The timber-covered flats of Chitina River are the most extensive low-bench deposits of the district. They represent more than one stage of the river's activity and range in height up to possibly 20 feet above the flood plain. Their greatest width is not over a mile. The lowest of the benches are little above the river, and, although they can not be considered properly as belonging to the present flood-plain deposits, they may be overflowed locally in times of exceptionally high water. Most of these old flood-plain gravels along Chitina River are so low, except near the mountain slope, that the water flowing through them is forced to the surface and forms clear-water streams that in their lower courses have cut channels in the benches to a depth of 6 to 8 feet. They are covered with a growth of poor timber and other vegetation, whereas the higher benches bear a heavy growth of fine timber. These gravels contain much well-rounded material with sand, silt, and probably a small proportion of wind-blown dust. The low-bench gravels of Chitina River, like the flood-plain gravels, from which they differ only in elevation, show a large proportion of light-colored granitic rock. They appear to have a greater proportion of fine material than the bench gravels, but this is due to the fact that the bench gravels are usually seen in section and the flood-plain gravels only on the surface, from which much of the fine sand and silt has been removed by the water or wind.

IGNEOUS ROCKS.

By R. M. OVERBECK.

GENERAL FEATURES.

Igneous rocks, both intrusive and extrusive, are widespread in the upper Chitina Valley. They occupy fully one-half of the area described in this report and occur both north and south of the Chitina River valley and on "islands" that rise from the level gravel-covered floor of the valley itself.

Some of the intrusive bodies are large batholiths; others are relatively small dikes, sills, or irregular masses. Two large intrusive bodies which are here classed as batholiths occur north of Chitina River between Barnard Glacier and Chitina Glacier. One huge batholith apparently forms the entire mountain range south of the Chitina from the Kiagna to the international boundary. The smaller intrusive bodies are distributed rather generally through the region. They cut limestones and schists of Paleozoic (?) age and greenstones of Carboniferous and Triassic (?) age, but they are especially abundant in the black Cretaceous shales near Young Creek and Canyon Creek.

Effusive and volcanic rocks occur in the region in great amounts. There are a few small areas of doubtfully tuffaceous or effusive rocks on Young Creek near the mouth of Sheep Creek, on the ridge just east of Canyon Creek near its mouth, and in the belt of highly altered rocks near the mouth of Canyon Creek. (See Pl. III, in pocket.) A striking series of effusive and volcanic rocks, several thousand feet thick, consists of tuffs and flows of Carboniferous and Triassic (?) age. The most recent volcanic rocks are the mounds of ash on the moraine of Barnard Glacier.

The rock types represented are as varied as their mode of occurrence. The large intrusive masses are formed of granites, quartz diorites, syenites, and diorites; the small intrusive masses consist of quartz diorite porphyries; the effusive and volcanic masses are chiefly rocks that have been highly altered. The doubtful tuffs and flows have already been noted. The Carboniferous and Triassic (?) tuffs and flows are now altered to greenstones, although the original character of the rock can still be roughly determined. The recent volcanic ash is unaltered.

The relative age of most of the igneous rocks of the region is known, but their geologic ages are rather doubtful. The greenstones, which are correlated with the Nikolai greenstone and the underlying tuffs in areas west of the region, are Carboniferous and Triassic (?). The larger intrusive masses north of the Chitina cut the greenstones and are probably post-Triassic. Some of the smaller intrusive masses cut Upper Cretaceous rocks and must be of Upper Cretaceous or post-Upper Cretaceous age. Most of the tuffs and flows of doubtful age rest on Cretaceous rocks. The recent volcanic ash is the product of an eruption that is supposed to have taken place less than 2,000 years ago.

In this paper the igneous rocks are subdivided chiefly according to the form of their occurrence. A classification according to age mould have been more desirable, but it is not yet possible, and on account of the same lack of definite knowledge the minor subdivisions made are subject to revision.

INTRUSIVE ROCKS.

BATHOLITHIC ROCKS.

GENERAL DISTRIBUTION, CHARACTER, AND AGE.

Outcrops of coarse-grained igneous rock that apparently represent the exposed portions of large, deep-seated intrusive bodies or batholiths occur both north and south of Chitina River. Two bodies of this type lie north of the river, between Barnard Glacier and Chitina Glacier, and a single batholith seems to form the range of mountains that stands along the south side of the valley within the area mapped. The coarse-grained igneous rocks on the "islands" that rise above the gravel-covered floor of the valley itself indicate the probable extent of these large masses beneath the gravel. The two bodies north of the Chitina, called here the eastern and the western, may be connected beneath the river gravel with one another and with the batholith south of the river. The eastern intrusive body lies along the north side of the Chitina Glacier near its lower end, and the western body extends along the north side of the Chitina Valley from Barnard Glacier eastward almost to the end of the Chitina Glacier. The outcrop of the body is relatively narrow, but the rock is evidently of the batholithic type rather than of the type seen in the smaller intrusive bodies near Young Creek. The south side of the river was not visited, so that the character of the rocks there can only be assumed.

The rocks of the three areas of deep-seated intrusion are of somewhat different types. The rocks north of the river are generally darker than those south of it. The rocks of the eastern intrusive body are mostly syenite and diorite; those of the western body are granite or granite porphyry; and those of the body south of the river and of the "islands" in the river are apparently quartz diorite.

These three large intrusive bodies are supposed to represent a single general intrusion or series of intrusions, which probably took place in Mesozoic time. (See p. 58.)

BATHOLITHIC ROCKS NORTH OF THE CHITINA.

Eastern intrusive Body.—The easternmost of the two batholithic intrusive bodies on the north side of the Chitina Valley lies along the Chitina Glacier near its lower end. (See Pl. III, in pocket.) The westernmost exposure of this body is about 3 miles east of the end of the glacier, and its outcrop extends with varying width, whose maximum is about 3 miles, for about 8 miles along the glacier. As a part of the body undoubtedly lies under the ice, its actual area of exposure has probably been much greater than that shown on the map. In outline it is somewhat irregular. The contact between it rind the greenstone, which it intrudes, is drawn only in a very general way, for the similarity in color and in topographic expression between the intrusive body and the intruded body makes their separation difficult from a distance. The intrusive rock weathers to a very dark reddish brown or greenish shade and forms ridges that have-rugged tops and precipitous sides.

Hand specimens taken from this intrusive body near the first tributary glacier from the north to the Chitina Glacier show that the prevailing type of. rock in it is syenite. This syenite is light pray, pink, or dark brown, and different specimens show gradations from coarse to medium grained. Most of the very coarse grained rocks are made up of roughly parallel long crystals of feldspar, the largest an inch long. The fine-grained rocks, in which the crystals are smaller, are of the same general type. The specimens range from those in which the light-colored minerals are largely in excess to those in which the light and the dark minerals are about equal. The crystals of feldspar, which are naturally light colored, are in these rocks filled with minute inclusions and are therefore generally rather dark. The notable feature about these rocks, however—a feature that differentiates them from granite, with which they might easily be confused in the hand specimen—is their lack of quartz. Light-colored igneous rocks that contain little or no quartz are rather uncommon in Alaska, so that their occurrence here is probably merely a local phenomenon.

The texture of the rock as seen in thin section under the microscope is somewhat variable. Many of the crystals of feldspar, the predominant mineral in the rock, are of prismatic form, though commonly without sharp crystal outline. Some of them show a subparallel arrangement, but others form no definite pattern. The subparallel arrangement seems to be more generally characteristic of the coarser-grained rocks. The dark minerals are not well crystallized in these coarser-grained rocks, but in the finer-grained rocks most of them show crystal outline, modified, however, by alteration. In these rocks orthoclase predominates, usually in large crystals of prismatic form in thin section, and it may or may not be well crystallized. Carlsbad twinning and perthitic intergrowth of orthoclase and albite are common. Most of the crystals are filled with minute opaque inclusions, which in the hand specimens give the feldspar its yellow, brown, or pink color. The orthoclase is somewhat decomposed. Crystals of plagioclase feldspar occur in the rocks but in amount subordinate to that of the orthoclase. A little albite (besides that perthitically intergrown with orthoclase), oligoclase-andesine, and andesine were recognized. All are somewhat altered, and some specimens show that the alteration started at the center of the feldspar crystal. The alteration product is, in part at least, sericite. Other constituents of the rocks are hornblende, pyroxene, biotite, olivine, apatite, pyrite, magnetite, chlorite, calcite, and epidote. Common green hornblende, which is the most abundant dark mineral, is found in shreds and patches altering to chlorite: Pyroxene was seen in only one or two mall grains in one thin section and was not determined specifically. Biotite occurs rather sparingly and is largely altered to chlorite. Olivine occurs in only one specimen in which it is almost completely altered to serpentine. Apatite mas noticed in varying amount in different specimens but is everywhere accessory. Pyrite and magnetite are not particularly abundant. Chlorite, sericite, calcite, and epidote are alteration products.

Only one of the samples from the eastern intrusive body could be properly called a diorite. The rock is medium grained, dark gray, and contains about equal amounts of light and dark constituents. The feldspars range from oligoclase-andesine to andesine. Hornblende, altered in large part to chlorite, is abundant. Accessory constituents are apatite, a little epidote, zoisite, titanite, magnetite, pyrite, and calcite. Epidote and calcite are probably alteration products.

The intrusion of these rocks took place probably in Mesozoic time. (See p. 58.)

***Western** intrusive* body.—The westernmost of the two large intrusive bodies on the north side of the Chitina Valley is comparatively narrow. It extends northwestward across the ridge in the angle between Barnard Glacier and Chitina River, and its southwestern edge is about $6\frac{1}{2}$ miles from the end of the glacier. On Chitina River the same edge lies about a mile and a half below the end of the Chitina Glacier. The outcrop is about half a mile wide and about 6 miles long. Its farther extension is concealed on the northwest by Barnard Glacier and on the southeast by Chitina Glacier. A rather large outcrop of intrusive rock on the northwest side of Barnard Glacier, which was not visited but which could be recognized as an intrusive from the south side of the glacier, may be a northwesterly continuation of this body. The body probably extends southeastward under the gravel and joins the large batholith south of the river. Seen from a distance, the rocks of this body appear dark red, and, like those of the eastern intrusive body, can not easily be distinguished from the greenstone into which part of them have been intruded. This greenstone here lies near limestones that are considered Paleozoic.

The rock that makes up this intrusive body is apparently homogeneous, so only a few hand specimens were collected and examined. All are granite or granite porphyry and are somewhat finer grained than the rocks of the eastern intrusive body. They are only fairly fresh, are pink, speckled with light and dark green, are of medium grain, and are to some extent porphyritic. The normally light-colored minerals, such as feldspar and quartz, are much more abundant than the dark minerals, such as hornblende, biotite, and other minerals rich in iron. The racks consist predominantly of pink orthoclase feldspar and of quartz, light-green decomposed plagioclase feldspar, shreds of hornblende, and altered biotite in relatively small amount.

An examination of thin sections of these rocks under the microscope shows that they are granular and that their texture is rather porphyritic, the crystals of orthoclase being generally larger than the crystals or grains of any of the other minerals. The rock shows an abundant micrographic intergrowth of orthoclase and quartz. The orthoclase occurs in prismatic forms that range from symmetric crystals to particles that show no external crystal outline. The crystals are filled with minute opaque inclusions and with a fine-grained product of decomposition. The inclusions probably give the feldspar its pinkish color. The plagioclase feldspars are altered beyond specific identification. Hornblende and biotite are altering or have altered to chlorite. Some calcite and some epidote also occur, probably in part as products of the decomposition of the plagioclase feldspar. The microscopic examination of these rocks confirms the determination from hand specimens that they are granites.

These rocks, like those of the eastern intrusive body, are probably Mesozoic.

BATHOLITHIC ROCKS SOUTH OF THE CHITINA.

Character.—The mountains south of Chitina River and east of Kiagna River are composed chiefly of light-colored, coarse-grained igneous rocks. The south side of the river was not visited, and knowledge of the rocks in that area was obtained from a consideration of the general appearance and topographic peculiarities of the range south of the Chitina; from the prevalence in the river gravel and on some of the "islands" that rise above the flood plain of the river of coarse-grained igneous rock different in type from the rocks of known areas north of the river; and from the statements of prospectors who had visited the creeks south of the river. The rocks that form the south side of the valley, except in one or two small areas, appear to be of the same general type from the mouth of the Kiagna eastward to the boundary and are probably all outcrops of a single huge batholith similar to those that stretch along the western side of the American continent. The mountains south of the Chitina are very rugged, being deeply cut by steep-walled canyons that alternate with narrow knife-edge ridges and include numerous sharp-pointed peaks that rise to a nearly uniform height of about 8,000 feet. The dark green of vegetation colors only the gentler slopes of the mountains; the steep-walled canyons, the precipitous slopes, and the sharp-pointed peaks are light gray. The topographic peculiarities of the range and the light-gray color of the rocks persist at least from the mouth of the Kiagna to the international boundary.

Mineral composition.—As no specimens of the rocks south of the Chitina were obtained the nature of these rocks can not be positively stated, but they are probably similar to those found on the river bars and that outcrop on "islands" not far from the south side of the valley. Specimens taken from these places prove to be parts of a light-colored, coarse-grained rock whose most obvious constituents are white feldspar, quartz, biotite, and hornblende. The feldspar in part shows crystal outline and in part irregular outline; quartz shows irregular outline; biotite occurs in shreds and patches and is somewhat altered; hornblende occurs in long, narrow, dark-green crystals; small brown crystals of titanite are fairly abundant. The light minerals are much more abundant than the dark, and the rock on a freshly broken surface is a very light gray.

A study of the rock in thin section under the microscope, by which the exact character of the feldspars can be determined, shows that it is a quartz diorite. Its texture for the most part is due to the simple interlocking of irregular crystal grains. Some of the crystals of feldspar are of prismatic form, and hornblende occurs commonly in long crystals. The feldspar ranges in composition from albite-oligoclase to oligoclase-andesine and shows albite twinning and zonal structure. Quartz is abundant. Biotite occurs in shreds and is in part altered to chlorite. Common green hornblende occurs in minor amount. A little epidote, undoubtedly an alteration product, was noted. The rock as a whole is fresh and the minerals show no strain phenomena, such as might be expected if the rock had been acted on by mountain-building forces.

The fact, that the few samples examined under the microscope are quartz diorite does not imply that all the light-colored igneous rocks south of the river are quartz diorite. In that area rocks that are closely related to quartz diorite and that can be discriminated from it only with the microscope—such as granodiorite, quartz monzonite, and possibly granite—may occur or may even predominate.

Age.—The age of the batholith south of Chitina River and of the two large intrusive masses north of the Chitina that are supposed to be related to it genetically can only be surmised; direct evidence of their age is lacking. Certain facts about these masses, however, suggest approximately the time of the intrusion. In all places where the boundaries of the intrusives were examined near at hand, the intruded rock is the greenstone tuff that was correlated with the greenstone and tuffaceous beds of Mississippian age that underlie the Nikolai greenstone in the districts to the west. The large body south of the river intrudes the bedded greenstone that was correlated with the Nikolai greenstone, which is probably of early Triassic age. As no rocks except greenstone are found where intrusion has taken place the earliest age that can be set for the intrusion is Mississippian or post-Mississippian, or even probably early Triassic or early Middle Triassic. An examination of the rocks that make up these batholiths' shows that they are relatively fresh in appearance, although somewhat altered superficially. A study of the minerals under the microscope shows no evidence that the rocks were subjected to the action of mountain-building forces after solidification. As rocks in the region as young as late Triassic hare undergone intense folding that would almost surely have registered itself on the intrusive masses if they had existed, these intrusive rocks are doubtless post-Triassic. The size, general appearance, and position of the large intrusive mass south of the river suggest that it is related to the batholithic intrusive rocks of the Coast Range of western Canada, which are regarded as of Jurassic or possibly early Cretaceous age. If, then, the body south of the river is correlated with the Coast Range intrusive rocks its age is roughly Jurassic or, possibly, Cretaceous.

MINOR INTRUSIVE ROCKS,

Minor intrusive bodies, such as dikes, sills, and relatively small irregular masses, are numerous in the district. Some of these bodies cut schist, limestone, and greenstone east of Canyon Creek, but most of them appear in the black Cretaceous shales just west of Canyon Creek. The intrusive rocks in greenstone were seen only at a distance and were recognized by their rather light brown or red weathering products.

INTRUSIVE BODIES IN PALEOZOIC (?) LIMESTONES AND SCHISTS.

Dikes occur here and there in the Paleozoic (?) calcareous schists and limestone of Barnard Glacier and in the white limestone at the head of the first northern tributary of the Chitina Glacier. The dikes are rather small but are prominent, owing to the light red-brown or blood-red color of their weathering products, which contrasts strongly with the blue-gray or white surrounding rocks. Most of the exposures are high on the mountain and are inaccessible, and the accessible exposures are so greatly weathered that it is difficult to get a hand specimen which appears even fairly fresh and impossible to get one whose original nature can be told with any certainty.

In the hand specimens the rock obtained from these dikes is very light yellow or greenish gray and on further alteration becomes deep yellow-brown. The rock appears to be porphyritic in texture and contains phenocrysts of altered feldspar and a little quartz. The general nature of the groundmass can not be told even with the microscope. In general appearance the rock resembles, roughly, the quartz diorite porphyry that intrudes the black Cretaceous shales farther west, but the resemblance alone is not sufficient to warrant the suggestion that the two porphyries are genetically related.

The geologic period in which these dikes were intruded can not be determined. The youngest rocks they are known to cut are probably of Paleozoic age and may not be older than Carboniferous.

INTRUSIVE BODIES IN CRETACEOUS SHALES.

Distribution and character.—Associated with the black Cretaceous shales of the western part of the region mapped are numerous intrusive quartz diorite porphyries. The intrusive bodies are of different forms and their light color contrasts sharply with that of the black shales. They occur as large irregular masses, many of which include blocks of shale (Pl. X, B, p. 30); as sills of great persistence both in horizontal extent and in thickness; and as irregular dikes that cut at different angles through the shale. Sills appear to be more abundant than dikes, although the absence of visible bedding in the black shales makes this merely a supposition based on the frequent occurrence of series of parallel, relatively thin, intrusive bodies. The black shale hills form smooth, rounded surfaces where they are not intruded, but where they have been intruded the shale, indurated and supported or protected by the less easily eroded igneous rocks, forms rather sharp peaks and ridges. (See Pl. IV, *A*, p. 10.) The quartz diorite porphyries do not disintegrate so rapidly as the shales but break down readily enough into platy pieces of rock, which form prominent light-colored talus slopes. Even a comparatively small intrusive body may have beneath it a pile of talus that effectually conceals the black shale and accentuates the size of the intrusive rock.

The black Cretaceous shales are confined to the western part of the district mapped, and the intrusive quartz diorites are coextensive with them. The intrusive rocks, although present at many places within the black shale area, are more abundant in some places than in others. The Cretaceous shales south of Young Creek and those north of Young Creek, west of Calamity Gulch, are intruded by small scattered dikes and sills, and the shales west of Canyon Creek from the Chitina northward have been almost entirely replaced by intrusive masses. (See Pl. X, B, p. 30.) A notable feature about the location of these intrusive rocks, as well as of those of similar type near Kennicott Glacier, is their abundance near the contact between the black shale and the Nikolai greenstone. (See Pl. X, B, p. 30.) At places in the district to the west both the black shale and the greenstone are intruded. The contact between the shale and greenstone therefore appears to have been a common locality of intrusion. This contact at some places is undoubtedly a fault, and it may be that it was a line of structural weakness that was favorable to intrusion. The greenstone, too, may have in some way directed the course of the intruding rock. Not all the large intrusive bodies occur at the contact, however; the intrusive body shown in Plate IV, *A*, is several miles away from the contact.

Mineral composition.—Hand specimens of these intrusive rocks show that they are dark gray, pink, and light gray when comparatively fresh. The lighter varieties weather to light yellow-brown through the breaking down of iron sulphides and the formation of iron oxides. In texture they range from fine grained to coarse grained and are porphyritic. Feldspar crystals, some of them long and some equidimensional, are the most common phenocrysts. The meaning of the term porphyry seems to be generally misapprehended by prospectors. In its simplest use it is a term applied to an igneous rock that is made up in part of large crystals that are set in a groundmass of smaller crystals or of glass; it does not indicate the kind of minerals that, make up the rock, it simply indicates the relative size of the crystals. These quartz porphyries, for instance, contain large grains or crystals of feldspar, quartz, or biotite, which are surrounded by an aggregate of fine-grained quartz, feldspar, and hornblende. Some of the hand specimens consist almost entirely of light-colored minerals, such as quartz, feldspar, and long needle-like crystals of common hornblende, and one specimen contains a preponderance of biotite, which in part shows crystal outline. Calcite is visible in some of the hand specimens but is here the result of the alteration of some of the calcium-bearing feldspar.

A study of the thin sections of these rocks shows that they are altered beyond specific identification. The slides show chiefly a mass of fine-grained, decomposed products, in which calcite and sericite alone could be recognized. The presence of quartz and of crystals of feldspars that still show albite twinning and the small proportion of dark minerals indicate a rock resembling quartz diorite in composition. Exactly similar intrusive rocks in black Cretaceous shales in the Nizina district, just to the west, where fresher material was obtained, have been studied in greater detail[1] under the microscope and classed as quartz diorite porphyries.

Age.—The intrusive quartz diorite porphyry of upper Young Creek cuts black shales, which, on evidence afforded by fossils, are assigned to the basal part of the Upper Cretaceous or to the topmost beds of the Lower Cretaceous. Fossils collected from similarly intruded black shales in the vicinity of Blei Gulch, in the Nizina district, have been identified certainly as Upper Cretaceous forms. Some of the intrusives, then, can not be older than Upper Cretaceous. The black Cretaceous shales in the Young Creek district are overlain by a series of arkosic sandstones, shales, and conglomerates that are of Cretaceous age and that, as their position shows, are younger than the black shales. Intrusive rocks were nowhere seen cutting these rocks or even reaching up to them. The intrusion of the quartz diorite porphyries would therefore seem to have taken place in later Cretaceous time.

[1] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, p. 64, 1911.

EFFUSIVE AND VOLCANIC ROCKS.

DISTRIBUTION.

Both effusive and volcanic rocks occur in the upper Chitina Valley. These rocks are among the most widespread on the north side of the valley and they occur in two relatively small areas near the river on the south side. (See Pl. III, in pocket.) The effusive and volcanic rocks in the district are represented chiefly by a thick series of greenstones and greenstone tuffs—altered basic lava flows and tuff beds. These greenstones, as will be pointed out later, are correlated with the Nikolai greenstone and underlying tuff beds of the Kotsina-Kuskulana district. Two small areas of doubtful volcanic or effusive rocks have been mapped—one in the Young Creek valley between Calamity Gulch and the "big bend," and the other on the low ridge along the north side of the Chitina between Canyon Creek and Hawkins Glacier. Recent volcanic material was found on the moraine of Barnard Glacier. Tuffaceous beds may possibly be included in the belt of highly altered rock along the slope of the ridge west of Canyon Creek, but if so they have not been mapped.

The age of the recognizable tuffaceous beds and lava flows of the district ranges from early Carboniferous to Recent. The most violent outbursts of volcanic activity recorded in the valley occurred in the Carboniferous and probably in the early Triassic periods.

TUFFS AND FLOWS OF CARBONIFEROUS AND TRIASSIC (?) AGE.

Distribution and character.—Greenstones are areally the most abundant of the igneous rocks north of Chitina River. They occur most extensively in the region between Canyon Creek and Barnard Glacier but are found also between Barnard Glacier and Chitina Glacier, on some of the "islands" that rise from the floor of the Chitina Valley, and probably in two rather large areas south of the Chitina. The greenstones form dark, forbidding-looking mountains whose steep sides are cut by deep, narrow gulches containing streams that are generally nothing more than series of cataracts. (See Pl. XIII, *A*, p. 37.) Except for mosses and lichens the greenstone mountains in the district mapped bear no vegetation. The prevailing dark color of the greenstones is relieved in places by the bright-yellow or dull-red dikes which cut them, and which have changed color under the influence of the weather, or by patches of light green, representing an advanced stage of decomposition of the greenstone itself. Talus derived from the mechanical breaking up of the greenstone is abundant only at the very bases of the mountains; the precipitous sides afford no lodging place for loose material. In this district the talus is nearly everywhere removed by rapid streams, such as Canyon Creek, or by glaciers on which it falls. Most of the talus that remains consists of angular pieces of dark-green rock cut by light stringers of alteration products and having shiny surfaces that result from shearing and from movement of the rocks under pressure.

The greenstone in the upper Chitina Valley is very thick. The mountains just east of Canyon Creek consist almost entirely of greenstone (see Pl. IV, B, p. 10); and those east and west of Hawkins Glacier, so far as can be seen, are composed wholly of greenstone. At the end of the mountain just west of Hawkins Glacier greenstone is exposed continuously from the top to the base and neither the top nor the bottom of the formation is in view. This exposure would represent a thickness of at least 3,000 feet. The upper 1,500 or 2,000 feet consists of distinctly bedded rocks that dip steeply but uniformly to the southwest; below these is a bed of limestone about 30 feet thick, and at the bottom is 1,000 or 1,500 feet that does not show bedding. (*See* Pl. IV, B, p. 10.) The section is at the west end of the high ridge between Canyon Creek and Hawkins Glacier.

Alteration.—The outcrops of the greenstone showed that they are altered basic lavas, intrusives, and tuffs. The typical rock is a dark green, rather fresh looking fine-grained rock, some of which undoubtedly represents a lava and the rest probably a tuff. Other specimens are highly altered coarse-grained rocks that still show the outlines of large feldspar crystals; these represent coarse-grained intrusive rocks. Still other specimens show an original tuffaceous nature. These tuffaceous rocks are abundant in the eastern part of the district. Only one outcrop that was examined showed rock with amygdaloidal texture. The absence of amygdaloidal rocks leads to the belief that much of the greenstone of the region belongs to tho tuffaceous rocks found farther west.

An examination of thin sections of these rocks under the microscope shows that the original minerals are almost completely altered. Chlorite is the chief alteration product and helps to give the rock its greenish appearance. A later type of alteration, which occurs chiefly along crevices and cracks, is marked by the presence of epidote and quartz, which replace the chloritized rock. Copper minerals are associated with epidote and quartz in many of these greenstones, and the epidote, quartz, and copper minerals may be genetically connected.

Correlation.—The greenstones and greenstone tuffs of the region have been correlated with the Nikolai greenstone and underlying tuffs of the Kotsina-Kuskulana district, which have been rather closely studied.[1] The greenstones and greenstone tuffs of the Kotsina-

[1] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska: U. S. Geol. Survey Special Pub., p. 40, 1901.

Moffit, F. H., and Mertie, J. B., jr., Geology and mineral resources of the Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. — (in preparation).

Kuskulana district, consist in general of a thick series of distinctly bedded, much altered basaltic lava flows and of an underlying series of basic lavas, tuffs, and some sedimentary deposits The sedimentary beds contain fossils of Mississippian age. They are overlain in the same district by the Nikolai greenstone, which in turn is overlain by Upper Triassic rocks. These greenstones and greenstone tuffs, then, are Lower Carboniferous (Mississippian) and, perhaps, post-Mississippian and pre-Upper Triassic. In the field the upper and the lower parts of the greenstones are differentiated by the presence of bedded lavas showing amygdaloidal texture in the upper part and of tuffs and some sedimentary beds in the lower part.

Both the upper part (the Nikolai greenstone) and the lower part were recognized in the upper Chitina Valley. The Nikolai greenstone occurs in the ridge between Canyon Creek and Hawkins Glacier, and around the head of Canyon Creek, where it is continuous with the known Nikolai of the Nizina district. (See Pl. IV, B, p. 10.) In the ridge west of Hawkins Glacier a bed of limestone about 30 feet thick lies at the base of the bedded greenstone. Most of the greenstone east of Hawkins Glacier, except that in some areas south of Chitina River, is tuffaceous and belongs apparently to the lower series. The age, then, of the large body of greenstones of the upper Chitina Valley, if the correlation with the Nikolai greenstone and underlying tuffs and greenstone of the Kotsina-Kuskulana district is correct, is in part Lower Carboniferous and in part probably early Triassic.

TUFFB AND FLOWS OF CRETACEOUS OR POST-CRETACEOUS AGE.

A small outcrop of a very fine grained cherty-looking brown rock of igneous origin occurs on Young Creek about 5 miles above the mouth of Calamity Gulch. The extent of its exposure could not be determined but is apparently small. The fact that it is thin bedded is shown in part by differences in shade and in part by differences in coarseness of grain. It breaks with conchoidal fracture. An examination of a thin section of this rock shows that it is so extremely fine grained that its constituent minerals can not be determined. The only clue to its origin was afforded by several very perfect spherulites. Whether the rock is a tuff or a flow could not be told from the thin section, but its appearance in the field and its general field relations suggest that it is a tuff.

These rocks rest apparently on shales that are Cretaceous in age; hence, they must be Cretaceous or younger.

Another isolated area of rocks of probable volcanic origin forms a cap on the low front ridge on the north side of the valley between Canyon Creek and Hawkins Glacier. Beds of sedimentary origin are associated with these tuffs, which outcrop in only one or two small areas. The exposures show a very light gray fine-grained rock of indeterminate nature, whose mineral constituents are not recognizable in the hand specimen. The microscope shows that the rock is much altered and consists largely of fine-grained material whose nature could not be determined. The rock is commonly iron stained. The presence of lath-shaped areas containing calcite, apparently the result of the alteration of feldspar, and the general character of the groundmass suggests its volcanic origin. Whether the rocks were originally tuffs or lavas can not be said with certainty, but, the field relations suggest that they axe tuffs.

The only evidence concerning the age of these rocks is that they rest on Cretaceous rocks. They are interbedded with sedimentary strata that are also almost certainly of Cretaceous age, although no evidence afforded by fossils is at hand.

RECENT VOLCANIC ASH.

Several mounds of volcanic ash and pumice were found in the terminal moraine and on the ice at the end of Barnard Glacier. The mounds are about 30 feet high and consist of loose light-gray material in fragments of many sizes, the smallest being a fine powder and the largest consisting of pieces of pumice an inch or more in diameter. Specimens of the pumice are light colored and have a low specific gravity—less than that of water. It is made up chiefly of fine threads of glass and is extremely porous. Perfect little hornblende crystals, biotite showing crystal outline, and light-colored feldspar crystals are visible under the hand lens, but these form only a small part of the whole rock, which the microscope shows to be glass.

Thin sections of the ash were not made owing to its relative unimportance in the district. The microscopic description of similar material from the White River region, given by Knopf,[1] is as follows:

> The "ash" is a white frothy glass, light enough to float on water. The larger fragments of the pumice inclose numerous small hexagonal plates of biotite, short prisms of hornblende a millimeter in length, and less conspicuous crystals of glassy feldspar. In thin section the hornblendes, which are deeply pleochroic in tones of brown, show ideally perfect cross sections and terminated prisms; the biotites are also finely developed and hold some inclusions of apatite. The feldspars are less perfectly crystallized. Both unstriated and lamellated varieties are present, but all possess indices notably higher than balsam. Zonal banding is not uncommon. Optical tests on striated Carlsbad twins prove that the feldspars belong to a species somewhat more calcic than Ab_1An_1. They inclose some minute foils of biotite. Grains of magnetite occur sporadically. The matrix holding these phenocrysts is a pumiceous glass, clear

[1] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, *Alaska*: *U.* S. Geol. Survey *Bull.* 417, pp. *43–44*, 1910.

and colorless, with a marked drawn-out, twisted, and fluidal appearance. Some of the phenocrysts show that they were broken by the movements of the surrounding glass. According to the microscopical determination the ash is an andesitic pumice.

This recent volcanic material has evidently been brought down by Barnard Glacier, for it has been found nowhere in the region except on the terminal moraine and on the ice of this glacier. It had its origin, undoubtedly, in the eruption[1] which covered much of the basin of the upper Yukon with ash. Barnard Glacier, on which the ash was found, extends 30 or 40 miles southwestward from its head to the Chitina. The presence on it of the large pieces of pumice with the finer ash indicates that its head was not far from the center of eruption.

Various estimates of the date of eruption have been made. Dawson and Hayes believe that it took place at least several hundred years ago, but scarcely more than a thousand. Capps,[2] considering the thickness and the rate of accumulation of the peaty material covering the ash, estimates that the eruption occurred about 1,400 years ago.

STRUCTURE.

The prominent structural features of the district are shown on Plate III (in pocket). All the rocks represented on the map have been folded and faulted, the younger formations less than the older. The degree of folding exhibited by the rocks in this district is a measure of their ability to withstand deformation and, to a certain extent, of their age, for the older rocks have been subjected to more deformation than the younger rocks. In consequence, the conglomerate-sandstone beds that cap the mountains about Young Creek valley, being the youngest rocks and not having been subjected to all the forces that deformed the older beds, show less folding than any of the other formations. The underlying soft shales and the Triassic shales near Canyon Creek are, on the other hand, much folded. Strong rocks like the Nikolai greenstone are less folded than the massive limestones near Chitina Glacier, but both are much deformed. The Nikolai greenstone accommodated itself to deforming forces largely by faulting and by movements along joint planes, which is really minor faulting, as is made evident by the slickensided surfaces that are so common in the greenstone blocks.

The strike of the sedimentary beds and of the bedded volcanic rocks is roughly northwest, approximately parallel with Chitina River. In the eastern part of the district the strike is more nearly

[1] Capps, S. R., An ancient volcanic eruption in the upper Yukon basin: U. S. Geol. Survey Prof. Paper 95, pp. 59–64, 1915.

[2] Idem, p. 64.