretaceous time, but, so far as the evidence goes, it may be that they were introduced after the deposition of the Tertiary volcanic rocks.

*Andesite cutting the Triassic.*—The mass of Castle Mountain is composed of a dark andesite, similar to that which forms the surface flows of the Wrangell region. On the western side of the mountain the contact with the shales and crumpled limestones may be clearly distinguished by the contrast between the dark-colored andesite and the sedimentary rocks which have been bleached and whitened through contact metamorphism. The appearance of Castle Mountain and the andesite contact is illustrated in Pl. IX, *A*. Looking at Castle Mountain from the southeast, one sees the contact running in a zigzag course down the ridge on the left side, as shown in the picture, and again with less distinctness at the right, which is at the base of the steep cliff.

*Intrusive rocks in Tertiary volcanic series.*—The occurrence of dikes of diorite-porphyry in the volcanic series has already been noted, and aside from this the only knowledge of cross-cutting massive rocks has been gained from a distant view of the region lying east of Nizina River, between Chitistone River and the first creek flowing into the Nizina. Above the foot of the glacier there is a mountainous mass which shows the topographic characters that are common in the case of massive rocks, and this mass is in part surrounded by the flows and tuffs of the volcanic series. This occurrence is the only evidence of the post-volcanic date of the intrusive rocks, and it must be admitted as incomplete.

*Andesite flows.*—The recent lavas which occur on the southern and western slopes of Mount Wrangell are typical hypersthene-andesites, composed of plagioclase at least as basic as labradorite, much hypersthene in sharply outlined phenocrysts, and a small amount of augite. Olivine is sometimes present. The groundmass varies from glassy to finely crystalline. In color the andesites vary from red to gray and black, and in texture from vesicular to close-grained porphyritic.

The age of the andesite is Pleistocene and Recent. The form of Mount Wrangell is the result of successive lava flows, by which its cone has been constructed. The great sheet of andesite to the north of the Kotsina drainage lies above the mass of the Pleistocene, but gravels are found resting upon it locally and glacial scoring is also observed, so that at some time since the most important outflows glaciation must have been more extensive than at present.

The edge of the lava flow forming the plateau north of the point at which Kotsina River emerges from the mountains seems unquestionably to have been in contact with the side of a glacier which extended outward from the upper valley at the time of the eruption. The same conditions may be suggested along the north side of Long Glacier.

The distribution of the andesite as represented on the map is only approximate, and underneath the latest gravels the lava undoubtedly has a much greater extent than is indicated, and over much of the area where it is represented gravels may be found above it.

Just north of Long Glacier the thickness of the andesite is several hundred feet, while at the edge of the flow, in the neighborhood of Chetaslina River, it is less that 150 feet, and where it reaches Copper River and at the crossing of the Nikolai trail on Kotsina River it is less than 50 feet.

## PLEISTOCENE AND RECENT DEPOSITS.

*Description.*—The great basin of the Upper Copper River is floored by a Pleistocene terrane made up of heterogeneous materials. It is composed of unconsolidated gravels, bowlder beds, and fine-grained silts. No complete study of these deposits has been made, but they have been observed along Klutina and Tonsina rivers and along the course of Copper River from Copper Center to Taral. In the observations made during the summer of 1898 Schrader seemed to find evidence that the materials were much finer in the central portion of the basin than at the edges, and upon this basis he concluded that the Pleistocene deposits were formed in a large body of standing water with encroaching glaciers furnishing gravel and bowlder clay around the edges of the basin, while the finer silts that were contributed by the glacial streams were naturally deposited at a distance from the shore. The more extended observations of last summer show that no such general relations of distribution are to be made out, but that the fine-grained silts where they seem to form the principal thickness of the basin terrane probably occupy rather limited areas and occur surrounded by coarser deposits which are not related to them as they would be upon the hypothesis of glacial streams entering a large body of water.

Along the course of the Military trail, on the south side of Mosquito Creek some 6 or 8 miles above the Tonsina bridge, banks of blue bowlder clay are exposed which are undoubtedly of glacial origin. From this point to the neighborhood of Tonsina River there are no exposures which are sufficiently good to give any clue to the character of the surface formation, but in the banks of the creek that joins the Tonsina at the bridge there is exposed a bluff, about 500 feet in height, composed of homogeneous stratified silts. At a distance of 1 mile below the bridge the upper part of the bluff, here some 600 feet in height, also exhibits fine-grained materials; but above these and forming the top of the neighboring table-land there are gravels mixed with finer materials. Still farther down the river there appears a deposit of true till, having a thickness of 20 feet and lying above a much greater thickness of cross-bedded sands and clays. In this till there is much material of volcanic origin, and in places the formation becomes composed mostly of andesitic fragments which may well be taken for volcanic bombs rather than for fragments that have been derived from any massive rock formation.

The stream gravels along Tonsina River are composed of a considerable variety of rocks, but the most prominent among them are andesites and porphyries, similar to those which occur in the Mount Wrangell district. With them there are also bowlders of gabbro, granite, and diorite, with occasional limestones. It is believed that the occurrence of these rocks is indicative of their origin in the Wrangell district and of their transportation across the Copper Basin, through the instrumentality of glacial ice.

Along the west bank of Copper River, from the vicinity of the Tonsina as far north as the mouth of the Chetaslina, typical glacial till forms the principal masses of the basin terrane, as shown in the banks of the river. The gravels and silts are of minor importance, but in the upper part of the bluffs there is a stratum composed very largely of volcanic materials, similar in all respects to that mentioned as occurring below the Tonsina bridge. A like deposit is found in the banks of the Chetaslina for a distance of about 5 or 6 miles, or as far as the observations were extended. It seems possible that a detailed study of the basin terrane would reveal a definite succession of events in the Pleistocene history of the region, but the data at present available are not sufficient for working out any such scheme.

In the relations exhibited along Chetaslina River an important event is recognized in the extrusion of andesite, which there rests upon the till and gravel. It is only a short distance below this lava that the deposit of fragmental volcanic material occurs, and here the character of the material is again very suggestive that it may have been distributed over the region directly by volcanic action, in the form of bombs thrown from a crater. It is thought that the occurrence of the andesite immediately above this deposit is in general corroborative of this view.

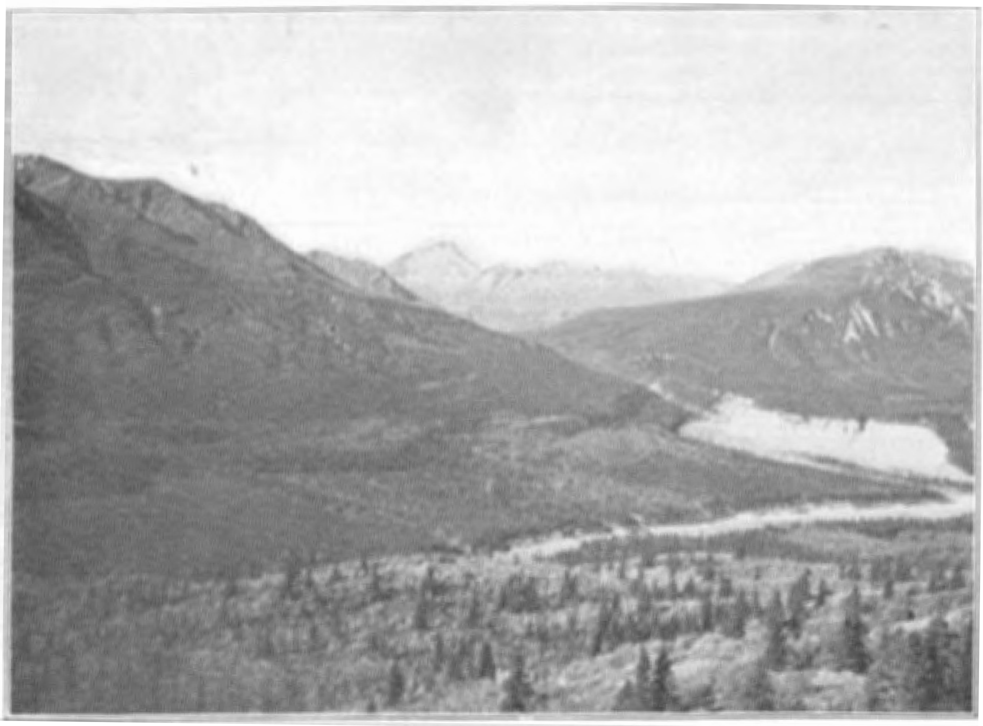
Below Tonsina River, on the east side of the Copper, the river banks have a height of 400 to 600 feet, and here they are composed very largely of till. Here also andesite occurs in the upper part of the deposit, and this occurrence appears to be the western extension of the general sheet of andesite which may be found at intervals and traced toward the east, becoming of more importance as the mountains are reached. East of the trail leading from Tonsina to the upper

Chitina the andesite is of considerable importance, and here gives rise to a prominent bench which may be traced northward to the point where it connects with the andesite already mentioned as occurring on Chetaslina River, and from this point still northward, forming a marked terrace for a distance of at least 10 miles. Wherever observed there is evidence that the andesite was poured out during the Glacial epoch. The greatest thickness of the glacial deposits is below it, but in protected places it always shows surfaces which have been smoothed by ice action, and there is no considerable area of the andesite exposed that does not carry exotic bowlders upon it. Locally there is also a considerable amount of gravel resting upon the andesite. This relation may be seen on Copper River in the vicinity of Bellum's, and also at the crossing on Kotsina River.

*Mode of occurrence.*—The basin of Copper River is a broad depression lying between the Chugach Mountains and the Mount Wrangell Range and opening northward to the region of low relief lying between the Chugach and the Alaskan Range. The general confines of the basin follow the course of Copper River, but the tributaries of that stream have cut back into the mountains on both sides and have produced broad valleys which join the main depression at right angles to the course of the Copper, and which show the same general type of topography and are veneered by the same kind of surface deposits. Upon any one of these tributaries—for instance, Tonsina River—it is found that the wide valley extends well back toward the main head of the drainage, and that while the hard rocks may be exposed in the upper part they become buried at no great distance from the head of the streams, underneath deposits of loose materials which are seen to have a considerable thickness. These deposits are evidently the result of an infilling of the older, deeper valleys, but they do not show the characteristics of gravels and sands laid down in standing water, for a body of quiet water that was completely filled by materials brought in by the rivers would result in the formation of a level surface. Such a level surface is not found, but, though the deposits seem to deepen with the downward course of the stream, they still slope from above downward, and the cross section of the valley at any point shows the surface to have always been much lower in the center than on either side.

There is a general fall of the basin surface from the broad divide between the Copper and the Sushitna drainage and the mouth of Wood Canyon, where the river enters the Chugach Mountains. The cross section of the basin also shows a general slope from the vicinity of the river toward the mountains on either side. The materials do not seem to vary, however, from the center to the side. The manner in which the beds occur seems to be conclusive evidence that their present surface is in accord with the bed-rock topography existing previous to the deposition of the basin terrane, and points to its origin as a result

*A*. UPPER VALLEY OF TEBAY RIVER, FROM HANAGITA VALLEY.
Showing type of glaciated valleys.



*B*. GRAVEL BENCH ON WEST SIDE OF TANA RIVER, ABOUT 6 MILES ABOVE JUNCTION WITH CHITINA.

of ice deposition and the redistribution of glacial materials through the instrumentality of glacial streams, with local lakes in which the finer silts were formed.

*Distribution and thickness.*—The distribution of the basin terrane is general in the valleys of Klutina and Tonsina rivers, which drain the Chugach Mountains, and in the great valley of the Chitina, which drains the region between the Chugach Range and the Wrangell and Skolai mountains. It also occurs as the floor of Hanagita Valley, connected directly with the surface formations in the vicinity of Tana River.

Along the northern side of the Chitina Basin there are knolls and hills of the basement rock rising through the gravel deposits, but toward the northwest, in the main basin along Copper River, the old topography seems to have been almost completely buried, and it is only occasionally that any bed rock is exposed even in the bottom of the canyons. The tributaries which have their rise in the plateau between the Copper drainage and that of Sushitna River lie almost completely in the deposits of the basin terrane, and it is reported by prospectors that there is no solid rock exposed except in the upper part of Chestochina River, which has its rise in the Alaskan Range. Still to the west of the Matanuska divide the Pleistocene deposits are known to occur over wide areas in the basin of Sushitna River.

The maximum thickness of the Pleistocene deposits which has been observed in the southern part of the Copper Basin is more than 500 feet, but the actual depth of the unconsolidated materials is probably in places considerably in excess of this figure.

*Sand dunes.*—Sand dunes are of very frequent occurrence along the top of the river bluffs within the Copper Basin. In many places the entire slope from the river bed to the top of the bank is covered with fine sand of eolian origin, and along the top of the bluff there are banks of sand from 10 to 20 feet in height. Dunes were observed along the northern bank of Tonsina River practically all the way from Trout Creek to its junction with Copper River. They are also prominent features along Chetaslina River and locally along Copper River itself, and have been observed in the upper basin of Chitina River. The sands of which these dunes are constructed seem to have been derived entirely from the bare flood plains of the rivers, since all the rest of the region is heavily covered with vegetation. These flood plains dry off with extreme rapidity after the heaviest rains and furnish plenty of fine rock dust which, being taken up by the wind, frequently fills the air, to the extreme discomfort of those who have occasion to travel along the beds or banks of the rivers.

Besides wind-blown deposits in the forms of dunes, the surface soil is frequently composed of fine sand, doubtless of similar origin, and careful investigation would probably show that eolian deposits are rather generally distributed over the Copper Basin.

## FAULTS.

Displacements of the formations occurring in the Wrangell region are not at all infrequent, and while the faults are usually of small importance structurally, they are frequently followed by mineral-bearing veins. An example of this is seen in the Nikolai vein, which follows a fault having a throw of several feet. Two faults of very considerable importance have, however, been recognized where they cross Nizina River, while, from the observed relations of the various formations, a third break is supposed to exist in the Kotsina region. On the west side of Copper Creek the Chitistone limestone is found dipping toward the west and overlying the Nikolai greenstone in its normal position, while on the east side of the creek the greenstone comes in contact with Triassic shales; and though the relations of the former were not studied sufficiently in detail to allow the representation of the fault on the geological map, a break has been shown in the geological cross section in accordance with the hypothesis of a fault.

There is a fault crossing Nizina River about 3 miles above the mouth of Chitistone River, and though its occurrence was noted, no opportunity was afforded for a detailed examination. This feature was observed by Hayes in 1891 and described as an overthrust fault having a displacement of over half a mile.[1] The representation of this fault on the geological map must be taken as only approximating the actual relations.

The most prominent fault which has been recognized is the one which limits the southern extension of the greenstone as it crosses Nizina River. Here the shales of the Triassic are brought against the Nikolai greenstone, and though the actual fault plane was not observed, it is seen from the horizons which come in contact that the displacement must amount to 3,000 or even 4,000 feet. East of Nizina River the continuance of the break is not known, since the region was not visited, but toward the west it probably extends for a considerable distance, and on the east side of Kennicott Glacier the displacement must still be in excess of 3,000 feet. The fault was also observed on the west side of Kennicott River, and from this place it is probably continuous to Lakina River, where there is a displacement of several hundred feet. In age this great structural break antedates the deposition of the Kennicott formation, and its production probably belongs to the post-Triassic period of uplift and deformation.

## PHYSIOGRAPHY.

### OUTLINE.

The physiographic features of the Copper River region fall naturally into four divisions: the Chugach Mountains, the Copper River Basin, the Wrangell Mountains, and Prince William Sound.

[1] An expedition through the Yukon district: Nat. Geog. Mag., Vol. IV, 1892, p. 141.

As indicated on the accompanying map, the Chugach Mountains occupy a coastal belt connected with mountains of the St. Elias Range toward the east and with Kenai Peninsula toward the west. The width of this belt is in general about 50 miles, and the mountain summits reach an elevation varying between 5,000 and 7,000 feet, though usually grouped about the elevation of 6,000 feet, while above this level occasional peaks rise to perhaps 8,000 feet. To one who crosses the range on the Military trail, keeping to the valleys and low passes, or to one who descends Copper River in a boat, this general uniformity of level is not apparent; but from any considerable elevation within the region the impression is very strikingly presented that the summits of the Chugach Mountains represent the surface of an ancient plateau from which the Chugach Mountains have been carved.

The range is completely ramified by deep valleys, between which the mountainous masses are graded in smooth slopes from the stream beds to the usually narrow ridges. Broad summits are of rare occurrence, and the river valleys are never canyon-like in their main features, though they may have narrow gorges in the bottoms of their otherwise open valleys. Topography of this type is characteristic of a mature stage of topographic development.

To the north of the elevated region occupied by the Chugach Mountains, and between them and the Alaskan Range and the Wrangell Mountains, lies the Copper River Basin, which is joined on the east by the wide valley of Chitina River and which opens toward the northwest into a broad plateau that is drained by the headwaters of the Matanuska and Sushitna rivers and by tributaries of the Tanana and the Copper. The width of the basin below Klutina River, where its features have been observed by the writers, varies from 10 to 25 miles, while toward the north it widens to more than 60 miles, measured from the foothills of Mount Sanford across to the headwaters of the Cook Inlet drainage. Arms of the basin extend as broad intaglio features up all the main tributaries that penetrate the neighboring mountains. An illustration of one of these tributary valleys is given in Pl. X, *A*, a drawing made from a photograph looking up Tonsina River into the Chugach Mountains. The floor of the Copper Basin slopes from the plateau level of about 3,000 feet on the north to about 1,000 feet at the lower end, where the waters that are collected within its confines cut across the Chugach Mountains on their way to the Pacific Ocean.

Beyond the Copper Basin lie the extremely rugged mountains of the Wrangell group, forming a great elevated mass with several prominent mountain peaks reaching above 12,000 feet, and in the case of Mount Blackburn above 16,000 feet. The Wrangell Mountains are made up in large part of igneous rocks, both in the form of intrusions and in that of extruded volcanic materials. The latter belong to two series, the older of which is supposed to have been thrown out in Tertiary time, while the younger is much more recent and contains outflows which show that volcanic activity has continued practically down to the present time.

Prince William Sound is the name applied at present to the body of salt water which lies between Copper River and Kenai Peninsula. It was formerly known as Chugach Gulf, but, strictly speaking, is an archipelago, since it is studded with islands to the number of fifty or more. The southernmost of these islands separate the waters of the sound from those of the Gulf of Alaska.

The physiography of the Copper River region has been studied in a general way by the writers, and from the features observed the principal events of the erosional history have been deduced. The region has been above the sea for a long time and has been affected by successive uplifts, with intervening pauses, during which erosive agencies were active in the production of topographic forms whose remnants have been preserved to the present time. Three distinct uplifts have been recognized, with possibly a fourth, for which evidence is not so strong as for the others. The events may be outlined as follows:

I. Uplift of the region subsequent to Kennicott deposition, followed by a very complete erosion, with the production of the Chugach peneplain.[1] Before the completion of the peneplain vast quantities of volcanic materials were erupted along the northeastern border of the region. The amount of the first uplift is unknown.

II. Uplift amounting to 3,000 or 3,500 feet subsequent to the production of the Chugach peneplain. After this uplift the streams cut their channels close down to base-level, and by headwater erosion reduced their divides to a fairly uniform height.

III. Uplift of from 2,000 to 2,500 feet, causing a revival of erosion and the incision of the older broad valleys. In this epoch vigorous and long-extended water erosion seems to have been followed by ice erosion, producing broad U-shaped valleys.

IV. Probable uplift, at least locally, with continued glacial erosion in the constricted valleys of the mountains and deposition of glacial débris in the more open basin of Copper River.

### POST-KENNICOTT UPLIFT AND EROSION OF CHUGACH PENEPLAIN.

The next event after the deposition of the Kennicott formation, of which we have any record, consisted in uplift accompanied by slight folding, but whether this elevation closely followed deposition or was separated from it by a considerable interval is not known. By this upward movement the region was brought above sea level, and apparently the relations of land and sea then established were maintained without important oscillation until the entire region now drained by Copper River was reduced to a rolling plain.

[1] The word peneplain is in general used for surfaces of low relief which, like the Chugach Plateau, have had their origin in long-continued erosion of the land.

The plateau character of the Chugach Mountains is well seen from any elevated point in the foothills of Mount Blackburn. The level crest line is a very striking feature to the eye, for at the distance of 25 or 30 miles the details of the dissection which this old plateau has suffered since its uplift are lost and only the upland is seen. On a clear day the snow-covered peaks in the vicinity of Mount St. Elias may be plainly distinguished, rising high above the general level of the plateau. The foothills of Mount Blackburn, and possibly those of the Wrangell Mountains that are not composed of recent andesites, fall into the Chugach Plateau, but are separated from the Chugach Range by the valleys of Chitina and Copper rivers, more than 4,000 feet in depth. In these foothills the peneplain is found to cut across the various sedimentary rocks, including the Kennicott formation, which gives the only direct evidence of the age of the erosional features, showing that they were produced later than the early Cretaceous.

In the Wrangell Mountains and east of them, in what have been called the Skolai Mountains, at the head of Nizina, White, and Tanana rivers, the erosion which reduced the Chugach region seems also to have been active, so that this region was more or less completely planed off, but now these mountains stand above the plateau level. The geology of these high mountains indicates that during the later stages of the reduction of the peneplain a vast amount of volcanic material was thrown out upon the surface of the land, over an area which must have been several hundred square miles in extent.[1] The relations of the comparatively flat-lying volcanic series to the underlying folded sedimentary rocks are illustrated in Pl. X, *B*, which has been drawn from photographs taken from the peneplain level upon the ridge between McCarthy Creek and Nizina River. In the region to the right of the field represented in the drawing the edge of the volcanic series is seen, and beyond their last exposures the surface upon which they rest may be followed in the uniform summits and identified with the peneplain level of the foothills.

The volcanic deposits were probably removed from much of their original area before the final completion of the peneplain in the surrounding country. They have also been still further eroded since the Chugach uplift, and the underlying land surface upon which they were thrown out has been rediscovered locally, as in the portion of the Skolai Mountains lying next to the Chitina Valley and in the Blackburn foothills.

The present uniform summits and level sky lines furnish ground for the belief that a similar complete reduction of the land was suffered by the coast range which lies to the southeast of Mount St. Elias, forming the lower strip of Alaska and extending into British

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[1] See pp. 51-52.

Columbia, and it is reasonable to suppose that the reduction of both regions was contemporaneous. The great mass of Mount St. Elias may always have stood somewhat above this plain as an unreduced area, but such evidence as has been gathered gives ground for supposing that there has been very recent local uplift in this region, so it is likely that in the general uplift of the present coastal belt there has been an excess of elevation to which the present height of the Mount St. Elias mass above the general level of the surrounding plateau is due.

The age of the peneplain is known to be later than the deposition and uplift of the Kennicott formation, since the strata of that formation were in part removed by its erosion. The age of the Kennicott formation is not younger than earliest Cretaceous, but it is probable that, while erosion may have been going on during the latter part of Cretaceous time, the final production of the lowland surface was not accomplished until Tertiary time. Of this there is no direct evidence in the field, but the Miocene is known to have been a period of erosion over a wide extent of country, both in Alaska and in British North America. Spurr has assigned the production of the Yukon Plateau to planation in Miocene time; thus it would differ in age from the corresponding interior plateau of British Columbia, which is considered by Dawson as of Eocene age. It may eventually be possible to correlate the Chugach peneplain with the Yukon Plateau, but the existing knowledge of the topography along the northern margin of the St. Elias Range southwestward as far as the vicinity of Mantasta Pass indicates a greater probability that the Yukon Plateau may correspond in age to the second erosion level of the Copper River district. In this case, if the Miocene age of the Yukon Plateau be accepted, the age of the Chugach peneplain will probably have to be placed in the Eocene.

## UPLIFT OF CHUGACH PENEPLAIN AND SECOND PERIOD OF EROSION.

The present character of the Chugach Mountains and of the Wrangell Mountains, except in so far as their topography was modified by upbuilding through volcanic agencies, is due to dissection, which has been the result of uplift from the low position relative to the sea which the entire region occupied on the completion of the Chugach peneplain. The total amount of uplift which the region has sustained to the present time has not been less than 6,000 feet, but the elevation was not all accomplished at once. This is indicated by several levels of partial down-cutting which are observable within the Chugach Mountains. It is believed that the first uplift following the production of the peneplain amounted to about 3,000 feet, or possibly somewhat more, and that the raising of the region was followed by a long pause during which the streams occupied nearly their original channels, wearing them down almost to sea level, and reducing many of the passes between the heads of the opposing streams to a level much lower than the surface of the old peneplain. Instances of such reduction of stream divides are seen in various parts of the Chugach Mountains along the line of the Military trail. Thomson Pass, between Lowe River and Ptarmigan Creek, and Kimball Pass, between two tributaries of Tonsina River, may be given as examples; but the still lower flat divides, such as Marshall Pass at the head of the Tonsina, the pass between the Kanata and Mosquito Creek, and the low divide which opens into the Tazlina drainage north of Klutina Lake, can hardly be explained in this way. Their significance will be referred to farther on.

Another set of related phenomena, probably produced during the same period of erosion, is seen in the hanging valleys that are found high up in the mountains. These are broad drains, often several miles in length, generally with sloping floors which seem to have been cut off by the erosion of the main valleys to which they are tributary at a date later than their production. One of these hanging valleys occurs on the west side of Copper River opposite Wood Canyon. The floors of this valley and several adjacent valleys have been truncated at an elevation somewhat below 3,000 feet. At their heads the mountains rise to approximately 6,000 feet. Wherever these broad valleys are found they bear the marks of having been occupied by glaciers, but it is considered that they must have existed as topographic features previous to the glaciation of the region and that the work accomplished on them by the ice has merely been the smoothing and widening of depressions excavated by stream erosion. The fact that they were not cut deeper by the ice is possibly due to the presence of a deep trunk glacier in the adjacent valley of Copper River at the time they were occupied by the ice.

An especially notable topographic feature of the region, the origin of which is related to the supposed period of arrested uplift following the elevation of the Chugach peneplain, is the depression which runs parallel with Chitina River within the Chugach Mountains. This depression was traversed by the survey exploring parties from the upper Chitina to Copper River, en route to the coast. It has been named Hanagita Valley, from the present chief of the Taral Indians, whose hunting grounds in the upper basin of the Chitina River are reached by the trail which follows its course. The general features of the valley and the surrounding mountains are well exhibited on the topographic map, and some of the detail is illustrated in Pls. XI and XII.

The bed-rock topography of Hanagita Valley has been greatly obscured by the deposition of a thick mantle of glacial débris extending throughout its whole length; no rock exposures were noted in the valley from the eastern end to the Tebay; here, however, gabbro is the prevailing rock, and bed rock again appears on the divide between the western branch of the Tebay and the stream which flows directly to Copper River. The present topography of this entire valley is wholly dependent upon the Pleistocene deposits by which it is floored, in which regard it resembles the main Copper River Basin. The streams in their lower courses have cut deep trenches into the unconsolidated débris, but have not yet drained the glacial lakes which lie in the upper parts of their drainage.

Underneath the covering of glacial materials the bed-rock floor is still very much above the stream beds of such rivers as the Tonsina, Tiekel, and others which have adjusted their channels to the position of the master stream of the region. The valley is thus several hundred feet higher than the bed of the adjacent Chitina River, to which the streams have not been able to reduce it through the process of head-water erosion.

To one who passes through the Hanagita Valley the impression is very strongly presented that it may have been occupied at one time by a continuous river which emptied into the Copper below Taral. Against the acceptance of this suggestion it may be noted that the present main tributaries of the Chitina which cross the Hanagita Valley and penetrate the Chugach Mountains are comparable in length and volume with those which drain directly into Copper River and which are supposed to have originated upon the Chugach peneplain. It is deemed more probable that such streams as Tebay and Chakina rivers were developed as tributaries of the Chitina at an early date than that the southern tributaries of that river could have been confined for a long period to the northern slopes of the narrow mountainous belt between the Chitina and Hanagita valleys, and afterwards have diverted the drainage of the interior valley. If the drainage of the Hanagita Valley had been tapped by the Chitina tributaries at a recent date, it would be anomalous that the southern affluents of the interior and less important stream should have been so much longer than those of the master stream at the date of the supposed piracy. It would also hardly have happened that the location of the pirating streams should have been exactly opposite the principal valleys leading into the Hanagita depression from the Chugach Range.

It is conceived as a necessary corollary of the existence of the peneplain in the Copper River district that the streams by which its reduction was accomplished were completely adjusted upon its surface long before the close of its erosion. It is also conceived that the entire present drainage system of the Chugach Mountains is inherited from the streams which were developed upon the peneplain. The regular spacing of the major streams and their tributaries, with the location of the main divides at equal distances from the master streams, as in the case of the pass between Kanata River and Mosquito Creek, together with the rectangular character of the drainage lines throughout the region, all seem to indicate a more perfect adjustment than could have resulted in so short a period as has elapsed since the uplift of the Chugach peneplain. Upon the basis of this argument the persistence of the Hanagita Valley as a line of drainage parallel to Chitina River after the completion of the peneplain would be distinctly anomalous in the general scheme of stream development, since the peneplain stage would be the time best suited for the diversion of its waters to the Chitina. On the other hand, if the parallel drainage to Copper River existed at the time of the uplift, it would seem most natural for it to have persisted to the present time, since it would have had an advantage over the short tributaries of the Chitina in the large volume of water that it received.

From these considerations it is considered most probable that the Hanagita Valley has been produced through the erosion of branches of the Chitina tributaries rather than by excavation of a continuous river which may once have occupied it. It would seem at first sight that the form of the valley might throw important light upon the problem, but there has been so much molding of the mountain sides by ice action, and so much infilling of the valley bottoms with materials of glacial origin, that all significant features have been either destroyed or covered up.

It is suggested as a hypothesis, which no opportunity was presented for testing, that the valley may mark the position of a zone of soft rock; but if this is the case it is to be wondered that there is no valley on the west side of the Copper Valley following a corresponding course. The presence of soft rock would be favorable to the excavation of the valley by either of the processes which have been suggested, but offers no means of distinguishing their relative validity.

On the topographic map a wind gap is shown crossing the mountains about halfway up the eastern tributary of Tebay River, and it is possible that this may indicate a former direct outlet to the Chitina Valley and the capture of the former tributary of the Chitina by Tebay River. If this evidence could be accepted, it would conclusively disprove the hypothesis of a continuous stream in the Hanagita Valley.

East of Chitina River evidence of the land surface produced in the second period of erosion is seldom presented. The only topographic features for which this origin can be suggested are the divide upon the trail to the Nikolai mine between Chokosna Creek and the Lakina drainage, and the high rock bench south of Lakina River, below the point at which it turns to the east. Both of these areas have been transgressed by ice, but in their broad character and their altitude both correspond with the features described above, and may be taken as representative of the land surface of the second period of erosion. Probably the prominent rock hills which lie in the Chitina Valley surrounded by Pleistocene deposits, and which reach elevations of about

3,000 feet, represent the floor of the broad depression produced by that river during the same period, though they have doubtless been somewhat reduced by glacial erosion.

In the Wrangell and Skolai mountains the second epoch of erosion, like the later part of the first, was devoted to the removal of the volcanic covering which had been thrown out upon the surface of the land and to the deepening of canyons in the underlying rocks. The deeper of the present canyons have not yet reduced their floors below 2,000 feet, so that the present relief is scarcely more rugged than that which existed at the close of the second epoch of erosion. Any lowlands which may have been produced along the deep and narrow canyons have been effaced by the subsequent erosion, largely that of the great glaciers, the wasted remnants of which extend well down in all of the mountain valleys. Throughout all this period, and continuing to the present time, there has been within the Wrangell region conflict between upbuilding by extravasation and degradation by erosion; Mount Wrangell has at intervals poured out great sheets of lava, and probably there have also been other centers of eruption. In this way the tendency has been to preserve the rugged character of the topography.

It is supposed that at the close of the second cycle of erosion the streams in the region at large, outside of the mountains mentioned in the preceding paragraph, were flowing in valleys which had been adjusted to low grades through long-continued erosion. Probably the Copper Basin was a broad, open valley, on the coastward side of which arose the Chugach Mountains to a general elevation of from 3,000 to 3,500 feet, with their plateau character even better exhibited than at present. The mountains of the Wrangell region doubtless reached a considerably higher elevation.

## THIRD UPLIFT AND EROSION OF COPPER BASIN.

The second epoch of erosion, the results of which have been outlined in the foregoing paragraphs, seems to have been followed by a general uplift, bringing about a third period of down-cutting. From the rock terraces which represent the result of this erosion it is estimated that the amount of the upward movement was 2,000 to 2,500 feet. The relations of the different land surfaces may be made out in the vicinity of Taral, where the floors of the hanging valleys are truncated at an elevation somewhat below 3,000 feet, while the top of the bench into which Wood Canyon has been cut has an elevation of about 1,000 feet, leaving 2,000 feet for the approximate amount of the elevation, though this determination has only the value of an approximation. The valley floors of the third period of erosion are represented from place to place all the way from Taral to the coast, as well as in the valleys of the tributaries of Copper River. Such a valley bottom was traced by Schrader[1] in 1898 all the way up Tonsina River to Marshall Pass, across which corresponding features were found in the head of Lowe River. On Tsina River rock benches are found above the present valley floor, and below the junction of Tsina and Kanata rivers, which unite to form the Tiekel, there is a similar feature with a recent canyon cut into it. In the case of the Kanata, the whole valley seems to be still upon the ancient floor, never having been excavated below the old grade; consequently the low divide at its head, with an elevation of 1,900 feet, would seem to represent the lowest of the three ancient land surfaces. Likewise the divide between Klutina Lake and Tazlina River, which has about the same elevation, is probably to be similarly correlated.

Erosion which has reached below the terraces seems to have been partly effected by the ice, but is also in part the result of general cutting by running water, accomplished since the valleys have been vacated by the ice. Wood Canyon has the character of a stream-cut gorge, and similar features are found along the tributaries of Copper and Lowe rivers, but the lower portions of the valleys which have been filled to great depth by the recent deposits of the river can hardly have been produced except by the gouging action of moving ice.

The great broadening of the basin of upper Copper River was probably accomplished in the second erosion epoch, when the hanging valleys and the divides at approximately 3,000 feet were produced. After the subsequent uplift the valley floors of the main rivers were raised to an elevation of not more than 3,000 feet, and probably not less than 2,500 feet. This estimate is made upon the basis of allowing a maximum of 500 feet for the difference in level between the master streams and the divides at the heads of the tributaries after the grading was completed. It is reasonable to suppose that after the uplift no great time was consumed by the streams in excavating canyons and in establishing new grades, and then the process of broadening the valleys was again taken up. Possibly much of the earlier erosion was made easier by the occurrence of soft rocks over the area of the present basin, and this was certainly a factor in the upper basin of the Chitina, where the present wide valley is due to the soft Triassic shales; but in the main Copper Basin the later erosion, at least, was in metamorphic rocks so far as the few exposures which have been observed give any indication. If the old basin floor as it existed after the third uplift were restored it would present a more or less rolling surface, having a general elevation of between 2,500 and 3,000 feet. This surface is now represented by the hills which rise through the Pleistocene deposits in the lower valley of Chitina River,

[1] A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, in 1898, by F. C. Schrader: Twentieth Ann. Rept. U. S. Geol. Survey, Part VII, 1900, p. 397.

but their original height has probably been somewhat reduced by the erosion of the ice sheet which recently occupied the basin.

The configuration of the rock surface below the Pleistocene deposits of the Copper Basin probably has considerable diversity of relief, but this is not now observable because of the thick covering of glacial débris. Near the confluence of Chitina and Copper rivers bed rock is known to lie below the elevation of 600 feet underneath the Pleistocene deposits, while below Chetaslina River there are exposures of bed rock at an elevation of approximately 700 feet above the water level of Copper River. From these figures it is seen that the relief of the present rock floor within the lower part of the basin amounts to as much as 2,000 feet. Concerning the northern portion of the valley no data are available and its features must be left out of the present discussion.

The accomplishment of such reduction as has been effected below the floor of the second epoch of erosion would seem to correspond in age with the production of the rock terraces of lower Copper River which have already been described. If, however, these features are correlated it must be that there has been a relative elevation of the region south of Chitina River in the vicinity of Copper River. The rock terrace at Wood Canyon is now 500 feet or more above the bed-rock floor of the adjacent part of the basin north of Taral, and this figure may be taken as the approximate amount of the uplift. It is this supposed uplift which is last mentioned in the outline of the physiographic history on page 64. From the freshness of the gorge at Wood Canyon it is thought probable that this deformation, which must be in the nature of a fault or an abrupt fold, took place during the occupation of the ice. It can not, however, be definitely stated that such an uplift actually took place, for there is no other evidence for its existence than the attitude of the barrier into which the river has cut a channel to the depth of 500 feet at Wood Canyon, where Copper River enters the Chugach Mountains.

On the hypothesis that the Copper Basin formerly drained into Sushitna River and thence into Cook Inlet, it may be supposed that the barrier at Wood Canyon represents an old divide between this drainage system and the coastward system of the lower Copper region, but, as will be shown in what follows, this hypothesis is at present believed to be untenable, so that if deformation can not be called upon in explanation of the topographic features at the head of the lower constricted portion of Copper River, the origin must remain a matter for further consideration. If the uplift be accepted, its very recent date may be inferred, because if it had preceded the ice it would seem anomalous that the rather narrow valley at Taral should not have been more deeply excavated by the flow of ice, which, from the configuration of the region, must have concentrated toward the low pass and produced the conditions best suited for lowering the barrier at least to the level of the valley floor above Taral; whereas the supposition that the present bench at Wood Canyon was formerly continuous with the rock floor of the basin above allows for much reduction having been completed previous to the very recent deformation.

The origin of the Copper River Basin has been the subject of speculation in two papers which appeared in the Twentieth Annual Report of the Geological Survey, Part VII. Mendenhall[1] suggests that the Copper Basin was at one time during the Pleistocene period occupied by a lake in which the silts and gravels that now cover the region were deposited. It is conceived that the materials were derived from bordering glaciers which probably never coalesced to fill the basin. This author also suggests the possibility that the waters of the Copper Basin once drained into Cook Inlet along the line of the present Sushitna River.

Schrader[2] makes similar suggestions. He supposes that after general erosion of the basin there was a broad depression opening northward to Sushitna River and Cook Inlet, with the valley of the lower Copper opening to the sea as at present; that a general subsidence amounting to somewhat more that the height of the old divide between these two lines of drainage (the location of which can not be determined because of the present Pleistocene covering) followed this erosion, allowing two arms of the sea to enter—one by way of lower Copper River and one by way of the Sushitna from Cook Inlet—and mingle their waters in the basin. In this estuary it is supposed that the Pleistocene terrane of the region was deposited as an essentially water-laid formation derived from adjacent encroaching glaciers. The present outlet of the basin drainage through the Chugach Range is conceived as having been established by a differential uplift by which the northern edge of the present basin was raised higher than the southern.

The observations made by the authors during the summer of 1900 were more extended than those which Mr. Schrader was able to make in the hurried trip of 1898, and are thought to be sufficient to show the fallacy of the argument for the deposition of the basin terrane as a whole in standing water, and therefore the incorrectness of the hypothesis of the former occupation of the region by an inlet from the sea or even of the presence of an inland lake as the condition of prime importance in the formation of the basin terrane. The deposits are in large part made up of typical till, to which an essentially glacial origin must be attributed. The attitude of the surficial deposits, aside from their glacial character, indicates that, during their deposition, the same directions of drainage prevailed as at present. Sloping as the

[1] Twentieth Ann. Rept. U. S. Geol. Survey, Part VII, 1890, pp. 332-335.
[2] Op. cit., pp. 400-402.

surface does toward the central drainage of the basin, and in the same direction as that drainage, also showing the same relations in the tributary valleys, it seems hardly possible that the Pleistocene terranes as a whole could have been deposited in the standing water of a lake. The unconsolidated covering seems to be a veneer which follows the general slopes of the old rock valleys, obliterating the minor inequalities of the basin. The origin here suggested for the Pleistocene terrane of the Copper Basin does not necessitate the depression of the valley to a position below sea level and subsequent uplift and erosion, but allows for its excavation under relations of land and sea very similar to those that now exist. It is supposed that the wide basin of Copper River beneath the present surface deposits was almost entirely eroded by the streams which occupied it previous to its occupation by the ice, though possible assistance was given in the later stages by the ice itself. It is further believed that the physiographic features of the lower part of the Copper Basin afford no reason for believing that its drainage ever reached the sea by any other than the present route.[1] On the other hand, in the similarity which Copper River shows to other rivers crossing the coastal mountains of Alaska, British Columbia, and northern United States, there is reason to believe that it is antecedent to the uplift of the Chugach region and of the Copper River district as a whole. In this case the river has persisted in the course which it developed upon the Chugach peneplain, and its history corresponds with the general antecedent character of the entire drainage of the Chugach region, as already described in the present discussion of the topographic development.

The Columbia, Fraser, Skeena, Naas, Stikine, Taku, and Alsek rivers all have their rise in the interior plateau back of the coast range, and are probably all antecedent streams. This view is not held by Dawson for Fraser River,[2] but Columbia River has been described as antecedent by Russell;[3] and the same origin is ascribed by Brooks[4] to Alsek River, which lies nearest to Copper River. Brooks has found and described an old waterway by which the upper part of Tanana River formerly drained eastward across the present valley of White River, and by way of Donjek River to Lake Kluane, and thence by way of the Tatshenshini and Alsek valleys to the sea; thus proving the very great age of the Alsek drainage, upon which there has been so very much encroachment by the rivers tributary to the Yukon.

[1] The physiographic features of the upper, broader portion of the Copper Basin are as yet very imperfectly known; the relations of the Pleistocene deposits to bed rock, and, indeed, even the character of the pre-Pleistocene formations, are entirely unstudied, and if it is eventually to be proved that the basin was ever drained by way of Sushitna River, the evidence must be afforded in this region.

[2] Summary Report, Geol. Survey Canada, 1879, p. 8 B.

[3] A reconnoissance in central Washington: Bull. U. S. Geol. Survey No. 108, 1893, p. 97.

[4] A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the upper White and Tanana rivers: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, 1900, p. 354.

Copper River does not reach into the interior to the great Yukon Plateau, as do the other rivers mentioned, but drains a large isolated basin lying back of the coastal range of mountains and separated from the Yukon drainage by a high mountainous mass, the northeastward-facing scarp of which is continuous with that of the St. Elias Range. The Copper thus drains a smaller area than the Alsek, but, flowing as it does from the interior basin across the coastal mountains, it seems not improbable that it has a like antecedent origin.

Copper River, from the head of its delta to Wood Canyon, at Taral, is nearly three times as long as the longest river heading within the Chugach Mountains and flowing to the coast, and the principal tributaries which join it below Taral are longer than any of the rivers which empty into Prince William Sound. From these relations it seems difficult to imagine that the Copper can have diverted the drainage of the interior basin from the former course to the sea by way of Cook Inlet through recent headwater erosion, for the Copper drainage within the Chugach Mountains is the most extended of all the coastward systems of the vicinity, and for this reason it is probably the oldest of these systems, and represents a survival of a river whose course was determined previous to the uplift of the region.

Before the great advance of the ice Copper River had hollowed out a wide valley between the Chugach and Wrangell mountains, and such tributaries as the Chitina, Tonsina, and Klutina had excavated wide trenches of measurably the same importance, which were graded to the level of the Copper as master stream. To the Glacial epoch belongs the infilling of these valleys and the origin of the present topography of the Copper Basin.

### TERRACES OF PRINCE WILLIAM SOUND.

To be correlated with the rock benches which were produced during the third period of erosion along the rivers of the Chugach Mountains are the forelands or low rock terraces to be seen at many places bordering the islands and shores of Prince William Sound. These terraces are narrow platforms, sometimes showing sea cliffs from 20 to 40 feet in height, and at other times rising with a gentle incline from the water level. From the vicinity of the shore they rise gradually to the base of the adjacent mountains, which ascend steeply to a height of several thousand feet. Sea cliffs are present only in exposed locations, where the forelands are being worn back and destroyed by the present wave action. Such cases suggest the hypothesis that the benches are wave-cut and that their present altitude is the result of a slight uplift of the land; but another origin must be sought, since equally good platforms occur in locations which are completely protected from the open sea, and in one instance they are found both on the mainland and on the adjacent islands, separated by a narrow channel. The long direction of the island is parallel to the main trend of the shore, and the island consequently protects the intervening strait from the waves of the open water. Under these conditions it seems that the forelands may be the remnants of old valley floors produced by ice erosion. The benches often bear the marks of glaciation, showing that they were formed either before the ice or as a result of ice action, and since the rock benches are traceable with practical continuity from Valdes Inlet up Lowe River, and thence by way of the Tasnuna and Copper back to the ocean, there can be little doubt that the origin which fits in one case is also applicable in the other. The form of the restored valleys within the mountains, and of the valley of Copper River in the vicinity of Taral, is that which would be produced by glacial erosion, and in the case of the valleys which penetrate the Chugach Mountains from Prince William Sound this character is even more marked, if only the cross section obtained by extending the sloping rock beds be considered. It is believed that the terraces represent old floors which were produced by glacial erosion, and that the excavation of the narrow fiords within the wider valleys may have been contemporaneous with or subsequent to the origin of the broader features. In either case they are likewise probably the result of ice erosion.

## GLACIATION.

### GENERAL DISCUSSION.

The events of the Glacial epoch very materially affected the topography of Prince William Sound and of the Copper Basin, in the one case by the erosional action of ice, in the other by deposition. In the valleys which lie within the Chugach Mountains glacial erosion was also active. Before proceeding to the discussion of the local work accomplished by the ice a few remarks of a general nature will not be out of place.

The mountains of the Pacific coast, from Oregon on the south to the region of Kuskokwim River on the northwest, were intensely glaciated at a time that is geologically very recent. At the period of maximum accumulation the valleys adjacent to the coast were filled with moving ice, and the mountains, which rose abruptly from the water, as at present, were covered with ice or perennial snows. Probably the icy mantle was broken only by the highest and most precipitous mountains, which towered above the snow fields. To the traveler who follows the usual steamboat route from Seattle to Juneau, and thence to Prince William Sound and Unalaska, evidences of regional glaciation are presented all the way from Puget Sound to Cook Inlet. In the region of Puget Sound glacial deposits and glacial topography are everywhere present, and these features extend northward into British

Columbia to the vicinity of Victoria and Vancouver Island. In the northern part of Vancouver Island, and thence as far as the upper end of the Alexander Archipelago, no glacial deposits can be made out by the passing observer, but throughout this region the topography shows the cirques, the broadened valleys, the corrugated slopes, and the rounded ridges which have resulted from the former presence of moving ice. In many localities in the vicinity of the high mountain masses about Mount St. Elias accumulations of ice are still very prominent. Some important glaciers empty into the lower part of Copper River, and others of considerable size occur at the heads of the inlets and fiords of Prince William Sound. Still other large ice streams are present in the valleys which head against Mount Wrangell and the other high mountains of the Wrangell district, but all these are mere wasted remnants of former larger glaciers and ice caps. The considerations to be brought out in what follows are sufficient to show the probability that at the time of maximum glaciation the Chugach Mountains supported a practically continuous sheet of ice upon their coastward side, through which only the higher mountains projected, and which reached the waters of the open ocean with a very considerable depth of ice. At the same time the mountains of the interior, including those grouped about Mount Wrangell and the Alaskan Range, were also the foci of vast accumulations of ice.

At first sight it seems improbable that meteorological conditions could ever have been sufficiently favorable for the accumulation of so great a mass of ice as is necessitated by the phenomena which have been observed in the Copper River Basin. It would seem that the very fact that great ice fields existed in the neighborhood of the coast would necessitate the conclusion that sufficient moisture was not retained in the atmosphere to furnish the required precipitation so far in the interior. However, the present glaciation of the Wrangell region is upon as large a scale as that observed along the coast, and it seems that any material increase in the annual precipitation or decrease in the average summer temperature would have as great an effect in one region as in the other, and that the very conditions which favor the maximum glaciation in the coast region would also favor maximum glaciation in the high mountains of the interior. It must be remembered that the summits of Mount Wrangell and Mount Blackburn, and of several other culminating points in this region, have more than double the elevation of any single mountain in the adjacent coast region, and that the general height of the mountain mass is nearly twice as great as the general level of the Chugach Plateau, which lies between it and the sea. From these relations it is readily seen that the Wrangell Mountains must necessarily serve as condensers for any moisture remaining in the clouds after they have passed over the coast range under the direction of prevailing winds from the Pacific.

## GLACIATION OF COPPER BASIN.

In the broad basin of Upper Copper River there is abundant evidence of former vigorous glaciation. This is seen in the basin terranes, which have been fully discussed on another page,[1] and which are made up of typical glacial till with gravels and silts, such as might result from the deposition of materials furnished by great glaciers; moreover, the Chugach Mountains everywhere show the rounded topography characteristic of regions smoothed under the action of moving ice.

It seems that during the period of maximum precipitation accumulation exceeded waste to so great an extent and for so long a time that a great ice cap was formed in the elevated region about Mount Wrangell and in the Alaskan Range, from which the ice flowed as a sheet, completely filling the great basin of Copper River and transgressing the northern front of the Chugach Mountains in the region where they have been observed by the writers. Evidence for the transgression of the Chugach front is seen in the smoothed and rounded slopes of the mountains as they face Copper River southeast of the Tonsina, and also south of the Chitina Valley. If it be suggested that the features observed may have been produced by glaciers of local origin, it seems difficult to find any sufficient area of accumulation, since there are no high mountains rising above the general crest of the range, and since the crest itself is so narrow, lying, as it does, between Copper River and Mosquito Creek, tributary to the Tonsina. The coastal glaciation could hardly have extended inland in such importance as to produce a flow toward the Copper Basin, since the mountains are not higher as the distance from the coast increases, and in former times there was probably a rapid diminution of precipitation from the coast toward the interior—a decrease which is even now notable in the practical absence of ice accumulation in the portion of the Chugach Mountains adjacent to the Copper Basin. It seems that previous to the glacial smoothing the mountain slopes must have been corrugated by valleys, and in the presence of ice moving down the slopes such valleys would have become the channels of ice streams and would consequently have been widened and deepened. As a matter of fact, the aspect of the region is quite the opposite. The mountain slope presents a smooth face toward the northeast and is drained by streams flowing in sharply incised trenches which have every appearance of having been eroded since the retreat of the ice. This is certainly the condition of affairs that would be expected as the effect of an ice stream overriding the mountains from the northeast.

Further support of the suggested ice sheet is found in the occurrence of exotic bowlders beyond the first mountains of the Chugach Range. Upon Fall and Ernestine creeks, at the head of Kanata River,

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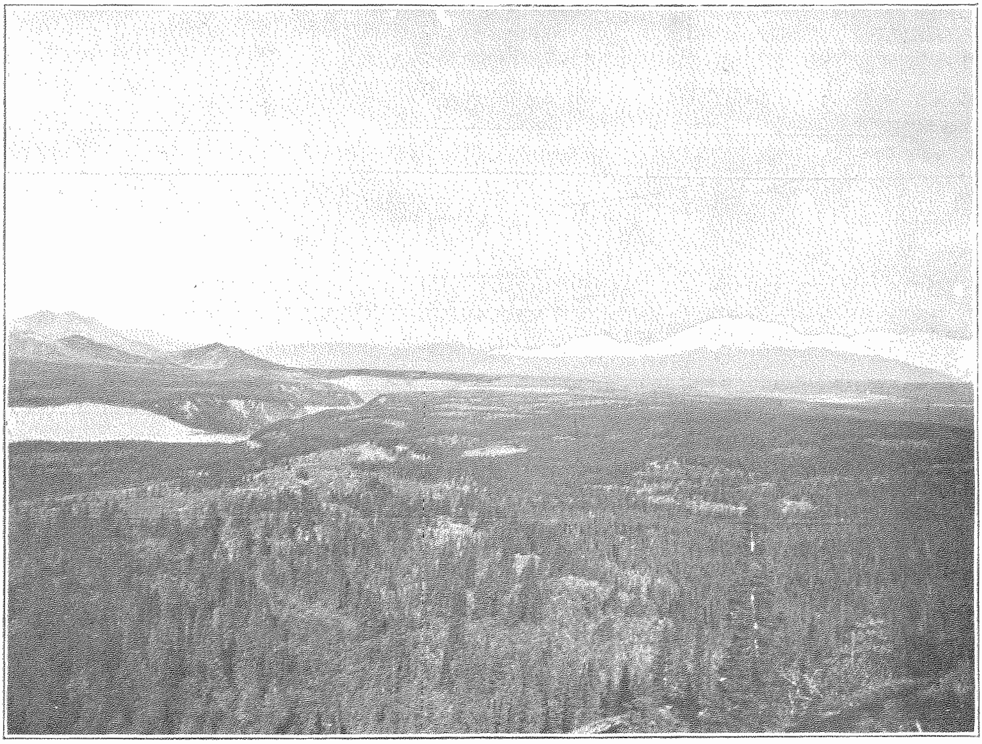
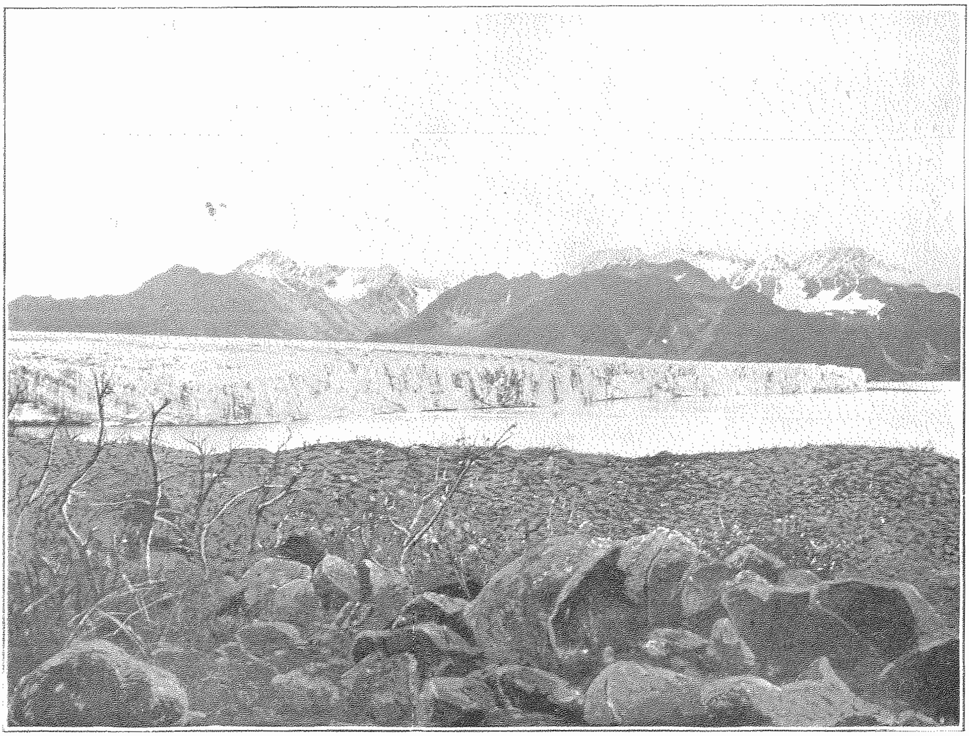
[1] Pages 58-61.



*A.* UPPER BASIN OF CHITINA RIVER, FROM TOWHEAD MOUNTAIN, BETWEEN CHITINA AND TANA RIVERS.

Illustrating character of glacial deposits.



*B.* FRONT OF MILES GLACIER, FROM MORAINE AT FOOT OF THE RAPIDS.

there are large rounded bowlders of diorite and greenstone similar to rocks occurring at various places in the Copper Basin, but which are not known in situ in the neighborhood of their present position. Similar occurrences of igneous rocks which can not be found in place are reported from the tributaries of the Upper Tonsina. In each of these localities gold occurs in the gravels, and its discovery has led to the search for gold-bearing veins, so that the absence of these varieties in the country rock has been noticed by prospectors. If further investigation should make it certain that the origin of these bowlders can not be local, it would be conclusive evidence that the ice which originated in the Wrangell region made its way nearly to the divide which separates the drainage of Copper River from Lowe and Valdes rivers. The ice from the Wrangell region penetrated the Chugach Range along the course of Tonsina River at least as far as Trout Creek, for the gravels of that stream contain quantities of volcanic material derived from the unconsolidated Pleistocene terrane, for which no other origin can be suggested. In the vicinity of Klutina Lake there are associated with the finer silts coarse deposits which are composed in part of such materials as might come only from the Wrangell lavas, though at the time they were observed a more local origin was considered probable.[1]

### ORIGIN OF THE DEPOSITS.

It is believed that the Pleistocene deposits of the Copper Basin were laid down in connection with the great ice sheet which had its origin in the Wrangell Mountains and in the adjacent Alaskan Range. A vast sheet of ice came down from these high ranges and piled up in the topographic depression occupied by Copper River, where its natural flow to the coast was checked by the opposing Chugach Range. It is conceived that the first ice to reach the bottom of the basin became the floor upon which later flows were piled, until finally the highest accumulations were able to find their way over the opposing rim of the basin. The ice below this rim must have remained stagnant to a very large extent, since the valley of Copper River could not carry off anything like the amount of ice furnished, because of its narrowness and because its lower course was probably clogged by ice accumulated in the mountains near the coast. Most of the material that had been picked up by the ice during the earlier part of the advance would in this way remain in the basin, and on the melting of the ice the débris embraced within its mass would be deposited—much of it as till or bowlder clay resulting from the quiet deposition of heterogeneous materials, and a large part as gravels and sands distributed by streams beneath the ice or at the ice front; while fine silts

[1]A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska, by F. C. Schrader: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, 1900, p. 411.

would be deposited wherever the streams loaded with rock flour were ponded in lakes resulting from the damming of drainage lines either by the ice or by glacial deposits. The most favorable time for the occurrence of such lakes was probably during the advance of the ice front, but they may have been locally present in the later stages of the glaciation as well.

After the wasting of the main mass of ice through melting, the valley floor was left with a deep covering of débris, which effaced the earlier drainage lines and produced a topography of rather smooth character, showing only the minor inequalities which are characteristic of glaciated regions. The occurrence of lakes is very frequent both upon the constricted ground between the present deep valleys and in localities that were never filled by the glacial deposits.

Before the glacial ice finally ceased to invade the basin from the slopes of Mount Wrangell there occurred a considerable outpouring of andesite, which flowed over the gravels and bowlder beds, extending an arm as far as Copper River at Bellum's, and reaching eastward to Kotsina River. The peculiar course of the Kotsina after it leaves the mountains seems to have been the result of a diversion due to the clogging of its former channel by the lava. This andesite flow is a prominent topographic feature of the eastern side of the basin from the vicinity of Kotsina River northward to Chetaslina River and for a considerable distance beyond, forming a line of hills and a terrace-like bench from 4 to 6 miles distant from the Copper.

Subsequent to the flow of andesite there was another advance of the ice, as is shown by striated surfaces upon the volcanic rock and by the occurrence of bowlders of limestone and of considerable deposits of gravel above the andesite.

## TERRACES IN COPPER BASIN.

Since the deposition of the Pleistocene terrane in the Copper Basin the streams have been able to excavate their channels to a depth of several hundred feet, but their presence below the general level of the basin floor is not necessarily, though it is possibly, the result of uplift. It seems more likely that there have been no significant changes in level, for the old channels lie at a level below the few exposures of the hard formations beneath the drift, and the present stream beds have not yet been excavated to solid rock, as would have happened if the old floor of the valley had been raised to any considerable degree from its former position. Furthermore, the old floor could not have stood much lower at the conclusion of its erosion than at present unless there had been a subsidence, for which no evidence has been observed. These considerations suggest that the drainage surface of the Copper Basin was raised entirely by the deposition of Pleistocene drift, instead of by actual uplift of the region.

Several terraces which occur from place to place along Tonsina and Copper rivers indicate that there were stages in the down-cutting—intervals of erosion alternating with the construction of flood plains. The terraces are usually best preserved near the tributary streams, as, for instance, at the mouth of the Chetaslina, where two marked benches are found below the general level of the basin. A fourth bench, at a distance of several miles from Copper River, is not a river terrace, but the front of an andesite flow that covers the main bed of Pleistocene material.

It is suggested that the production of these terraces is the result of variations in the ability of the streams to corrade their channels, and that these variations were founded upon climatic changes. An increase of precipitation, by increasing the activity of glacial streams, would bring about periods in which the rivers, being overloaded, would form flood plains, while intervening drier periods, when less material was furnished for transportation by the rivers, would be productive of conditions favorable for lowering the valley floors. Inasmuch as the variations of the present glaciers of Alaska are indicative of secular variation in the amount of precipitation, it seems not unreasonable to accept the probability of the above suggestion as applicable to the origin of the terraces in the Copper Basin.

### GLACIATION OF PRINCE WILLIAM SOUND.

In the region of Prince William Sound the evidence of glaciation extends to the water's edge along the mainland, as shown by the presence of gravel and striated rock surfaces along the shore. On many of the islands of the sound there are also scored surfaces, and in addition there are gravel deposits made up in part of rocks peculiar to the mainland adjoining. On Glacier Island fragments of granite have been found similar to that occurring in place upon the adjacent mainland; on Bligh Island also there are gravel deposits containing exotic materials, and on the shores of Hawkins Island coarse granite has been observed which is believed to have had its origin in the neighboring mountains of the mainland in the vicinity of Sheep Bay. These observations are deemed sufficient to show the former greater extent of glacial ice in the sound region.

The forelands that frequently occur between the water and the steep slopes of the mountains have already been mentioned and their origin has been attributed to ice erosion. The fiords, which have been excavated to a considerable depth below the forelands, are also considered indicative of vigorous glaciation, while the high mountains themselves show characteristic rounded topography, indicating that they were at one time practically buried beneath a great ice sheet.

The deposition of the silts, gravels, and bowlder clays in the Copper Basin was the result of slackened movement in the ice streams, which had its origin in the necessity of filling the topographic depression before a free outlet for the accumulating ice could be gained. In the constricted valleys within the Chugach Mountains and along the coast the movement could have been at no time sluggish, and, instead of depositing, the strong and relatively rapid ice streams were actively eroding the ground over which they passed. The materials which the ice derived from this corrasion must have been deposited some distance from the present coast line, underneath the waters of the ocean.

The islands of the sound are considerably lower than the mountains of the adjacent mainland, and it seems probable that this may be due to their having been eroded by the ice. It is also suggested that the channels between them, with the deep fiords, and, in fact, all of the topography of the sound, is the result of glacial erosion.

The hypothesis which first suggests itself for explaining the deep fiords is that they are valleys which were excavated by water or ice action when the land had a somewhat higher elevation than at present; but all the physiographic evidence throughout the Copper River region points to repeated uplift since the beginning of the erosional history, and there is no sufficient evidence for supposing that there have been any intervening periods of subsidence. From this it seems probable that the fiords were excavated while the land stood practically in its present relation to the sea, and if this be so, their erosion was accomplished below the level of the sea, and must, therefore, be attributed to glacial action. The valley of the lower Copper was probably at one time a fiord which has been filled up with materials brought down by the river, and to it a similar origin is attributed.

## MINERAL RESOURCES.

### COPPER DEPOSITS OF THE INTERIOR.

*General statement.*—The occurrence of rich copper deposits within the basin of Copper and Chitina rivers has been commonly reported for many years, but it was not until the summer of 1898 that efforts to locate the ores proved successful. In this year several prospectors reached the interior and made some locations, while in 1899 a number of men penetrated the Wrangell Mountains by way of Kotsina River and discovered good indications at many places; others, exploring toward the east, proved the continuance of the copper-bearing belt in the direction of White River, where copper occurs in important quantities. In this region the Nikolai mine was discovered in July, 1899, under the guidance of a native sent by Chief Nikolai. During the summer of 1900 several prospecting parties were operating in the Kotsina and Chitina regions, and many additional locations were made, and upon the most promising properties considerable development work was done.

The examinations of the copper deposits made by geologists of the United States Geological Survey were in no case exhaustive and in most instances were necessarily of a very superficial nature, but sufficient general knowledge was gained of the manner in which the ores occur and of their extent and distribution to show the very great prospective importance of the region as a producer of copper.

The copper ores occur in association with an ancient mass of basalt or diabase, which has been named the Nikolai greenstone. It is probable that this igneous rock is the original source from which the copper was derived by circulating waters and deposited in the form in which it exists. Two distinct modes of occurrence are generally observable throughout the region. In the first cases the metal occurs native, either filling former cavities in the greenstone or in the form of stringers penetrating the parent rock. The copper does not, however, seem to be generally distributed through the rock, but seems to follow along a general trend, as though it were an imperfect vein. In such cases fracturing or shearing may frequently be observed, and though well-marked fissures may not have been developed, it is probable that the presence of the copper indicates a line along which the circulating waters could easily penetrate. Certain well-marked veins which carry metallic sulphides are bordered by native copper in the country rock near by.

The second class of copper deposits comprise the sulphides occurring in true fissure veins, and it is to these deposits that we must look primarily for the future development of the region. The fissure veins are found at various places throughout the area in which the Nikolai greenstone occurs, but it has been observed that the amount of ore always increases in the vicinity of the contact between the igneous rock and the overlying limestone. Certain veins may be traced from the greenstone upward into the limestone, and in such cases there is frequently an increase in the size of the ore body at the contact. In some cases there is a development of flat ore bodies upon either side of the vein along the contact or in the stratification of the limestone adjacent to it. The contrasting green and white of the basalt and limestone are very striking features throughout the region, and may be easily followed by the prospector or geologist, and those who have recognized the tendency of ore bodies to occur near the contact of these two formations have generally been rewarded, in tracing its outcrop, with the discovery of good indications of ore, and in several instances by very large shoots of ore. The outcrop of this important geological horizon has been represented on the map of the formations which accompanies this report, and in so far as it is complete it exhibits the localities where the important contact ores are to be expected.

The copper properties of the Kotsina and Chitina regions are yet entirely in the stage of development, and no ore has been brought out excepting in small quantities for assay and for mill tests. It is understood that many of these tests have been very satisfactory, and the value of the ores in general has been proved by assays made on samples collected by the writers upon the ground. It is believed that when facilities for transportation are forthcoming many valuable mines will be developed within the district. This impression is based upon what has been seen of certain ore bodies, especially those near the greenstone-limestone contact, and the large amounts of copper ore occurring as float everywhere throughout the region covered by the greenstone.

The very general distribution of the copper might at first be taken as an indication that no large bodies of ore are to be expected, but the surface exposures are sufficient to show that in some instances immense ore shoots do occur. On the whole it is regarded as conservative to say that the indications in the Copper River district are exceptionally favorable for the presence of copper in quantities of sufficient importance to warrant the expenditure of capital for very thorough exploitation.

*Copper deposits on Kotsina River.*—Copper ores and native copper have been discovered in various localities within the Kotsina drainage. Good specimens, mostly of bornite ore from the head of Clear Creek, were seen by the writers, and good prospects are reported to occur on Barrett and Elliot creeks, but the only deposits which it was possible to examine where any development work had been done were those on Rock Creek and Copper Creek.

The Warner prospect is located on the southeast side of Rock Creek half a mile above its mouth. At the time of visit a tunnel had been driven along the vein into the greenstone for a distance of 10 feet. At the mouth of the tunnel the vein is very nearly vertical, and has a width of about 2 feet, being composed of crystalline calcite. The course of the fissure is approximately S. 40° W., and upon the surface the vein may be traced for about 15 feet, when it is lost underneath the vegetation, but reappears with the same general course 100 feet farther up the slope, whence it may be traced to the contact of the greenstone and the massive limestone. The distance from the mouth of the tunnel to the contact where the original discovery was made is about 450 feet.

In the tunnel there is from 8 inches to a foot of bornite, with a small amount of quartz, though upon the surface the ore pinches to less than 5 inches. The vein seems to be a true fissure vein, with well-marked walls wherever it is sufficiently exposed for examination, but there are several stringers which evidently separate from the main vein.

If further development should prove the value of this property, its location at a low altitude and its accessibility from the Kotsina trail will be advantageous for its economical operation.

The discovery which has been made on Copper Creek is about 3½ miles above Kotsina River, at an elevation of approximately 4,000 feet. The deposit is situated upon a steep slope several hundred yards west of the point where the base of the massive Chitistone limestone crosses the creek. In developing this property an open cut some 15 feet in length has been made, and at its end a shallow shaft has been dug. The excavations have disclosed three poorly defined zones of mineralized material, each from 1 to 3 feet in thickness, and apparently made up of altered limestone rather than of ordinary vein materials. There is no well-defined vein, but a general north-south trend is observed, and there is a cleavage in the rocks having a steep dip toward the east. The deposit is made up of chalcopyrite and bornite somewhat stained with malachite and iron oxide. The ore appears to be a replacement of the limestone which forms the country rock.

A ton or more of the material has been taken out and lies upon the ground, and two selected samples which have been assayed gave over 30 per cent of copper, and one of them somewhat more than 2 ounces of silver. One also showed one-tenth of an ounce of gold. Although this prospect is situated at a considerable elevation, there will be no serious difficulty in reaching it with pack horses should future development warrant its being opened upon a commercial scale.

*Strelna Creek deposits.*—A considerable amount of prospecting has been done within the region drained by Strelna Creek, several mineral-bearing veins have been recognized, and some good prospects have been located. The ores comprise bornite, chalcopyrite, and a native copper.

About 2 miles above the fork the north branch of this stream is crossed by the contact of the massive limestone and the greenstone, along which there is a mineralized zone some 40 feet or more in width. This zone is impregnated to a greater or less extent throughout with sulphides of iron and copper, but the 8 or 10 feet of limestone next to the contact is considerably altered and contains a larger amount of the sulphides than the neighboring rock. The greenstone is mineralized only a short distance from the contact.

There are many evidences that movement has taken place in this vicinity, since the rocks are folded and crushed and the planes of shearing show slickenside surfaces. In one case a considerable fault was observed dislocating the base of the limestone. This mineralized zone is an example of the contact as a favorable position for the deposition of ores.

*Copper on Kuskulana River.*—At the time of the writers' visit there had been no effective prospecting along the tributaries of the Kuskulana, but in traversing the region good float was noticed in many places, and in one instance a well-marked vein was found. In the bed of the stream that has been named Nugget Creek a large mass of copper was discovered partly buried in the gravel. This was afterwards uncovered by prospectors and reported to be about 8 feet in length, with other dimensions from 3 to 5 feet. Along the southeastern side of the glacier fragments of copper ore were also observed at several places, and there can be but little doubt that good discoveries will be reported from the Kuskulana drainage.

*Bonanza claim.*—The Bonanza claim is located upon a high ridge between Kennicott Glacier and McCarthy Creek, at the contact of the greenstone and the limestone. It is 6 miles or more above the foot of the glacier and about 8 miles west of Nikolai mine. Here, upon the western slope of the ridge, is exposed the largest and richest body of ore thus far reported from the Chitina region. The vein is a true fissure, which cuts across the contact of the greenstone and limestone, though for some distance below the contact the vein is barren. The mass of the ore occurs in the limestone, from the contact to a height of perhaps 150 feet along the slope, and is exposed for a horizontal distance of nearly 4 feet. In width the vein is irregular, varying from 2 to 7 feet. Its course is N. 40° E. There is no quartz or other vein mineral associated with the ore, though between the walls of the vein there is sometimes a considerable amount of crushed limestone. The ore is practically pure chalcocite, or copper glance, and is stained upon the surface by copper carbonates. Solid masses of the ore from 2 to 4 feet across and 15 feet or more in length are exposed in several places, their depth being not apparent. Besides the ore within the fissure there are also bedded ore bodies running off into the limestone along the planes of stratification. The relations of the ore are such as to indicate that it was formed as a replacement of the limestone.

The amount of ore in sight, with practically no development, amounts to several hundred tons. An assay of a sample collected gave over 70 per cent of copper and 14 ounces of silver, besides a trace of gold.

The claim is situated about 1,500 feet above timber line, at an elevation somewhat above 4,500 feet, but the nature of the topography is such that a good trail could be built to it without great difficulty.

Besides the Bonanza claim several other locations have been made along the outcrop of the contact, on the Kennicott side of the ridge and, in one case, on McCarthy Creek. The ore in all of these claims is, however, bornite or chalcopyrite instead of chalcocite.

*Nikolai mine.*—The Nikolai mine is located on the creek of the same name tributary to McCarthy Creek from the east. The occurrence has probably been known to the natives for a long time and was revealed to Mr. Edward Gates by an Indian named Jack, who, though he had never visited the locality, was able to find it with aid of a map drawn by Nikolai, late chief of the Taral Indians.

The Nikolai mine is situated 1,000 feet or more above timber line, at an elevation of about 4,200 feet. The country rock in the lower part of the creek is Triassic shale intruded by porphyry, but a great fault brings up the Nikolai greenstone, which forms the bed rock from the vicinity of the main forks of the creek to a point above the mine. On the south side of the gulch opposite the mine the greenstone is opposed by the unconformable beds of the Kennicott formation, but to the north the Chitistone massive limestone is seen dipping steeply into the mountains, and this is followed by the Triassic shales, covering a large area between McCarthy Creek and Nizina River.

The vein occurs in the greenstone at a horizon not more than 50 feet below the bottom of the limestone, which outcrops in the creek bed a few hundred feet above the shaft. It is a true fissure vein, with well-marked walls, and there has been displacement or faulting along it to the amount of perhaps 50 feet, with the upthrow on the northwest. The course of the fissure varies from N. 50° E. to N. 55° E., and the vein dips about 65° SW. It may be traced for several thousand feet, though it shows no ore on the surface except near the place of discovery. The main fissure is paralleled at a distance of 90 and 140 feet, respectively, by two fissures which, though less prominent, also contain copper minerals, and the rock between is cut by many stringers of ore. In the vicinity of the shaft the main vein has a width of from 8 to 12 feet and is divided about equally by a horse of greenstone 3 or 4 feet across, in which the shaft has been sunk. The ore on either side of the horse is practically pure bornite, with only a small amount of quartz associated in an irregular way. Locally, as shown near the chalk bed, there is a band of chalcopyrite lying next to the hanging wall. The development in the latter part of August, 1900, consisted of a shaft 30 feet in depth and an open cut along the vein for perhaps 50 feet. Throughout this distance ore having a thickness of from 2 to 4 feet had been exposed, and in the bottom of the shaft the horse had been penetrated and bornite ore was found on the foot-wall side. The development has been sufficient to show the presence of a large shoot of ore which can be mined from the present shaft or from a short adit which could be driven to cut the vein at a depth of perhaps 100 feet, but whether the ore is generally distributed or whether there are other large ore bodies along its course is yet to be determined.

A good trail, a mile or more in length, had been constructed from the camp at timber line to the mine. During the summer of 1900 about a dozen men were engaged in the exploitation of the Nikolai mine.

*Other occurrences.*—Rich deposits of native copper are reported to occur at the headwaters of Chitina River, and since the geological structure of the region adjacent on the west indicates the probable continuation of the greenstone belt into this region, it seems likely that workable amounts of copper will be found there. The region lies directly between the exposures of greenstone on the Nizina and those which carry native copper at the head of White River across the intervening range.

The natives also report the occurrence of copper in the mountains between Hanagita Valley and Chitina River, though the localities can not be determined from their descriptions.

In the lower part of the Chitina Valley several locations have been made, and though these were not visited the rocks of the region were seen and found to consist of gabbros and diorites, probably intrusive in limestones and amygdaloidal greenstones. These ores are made up almost entirely of chalcopyrite.

## COPPER IN PRINCE WILLIAM SOUND.

*General statement.*—The copper ores of Prince William Sound have been attracting the attention of prospectors and miners for several years, and in 1898 several claims were visited by Mr. Schrader and described by him in a report on the region.[1] Many of these claims have since changed hands, and upon some of them considerable development work has been done. Many new locations have also been made, and it is to be regretted that only a very inadequate study of the geology and mineral deposits of the Sound region was possible during the autumn of 1900. In Prince William Sound the copper occurs in two ways: first, in fissure veins; second, in mineralized zones which seem to be nearly or quite parallel to the bedding of the heterogeneous strata composing the Orca formation. The deposits of Copper Mountain, in Landlocked Bay, are of the fissure-vein type, and other instances of fissure veins were observed in claims located south of Orca in the vicinity of Flemming Spit. In both of these localities the country rock is greenstone diabase or basalt, apparently occurring in large masses. All of the other occurrences, so far as they are at present known, are impregnations of zones of more or less crushed country rock by sulphides of copper and iron. In most instances the ore occurs in the interbedded flows of greenstone, which are commonly regarded by the prospectors of the region as dikes; but it is also found in the arkose sandstones and in the shales. The mode of occurrence may be compared, in a very general way, to that of a portion of the copper deposits of Lake Superior, though in the present instance sulphides are found in the place of metallic copper. The association of the ores with the greenstone is very general, for even when they lie in sedimentary rocks the igneous rock is never very far distant. It may be suggested that the origin of the copper is to be sought in the flows or intrusions of basalt or diabase, from which it has been concentrated by means of circulating waters.

[1] A reconnaissance of a part of Prince William Sound and the Copper River district, Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, Part VII, 1900, pp. 417–420.

Copper claims have been located in various parts of Prince William Sound, and by their distribution show the very general occurrence of the ores throughout the region. The best-known claims are on Latouche and Knight islands and on the mainland in the vicinity of Copper Mountain, and at Ellamar, where the Gladhaugh property is situated. Other claims are situated on Montague, Hinchinbrook, and Glacier islands, and at various places on the mainland.

*Latouche Island.*—The Bonanza claim is located near the shore on the western side of Latouche Island, at an elevation of about 200 feet. At the place of discovery there is exposed a sloping face of bare, iron-stained sandstone and shale, about 300 feet in length and 100 feet in height. The yellow and brown staining has resulted from the weathering of iron pyrites, and both this mineral and bornite, by which it is accompanied, are quite generally distributed through the rock over the entire exposure. A tunnel has been driven into this mineralized rock for a distance of about 60 feet, and though it appears to run across the trend of the deposit it has not yet passed through the mineral-bearing zone. A sample taken along the entire length of the tunnel gave an assay of over 9 per cent of copper with 1¼ ounces silver. Gold was not present in any valuable amount.

A property known as the Whale claim is located on the southeast side of Latouche Island. Here the ore, consisting of chalcopyrite and bornite, occurs in the form of stringers and is disseminated through the country rock of gray sandstone and black slate. The impregnations seem to be confined to a fractured zone following the general trend of the rocks, which have a strike N. 75° E.

*Gladhaugh mine.*—In the vicinity of the Gladhaugh mine, at Ellamar, the strike of the folded and sheared black shales of the Orca series is variable, but its general direction is northwest-southeast. The dips are usually toward the north. The Gladhaugh vein is a practically solid mass of iron and copper pyrites. It has a width of more than 125 feet where exposed, and extends along the strike for a known distance of more than 300 feet. The north wall of the vein, where it comes in contact with the shale, has a course N. 45° W., and the dip is 30° toward the north; but possibly the general dip is considerably steeper, since the foot wall is known to have a much greater pitch.

Locally there are some small inclusions of country rock within the vein, and occasional lenses of calcite are found, with a small amount of bornite. A general sample taken across the vein gave an assay of 5.4 per cent of copper, with one-tenth of an ounce of gold; but since the chalcopyrite seems to be not uniformly distributed, it is probable that a much higher percentage may be attained by selecting the ore.

In November, 1900, work was being rapidly pushed upon a shaft which it was the intention to sink to a depth of 150 feet before running a crosscut to reach the vein.

## OCCURRENCE OF GOLD.

### VEIN DEPOSITS.

*Alaganik.*—The only gold deposits in place which are known in the Copper River region are located at McKinley Lake, near Alaganik, on the north side of the Copper River delta. At this place several veins of quartz have been opened and found to contain gold in varying quantities. A short study of this field was sufficient to show that the principal veins lie parallel to the stratification of the sedimentary rocks and that they usually follow the contact of two beds of different character, as of massive arkose sandstone against shale. In many cases ledges varying in width from a few inches to several feet may be traced for long distances. In one claim the quartz shows a large amount of free gold in small stringers, but this claim has not been sufficiently exploited to determine either the permanence of the vein or its character.

Besides these veins in the planes of stratification there are others transverse to the bedding which have a width up to 4 feet and are known to be continuous for 100 feet or more. One of these, which shows no free gold, was sampled and found to contain sixty-four one-hundredths of an ounce of gold. On the whole, the Alaganik region seems worthy of the further attention of mining men.

### PLACERS.

Gold is of general occurrence in the stream gravels throughout the Copper River district and along the adjacent shores of the Pacific Ocean, but has not been shown to be of economic importance except in a few localities.

*Fall Creek.*—Gold was discovered on Fall Creek, near the head of Kanata River, in 1898. It is estimated that $500 was produced during the summer of 1899. The diggings begin about a mile above Kanata River and extend for 5 or 6 miles up the creek. The gravels are from a few feet to 600 feet in thickness, and from their mode of occurrence are supposed to be of glacial origin. From these gravels the gold has been concentrated by the action of running water and is found where bed rock can be reached. Some of the gold is coarse, nuggets having been found up to $5 or $6 in value. It is hardly probable that the Fall Creek placers will ever become important producers.

*Quartz Creek.*—Gold was discovered in the tributaries of Tonsina River in 1898, and assessment work has been done on a few claims each year since. The origin of the gold is probably similar to that suggested for the deposits of Fall Creek. The entire production of the creek to date is probably not in excess of $1,200.

*Mount Drum region.*—In the vicinity of Mount Drum platinum was discovered in 1899 in the stream gravels. No definite information concerning the deposits is at hand, but there can be no doubt that the metal actually occurs, though in what amount is not known.

*Chestochina region.*—During 1899 placer gold was discovered on the tributaries of Chestochina River, and in 1900 perhaps 25 men found their way to these diggings. The value of the output is variously estimated at from $10,000 to $100,000, though the former figure is more likely to approximate the correct amount. The gold is very much flattened, as though it had traveled some distance; but frequently fragments of schist and vein quartz still cling to it, showing its origin from vein deposits. From the general knowledge of the surface deposits of the upper Copper Basin it is supposed that these placers must be secondary concentrations from gravels of glacial origin. An examination of a sample of the medium coarse gold shows it to contain about 1 per cent of platinum. At the time of this writing, in March, 1901, several hundred men are reported to have started for the Chestochina country by way of Valdes.

*Gold along the coast.*—In the vicinity of Yakutat Bay beach diggings have been known for several years, and though these attracted considerable interest in 1900, they seem to be of only moderate value. A small amount of platinum is said to occur with the gold.

At various places along the shores of Kayak Island auriferous sands are known to occur, but they have thus far proved to be of little value. Also, upon Little Kayak gold is present in the beach sands.

## COAL AND OIL.

Concerning the presence of coal in the Copper River region no definite information is available, except a note of the occurrence of thin seams on Buff Creek near the headwaters of Taslina River.[1]

There are also rumors of coal occurring in the upper part of Gakona River and in the Alaskan Mountains at the head of Chestochina River.

The following proximate analysis of a specimen of coal reported to have come from the head of Chilkat River, about 50 miles east of the mouth of Copper River, in the Kayak region, was made in the Survey laboratory by W. F. Hillebrand:

*Analysis of coal from Chilkat River.*

| | |
|---|---|
| Ash | 3.08 |
| Moisture at 105° | .77 |
| Volatile combustible | 13.79 |
| Fixed carbon | 82.36 |
| | 100.00 |
| Sulphur | 2.68 |

The ash is brownish in color, largely composed of ferric oxide, and contains some sulphur, probably in the form of calcium sulphate. The coke is very incoherent. The analysis indicates a coal of very good

[1] A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898, by W. C. Mendenhall: Twentieth Ann. Rept. U. S. Geol. Survey, Pt. VII, 1900, p. 324.

quality, and is to be rated as semianthracite upon the high percentage of fixed carbon contained.

Two specimens of petroleum were procured from parties interested in the Catalla and Kayak fields. That from Catalla is of a dark-brown color, as liquid as ordinary kerosene, which it resembles in odor. It was tested by H. N. Stokes, of the Survey, and found to contain no sulphur. The specimen from the Kayak region is also dark brown in color and very viscous. There is no odor of kerosene, and the sample was found by Dr. Stokes to contain a slight trace of sulphur.

The age of the rocks in which the coal and oil occur is probably Eocene, like the coal-bearing series of Cook Inlet.

## RAILROAD CONSTRUCTION.

Engineers who have examined the approaches to the divide and the passes that cross it regard the Valdes route as practicable for the construction of a railroad to Copper River, and the observations of the writers' party are entirely corroborative of this judgment. The greatest obstacles to be overcome are the crossing of the coastal mountains, but here practicable grades can be located. Other formidable difficulties are the glacial streams, often flowing in trenches several hundred feet below the general surface of the interior basin; but these are not extraordinary, except for their number. The character of much of the ground is very swampy; but this for the most part is the result of the vegetation, consisting largely of moss, which prevents good drainage and protects the frozen ground from thawing to any great depth. The stripping of this vegetation and the construction of a slightly elevated roadbed from the gravels which everywhere underlie the surface would probably obviate this difficulty.

After reaching Copper River a line could be run to the copper districts of Kotsina and Chitina rivers, should future development be equal to present indications of their value. Eventually a line would also be extended to Eagle City by way of Mentasta Pass, affording an all-American rail route from the coast to the Yukon country.

## TIMBER.

Within the Copper Basin and along all of its tributaries there is spruce timber in sufficient amounts for all the purposes of mining, and aspen occurs in many places where the spruce has been burned off. In swampy places the spruce is found to be small; but where the drainage is good, along river bottoms and on the side hills, the trees frequently reach a diameter of 3 feet, or even more, and would furnish good saw logs. Timber line is usually located in the vicinity of 3,000 feet elevation, but locally the trees extend from 300 to 500 feet higher.

APRIL 1, 1901.

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