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THE UPPER CHITINA VALLEY, ALASKA

BY

FRED H. MOFFIT

WITH A DESCRIPTION OF

THE IGNEOUS ROCKS

BY

R. M. OVERBECK

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PREFACE.

By Alfred H. Brooks.

The completion of the topographic and geologic reconnaissance surveys of all the developed mining districts in the Copper River basin has justified the utilization of the available funds for the extension of work into adjacent areas. As a part of this plan, the survey of the upper Chitina Valley was undertaken in 1915, and the results of this survey are here presented.

Though this report deals largely with the more purely scientific aspects of the geologic problems, the solving of them has a definite economic value. It has been proved that the copper-bearing rocks, which have yielded valuable deposits in the lower Chitina Valley, occur also in the upper valley. It is also shown that the formations from which the Nizina placers have derived their gold occur in this region. On the other hand, no mineral deposits of proved value have yet been exploited in the upper Chitina basin. It must be said, however, that comparatively little prospecting has been done in this field.

THE UPPER CHITINA VALLEY, ALASKA.

By FRED H. MOFFIT.

INTRODUCTION.

PREVIOUS EXPLORATIONS.

Chitina River has its source in the high mountains near the international boundary north of Mount St. Elias. Its waters are supplied in large part by the great glaciers that originate on the north slopes of Mount St. Elias, the west slopes of Mount Logan, and the south slopes of Mount Natazhat. It follows a westerly course between the Chugach and Wrangell mountains and joins Copper River about 100 miles above the mouth of that stream. Only the headwater part of the Chitina Valley (the part east of Tana River) is considered in this report (Pl. I, p. 8).

Though most of the eastward travel in the Chitina Valley has ended at the placer camps of Chititu and Dan creeks or has been diverted up Nizina River and over Skolai Pass to White River, yet the district is known to the prospector and has been visited by agents of the Federal Government. In the course of topographic surveys made in 1900 D. C. Witherspoon mapped the upper Chitina Valley as far east as Canyon Creek, and again, in 1908, made a detailed topographic map that included part of the Young Creek valley.

The discovery of copper on the south slopes of the Wrangell Mountains and of placer gold on Dan and Chititu creeks brought into the Nizina district between 1900 and 1905 a large number of prospectors, some of whom made their way into the upper Chitina Valley. From year to year, since 1905, other prospectors and a few hunters have visited the district.

From 1900 until 1912 no further work was done in the upper Chitina Valley by the Federal Government. In 1912 and 1913, however, the International Boundary Commission, while surveying and marking the boundary between Alaska and Yukon Territory (the 141st meridian), sent a large party to the head of Chitina River. The work of this party involved, first, carrying a system of triangulation up White River, across Skolai Pass to Nizina River, and then up the

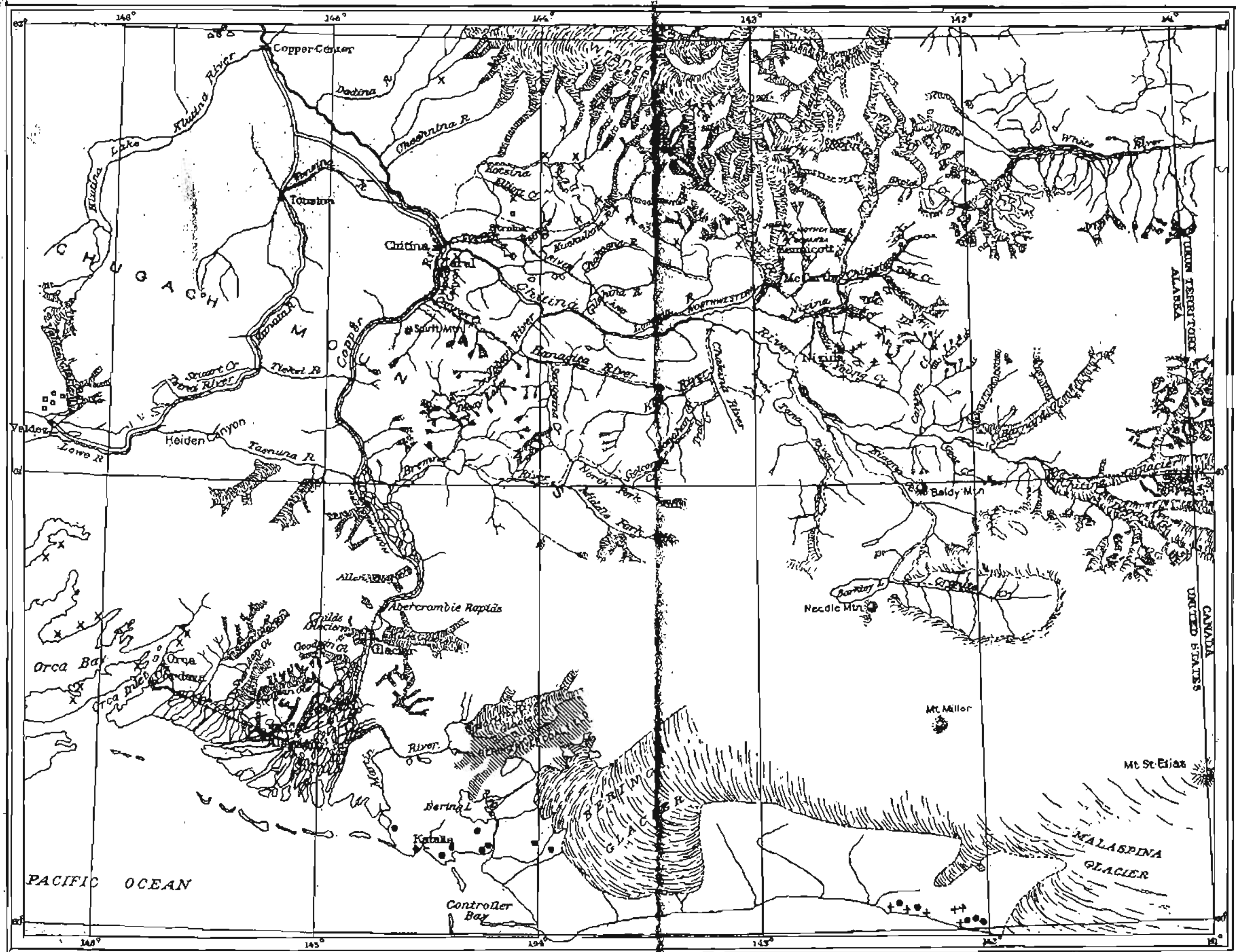
Chitina; second, projecting the boundary line north and south from points established by the triangulation. The detour through Skolai Pass was made on account of the difficulty of projecting the boundary line south of White River across the high mountains between the White and the Chitina. While establishing the boundary line the surveying parties mapped topographically a strip of land extending not less than 2 miles on each side of the line and having a total width averaging probably not less than 5 miles. This topographic mapping was extended westward in the Chitina Valley so as to include the Chitina Glacier and the mountain slopes along Chitina River as far west as Canyon Creek. The mapping is of a reconnaissance kind, similar to that done by the United States Geological Survey in many parts of Alaska, and was of much value in the geologic surveys carried on in 1915.

EXPLORATION IN 1915.

The survey made in 1915, whose results are given in this bulletin, was undertaken to extend the knowledge of the geology of the Nizina district, so that it would cover the region that lies in the Chitina Valley and extend eastward to the international boundary, to investigate the mineral deposits of the area surveyed, and particularly to trace the Nikolai greenstone and the Chitistone limestone, the principal copper-bearing rocks of the lower Chitina Valley, and to determine their eastern limits and their distribution. It was further planned to cross Chitina River and investigate the reported placer prospects of Kiagna River, the first large southern tributary of the Chitina above Tana River, but this plan was not carried out, for very high water in July and early in August made crossing the river exceedingly dangerous for horses.

The topographic map prepared by the International Boundary Commission in 1912 and 1913 represents only the mountain slopes adjacent to Chitina River and the branches of Chitina Glacier. In the exploration made in 1915 areas that lay beyond those shown on this map were surveyed by the use of a small plane table and a Gale alidade, a little more than 350 square miles being mapped topographically. The topographic work was facilitated by the fact that many of the triangulation stations established by the boundary survey parties had been plotted on the map and could be recognized in the field. Fine weather also favored this work during the whole season. Considerable difficulty, however, was caused by the smoke of burning forests in the lower Chitina Valley, which made it necessary to suspend topographic work for a number of days late in July.

The party consisted of five men and was provided with the necessary camp equipment and a pack train of eleven horses. Provisions



10 0 10 20 30 Miles

X Copper prospect + Gold placer o Gold lode prospect • Petroleum seepage X Copper mine ——Trail

MAP OF LOWER COPPER RIVER AND CHITINA VALLEYS.

Area represented on Plates II and III is bounded approximately by parallels 60° 55′ and 61° 20′ north latitude and meridians 141° and 142° 40′ west longitude.

for the whole summer were carried, so that a large number of horses were required. Some tools and special supplies to be used in building a boat were carried as far as Chitina River but were not used.

The party left Seattle on June 6, and arrived at McCarthy, on the Copper River & Northwestern Railway, on June 14. A delay of several days for arranging saddle gear and packs gave opportunity to collect some information about the Kiagna placers from prospectors. After crossing Nizina River and spending several days at the placer camps on Chititu Creek, the party crossed to Young Creek and began the principal work of the season.

The field season included nearly 100 days, from June 14 to September 22, when the party left McCarthy for home. Of this time 17 days were spent in unpacking at the beginning of the season and repacking at its end, in traveling to and from the Chitina, and in visiting the placer camps of Chititu and Dan creeks.

Mr. R. M. Overbeck efficiently assisted the writer in the field work and in the preparation of this report. He prepared the geologic map and sections and studied the rock specimens and their thin sections and describes them in the report.

GEOGRAPHY.

LOCATION AND AREA OF THE DISTRICT.

Most of the district to be described (Pl. I, p. 8, and Pl. II, in pocket) is included between parallels 61° and 61° 20′ north latitude and meridians 141° and 142° 40′ west longitude. It is limited on the east by Canadian possessions, for the 141st meridian forms the boundary line between Alaska and Yukon Territory. If defined as indicated the district has a length of 55 miles from east to west and a width of 23 miles. Its total area is therefore about 1,200 square miles, only about 900 square miles of which was mapped geologically in 1915. The upper Chitina Valley has the same latitude as southern Norway and is only a few miles farther north than Petrograd. Much of the Russian Empire lies north of this latitude.

TOPOGRAPHY.

RELIEF.

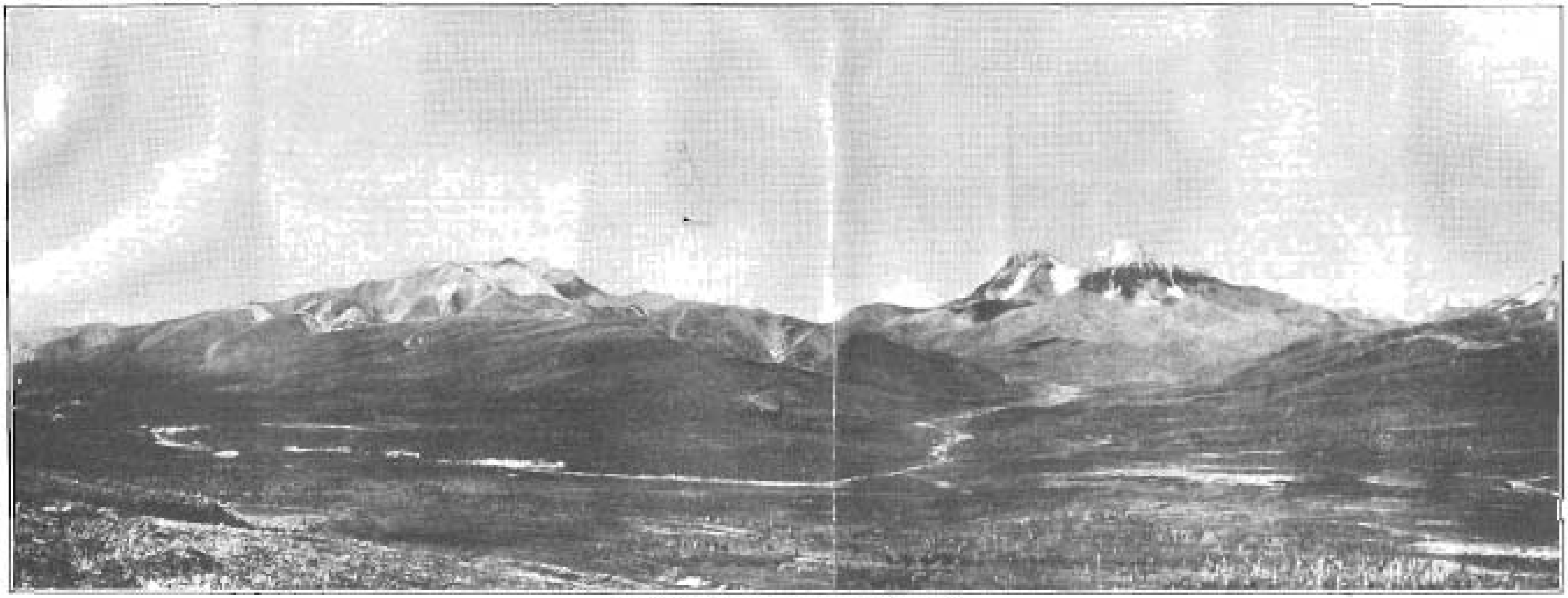
Lofty snow-covered mountains, the gathering places of numerous glaciers, surround the head of Chitina River. These mountains reach their greatest heights in Mount St. Elias (18,024 feet), in Mount Logan (19,539 feet), and in one or two unnamed peaks (Pls. IV, *B*, p. 10, and V, *A*, p. 10) between Chitina and White rivers, whose altitudes have not been determined with even approximate accuracy, but which are certainly 15,000 feet and probably more than 16,000 feet high. Many less conspicuous peaks rise above 10,000 feet, and most of the others probably average between 7,000 and 8,000 feet. An idea of the relief of this area may be gained from the fact that the west end of Chitina Glacier is 2,050 feet above the sea and that the mouth of Tana River is about 1,000 feet lower.

One of the most conspicuous topographic features of the district is found in the form of the valleys. Chitina River and its larger tributaries, except the lower part of Canyon Creek, flow through valleys that are bounded by steep straight walls, and floored, where free from ice, with extensive gravel deposits laid down by glacial waters. These valleys have the conspicuous U-shaped cross section that is commonly recognized as an evidence of pronounced mountain glaciation. Such straight, oversteepened valley walls are formed wherever moving ice has acted long enough to cut away the projecting spurs, yet the broad rounded cross section of the valley is doubtless accentuated by the gravel covering of the valley floor and by the talus slopes along its margin. Truncated spurs on every side show smooth triangular faces (Pl. IV, *B*), but some are complicated by one or more rock-cut terraces that apparently indicate periods of relative stability in the level of the ice that formed them.

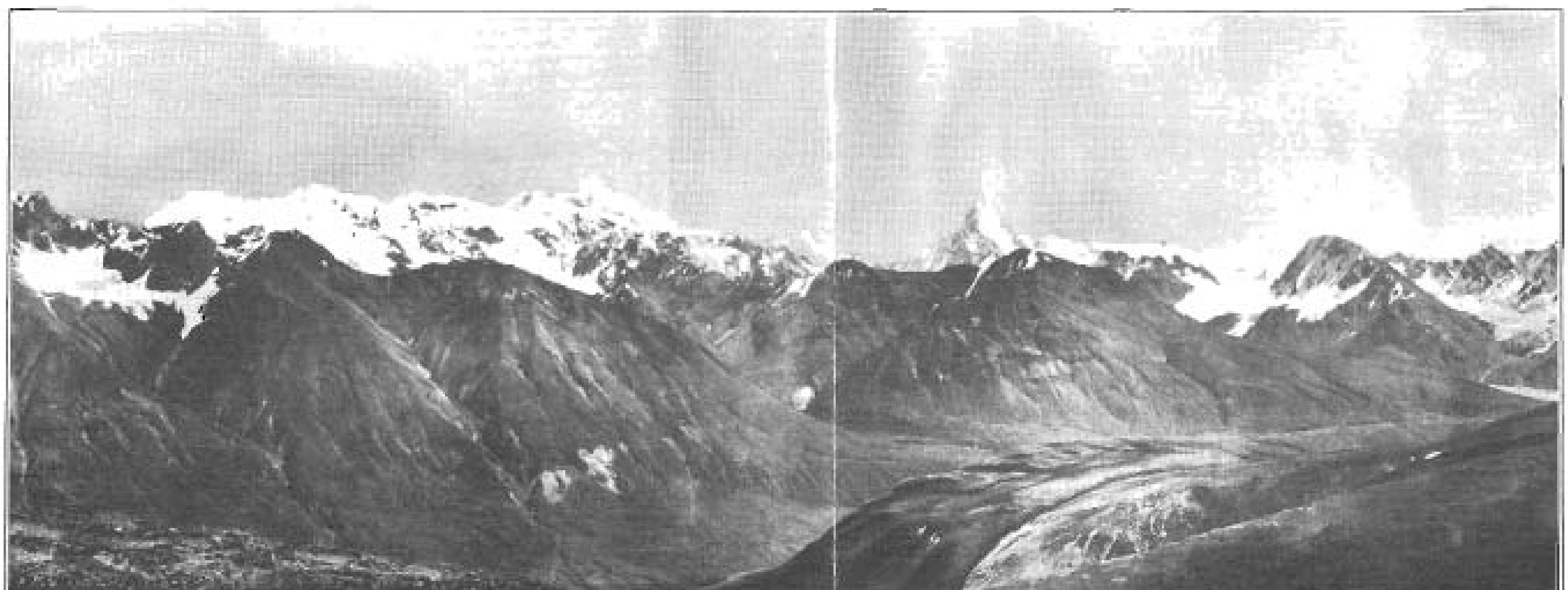
Nearly all the valleys tributary to the Chitina Valley, as well as the smaller valleys tributary to them, head in steep-walled amphitheaters or cirque basins that are filled with snow and ice and help to feed the great valley glaciers below.

Sharp peaks and rugged contours are characteristic of most of the mountains in the district (Pls. IV, *B*; V, *A*; VIII, *A*, *B*, p. 20; and XIII, *B*, p. 37), but on Young Creek and lower Canyon Creek the soft shales and sandstones, except where they are protected by intruded dikes or by a capping of conglomerate, have weathered more rapidly than the greenstones, limestones, and granites to the east and have given rise to groups of hills that have smooth rounded contours (Pl. XII, p. 36) and lower average elevation than the mountains. At many places, however, this smoothness of contour is being destroyed by rapid erosion; the shale hills are gashed by deep gulches whose smooth bare sides are too steep and break down too rapidly to allow vegetation to get a foothold on them.

The lower Canyon Creek valley is also an exception to the type of valley common throughout this district. Canyon Creek formerly flowed westward into Young Creek through the broad lake-dotted flat that now separates these two streams, but at some time not long ago, geologically, it was compelled to change its course and has cut through the hills that formerly separated it from Chitina River a narrow, steep-walled canyon more than 2,000 feet deep, which

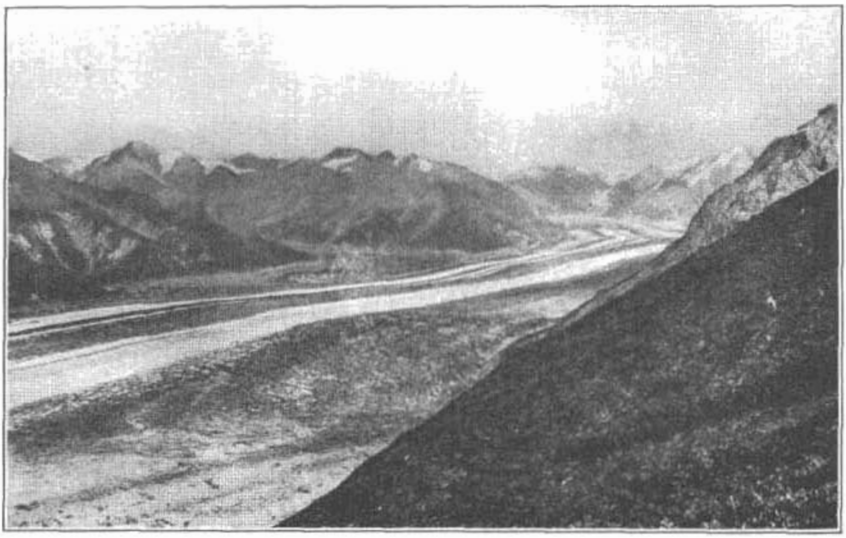


A. UPPER VALLEY OF YOUNG CREEK.



B. MOUNTAINS EAST OF CANYON CREEK.

A. GLACIER OF LARGEST EASTERN TRIBUTARY OF CANYON CREEK.



B. GLACIER-FILLED VALLEY DRAINED BY SHORT RIVER.

the Kiagna heads. This trail has been little traveled by horses but is said to be in fair condition. No other trails, except one or two short ones leading to mining claims, have been made in the upper Chitina Valley.

Kiagna River was first explored by men who crossed the ice fields from Yakataga Beach, hauling their supplies on sleds or packing them, but this route is scarcely practicable for extensive prospecting and probably will not be used in the future.

CLIMATE.

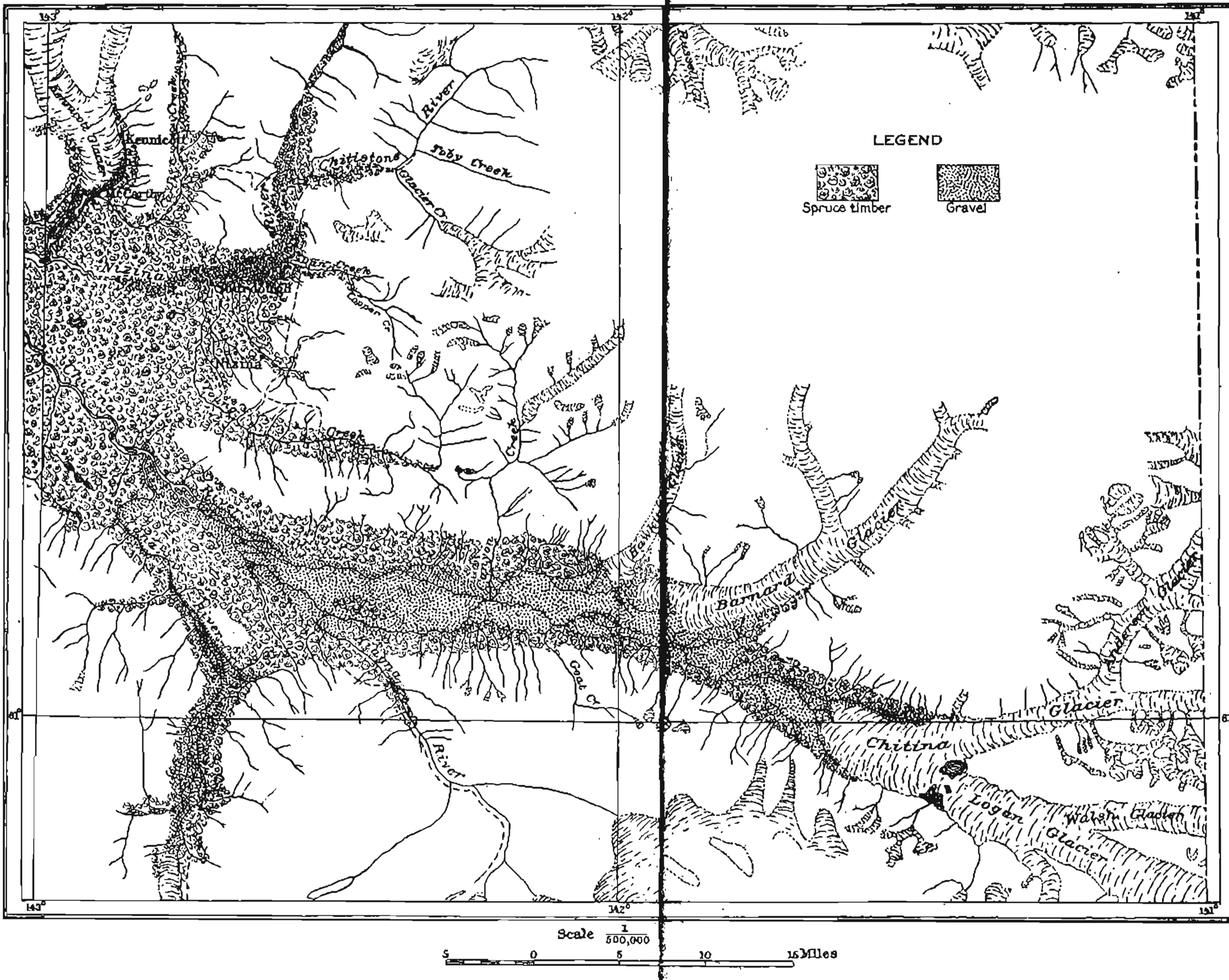
If the summer of 1915 was normal the summers of the upper Chitina Valley are dry and hot, for practically no rain fell from early in June until late in August, and for a week or more in midsummer the thermometer stood near 85° each day. It may be that these conditions were exceptional, but the precipitation in this part of the valley is certainly light, both in summer and in winter. Very little snow fell in Chitina Valley in the winter of 1914–15, and the vegetation in the upper valley indicates that the snowfall there is not heavy. The upper valley is a basin that is broken through on the west and shut in on the other sides by high mountains, which probably precipitate most of the moisture carried by the clouds before they reach the valley. The vast snow fields and the great glaciers that descend from the mountains seem to bear out this conclusion; yet, although there was little precipitation during the summer, there was no lack of water in the river.

In this protected valley the snow goes early in spring and comes late in autumn, so that summer is comparatively long. The vegetation, particularly the timber, indicates that in general the winds are not so strong as those on the lower river and on the Copper. The trees grow tall and straight; windfalls are not conspicuous; no severe dust storms like those on Copper River were experienced during the summer in 1915; and the coating of wind-blown dust on the trees and brush is much less than that along the Copper. The upper Chitina Valley is not without strong winds, however, for such, especially in spring and early in summer, were reported by the International Boundary Survey party.

VEGETATION.

The prospector's chief interest in the vegetation of this district is concerned with the amount and quality of the timber available for use in mining and with the abundance and distribution of forage.

Spruce is the only timber of economic value in the district. Its distribution is shown on the map (Pl. VII). Spruce timber extends in Chitina Valley for 8 to 10 miles above the lower end of the glacier and



SKETCH MAP SHOWING DISTRIBUTION OF SPRUCE TIMBER IN UPPER CHITINA VALLEY.

is found in scattered clumps still farther east. It covers the low benches along the river and extends up the mountain slopes in the main valley to an elevation of nearly 4,000 feet, almost, if not quite, a thousand feet higher than in lower Chitina Valley. The timber on the flats is neither large nor thrifty. Benches that stand 4 to 6 feet above the flood plain support a scanty growth of spruce trees, some of which are 8 inches in diameter, although most of them are smaller. The mountain slopes to an elevation of possibly 1,000 feet above the river are covered with a fine growth of tall straight trees, which reach their best development on the slopes that border the valley floor. Trees 2 feet in diameter and 75 to 90 feet high were seen at several places along the north side of the valley above Canyon Creek. The largest trees growing on the delta of Canyon Creek are about 18 inches in diameter but are not so tall in proportion to their diameter as the trees on the mountain slopes.

A great deal of the timber below Canyon Creek, both on the flats and on the mountain sides, has been killed, not by fire but probably by beetles. Great patches of such timber, some standing and some fallen, are seen on the mountain sides. Between the patches of dead trees are areas of fine green timber, through which dead trees are scattered here and there. This district no doubt contains some of the finest timber of the whole Copper River basin.

Grass is not plentiful around the head of Chitina River, but its scarcity is compensated for in large degree by the abundance of several varieties of "pea vine," which grow on the low gravel benches and furnish excellent forage. These plants come up early in the spring, and their value as feed, unlike that of some of the ranker grasses, is not injured by freezing. Stock thrives on them late in autumn and even early in winter, as long as the animals are able to dig the vines from under the snow. About 25 horses were turned loose on the river bars in September, 1915, and allowed to run there during the winter.

The largest areas of pea vine lie along the north side of Chitina River and extend as far east as Short River. Forage of all kinds is scarce above Short River, and in 1915 the little that ordinarily might have been expected was eaten by grasshoppers, which devoured practically everything green, including the leaves on the cottonwoods.

The grass in this district is chiefly what the prospectors call "bunch grass." It grows in open places and between the willows on the dry gravel bars along the smaller streams like Young Creek, and in some of the little valleys and gulches near timber line. Horses prefer the pea vine, however, and, especially after the grass has got dry, late in summer, they will not stay on it if they can reach the other. The traveler should therefore keep close watch of his horses, for if they know where the pea vine grows they are likely to leave him. The bars of upper Chitina River will furnish feed for a great many horses so long as the pea vine is not killed by close feeding.

GAME.

Sheep, goats, and bear are plentiful in the upper Chitina Valley. Both moose and caribou were formerly present, but caribou have disappeared and moose are rare. Many cast-off horns, especially of the moose, are seen.

Sheep may be found on the mountains north of the river at almost any time in summer. They feed on the grassy south slopes high above timber, and at times they even come down into the valleys below timber line. If disturbed they make their way back among the glaciers and snow peaks. During the last two or three years many of them have been killed for the market, but on the whole they have been disturbed so little by hunters that they have no great fear of man. Recently a game warden was appointed and a stop has been put to market hunting out of season.

Goats were not seen north of Chitina River, but they are reported to be numerous about the head of Kiagna River, on Granite Creek, and in the mountains south of Chitina Glacier, and it is believed that they are restricted to the south side of the river. The sheep and the goats seem to be thus separated throughout Chitina Valley, for although there are a few sheep in the mountains south of the river near Taral and a few goats about Kennicott Glacier, the sheep generally occupy the north side and the goats the south side.

Bears are especially numerous, at least two kinds being present, the black bear and a much larger bear, known by several names but generally called the "brown bear." Both kinds frequent the vicinity of the glaciers but are likely to be found at any place where cover is handy. The black bear is timid and hastily seeks a hiding place when surprised. The "brown bear" appears at times to be almost fearless and may show great indifference to man. It is unsafe to leave supplies for even a few days without placing them well out of reach of bears. Several bears were seen by the Geological Survey party in 1915, and at one place above timber line some provisions that were left unprotected for two or three days were eaten by a bear.

In spring and early in summer signs of bear were seen frequently on the mountains, but the numerous tracks made along the clear-water streams as soon as the salmon began running showed that the bears had come down for a feast of fish. Some of the "brown bears" are large, and although not regarded as dangerous except when surprised or when accompanied by cubs they are likely to make most people uneasy.

GENERAL GEOLOGY.

STRATIGRAPHY.

SEQUENCE OF THE ROCKS.

The upper Chitina district contains both sedimentary and igneous rocks which range in age from Carboniferous to Cretaceous. (See Pl. III, in pocket.) Among the sedimentary rocks are limestone, shale, arkose, chert, sandstone, and conglomerate. The principal igneous rocks are granite and related granitic rocks, basaltic lava, and tuff.

The oldest rocks known are hard fossiliferous grit and conglomerate associated with limestone, calcareous schist, argillite, and greenstone. They are exposed in the high mountains north of Chitina River near the glacier. West of them is a succession of lava flows and tuffs, corresponding in part at least to the lava flows and tuffs long known in the lower Chitina Valley as the Nikolai greenstone. A group of rocks of unknown age is exposed on lower Canyon Creek and in near-by localities and should perhaps be included with the tuffs and basaltic flows just mentioned. It includes altered igneous rock, or greenstone; crystalline limestone; fine-grained schist, probably of sedimentary origin; and chert. A massive limestone, the Chitistone, of Upper Triassic age, overlies the Nikolai greenstone. It has been recognized with certainty only near the head of Canyon Creek. The next younger rocks are Upper Triassic shales (McCarthy shale), which are exposed in a small area near the lower end of Canyon Creek and in the gulches on the south slope of the low rounded mountain to the east.

Beds of gray and brownish Jurassic sandstone rest unconformably on the Triassic (McCarthy) shales and older rocks in a small area on the north slope of Chitina Valley west of Canyon Creek and lie in horizontal beds on the tops of the high mountains between Canyon Creek and Chitina Glacier. These beds of sandstone are associated with and are lithologically similar to beds of sandstone that form part of a thick section of Cretaceous red and black shales, conglomerate, sandstone, and arkose that is best displayed on Young Creek. The structural relation of the two sandstones is not known. The beds assigned to the Cretaceous measure probably not less than 5,000 feet, but at least 2,000 feet of conglomerate, sandstone, and arkose at the top of the series is of undetermined age and is only tentatively assigned to this group.

The rocks described constitute all the consolidated sedimentary rocks of the district. They have been greatly folded and faulted and are intruded by granites and related igneous rocks whose intrusion, so far as is known, took place at two or more periods in the Mesozoic era.

Stream gravels and morainal deposits are the most important unconsolidated deposits of the district.

The following section shows the bedded sedimentary and igneous rocks of the district:

Quaternary: Sands, gravel, morainal and other unconsolidated deposits.
Cretaceous (?): Conglomerate, arkosic sandstone, and shale.
Cretaceous:
    Black and red shales.
    Sandstone.
Upper Jurassic: Sandstone.
Upper Triassic:
    McCarthy shale.
    Chitistone limestone.
Triassic (?) and Carboniferous: Altered lava flows (Nikolai greenstone), tuffs, fine-grained basalts, dark massive conglomerate, argillite, and graywacke.
Carboniferous or older: Massive white limestone, impure schistose limestone, fine conglomerate or coarse grit, argillite, and greenstone, schist, and crystalline limestone.

Some of the rocks assigned to the lower part of this section—the part below the Chitistone limestone—are placed there only tentatively, for no fossils were found in them, and they have been so much disturbed by folding, and especially by faulting, that their stratigraphic relations can be determined only by the expenditure of much time and labor. Some of them may prove to be of greatly different age from that to which they are here assigned.

PALEOZOIC ROCKS.

Some of the supposedly Paleozoic rocks of the district are known from the evidence of fossils to be of lower Carboniferous (Mississippian) age, but others have not yielded fossils, and their assignment even to the Paleozoic is provisional. Some are so assigned because of their metamorphism and others because of their geologic relations. It is not believed that any of them are older than Carboniferous, although it would hardly be surprising to find that some are Devonian. On the other hand, some may prove to be younger than Paleozoic. The Paleozoic rocks to be considered include schist, crystalline limestone, impure schistose limestone, massive limestone, conglomerate, grit, argillite, tuffs, and chert. The stratigraphic positions of most of these rocks are not known, for they have been greatly disturbed, and therefore it is by no means certain that they are here described in proper sequence.

The mountains along the east side of Barnard Glacier, from a point about 6 miles above Short River to the head of the glacier, are made up almost wholly of a massive limestone that extends eastward to the north branch of the Chitina Glacier or farther. The small tributary (Pl. VIII, *A*, p. 20) that joins Chitina Glacier from the north, 7 miles above the western end, heads in this area, and the moraines of Chitina Glacier above this tributary show so great a quantity of limestone that there can be little doubt that its area is extensive. A distant view (Pl. VIII, *B*) of the mountains near the boundary line, between Logan and Chitina glaciers, also shows the presence of limestone in smaller quantity, associated with dark rocks that were not identified. Limestone that has been more or less folded, faulted, and recrystallized forms a narrow belt along the north side of the west end of Chitina Glacier. This belt of limestone is probably part of the older limestone described below.

At least two limestones are present in the mountains east of Barnard Glacier. One is a greatly altered rock, locally schistose and impure and everywhere much folded. The other is a thick-bedded limestone which has been so much folded that in places it stands vertical but which shows no such pronounced alteration as the first. This massive, thick-bedded limestone predominates over the other.

The greatly altered limestone was examined chiefly near its contact with the greenstone of Barnard Glacier but was seen also at other places farther up the glacier. It varies much in composition, grading from a nearly pure limestone to a calcareous hornblende schist. The color of the limestone is dark blue and the general aspect of the rock as a whole, including the schistose varieties, is bluish gray. Favorable exposures show that the rock is banded, and that the bands, representing bedding, have been intricately folded. The schistose varieties are believed to have been produced by the alteration of impure limestones or calcareous shales. They tend to weather into long, slender fragments like sticks of wood. This formation has been cut by porphyritic intrusives. It contrasts sharply with the overlying lighter-colored limestone, and in many places its true nature would not be suspected from a casual observation. No fossils were found in it, and its age can be inferred only from its association with neighboring rocks whose age is known. In general appearance, particularly in its alteration, it is decidedly older than the Chitistone limestone farther west in Chitina Valley, and, as the other known limestones of this region are Carboniferous, it is tentatively correlated with them.

This older limestone is overlain unconformably by the younger limestone—a light bluish gray rock that weathers to a light gray or, in places, to a yellowish color. It forms much the greater part of the mountains east of Barnard Glacier and has a distinct topographic expression, which presents a sharp contrast to that of the neighboring greenstone and shale mountains west of Barnard Glacier. The limestone mountains are exceedingly rugged, with precipitous slopes, lowering spires, and generally angular contours. (See Pl. VIII, *A*.) They are separated by narrow steep-walled valleys that are occupied by ice streams and are practically impassable.

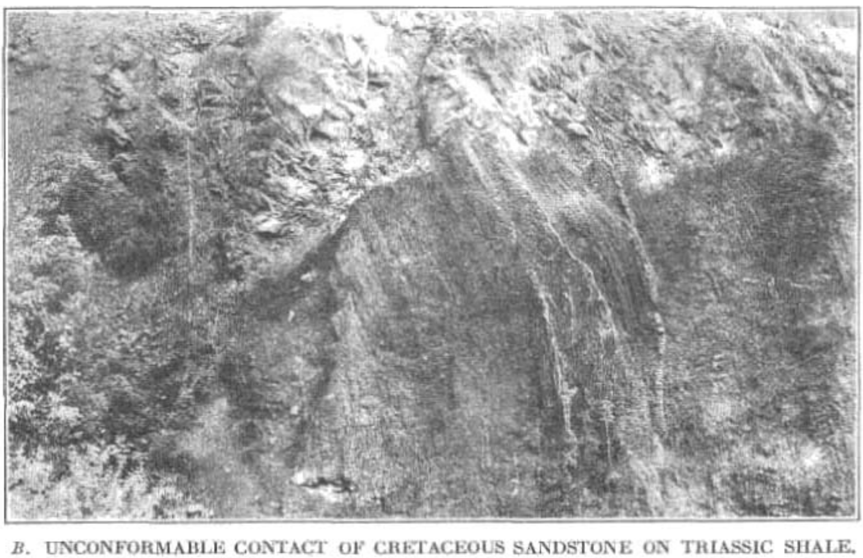
The limestone is massive and is commonly without indication of stratification, although in one place it was seen to consist of beds, 1 to 4 feet thick, that stand vertically and yet do not exhibit the contorted structure seen in the older limestone. At one point greenstone rests unconformably on the gray limestone. At another an altered igneous rock that resembles the greenstone was in contact with the limestone and contained silicified fragments of the limestone. Copper minerals were found at this contact.

The age of the upper massive limestone was not determined. No fossils were found in it and its stratigraphic relation to other rocks of known age was not made out. At one place it is overlain by greenstone; at another it rests on the schistose limestone. It resembles the massive basal beds of the Chitistone limestone and on lithologic grounds might readily be correlated with it. If it is Chitistone, it is thicker here than elsewhere, the name Chitistone being now restricted to the massive basal part of the limestone exposed near the mouth of Chitistone River. Although the thickness of the limestone was not measured and would be difficult to measure because of the folding to which the beds have been subjected, it is believed that it is thousands rather than hundreds of feet. This limestone further resembles the Chitistone limestone in its seeming lack of fossils, for no fossils were found in the Chitistone limestone for several years after it was first described. In this respect, also, it resembles the somewhat more altered Carboniferous limestone of Hanagita Valley but differs from the late Carboniferous limestones of White River (Gschelian) and of Skolai Creek (Artinskian), which are abundantly fossiliferous.

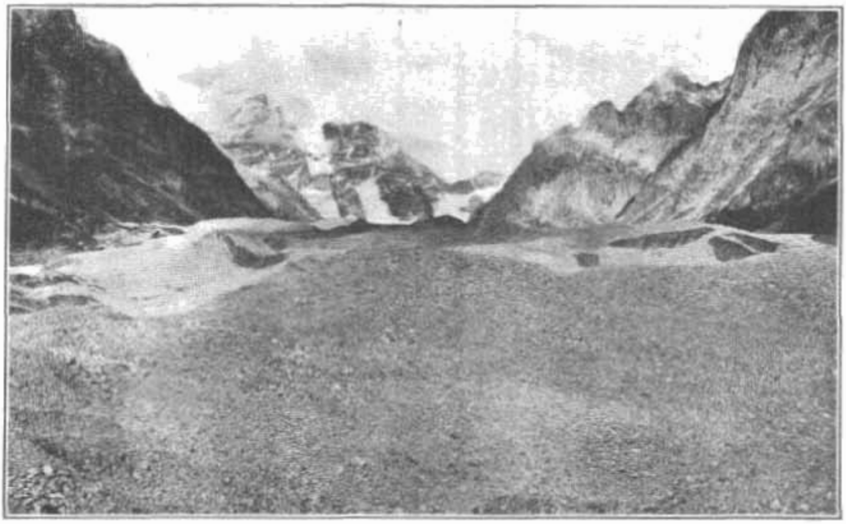
Although the limestone bears a greater lithologic resemblance to the Chitistone than to any other limestone of known age in the region, resemblance alone is not sufficient to justify a definite correlation, so it appears advisable to include this limestone with the older rocks.

The known Carboniferous rocks include arkosic sandstones and conglomerate and are exposed in the mountains north of the lower end of Chitina Glacier. Their areal extent and thickness were not learned, but the quantity of their débris brought down by the glacier and left in the moraines or strewn over the river bars indicates that in this locality they form a large mass. These rocks are dark gray in color. They are calcareous and contain many fragments of limestone and are so thoroughly indurated that they break across rather than

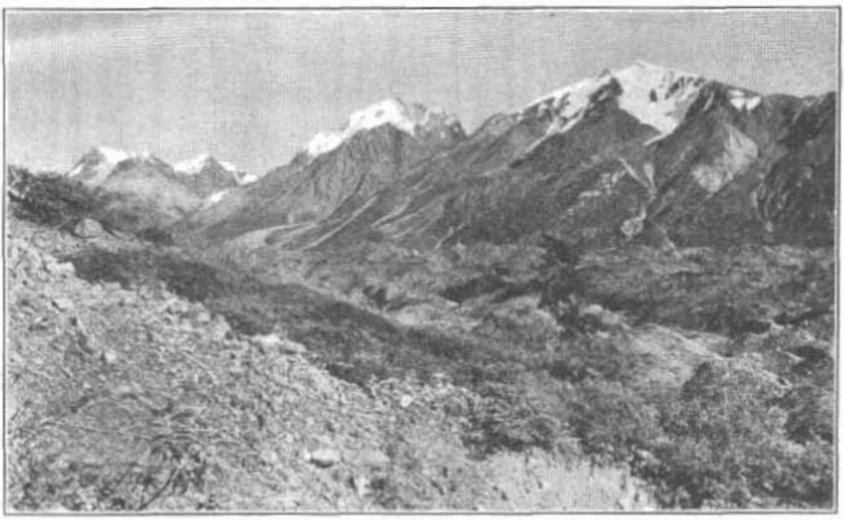
A. PART OF SOUTH SLOPE OF PYRAMID MOUNTAIN.



B. UNCONFORMABLE CONTACT OF CRETACEOUS SANDSTONE ON TRIASSIC SHALE.



A. SMALL NORTHERN TRIBUTARY OF CHITINA GLACIER.



B. VIEW ACROSS CHITINA GLACIER

around the fragments. They are abundantly fossiliferous, and the fossils collected indicate that they may be equivalent in age to the sedimentary and tuffaceous beds and the fine-grained basalts that underlie the Nikolai greenstone in the Kotsina-Kuskulana district. They would therefore seem to be of the same age as the tuffaceous beds and basalts (pp. 63–64) that underlie the Nikolai greenstone in this district.

The fossils collected from the conglomerate and arkose were submitted for identification to G. H. Girty, whose analysis of them follows:

The collections referred to me apparently represent two areas and two faunas, one group, comprising lot 17, being from the Short River [Barnard] Glacier, and the other, comprising lots 20–26, being from Chitina Glacier.

The objects shown by lot 17 are probably organic, and if so they may be corals of the genus *Syringopora*, but they are quite indeterminable.

The other collections represent perhaps a single fauna, which is probably of Mississippian age; but beyond the fact that they are clearly Carboniferous I can state nothing definite. The collections are rather small and the preservation is distinctly poor; furthermore, most of the faunas lack those types by which geologic age can be most readily and certainly determined. The condition of the few specimens that appear to represent such types forbids an accurate determination of their identity. There are several well-marked faunas in the Carboniferous of Alaska, but none of these appears in Mr. Moffit's collections, at least in typical facies.

On the whole, the evidence seems to me to favor an assignment to the Mississippian (Lisburne), and the specific relations are indicated in conformity with this conception, but many of the species are naturally related to both Mississippian and Pennsylvanian types. It must be understood, however, that better collections may show that the fauna or faunas collected by Mr. Moffit belong in the Pennsylvanian rather than in the Mississippian.

The species which I have identified in these collections are shown in the following lists, the numbers heading each list being, first, the number assigned in the permanent Survey record and, second (in parentheses), the number given by the geologist in the field, the number under which it was transferred to me.

1807 (17).

Syringopora? sp. (indeterminable).

1808 (20).

Schizophoria aff. S. resupinata.
Derbya? sp.
Spirifer aff. S. convolutus.
Spirifer aff. S. integricosta.
Squamularia? sp.
Plagioglypta? sp.

1808a (21).

Schizophoria aff. S. resupinata.
Chonetes sp.
Pustula aff. P. venusta.
Camarophoria sp.
Spirifer aff. S. striatus.
Cliothyridina? sp.
Schizodus? sp.
Straparollus sp.
Euphemus? sp.

1808b (22).

Zaphrentis sp.
Productus sp.
Conocardium? sp.
Cypricardella? sp.
Pleurotomaria sp.

1808c (23).

Platycrinus? sp.
Schizophoria aff. S. resupinata.
Productus semireticulatus.
Productus sp.
Pustula aff. P. venusta.
Spirifer sp.

1808d (24).

Batostomella sp.
Schizophoria aff. S. resupinata.
Overtonia? aff. O. fimbriata.
Spirifer sp.

1808e (25).

Schizophoria aff. S. resupinata.

1808f (26).

Productus semireticulatus.
Productus aff. P. longispina.

The lower Carboniferous conglomerate and arkose are associated with a massive, coarse, dark-greenish conglomerate, which is exposed on the tops of the mountains north of the lower end of the Chitina Glacier. The relations of these rocks in age are not known, but the coarse green conglomerate may be considerably younger than the Carboniferous conglomerate and arkose. This conglomerate will receive further consideration.

A northeast-southwest section of the rock exposed in the point of mountains between Short River and Chitina Glacier shows greenstone on the southwest, followed successively on the northeast by granite, crystalline limestone and calcareous schist, basalt and tuffs, and massive dark-green conglomerate containing beds of argillite and graywacke and overlain in places by horizontal Jurassic sandstone. A short distance beyond the conglomerate lies a great area of limestone. These rocks are shown diagrammatically in figure 1.

The rocks of the section dip northeastward, but some of the contacts, notably those at the top and bottom of the limestone and calcareous schist, are fault contacts and may give a false idea of the structure.

The fossiliferous arkoses and conglomerate may correspond to some part of the beds called graywacke and argillite in figure 1, but they are more probably older and underlie them. The massive conglomerate is thick, measuring probably at least 2,000 to 3,000 feet and possibly much more. It is dark greenish, and it weathers rough, producing an exceedingly rugged topography. The conglomerate is in places tuffaceous and contains beds of graywacke and argillite, which indicate the structure and in large exposures show that the whole mass has been considerably folded. At one point (see Pl. III, in pocket) it is overlain with apparent unconformity by about 500 feet of horizontally bedded Jurassic sandstone.

Conglomerate of similar appearance but composed of material somewhat less coarse is exposed in the gulches a mile or more west of the south end of the first glacier above Canyon Creek. Its geologic relations were not made out, but it may belong to the Cretaceous series.

Considerable difficulty has been experienced in the attempt to assign the conglomerate near Chitina Glacier to its proper position in the geologic column. It overlies limestones and other rocks that are regarded as Carboniferous, but its position may be due entirely to faulting. On the other hand, it may be older than the Jurassic

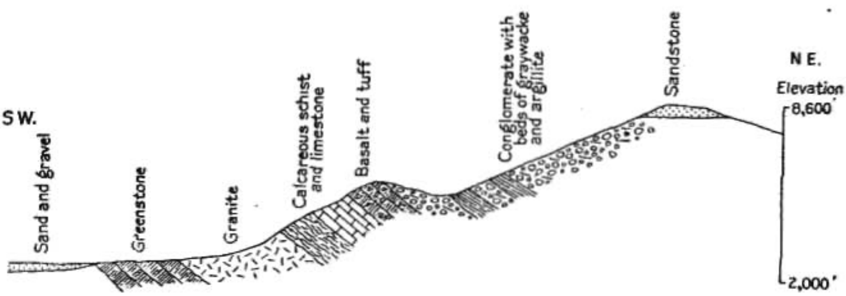


FIGURE 1.—Diagrammatic section of the rocks exposed between Barnard and Chitina glaciers.

sandstone, for it underlies it. The conglomerate resembles a conglomerate mapped in the lower Chitina Valley[1] more than any other formation of the region, and, like that conglomerate, it is overlain by Jurassic sandstone; but though the conglomerate of the lower Chitina Valley overlies rocks as young as Upper Triassic, this conglomerate is believed to rest on much older rocks and possibly to be the source of Carboniferous fossils.

Another series of rocks whose age is in question, but which are believed to be older than the known Triassic rocks if not Paleozoic, is found in several small areas near the mouth of Canyon Creek and in some of the rocky islands that project above the Chitina River flood plain. These rocks include crystalline limestone, schist, chert, and greenstones. They show decided metamorphism and are among the most altered rocks of the district. The limestone is at least several hundred feet thick and is exposed chiefly in the islands mentioned;

[1] Moffit, F. H., The Kotsina Kuskulana district, Alaska: U. S. Geol. Survey Bull. — (in preparation).

the schist, chert, and greenstone outcrop in the canyon of Canyon Creek and in the gulches on the north slope of Chitina Valley just west of the mouth of Canyon Creek. The rocks at the locality last named are surrounded by rocks of Mesozoic age, including those of the Triassic, Jurassic, and Cretaceous periods, and perhaps reached their present position through faulting. The cherts are exposed at the mouth of the canyon, where the contact between them and the overlying Cretaceous fine-grained conglomerate, or grit, and sandstone is exposed. They are dense, hard rocks, distinctly banded and much folded, and intruded by numerous dikes. They contain sulphides that give their weathered surfaces a yellow color.

Associated with the cherts are schist, believed to be derived from rocks of sedimentary origin, and greenstone that is in part an altered basic intrusive rock of rather coarse grain. The greenstone predominates over the associated rocks. Possibly the rocks of this small area, extending west from the mouth of Canyon Creek, owe their present condition to the alteration that accompanied intrusion and the movements that folded and faulted them. It is this fact that throws doubt on the propriety of including them with the Paleozoic rocks, although they are unconformably overlain by Jurassic and Cretaceous sandstones. No good reason for including the limestone exposed in the islands east of Canyon Creek with either the Chitistone or the older limestone is at hand. This limestone has undergone recrystallization due to folding and faulting and perhaps to intrusion by igneous rocks, but it resembles in general appearance the grayish or bluish-gray massive beds of the Chitistone. It is probably several hundred feet thick. No fossils were obtained from it and its outcrops are so isolated that its stratigraphic relation to neighboring rocks is not known. It occurs near a zone of disturbance not far from an area of Upper Triassic (McCarthy) shale and Nikolai greenstone, between which the Chitistone limestone should normally lie. This, however, is not considered to be sufficient reason for correlating it with the Chitistone limestone.

MESOZOIC ROCKS.

PERIODS REPRESENTED.

The Mesozoic rocks of this district include Upper Triassic limestone (Chitistone limestone) and shale (McCarthy shale); Upper Jurassic sandstone; and Cretaceous shale, sandstone, arkose, and conglomerate. All these rocks or their equivalents are present at other places on the north side of Chitina Valley and their ages are known with fair certainty from the fossils they contain. No evidence that a structural unconformity exists between the Triassic and the underlying rocks has yet been found. The Triassic and Jurassic rocks, on the other hand, are separated by a great unconformity, and at most places no serious difficulty is likely to arise in distinguishing between them. The separation of the Jurassic and Cretaceous beds is subject to some confusion, owing largely to the lack of collections of decisive fossils, and much work in regard to them remains to be done.

All the investigations of recent years have tended to show with increasing emphasis that the Mesozoic rocks of the Chitina Valley are more widely distributed, include a greater part of the geologic column, and have a more complicated structure than was realized in the earlier years.

UPPER TRIASSIC ROCKS.

CHITISTONE LIMESTONE.

The Chitistone is prevailingly a thick-bedded, light-gray or bluish-gray limestone, which as now defined has a thickness of 1,800 or possibly 2,000 feet at its type locality.

Within the district mapped, Chitistone limestone has been identified with certainty only at the head of Canyon Creek, where it is the direct eastward continuation of the limestone between Dan Creek and Chitistone River and caps the Nikolai greenstone in massive, seemingly nearly horizontal beds. Seen from the south, the high mountains north of the upper western branches of Canyon Creek present a fairly even sky line, broken, however, by a number of prominent limestone buttes. The limestone does not extend eastward on the ridge north of the eastern branches of Canyon Creek, and this area thus forms the eastern edge of the high island-like mass of limestone north of Dan Creek.

The type locality of the Chitistone limestone is at the mouth of Chitistone River, where there is about 3,000 feet of Upper Triassic limestone, the upper 1,200 feet of which is more thinly bedded than the basal part and contains a considerable amount of black shale. Martin[1] has recently restricted the name Chitistone to the thick-bedded basal part and introduced the name Nizina limestone for the overlying thin-bedded limestone and shale. The Nizina limestone rests conformably on the Chitistone limestone and differs from it further in the brownish color it assumes on weathering, as contrasted with the light gray or bluish weathering of the older beds.

The thickness of the Upper Triassic limestone on Canyon Creek was not determined, for the limestone was not examined in detail, but near by on Dan Creek it is about 2,000 feet. This thickness would perhaps indicate the presence of some of the overlying thinner beds of the Nizina limestone.

[1] Martin, G. C., The Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 37, p. 693, 1916.

Although the Chitistone limestone was not identified in the mountains in Chitina Valley east of Canyon Creek, some of the massive limestone between the Barnard Glacier and the Chitina Glacier and that in some of the rock islands along the river may be Chitistone, but in the absence of fossils and other evidence it has seemed best not to make this correlation.

McCARTHY SHALE.

The canyon walls along the lower part of Canyon Creek and along several of the little streams between Canyon Creek and the "first glacier" stream give exposures of much-folded black shale that locally shows distinct bedding and appears to have undergone greater alteration and deformation than the shale on Young Creek. Unlike the shale on Young Creek, which weathers into soft, small, angular fragments, this shale breaks up into thin slaty plates and locally appears almost schistose. It is overlain unconformably by Cretaceous sandstone (Pl. IX, *B*, p. 21), but its other stratigraphic relations in this locality were not determined; nor was its thickness measured. The exposures indicate only a small area of the shale.

The age of the shale is known from its characteristic fossil, *Pseudomonotis subcircularis*, which was found at several places and which shows that it is of Upper Triassic age. The shale is therefore correlated with the McCarthy formation, which is the uppermost Triassic of the Nizina district. The McCarthy formation consists chiefly of shale but contains chert and thin beds of limestone at its base. Its thickness is probably not less than 2,500 feet.[1] This formation and its equivalents are of wide distribution in Alaska and are everywhere characterized by the fossil mentioned. After studying all the known Triassic rocks of Alaska, Martin[2] has shown that a widespread unconformity probably occurs at the base of the beds containing *Pseudomonotis subcircularis*. If this unconformity exists in the Chitina Valley, then unconformities exist both above and below the McCarthy shale. Structural discordance between the beds at the top of the Nizina limestone and the base of the McCarthy formation was not discovered in the Nizina district, where each of the Triassic limestones and the shale appear to have been deposited conformably on the rocks that underlie them, but the existence of such an unconformity in the Kotsina-Kuskulana district is suggested by variations in the thickness of the Chitistone limestone and by the presence of thin-bedded Triassic limestones overlying the

[1] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, p. 29, 1911.

[2] Martin, G. C., unpublished manuscript.

Chitistone limestone in some places and their absence in near-by localities. Such an unconformity would account for the absence of many hundreds or thousands of feet of thin-bedded limestone and of part of the Chitistone limestone in the western end of the Chitina Valley. Such an unconformity might also account for the apparent absence of the Triassic limestones between the Triassic shale and the Nikolai greenstone on Canyon Creek and the low rounded hill to the east, although there is reason for suspecting the presence of a fault in this place.

UPPER JURASSIC ROCKS.

CHARACTER AND DISTRIBUTION.

The known Jurassic rocks include only soft brownish or pinkish sandstone and gray sandstone, both of which contain concretions, the largest 2 feet or more in diameter, some of them abundantly fossiliferous. The sandstones are exposed in gulches near the trail leading from the Chitina to upper Young Creek over the mountain

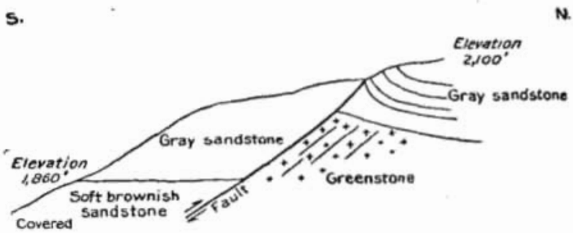


FIGURE 2.—Sketch showing the relation of the Jurassic sandstone to the greenstone near the trail from Young Creek to Chitina River.

slope overlooking Chitina River, but they are of much greater extent in the high mountains between Canyon Creek and Chitina Glacier, where they cap the older rocks and appear to be little disturbed.

In the locality first named, near the trail from Young Creek to Chitina River, the deep canyon-like gulches give a good opportunity for studying the Jurassic rocks. The soft brownish sandstone is overlain by the harder gray sandstone, and both are faulted against greenstone. (See fig. 2.)

The underlying sandstone is very soft and crumbles readily. Its thickness is not known, for its base is not exposed. Fossils were collected from the concretions of the overlying gray sandstone.

Sandstone in nearly horizontal beds forms isolated areas on both sides of Barnard Glacier, where it overlies the older formations and accounts for the flat summits of the mountains. Its largest area lies north of the glacier, but the area south of it was examined close at hand and yielded the fossils by which its age was determined.

About 500 feet of sandstone is exposed. It is of rather uniform character so far as is now known, but it contains two prominent thick beds, one at the base and the other near the middle, that are clearly distinguishable from the rest of the mass. These isolated areas are doubtless the remnants of what was once a widespread and continuous formation that once extended over much of the Chitina Valley but that is now almost removed by erosion.

AGE AND CORRELATION.

Fossils that were collected principally from concretions in the Jurassic sandstones indicate the age of these rocks. A list of the fossils, with locality numbers and descriptions by T. W. Stanton, is given below:

9484. F 19. Four miles northwest of lower end of Chitina Glacier. Elevation 2,500 feet. Gray sandstone float from top of mountain on the north.

Serpula? sp.
Rhynchonella sp.
Aucella? sp.
Tancredia? sp.
Probably Upper Jurassic.

9489. F 31. South side of ridge between Young Creek and Chitina River, near trail. Elevation 1,900 feet. From concretions in sandstone.

Aucella pallasi Keyserling?
Dentalium? sp.
Natica? sp.
Lytoceras sp.
Perisphinctes? sp.
Probably Upper Jurassic.

Aucella pallasi is the distinctive form which justifies the separation of the Jurassic from the Cretaceous rocks and which links the Jurassic sandstones of the upper Chitina Valley with the rocks that Rohn [1] saw west of Kennicott Glacier and called the Kennicott series. This "series," according to Rohn, includes arkoses, shales, and limestones, which he found between Lakina River and Kennicott Glacier, and which he correlated with conglomerate and sandstone in the mountains east of McCarthy Creek. The name Kennicott was, in fact, used by Rohn and by the later workers in the Chitina Valley to designate rocks believed to be Jurassic without regard to their lithologic character. Martin,[2] however, has proposed to restrict the name Kennicott to rocks containing the fauna of the Kennicott locality, among which *Aucella* is most characteristic. It is in this use of the term Kennicott that *Aucella*-bearing beds of the upper Chitina Valley are correlated with the Kennicott formation.

[1] Rohn, Oscar, A reconnaissance of the Chitina River and Skolai Mountains, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, p. 424, 1900.

[2] Martin, G. C., unpublished manuscript.

CRETACEOUS ROCKS.

LITHOLOGIC DIVISIONS.

The Cretaceous rocks of the district may be divided into three members, which, designated in ascending order, are sandstone, black and red shale, and a succession of beds that includes coarse and fine grained conglomerate, sandstone, arkose, and sandy shale. The largest masses of these rocks are found in the mountains around Young Creek and in the rounded mountains east of lower Canyon Creek. The ages of the basal sandstone and of the red and black shales were determined from the fossils that they yielded; that of the overlying series of conglomerate, arkose, and shale is inferred from its geologic relations.

SANDSTONES.

The lowest Cretaceous rocks exposed in this district are sandstones, which lie unconformably on the older rocks beneath them. Good exposures of the basal contact were seen at several places, but no good section of the sandstones as a whole was found. At one basal contact (Pl. IX, *B*, p. 21), exposed in a deep gulch between the mouth of Canyon Creek and the "first" glacier, the sandstone rests on folded Triassic shale and bears a striking resemblance to the Jurassic sandstones near the Chitina River–Young Creek trail. At the base is soft brownish sandstone, possibly 75 feet thick. This is overlain by harder gray sandstone. Both sandstones contain rounded concretions, and those of the gray sandstone contain abundant fossils.

At another contact, in the canyon at the mouth of Canyon Creek, 2 feet of fine conglomerate or grit forms the base of the Cretaceous section and rests on contorted cherts and tuffs. The grit is overlain by about 100 feet of greenish-gray sandstone, on which lies shaly, crumbling yellowish sandstone containing limy concretions, the largest 3 feet in diameter, and numerous fossils. At least 250 feet of the shaly sandstone is in view. These beds dip 15° S. at the most southern exposure to 45° S. at the basal contact.

Still another contact on the west side of Canyon Creek, 5 miles above the mouth, was examined. Here the Triassic shales, which dip 30° SW., are overlain by sandstone in nearly horizontal beds. No fossils were found in the sandstone, although the concretions are present. The beds are exposed on both sides of Canyon Creek and are believed to be continuous with those at the locality first described and to be probably the same as those exposed at the bend of Young Creek.

A brownish sandstone of medium grain, containing numerous fossiliferous limy concretions, is exposed at the bend of Young Creek in the walls of a canyon about 75 feet deep. Both walls of the canyon are composed of this rock, which forms a narrow east-west belt along the creek and is cut off on the north within a short distance by black shale and on the south within 150 feet by a vertical east-west fault, probably of small displacement, beyond which is a sandy shale, which weathers brownish and contains many concretions, in which, however, no fossils could be found. The sandy shale and the sandstone occupy opposite sides of a low point of land between two streams.

The sandstone continues downstream for a mile or more and gives place to sandy shale that seems to grade up into banded cherts and hard gray platy shale. A short distance above Sheep Creek, about 2 miles below the bend, the sandy shale is seen overlying black shale in a bluff on the north side of the creek. This exposure gives the only direct evidence that was obtained concerning the stratigraphic position of the sandstone beds, and it can not be regarded as conclusive, for the rocks have been folded and are much faulted.

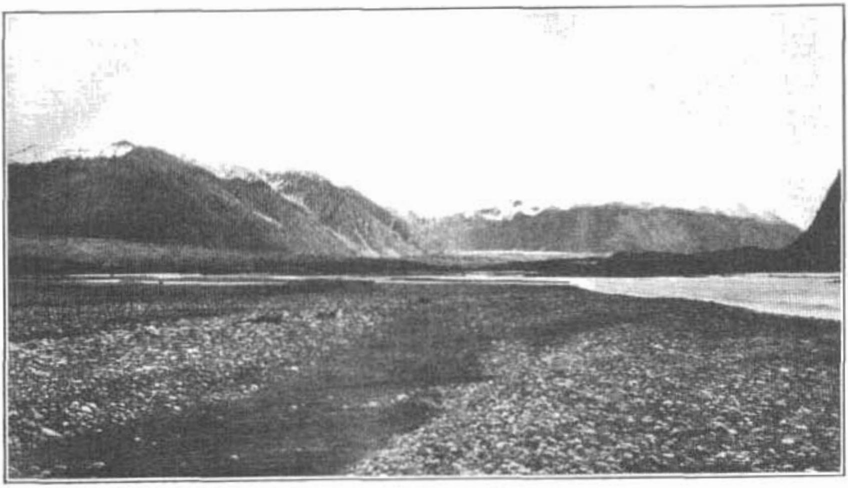
Apparently the section is somewhat as follows: At the base is a sandstone, possibly 100 or 200 feet thick, with massive basal beds grading upward into thin-bedded sandstone and sandy shale. Above these are banded cherts and hard platy shales. Possibly the sandstone and sandy shale replace each other along the bedding planes, but this is not probable. The thickness appears to be not less than 500 feet.

The basal Cretaceous sandstone is nearly everywhere fossiliferous, at least at certain horizons; but nearly all the fossils are found in the round concretions and few or none in the sandstone beds. No sandstones that are definitely known to be Cretaceous were seen east of Hawkins Glacier, but a small exposure of sandstone near the Chitina Glacier may prove to be Cretaceous.

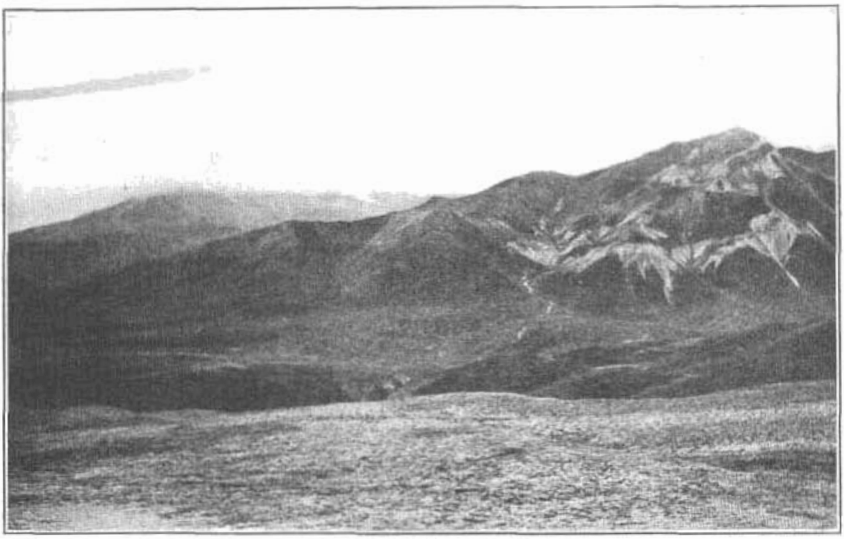
The discrimination of the Jurassic and Cretaceous sandstones, as shown on the map (Pl. III, in pocket) and as here described, is based on the evidence afforded by the fossils. It was not made in the field, for the sandstones are lithologically so much alike that no suspicion regarding a difference in their age was aroused. Both contain the same round concretionary masses and both within a short distance of each other were found resting unconformably on the same kind of rocks. If they are correctly discriminated it seems probable that the two formations are separated from each other by an unconformity.

SHALES.

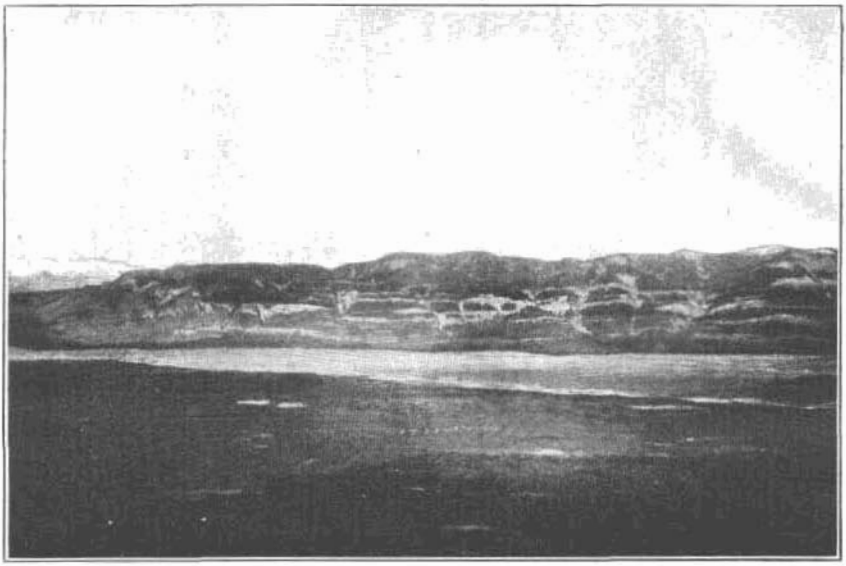
Shales of Young Creek.—Shales are the prevailing rocks of the Young Creek valley. They form all the lower hills and the bases of all the higher mountains inclosing it. On account of their softness and the ease with which they are cut by the streams, they are



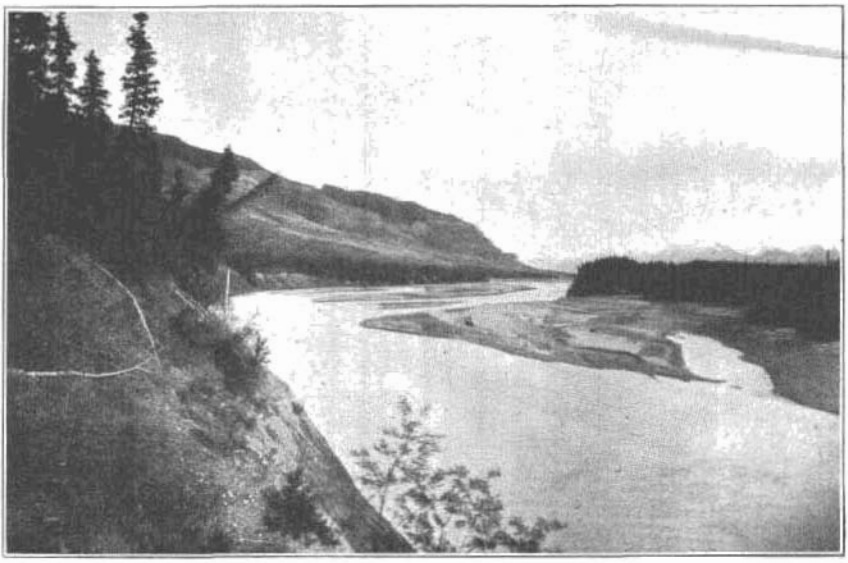
A. VIEW IN CHITINA VALLEY.



B. BLACK SHALE MOUNTAINS BETWEEN YOUNG AND CANYON CREEKS.



A. RIDGE BETWEEN CHITINA RIVER AND YOUNG CREEK.



B. VIEW UP CHITINA RIVER FROM NORTH BANK.

well exposed in many places, especially in the canyon walls along the creek and in the numerous gulches and small streams coming down from the mountains. Most of the streams running through shale are deeply intrenched and in their upper parts flow in deep narrow V-shaped gulches with bare smooth walls. The weathered shale is so soft and so easily removed that the water in such streams is nearly always muddy.

These soft rocks have given to the valley a topography unlike that in the remainder of the district and for this reason recognizable at a distance. Broad, relatively low ridges with smooth contours are characteristic of the shale area (Pls. IV, *A*, p. 10, and XII, p. 36), although the smoothness of contour has been destroyed locally by postglacial stream cutting. Moreover, in places, harder rocks within the shale or overlying it have given rise to a more rugged topography (Pls. IV, *A*, and X, *B*) than that where shale is the controlling factor in determining the form of the land.

The shales are prevailingly black and red or reddish brown but include some that are gray and greenish gray. They contain lime concretions and limestone beds, which are not distributed uniformly, and which form only a small proportion of the total thickness of the sediments, but which are highly conspicuous because of the contrast in color. Locally they contain also a relatively small amount of brownish-weathering sandy shale and sandstone. Dikes and sills of light-colored porphyritic rock (Pls. X, *B*, and XIII, *B*, p. 37) and numerous thin "dikes" of sandstone cut them.

Nearly all the shale exposed in the canyon of Young Creek is black, except that toward the western end, which is red. It contains thin, widely separated, brownish-weathering calcareous beds and limy concretions, which when seen in a large exposure give about the only evidence of structure that can be distinguished. The shale itself is broken into small fragments and commonly is without lines of bedding.

The banks of several small streams that come into Young Creek from the south, above Calamity Gulch, were examined with care for the purpose of determining the age and structure of the shales. The exposures on the westernmost of these streams are all of black shale for nearly a mile above the mouth of the creek. Then comes a vertical bed of limestone about 15 feet thick, which is succeeded on the south by much disturbed, steeply dipping shale. About a mile from the mouth of the creek there is an impure shaly limestone, which is included between two fault planes and which contains numerous limy concretions and, in places, thin-bedded white limestones. Some of the concretions are large, having a diameter of 2 feet or more. They are arranged along the bedding planes, and the lines of bedding cross them. The red shales are interstratified with a smaller proporout, the conviction was reached that all the shales except those on Canyon Creek, which are referred to the Triassic, belong to one formation. This conviction appears to be fully confirmed by the evidence afforded by the fossils collected at different horizons and at many places.

The structure of the shales and their relation to the sandstones at the big bend and to the sandstone, shale, and conglomerate (see p. 35) that overlie them in the mountains both north and south of Young Creek are not clear. The shales are much folded and repeatedly faulted. It appears probable that Young Creek runs along the axis of a low anticline in the folded black and red shales that overlie the sandstone at the bend. The sandstone and shale, however, have been so faulted that in at least one place the sandstone overlies the shale. Yet this is not believed to be the natural relation of these beds, for at many places (p. 29) the sandstone was found to be deposited unconformably on older rocks, and there is little reason to doubt that it is one of the basal members of the Cretaceous section.

An estimate of the thickness of shale exposed in the Young Creek valley, based on the data at hand, is subject to corrections that may be considerable. No beds that can be identified throughout the valley are known. The strata are much folded and have been displaced by faults of unknown magnitude. These conditions make accurate measurements of thickness almost, if not quite, impossible and even approximately correct estimates difficult.

The sandstones at the bend of Young Creek are believed to underlie the black and red shales and to be exposed in their present position because of folding or faulting, or both, followed by removal of the overlying beds. They are thought to indicate an anticlinal structure for the valley, and therefore also the approximate base of the shales. If this is true the shales appear to have a thickness, after making allowance for the folding of the beds, not less than the difference between the elevation of Young Creek and the base of the sandstones capping Pyramid Peak and the mountains at the head of Calamity Gulch, or about 3,000 feet. The shales are probably more than 3,000 feet thick. The same sort of approximation applied to the shales south of Young Creek would give a less thickness, but there appears to be more evidence for complication by faulting south of the creek than north of it, and the estimate of thickness is therefore more uncertain.

The thickness of these same shales was estimated at about 7,500 feet by Moffit and Capps,[1] who correlated them with the Kennicott

[1] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, p. 37, 1911.

(Upper Jurassic) formation by means of collections of fossils that were less diagnostic than collections made later. This estimate was based on observations made on Dan and Rex creeks, that involve a possible error, which, however, was then unavoidable. (See pp. 44–45.) No cause for changing the estimate of the thickness of the rocks actually considered has arisen, but an unknown thickness of the basal beds in the section considered may be older than the shales of Young Creek.

Other shale areas.—Three other areas of black shale are indicated on the geologic map (Pl. III, in pocket). One is on the north side of Barnard Glacier, another on the north fork of Chitina Glacier, and the third on Kiagna River. These areas were not studied close at hand and the age of the rocks is not known.

The two areas north of Chitina River have given rise to topography like that of the shales on Young Creek. Mountain slopes and summits that were smooth and rounded when the ice withdrew from them have been gashed with deep gulches by postglacial erosion or have been carved into smooth sharp ridges and pointed peaks. These two shale areas are probably remnants of a widespread Cretaceous shale formation.

The shale area of Barnard Glacier lies above the first tributary glacier on the right-hand side. The shale appears from a distance to overlie massive limestone exposed along the edge of the main glacier. This relation may be the result of faulting. A high mountain on the east side of the tributary glacier is capped by distinctly bedded, westward dipping light-colored sediments, which resemble thin-bedded limestone or sandstone.

The shale area on Kiagna River is known only from the reports of prospectors. The general strike of the beds in this district would indicate that this shale is to be correlated with some of the shales of Bremner River or Hanagita Valley rather than with the black shales north of Chitina River.

CONGLOMERATE, ARKOSE, AND SHALE.

The ridge south of Young Creek, when seen from the north, appears to be made up of black shale capped by a succession of nearly horizontal conglomerate and sandstone beds. These beds, however, form not only the top of the ridge but also most of the precipitous south slope on the Chitina River side. (See Pl. XI, *A*, p. 31.) They occupy an area about 15 miles in length and 3 miles in maximum width and are distinctly indicated by the topography of the ridge. This topographic expression is seen in the table-like summits along the ridge and in the cliffs facing the Chitina.

The beds consist of conglomerate, sandstone, sandy shale, and arkose; and, although the conglomerate is at first sight the most noticeable component of the whole mass, the sandstone, shale, and arkose predominate. These rocks are well exposed at the heads of the gulches that come into Young Creek from the south. In the first gulch above Calamity Gulch the contact of the shale and overlying conglomerate-arkose-shale succession is seen in the creek bed about 1,200 feet above Young Creek. At this place the contact is a fault contact. A massive conglomerate dipping about 40° S. and consisting of cobbles and boulders up to a foot in diameter, set in a rather coarse greenish sandstone matrix, rests on much-folded black shale. The fault plane is nearly parallel with the bedding of the conglomerate, crossing it at a slight angle.

The conglomerate is made up chiefly of igneous rocks—granite and greenstone—in well-rounded pebbles and cobbles, most of which do not exceed 6 inches in diameter. Beds of greenish sandstone are included in the conglomerate.

Above this lower coarse conglomerate are beds of finer conglomerate, associated with sandstone, included between beds of shale. In the following section the thicknesses given are only approximate:

Section of Cretaceous conglomerate, arkose, and shale of Young Creek.

	Feet.
Sandstone, coarse, green, and gray, interbedded with dark shales containing imperfect plant remains	700
Shale, brown and gray, with subordinate dark beds	700
Sandstone, greenish or greenish gray	100
Shale, fine grained, brown, gray, or greenish gray	700
Conglomerate and sandstone	300
	2, 500

The total thickness of the beds was confirmed by measurements made at other places, but it does not necessarily represent the original thickness of the deposits, for part of them have been removed by erosion. The coarse sandstone near the top of the series was thought in the field to be a tuff but on further study was found to be a sandstone consisting chiefly of fairly fresh angular grains of feldspar and quartz set in a greenish fine-grained groundmass. It probably represents the material produced by rapid erosion of a neighboring land mass consisting chiefly of igneous rocks like those in the conglomerate.

Imperfect plant remains were obtained from the sandstone, but they were too poor to be of use in determining the age of the rocks.

A fine section of the series is afforded by the cliffs facing Chitina River (Pl. XI, *A*, *B*, p. 31), but it was impossible to examine it in detail. Its most characteristic feature is well-marked stratification.

The beds that were seen to dip south on the north side of the ridge are here practically horizontal. Some minor flexures associated with faulting are exhibited in the cliffs, but on the whole the beds are not greatly disturbed.

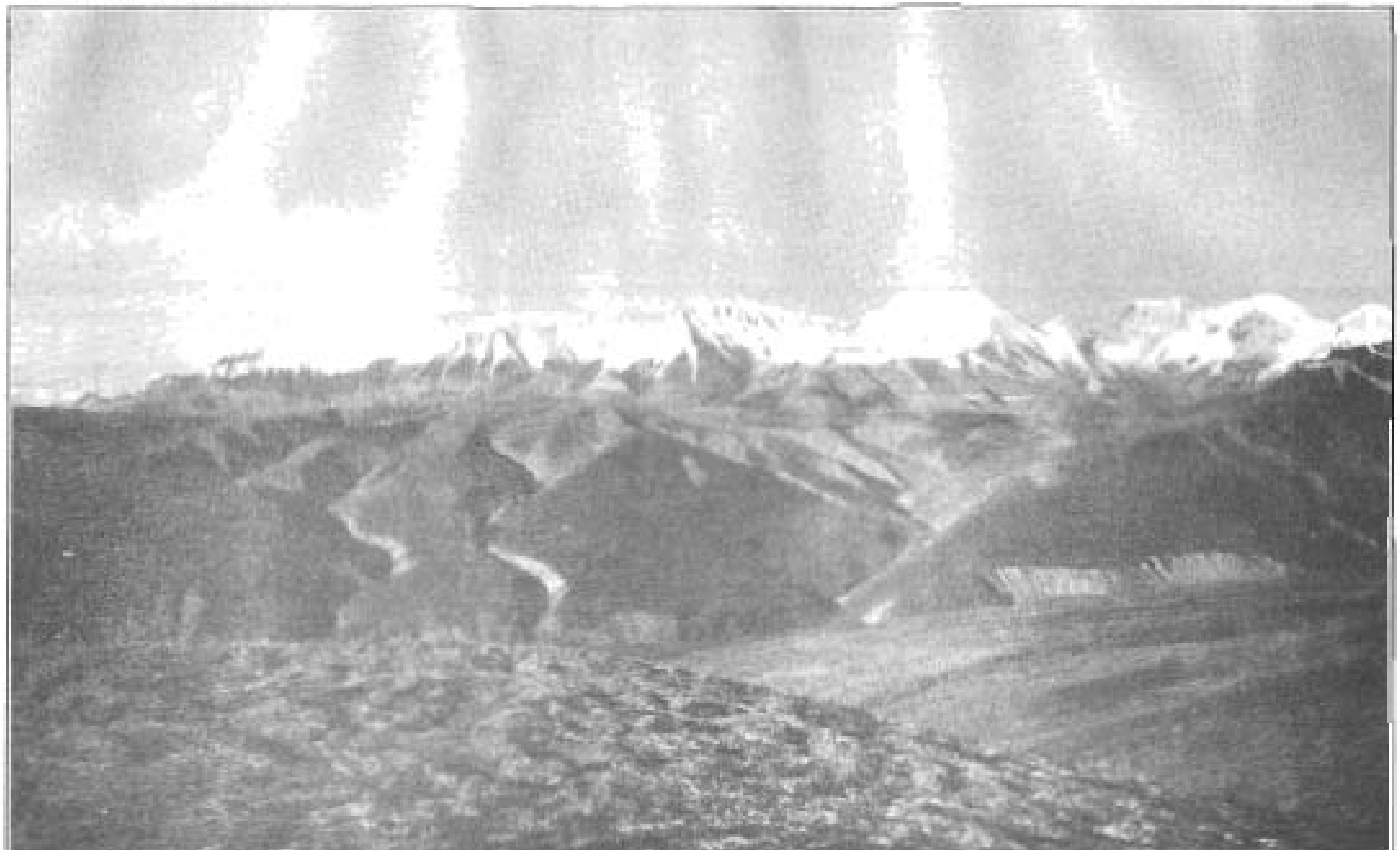
Sandstone and shale, with subordinate conglomerate, correlated with the similar beds south of Young Creek, cap Pyramid Mountain (Pl. IV, *A*, p. 10) and the highest peaks west of the upper part of Young Creek (Pls. XII and XIII, *B*). They are particularly well seen in Pyramid Mountain, where they rest on black shale and appear to be horizontal, although they dip slightly to the southwest. (See Pl. IX, *A*, p. 21.) Here, also, a thickness of about 2,500 feet is exposed, but the massive basal conglomerate was not observed.

Dikes and sills were not seen in the beds of sandstone and conglomerate, a fact that would suggest that the intrusive rocks in the black shales were introduced before the coarser beds were deposited, but that might mean, on the other hand, that the shales were more easily invaded.

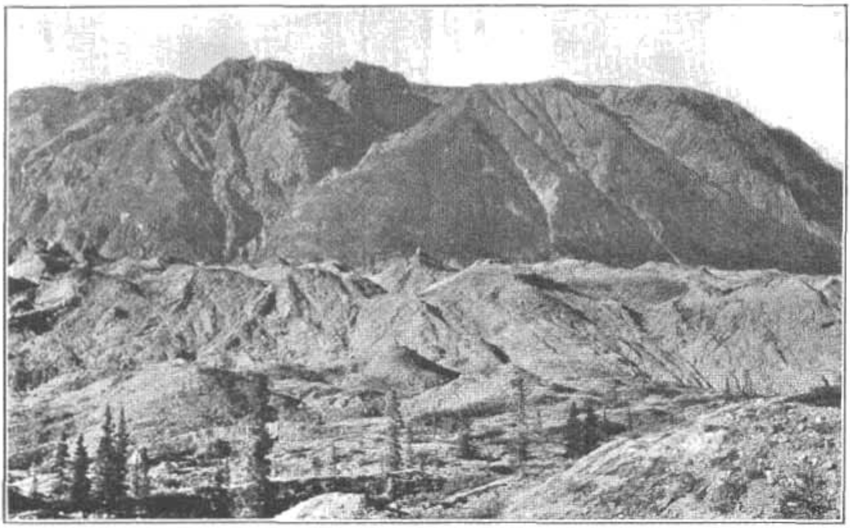
In regard to the stratigraphic position of the sandstones of Pyramid Peak and the high mountains to the west there is no doubt. The nearly horizontal sandstone beds overlie the shale. The sandstone, shale, and conglomerate on top of the ridge south of Young Creek also overlie the shale, but in both places the exact nature of the contact is unknown. The contact south of Young Creek is, at least in places, a fault contact. In Pyramid Peak the sandstones have a slight southward dip, hardly enough to notice, but they show practically no folding. (See Pl. IX, *A*, p. 21.) The underlying shales, on the other hand, are folded. This might seem to indicate depositional unconformity and folding of the shale before the sandstone was laid down; yet it should be remembered that the soft shales are much less able to withstand deforming pressure than the sandstone. In the places where the sandstone-shale contact was observed, on the west branch of Young Creek, the two formations appear to be conformable. The porphyry dike in the shale some distance below the contact at one of these localities is parallel with the contact, suggesting that it was intruded along the bedding plane. The same apparently conformable relation was observed in the high peaks between Rex and White creeks.

AGE AND CORRELATION.

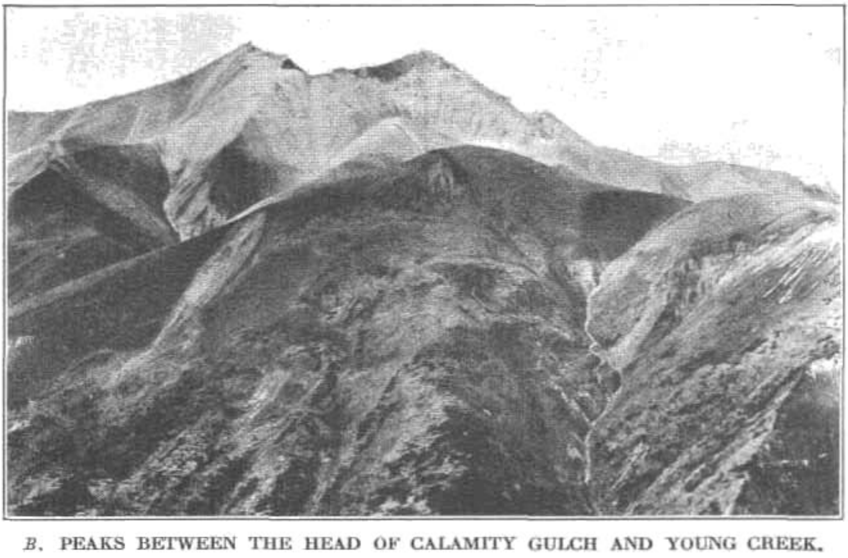
Although fossils are not abundant in a great part of the rocks assigned to the Cretaceous period, they are so numerous in certain of the basal beds and they were collected from horizons so widely separated throughout the beds below the massive conglomerate that



NORTH SIDE OF YOUNG CREEK VALLEY.



A. VIEW NORTHWARD ACROSS BARNARD GLACIER.



B. PEAKS BETWEEN THE HEAD OF CALAMITY GULCH AND YOUNG CREEK.

there can be little doubt concerning the propriety of regarding all the lower beds as of the same geologic age. A conflict of opinion has arisen, however, in regard to the interpretation of the fossils, the fauna having been interpreted as indicating a Cretaceous age and the flora a Jurassic age for the same rocks. The writer, being under the necessity of choosing between these two interpretations, has adopted that from the fauna rather than the flora, one reason being the greater number and size of the faunal collections. He is inclined, however, from the field evidence, to think that the rocks of this district that have been assigned to the Jurassic and Cretaceous on the evidence of the fossils may, on the study of more and better collections, prove to be of the same age.

The collections of fossils were submitted to T. W. Stanton and F. H. Knowlton for identification. Their reports are quoted in full in order to show the basis for the conclusions that were reached. Lists of the fossils, with their localities, are given, the two locality numbers being those of the National Museum and those used in the field. Mr. Stanton's report is as follows:

These collections have proved of more than usual interest from the fact that they present positive evidence of a Cretaceous fauna, not previously recognized in Alaska, by means of which the beds containing it may be correlated with those at certain horizons in the Cretaceous of Queen Charlotte Islands, California, and India. Before attempting any general discussion of the fauna it will be convenient to present the lists of forms recognized in the separate lots, as follows:

9467. F 1. In Gulch, south side of Young Creek, three-fourths of a mile above mouth of Calamity Gulch; nodular limestone in reddish shale:

Serpula sp.
Ostrea sp., small specimen.
Avicula sp.
Inoceramus sp., fragments of thick shell.
Isocardia? sp.
Clisocolus? sp.
Cyprina? sp.
Solemya sp.
Undetermined large gastropod.
Fragment of crustacean claw.
Probably Cretaceous.

9468. F 2 and F 2a. Creek on south side Young Creek, about a mile above Calamity Gulch; float in stream:

Anomia? sp.
Inoceramus sp., fragments of thick shell.
Cyprina occidentalis Whiteaves?
Probably Cretaceous.

9469. F 3. Near head of Sheep Creek, elevation about 5,200 feet:

Inoceramus sp.
Lucina sp.
Undetermined pelecypod.
Probably Cretaceous.

9470. F 4. South side of Young Creek on ridge west of Young Creek–Chitina River trail, elevation about 5,100 feet:

Inoceramus sp. cf. I. concentricus Parkinson.
Desmoceras? sp.
Cretaceous.

9471. F 5. West branch of Young Creek, 2 miles above forks, elevation 4,200 feet; float:

Anomia sp.
Probably Cretaceous.

9472. F 6. West fork of Young Creek, about 2 miles above forks and opposite first glacier from west, elevation 4,300 feet; from nodular limestone:

Anomia sp.
Inoceramus sp., fragments.
Probably Cretaceous.

9473. F 7. West branch of Young Creek above first glacier from west, elevation 4,400 feet; float:

Anomia sp.
Isocardia? sp.
Undetermined venerid?
Probably Cretaceous.

9474. F 8. Above F 7 (9473) on west branch of Young Creek, elevation 4,500 feet; float:

Anisoceras? sp. cf. A. armatum Sowerby.
Cretaceous.

9475. F 9. West branch of Young Creek, just below first glacier from the west, elevation 4,300 feet; float:

Serpula? sp.
Thyasira sp.
Undetermined small pelecypod.
Hauericeras? sp.
Cretaceous.

9476. F 10. East branch of Young Creek, on stream from the north, elevation 4,300 feet; float:

Inoceramus sp.
Probably Cretaceous.

9477. F 11. Young-Canyon Creek divide, elevation 5,600 feet; from black and gray shale:

Inoceramus sp. cf. I. concentricus Parkinson.
Cretaceous.

9478. F 12. Young-Canyon Creek divide, north of F 11 (9477), elevation 5,750 feet; from black and gray shale:

Anisoceras? sp., fragments of a small species.
Pachydiscus sp.
Cretaceous.

9479. F 13. Head of east branch of Young Creek; float:

Inoceramus sp.
Probably Cretaceous.

9480. F 14. Same locality as F 13 (9479):

Desmoceras (Puzosia) sp.
Cretaceous.

9481. F 15. North side of the Chitina, 1.4 miles N. 15° W. from Gibraltar; from round calcareous concretions in gray slaty sandstone:

Inoceramus sp. cf. I. concentricus Parkinson.
Inoceramus sulcatus Parkinson.
Inoceramus sp.
Pinna sp.
Nucula sp.
Amauropsis tenuistriata Whiteaves?
Baculites sp. cf. B. teres Forbes.
Lytoceras (Tetragonites) timotheanum (Mayor).
Lytoceras (Gaudryceras) sacya (Forbes).
Holcodiscus sp.
Holcodiscus sp. cf. H. cumshewaensis Whiteaves.
Phylloceras sp. cf. P. ramosum Meek.
Phylloceras sp.
Desmoceras sp.

Cretaceous.

9483. F 18. Top of ridge between Short River [Barnard] and Chitina glaciers, elevation 6,475 feet; from platy sandstone:

Protocardia? sp.
Thracia? sp.
Imprint of young ammonite.

Not sufficient for determining age.

9485. F 27. Creek 2 miles east of Canyon Creek, tributary to Chitina River, elevation 2,125 feet; from nodules in pinkish sandstone:

Trigonia sp.
Cylichna? sp.
Undetermined fragmentary gastropods.
Baculites sp. cf. B. teres Forbes.
Lytoceras (Tetragonites) timotheanum (Mayor).
Lytoceras sp.
Holcodiscus sp. cf. H. cumshewaensis Whiteaves.
Desmoceras sp.

Cretaceous; same fauna as in F 15.

9486. F 28. Creek 2 miles east of Canyon Creek, tributary to Chitina River, elevation 2,150 feet:

Inoceramus sp. cf. I. concentricus Parkinson.
Astarte? sp.
Amauropsis tenuistriata Whiteaves?
Tessarolax? sp.
Baculites sp. cf. B. teres Forbes.
Lytoceras (Tetragonites) timotheanum (Mayor).
Desmoceras? sp.

Cretaceous; same fauna as F 15.

9487. F 29. Mouth of Canyon Creek, elevation 1,460 feet; nodules in gray sandy shale:

Inoceramus? sp. cf. I. concentricus Parkinson.
Leda sp.
Astarte? sp.
Thracia sp.
Dentalium sp.
Turbo? sp.

Trichotropis? sp. cf. T. koninckl (Müller), as figured by Stoliczka.
Baculites sp. cf. B. teres Forbes.
Lytoceras (Tetragonites) timotheanum (Mayor).
Lytoceras (Gaudryceras) sacya (Forbes).
Phylloceras sp.
Holcodiscus sp.
Desmoceras haydeni (Gabb).
Desmoceras? several unidentified species.
Cretaceous; same fauna as F 15.

9488. F 30. Mouth of Canyon Creek, elevation 1,470 feet; from conglomerate at base of sandy beds:

Camptonectes sp. The genus Camptonectes ranges from Jurassic to Upper Cretaceous, inclusive.

9490. F 32. Southeast of bend of Young Creek, elevation 4,400 feet; float in stream:

Fragment of large ammonite, not enough for determination of genus or horizon.

9491. F 33. Southeast of bend of Young Creek, in gulch, elevation 4,000 feet:

Inoceramus? sp. Poorly preserved fragmentary cast, probably belonging to Inoceramus. If so, it is either Cretaceous or Jurassic.

9492. F 34. Bluffs of Young Creek, west of big bend; from concretions in sandstone:

Pecten sp.
Inoceramus sp. cf. I. concentricus Parkinson.
Leda sp.
Nucula sp.
Trigonia sp.
Astarte? sp.
Solemya? sp.
Undetermined venerid.
Corbula sp.
Dentalium sp.
Amauropsis tenuistriata Whiteaves?
Anchura or Aporrhais sp.
Actaeon? sp.
Cinulia? sp.
Phylloceras sp. cf. P. ramosum Meek.
Phylloceras sp.
Lytoceras (Tetragonites) timotheanum (Mayor).
Lytoceras (Guadryceras) sacya (Forbes).
Desmoceras breweri (Gabb).
Desmoceras haydeni (Gabb).
Desmoceras (Puzosia), several undetermined species.
Aptychus? of an ammonite.
Several additional ammonite species represented by small specimens not generically determined.
Cretaceous; same as F 15.

9493. F 35. Stream on south side of Young Creek, three-fourths of a mile above Calamity Gulch, elevation 3,225 feet; from concretions in black shale:

Inoceramus. Two species represented by fragmentary specimens. Probably Cretaceous.

9494. F 36. Same stream as F 35 (9493), elevation 4,500 feet; from horizontal sandstone beds:

Inoceramus sp., obscure imprint of a single specimen. Probably Cretaceous.

The entire collection is believed to be Cretaceous, though a few of the smaller lots are uncertain because of the poor preservation or the great vertical range of the types represented. Lots 9481 (F 15), 9485 (F 27), 9486 (F 28), 9487 (F 29), and 9492 (F 34) contain enough distinctive ammonites and other diagnostic forms to leave no doubt that they are of Cretaceous age, and enough species are common to two or more of these lots to show that they all belong to a single fauna. The forms most important for correlation in these lists are the following:

Inoceramus sp. cf. I. concentricus Parkinson.
Inoceramus sulcatus Parkinson.
Amauropsis tenuistriata Whiteaves.
Baculites sp. cf. B. teres Forbes.
Lytoceras (Tetragonites) timotheanum (Mayor).
Lytoceras (Gaudryceras) sacya (Forbes).
Holcodiscus sp. cf. H. cumshewaensis Whiteaves.
Phylloceras cf. P. ramosum Meek.
Desmoceras haydeni (Gabb).
Desmoceras breweri (Gabb).

All these species except possibly the *Baculites* and the *Phylloceras* occur in the Haida formation, recently described by Mackenzie[1] as the lowest formation of the Queen Charlotte series, which series name is applied to all of the Cretaceous rocks of the Queen Charlotte Islands. Several of the species were in the collections which I identified for Mr. Mackenzie last year, and the others are listed and described in earlier reports by Whiteaves. The two species of *Lytoceras* and the two species of *Desmoceras* are also found in California, where they occur in the upper part of the Horsetown formation or the lowest part of the Chico. *Phylloceras ramosum* Meek also comes from the same part of the section in California. From these comparisons with the Cretaceous of Queen Charlotte Islands and of California I would assign the collections represented by the list above given to the basal part of the Upper Cretaceous or to near the top of the Lower Cretaceous.

If the comparisons are carried to more distant regions the same general results are obtained. Thus the two species of *Inoceramus* listed are English species and are reported from the Gault and upper Greensand of England. They are also of types not known anywhere in older rocks than the Gault. *Baculites teres*, *Lytoceras timotheanum*, and *L. sacya* occur in the Ootatoor group of India, which is assigned to the lower part of the Upper Cretaceous and contains many other species identical with or closely related to those of the Haida and upper Horsetown. Furthermore, these two *Lytoceras* species belong to the groups *Tetragonites* and *Gaudryceras*, respectively, by some treated as distinct genera, which are characteristically Cretaceous. *Baculites*, also, is unknown in pre-Cretaceous rocks. There is a possibility that the little form referred to *Baculites* in these collections may belong to *Ptychoceras*, another characteristic Cretaceous genus in which the long straight shell is bent back on itself. An example of *Ptychoceras* has lately been discovered (or rather uncovered) in one of Martin's collections of 1914 from Bear Creek (No. 8872). I am therefore changing the assignment of that lot from Upper Jurassic to

[1] Canada Geol. Survey Summary Rept. for 1913, pp. 43–47, 1914.

Cretaceous. Some additional genera, such as *Anisoceras*, *Pachydiscus*, and *Thyasira*, found in the smaller lots of this collection, are not known from pre-Cretaceous rocks elsewhere.

As I see it, therefore, the invertebrate evidence is all strongly in favor of the Cretaceous age of the entire collection. The fauna of the best localities indicates a horizon slightly lower than that of the Cretaceous of the Matanuska Valley, but still far above the basal Cretaceous. There is no suggestion of an admixture of Jurassic types such as might be expected in the lowest Cretaceous, and my judgment is that the fauna is considerably younger than even the latest Knoxville. The fossil plants which, as Knowlton reports, belong to a Jurassic flora, are intimately associated in the same beds with the ammonites and other invertebrates which are referred to a Cretaceous fauna, the two localities (F 15 and F 34) which yielded the best collections of plants having also yielded the best collections of invertebrates. I think that the vertical range of the ammonites is better established than that of the plants.

The plants were collected from the same localities (F 15, F 18, F 28, F 31, and F 34) as certain of the animal remains already identified by Mr. Stanton. F. H. Knowlton's report on them follows:

This material consists of five lots, all the specimens being small and many of them mere scraps. Although this material is very fragmentary, most of it permits the easy recognition of generic types, but some of the species have been identified with difficulty and doubt. However, the material has been studied with great care and much literature has been consulted. The following specimens have been identified with reasonable certainty:

Elatides curvifolia.
Pagiophyllum peregrinum.
Pagiophyllum sp.?
Pinus nordenskiöldi.
Ginkgo schmidtiana.
Podozamites or Zamites sp.
Otozamites beani.
Otozamites bunburyanus.
Taeniopteris lindgreni.
Taeniopteris parvula? Heer.
Sagenopteris phillipsi.
Sagenopteris sp.?
Hausmannia cf. H. forschhammeri or dichotoma.
Dictyophyllum sp.
Cladophlebis cf. C. moissenti.
Cladophlebis sp.

The species first named (*Elatides curvifolia*), although first described (under the name of *Lycopodites curvifolius*) from the Wealden of Germany, has since been found abundantly in the Upper Jurassic of Spitzbergen. It is also found in the Upper Jurassic of Cape Lisburne. *Pagiophyllum peregrinum* is abundant in the English Jurassic and, so far as I recall, has not been found above this horizon. *Pinus nordenskiöldi* was described from the Upper Jurassic of Siberia by Heer and later was reported with some question from the Kootenai by Dawson. The *Ginkgo* is known only from the Upper Jurassic of the Amour. The *Podozamites* is of the type of *P. lanceolata* and may be one of the forms of that variable species, but as it has fewer nerves than is usual it is not identified specifically and may be new. It also resembles small leaflets of *Zamites* such as *Z. megaphyllus*. *Taeniopteris lindgreni* is known only from the Upper Jurassic of

Advent Bay, Spitzbergen. The other species of *Taeniopteris* is represented by a single fragment and is questionable. It is indistinguishable, so far as this fragment goes, from *T. parvula*, a well-known Upper Jurassic form. *Sagenopteris phillipsi* is a variable small species described from the Upper Jurassic of Yorkshire, England. The unnamed *Sagenopteris* may be one of the forms of the first-mentioned species, but as it is fragmentary it has not been positively identified. The *Otozamites* are mostly in the form of detached leaflets, in which, however, the nervation has been beautifully preserved. They may represent only one species, but as they differ very considerably in size they are referred to the two species distinguished by Seward, both of which are found in the Upper Jurassic of Yorkshire as well as in beds of similar age in France. The *Hausmannia* is represented by a single broken specimen which might with nearly equal propriety be identified with one of the forms of *H. forschhammeri* from the Lias or Rhaetic of Sweden or with *H. dichotoma* from the Wealden of Auddinburg, Germany, and elsewhere. The genus ranges through the Jurassic and Wealden but is not well authenticated in later Cretaceous beds. The *Dictyophyllum* is a mere fragment that can not be positively determined. It might well enough be *D. rugosum*, which is found in the Yorkshire beds. This genus is mainly confined to the Rhaetic and Lias but is represented in the Jurassic and Wealden, and a single species is known from the Kome of Greenland. The forms of *Cladophlebis* are more or less uncertain. They are represented by mere fragments of only a few pinnules with mostly obscure nervation and are very difficult to identify. One form may be compared with *C. moissenti*, from the French Jurassic, or with *C. heterophylla* as known from the Kootenai. They could also be compared with species from the Upper Jurassic and Wealden, but in truth the material is too scanty to permit a positive decision.

With the data available we now come to the point of deciding the probable age of these plants. It is obvious that most of the positively identified forms are found in the Upper Jurassic, and at least half of them have not been found in beds younger than this. Only two of the named species are known to range into beds as young as the Wealden or its approximate equivalent. As pointed out, however, the more or less fragmentary material by which several of the unnamed forms are represented might be assigned to either Upper Jurassic or Wealden species; but clearly, if they can not be positively identified as one or the other, they can not be allowed to weigh in the balance against those that can be and have been identified with reasonable certainty. I therefore express my conviction that these plant beds are Upper Jurassic in age, thus confirming the determination reached in the field.

According to a statement made by Moffit and accompanying the specimens: "These beds were referred to the Upper Jurassic on the basis of an assumption that only one known fossil flora occurs in the Chitina Valley and that these plants are the same as those that Martin and Overbeck obtained in 1914 from the Upper Jurassic *Aucella*-bearing beds on Fohlin Creek."

I believe this reasoning is correct, at least so far as it applies to the identity between the material here reported on and that from Fohlin Creek. There were only four positively named species in Martin's collections of 1914, and two of these are abundant and unmistakable in the present collections. I have reexamined the Fohlin Creek material in the light of the present collection and find that what I there called *Sagenopteris alaskensis?* is without much doubt the same as *Sagenopteris* sp.? in the Moffit material, and one specimen strongly suggests *S. phillipsi*. I am now quite convinced that they are not the same as Fontaine's *S. alaskensis*. I also find in the Fohlin Creek lots what I failed to note before, namely, a single leaf that appears to be the same as what I am calling *Pinus nordenskiöldi* in this report; and I find, furthermore, that the *Zamites megaphyllus* of the Martin report (1914) is pretty close to, if not the same as, the *Podozamites* or *Zamites* sp. of the present report. This appears to me to afford strong presumption for the identity of the beds of Fohlin Creek and the present (1915) collections. The localities are separated by only 35 miles, I believe, and this is a short distance in Alaska.

I, of course, have no opinion as to the stratigraphic relations of the beds whence came the *Sagenopteris alaskensis* of Fontaine, my only contention being that the species is not the same as those that represent this genus in the collections from the Chitina Valley.

This flora has been carefully compared with the small flora, consisting of about fourteen forms, reported by Dawson and Penhallow from the Queen Charlotte Islands, and so far as can be made out the two have not a single form in common.

Below is given an enumeration of the several localities with the forms found at each:

7034. F 15. North side of the Chitina, N. 15° W. and 1.4 miles from Gibraltar; from round calcareous concretions in gray platy sandstone:

Elatides curvifolia (Dunker) Nathorst.
Pagiophyllum sp.
Otozamites beani (Lindley and Hutton) Seward.
Otozamites bunburyanus Zigno.
Taeniopteris lindgreni Nathorst.
Taeniopteris parvula? Heer.
Sagenopteris phillipsi (Lindley and Hutton).
Sagenopteris sp.?
Cladophlebis cf. C. moissenti Saporta.
Cladophlebis sp.

7035. F 18. Chitina Valley, between Short River and Chitina glaciers, elevation 6,475 feet; from platy sandstone capping ridge:

Elatides curvifolia (Dunker) Nathorst.

7036. F 28. Chitina Valley, most easterly of three creeks entering lake together 2 miles east of Canyon Creek, elevation 2,150 feet:

Cladophlebis sp.

7037. F 31. Chitina Valley, at fork of stream near Chitina River-Young Creek trail; from sandstone nodules:

Sagenopteris sp. Material fragmentary.

7038. F 34. Chitina Valley, bluffs on Young Creek, west of big bend; from concretions in sandstone:

Pagiophyllum peregrinum Schimper.
Pinus nordenskiöldi Heer.
Podozamites or Zamites sp.
Ginkgo schmidtiana Heer.
Hausmannia cf. H. forschhammeri or dichotoma.
Dictyophyllum sp.
Sagenopteris phillipsi (Lindley and Hutton).

The black and red shales of Young Creek form part of a shale area that includes Chititu, White, and Rex creeks and part of Dan Creek. They were correlated by Schrader and Spencer[1] with the black shales overlying the Upper Triassic (then thought to be Carboniferous) limestone of Chitina Valley and were regarded as of

[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., 1901. See geologic map.

Upper Triassic age. They were considered by Moffit and Capps[1] as probably of Upper Jurassic though possibly of Lower Cretaceous age, the assignment being made on the evidence afforded by fossils collected from several localities, and were correlated with the Kennicott formation, the term Kennicott being used to designate the supposed Upper Jurassic rocks of Chitina Valley and not a particular lithologic unit. This was the usage of Schrader and Spencer[2] and in effect was the usage of Rohn, although he refers to the "arkoses, shales, and limestones [his Kennicott series] between the Lakina River and Kennicott Glacier" in one place[3] as Jurassic and in another as Cretaceous and designates them as Jurassic-Cretaceous on his map.

The Cretaceous shales occupy areas on both sides of Kennicott River, but their westward extension has not been determined. It is probable that they do not extend much beyond Lakina River.

Determinable fossils were not found in the sandstone and shale beds assigned to the top of the Cretaceous section. The position of the beds, however, and their comparatively undisturbed condition lead to the belief that they are the youngest rocks of the district. They overlie Cretaceous shale and therefore would appear to be either Cretaceous or Tertiary in age. South of Young Creek the contact relations in a number of places are those that have resulted from faulting. It was not determined whether there is depositional unconformity also, although it is known that the underlying shales are much more folded than the sandstone, a condition that is common throughout the Chitina Valley, where strong and weak beds have been involved in folding.

The contact at Pyramid Peak and in the mountains west of Young Creek was not seen close at hand, but its appearance from a short distance does not suggest unconformity. Tertiary sediments are not known in Chitina Valley, and there appears to be little reason for regarding these rocks of Young Creek as Tertiary in age.

CENOZOIC ROCKS.

QUATERNARY DEPOSITS.

KINDS OF DEPOSITS.

The Quaternary deposits of the district are unconsolidated glacial débris, sand, gravel, and loose rock waste that collects as the result of weathering on the mountain and hill slopes and on the hill tops.

[1] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 31–43, 1911. See also geologic map, pl. 2, in pocket.

[2] Op cit., p. 48.

[3] Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 424 and 428, 1900.

Among these deposits those that owe their origin to the action of glacial ice and of water in streams or in lakes call for most attention and are considered in this report to the practical exclusion of all others. The heaps of débris that collect at the bases of cliffs, the fan-shaped accumulations of rock fragments at the mouths of steep gulches, the rock slides, and the thin veneer of unsorted rock waste on gentle slopes and flat hill tops (except that left by the retreating glaciers) do not owe their present form or position primarily to the action of ice or water, although they eventually find their way into the streams to be sorted, transported, and laid down as some sort of unconsolidated deposit. Such accumulations of unconsolidated material are widespread throughout this district, yet they will not receive special consideration here. Neither will the wind-blown deposits require attention. Sand and dust swept up from the gravel bars of Chitina River by the wind have helped to build up the low benches that adjoin the flood plain, but they form no such conspicuous and independent deposits as are seen on the lower Chitina and along Copper River and some of its tributaries (for example, Tonsina River); and they are therefore passed over.

GLACIAL DEPOSITS.

Two kinds of glacial deposits are more or less conspicuous in this district—(1) a thin sheet of till, which may be seen at many places and which probably was laid down over much of the area not now occupied by ice except the high mountain tops, and (2) the terminal and lateral moraines of the present glaciers. In order to understand more fully the distribution of these two types of deposits the past and present glaciers will be briefly described.

The present glaciers, large as they seem, are insignificant in comparison with the great ice mass that formerly extended over this mountain region. It is believed that all the present valleys were filled with ice, and that only the higher mountain peaks projected above its surface. The ice moved down from the principal gathering places in the central high areas to the main valleys, and in this district flowed westward through the Chitina Valley. A branch of the Chitina Glacier, including in its mass glaciers from upper Young and Canyon creeks, was diverted from the main valley and flowed down Young Creek to the Nizina. No barrier to its progress was offered by the ridge south of Young Creek or by that between Young and Chititu creeks, for the erratic boulders on their summits show that these ridges were overridden.

The maximum extension of the glaciers indicated was maintained for a long time, but at length a change in climatic adjustments took place, so that the rate of ice accumulation no longer exceeded or equaled the rate of melting, and the glaciers slowly receded to their present positions. Their recession probably did not take place regularly and without interruption. Periods of advance may have followed periods of retreat, and for long intervals possibly neither advance nor retreat occurred. As the ice melted it deposited the load of rock débris that rested on its surface or was contained within it. Some of this material was laid down at the margin of the ice, where it either remained or whence it was carried away by running water and redeposited elsewhere. Some of it, by the gradual melting of areas of stagnant ice, was let down on the bare rock beneath and underwent little or no sorting by the water from the melting ice. These unsorted and unstratified deposits, however laid down, are properly called glacial deposits; yet it should be borne in mind that much of the bench and stream gravel is the product of both glacial and stream work, and that all the glacial deposits have been affected to some degree by moving water.

Young Creek valley offers many good exposures of glacial deposits in the form of a thin, widely extended veneer of angular, unsorted rock fragments. Such exposures are most common along canyons and gulches that are being rapidly eroded in the soft shale bedrock. The deposits are commonly not more than a foot or two thick, but they extend well up on the mountain slopes. In places they have been removed by the streams and incorporated in the stream gravels. Some of the smaller stream beds are filled with more or less rounded boulders and cobbles derived from the glacial deposits and contain little local material. Deposits of the kind just described are best preserved on gentle slopes, on flat-topped hills, and on valley floors where they have been undisturbed by streams, and are less likely to be laid down and preserved on steep slopes, so that the valley of Young Creek and the lower hills east of Canyon Creek are favorable places for their occurrence.

Terminal and lateral moraines of different sizes mark the margins of some of the existing glaciers but have not been preserved elsewhere in the upper part of the Chitina Valley nor in the Young Creek valley; at least, no conspicuous glacial deposits of this kind were observed. Chitina Glacier and the two large glaciers below it on the north side of Chitina River carry heavy loads of rock débris, which has collected on their lower ends until it has hidden the ice from view and in places has even been overgrown with timber and other vegetation. Along the active front of the glacier the débris is discharged as the ice melts, so that on warm days there is an almost continuous rumble of falling rock; but the heaps of loose fragments formed in this way do not remain long, for they are attacked by the glacial waters and are soon carried into the stream gravels.

The terminal moraine of Barnard Glacier contains a large quantity of pumice similar to that of White River, recently described by Capps.[1] Barnard Glacier heads in the mountains southwest of Mount Natazhat, which are believed to be near the volcanic vent from which the pumice came. Pumice was not found on the glacier between Short River and Canyon Creek nor on the Chitina Glacier, the north branch of which also heads in the vicinity of Natazhat. It would seem remarkable if the Chitina Glacier were entirely outside of the area of volcanic dust, and the seeming absence of pumice in its moraines may be due to its removal by the river.

The pumice consists chiefly of dust and sand but contains fragments up to an inch or more in diameter. It is white or yellowish-white and includes many tiny crystals of hornblende. The heaps of loosely piled white pumice stand out distinctly among the moraines of darker rock, for vegetation has difficulty in getting a foothold in the loose material on their surfaces and their sides are bare. This volcanic material will receive further consideration in the section on igneous rocks.

Lateral moraines are more stable than terminal moraines, for they are less subject to destruction by the glacial waters. Such moraines are found along nearly all the glaciers. They appear like immense railway embankments, except that their tops are not flat and they themselves are not continuous, for they are broken through here and there by streams or were placed originally with ends overlapping one another.

STREAM DEPOSITS.

Classes.—Stream deposits include sands, gravels, and other fragmental material deposited by running water. Many of them are of glaciofluvial origin—that is, they owe their present condition to the action of both ice and water, for the material in them was transported from its place of origin by the glaciers and was then laid down by the waters from the melting ice. Such deposits in general consist of angular and subangular fragments of a wide range in size, embedded in glacial silt. They are not well sorted and do not show well-developed bedding.

Unconsolidated deposits that are distinctly glaciofluvial grade into deposits that show less and less their glacial origin and take on more and more the features that are due solely to deposition in running water—better sorting of the material, more pronounced bedding, and less angularity of fragments—features that are due to the long-continued action of running water by which the gravels are repeatedly deposited, undermined, and redeposited.

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

The stream gravels of the district may be conveniently described as bench gravels and flood-plain gravels, but it should be remembered that the bench gravels were at one time flood-plain gravels and that the present flood-plain gravels may in time become bench gravels.

Flood-plain gravels.—Flood-plain gravels are gravel deposits that are subject to overflow by the streams only at times of high water. Their margins ordinarily are defined by gravel benches or by rock walls, and they are bare of vegetation. The stream shifts its channel back and forth across the flood plain, slowly moving the gravels downstream or, when it can no longer carry the load, spreading them out over the valley floor. Such deposits are found along all the streams in this district and commonly have a width that bears some relation to the size of the stream. They are best developed on the Chitina, the flood plain of which, above Tana River, ranges in width from 2 to 3 miles and at times of high water is practically covered from bank to bank, though at low water the river is confined in a few narrow channels.

The broad bars of Chitina River are composed of gravel and sand. The gravel is made up of well-rounded rock fragments ranging up to a foot or more in diameter, but boulders of this maximum size are only a subordinate part of the gravel exposed. The gravel is composed largely of granite or some closely related granitic rock, but it includes much greenstone. The large proportion of granite indicates the resistance of granite to wear as well as its prevalence at the upper end of Chitina Valley.

Sand beds accumulate on the flood plain at time of high water in places where the velocity of the current is decreased enough to allow the sand to settle. It collects particularly at the lower ends of gravel bars, but when the water is low the dry sand is likely to be blown away. Beds of water-saturated sand on the flood plain or in the stream channel make parts of the Chitina dangerous for horses in fording, so that great care must be taken by parties crossing the river.

The flood-plain gravels of Chitina River are saturated with water, which flows through them freely and comes to the surface in numerous clear-water springs. The depth of the gravel is not known but is thought not to be great. A number of rock islands covered with peat and growing timber project above the flood plain in the upper valley, having withstood the attack of the moving ice and the river. The largest of these is Gibraltar, with a height of about 700 feet.

Several of the streams that empty into Chitina River, such as Canyon Creek, Goat Creek, and the stream from Hawkins Glacier, have thrown out immense amounts of gravel in wide fan-shaped deposits, which begin where the stream emerges from its canyon, and one or two of which extend more than a mile into the main valley. These deposits slope away radially from the highest point at the canyon mouth to the margin, in places crowding the river channels toward the farther side of the valley. The stream flowing over the gravel fan commonly discharges through a number of radiating channels whose positions are not fixed but are shifted from time to time as the currents are choked by the deposition of the loads of gravel. Some of the gravel fans are partly covered with brush or with timber, but even such areas are likely to be invaded by the stream.

The flood-plain gravels of upper Young Creek range in width from 50 to 200 feet. They are confined between low benches, which in only a few places reach a height of 15 feet or more, and show a larger proportion of local material than the gravels lower downstream. Within the canyon the flood plain is narrower and in places is almost absent.

Canyon Creek flows in a canyon throughout most of its course, so that the flood-plain gravels are less prominent than would be expected from the size of the stream. In the vicinity of Erickson Gulch they are nearly as wide as those on Young Creek.

Flood-plain gravels are the only gravels on some of the smaller creeks and gulches at places where the channel is confined by rock walls.

Bench gravels.—Two sorts of bench gravels are considered here. The most widespread are those that lie near the flood-plain gravels and only a little above them. Their height above the flood plain commonly ranges from a foot to 20 feet, but at a few places is greater. Probably the tops of most of them would average not less than 10 feet above the flood-plain gravels. Although generally overgrown with vegetation, many of them, especially those of Chitina River, show by their surface form that they are old flood plains in which the streams have entrenched their channels.

The second kind of bench gravel includes deposits that stand high above the present streams and are no longer subject to their direct attack either by overflow or by lateral cutting. They are best represented on the lower part of Young Creek and are older than the low-bench and flood-plain gravels.

The benches of Young Creek include both high-bench and low-bench gravels. The benches of upper Young Creek and the benches within the canyon of Young Creek are of low-bench gravels, although some of the gravels in the canyon are now so high above the creek that the water can not attack them except by undermining the bedrock on which they rest.

High benches occur on Young Creek only below Calamity Gulch, and those that were observed are of glaciofluvial origin. The great mass of ice that moved down Young Creek from the east swept the valley clean, but on its retreat it deposited an immense amount of débris, some of which was partly worked over by the water and now forms the high benches of lower Young Creek. Some of the deposits near the Nizina Valley may have been contributed in part by the Nizina Glacier, which possibly obstructed the mouth of Young Creek after the Young Creek Glacier had retreated from the locality.

The high benches of Young Creek have been trenched by the creek, which in places has cut through them and into the soft shale bedrock beneath, so that the gravels now cap the rock walls.

These gravels a few miles below Calamity Gulch have a thickness of several hundred feet. They contain a great proportion of granite, greenstone, and other rocks foreign to the Young Creek valley, set in bluish glacial mud, and imperfectly stratified. Toward the west, however, the better sorting of the material and the more plainly marked bedding become noticeable. The high-bench gravels contributed material to the younger stream gravels of Young Creek and are the source of some of the gold contained in them.

Upper Chitina River, like the upper end of Young Creek, is without important high-bench deposits. The valley was swept clean of any gravels that had accumulated in preglacial time, and the gravels that were laid down as the ice retreated are nearly all contained in the low-bench and flood-plain deposits. Near the end of Chitina Glacier and along its north side are high banks of gravel that were deposited by streams at the edge of the melting ice. Other gravel banks of the same nature may be seen in a few places along the mountain slopes of the north side of the valley but are far less numerous than might be supposed.

Large parts of the valley floors of upper Young Creek and of Chitina River and such of its tributaries as are not buried in ice are occupied by low-bench gravels—old flood-plain deposits, in which the streams have intrenched themselves so deeply that they are no longer able to attack them except by lateral cutting.

At some places on the upper part of Young Creek these deposits stand as much as 15 feet above the flood-plain gravels. Their surfaces merge into the lower slopes of the hills back of them and are covered with vegetation, so that it is difficult to estimate their width. In the canyon of Young Creek they form a narrow spruce-covered belt between the creek and the canyon walls. Commonly, they are best developed on only one side of the creek, for the channel swings back and forth from one side of the canyon to the other. In places the creek has entrenched itself in the shale and has left narrow shelves of bedrock on which masses of gravel remain. Prospecting has shown that the gravel on these benches, like the creek gravels and the high benches above, contains gold.

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 would 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 and 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 gray, 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 small 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 was 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 6½ 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 rocks 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 have 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.

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[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 the 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.

TUFFS 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 are 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.

northward, and in the western part it swings somewhat to the south. (See Pl. III, in pocket.)

Some of the rocks are schistose, especially the sedimentary and igneous rocks in a narrow belt east and west of lower Canyon Creek and the impure limestones east of the lower end of Barnard Glacier, but schistosity is not common in the district. The rocks at the end of Barnard Glacier have been much folded and faulted and are believed to be much older than most of the beds farther west.

Faults are common throughout the district, and have displaced all the beds, complicating the structure far more than would folding alone. A further structural complication arises from the unconformable relations between some of the formations. The southwest boundary of the greenstone area on Canyon Creek is in line with the great fault that extends northwestward from the head of Copper Creek, north of Pyramid Peak, to McCarthy Creek and possibly beyond Kennicott Glacier. So far as the evidence seen in the Chitina Valley indicates this contact may represent either an unconformity of deposition or one of faulting; but in the Nizina district there is good evidence of a great major fault. This fault probably continues into the Chitina Valley, bringing the greenstone up into contact with the younger rocks, a displacement which, if the known thickness of the Triassic beds in the Chitina Valley is involved, would amount to possibly 5,000 feet. Doubt is thrown on the suggested magnitude of this displacement and even on the very existence of the fault itself by the fact that one and possibly two periods of erosion intervened between the pouring out of the Nikolai lavas and the deposition of the Cretaceous shales in contact with the lavas on Canyon Creek, and were it not for the evidence found in the Nizina district,[1] the shale-greenstone contact of Canyon Creek might be explained as due to depositional unconformity alone.

Several faults were noted on Young Creek. Their trend is approximately parallel to the lower part of the creek below Calamity Gulch, and their dip ranges from about 45° S. to nearly vertical. One or more of these faults cut the shales south of Young Creek; one is at the base of the conglomerate on the ridge south of Young Creek; and one follows the limestone exposures east of Sheep Creek.

Faults were also seen near the foot of Chitina Glacier. Both contacts of the white limestone belt at this locality are fault contacts, dipping northeast, unlike the fault dips on Young Creek. More careful study of this area would doubtless show other important faults that would help to make clearer the complicated structure seen in the field.

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[1] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, p. 68, 1911.

GEOLOGIC HISTORY.

Many facts concerning the geologic history of the upper Chitina Valley have already been mentioned. These facts will now be brought together, and their relations will be more clearly shown, but it will be impossible to do more than outline briefly the great geologic events, for much more must be learned before the geologic history of the region can be fully given.

CARBONIFEROUS SEDIMENTATION.

The earliest event of which any record was found in the upper Chitina Valley is the deposition of Carboniferous sediments, including conglomerates, grits, and limestone. The order of deposition of these rocks can not be stated, for little is known about them, but they were probably formed earlier than the tuffs, fine-grained basalts, and intercalated sedimentary beds that underlie the Nikolai greenstone. The limestones included in the tuffs and basalts of Strelna Creek, in the lower Chitina Valley, contain Carboniferous fossils that indicate approximately, if not exactly, the same age[1] as those found near the Chitina Glacier. The tuffs and basalts underlie the Nikolai greenstone with seeming conformity, and are therefore considered younger than the sedimentary beds near Chitina Glacier.

CARBONIFEROUS AND TRIASSIC VOLCANISM.

The tuffs and basalts mark the commencement of a long period of volcanic activity, which began in early Carboniferous time and, so far as is indicated by any evidence yet collected in the Chitina Valley, continued till the last of the Nikolai lava flows had been poured out. During the early part of this period volcanic activity was interrupted at times, as is indicated by the beds of shale and limestone interstratified with the tuffs and basalt flows, but during its later part one flow succeeded another without pause, geologically speaking, and continued till 5,000 feet or more of lava had accumulated. Evidence has not been found to show when these lava flows took place. They are widespread in the Wrangell Mountains and extend westward along the south side of the Alaska Range to the headwaters of Susitna River and are probably represented in other localities south of the range. At the west end of the Chitina Valley they rest with seeming conformity on tuffs, basalts, and shales that include fossiliferous limestone of lower Carboniferous age. They are thought, however, to be younger than the lower Permian (Artinskian) limestones of Skolai Creek and were therefore probably extruded in Permian or

[1] Moffit, F. H., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. — (in preparation).

Triassic time. Their extrusion apparently marks the end of the principal volcanic activity in the upper part of the Chitina Valley, although not in the neighboring mountains on the north.

TRIASSIC SEDIMENTATION.

Alaska is believed to have stood above the sea during most of early and middle Triassic time, for no Lower Triassic sediments and only one small area of Middle Triassic rocks, concerning which almost nothing is known, have been found, indicating either that sedimentary deposits of this age had never been formed or that, if formed, they had been entirely removed by erosion, an assumption that seems improbable.

Late Triassic time brought about a change of conditions. The land was submerged and a great thickness of limestone, part of the much more widely distributed synchronous deposits in the region south of the Alaska Range and in other parts of Alaska, was deposited in the Chitina Valley region. These limestone deposits include the Chitistone limestone and the conformably overlying thin-bedded Nizina limestone, which together have a thickness of about 3,000 feet and, according to Martin, contain a warm-water fauna. Martin[1] has given reasons for believing that a significant unconformity exists between the Nizina limestone and the overlying Triassic McCarthy shale. This unconformity would imply that the land emerged from the sea after the Triassic limestones of the Chitina Valley were deposited, that the rocks were extensively eroded, and that the land was again submerged before the black shales of the McCarthy formation were deposited. These black shales have been found within the upper Chitina Valley in only one small area near the mouth of Canyon Creek, but they or rocks of the same age, as determined by the characteristic fauna, are of wide distribution; so that all of Alaska is regarded as having been submerged at the end of Triassic time. An interesting fact in this connection is that the fauna of the later Triassic deposits indicates the presence of colder water than that of the seas in which the Triassic limestones were formed.

JURASSIC AND CRETACEOUS EROSION AND DEPOSITION.

Deposition of the Triassic rocks was followed by elevation of the land, which then underwent a long period of erosion, lasting throughout early Jurassic time. The beds were folded, the folds were truncated, and at many places the more recent deposits were removed and the underlying rocks brought to view.

[1] Martin, G. C., unpublished manuscript.

Another submergence of the land took place in late Jurassic time. Evidence of this submergence is seen in the sandstones near the Young Creek–Chitina River trail and on the high mountains about Barnard Glacier. Submergence and deposition may have continued without break well into the Cretaceous period or may have been interrupted during the early part of that period. If the fauna regarded as Jurassic is correctly interpreted, this period of deposition ended early in Cretaceous time, for both the Jurassic and the Cretaceous sandstones were deposited unconformably on older rocks. The fauna of the lowest Cretaceous rocks would indicate an unconformity—that is, elevation and erosion followed by submergence of the land, for it belongs to a horizon near the dividing line between Lower and Upper Cretaceous. The field evidence, on the other hand, does not uphold this view, for neither the lithology nor the structural interrelations of the Jurassic and Cretaceous sandstones to the associated rocks suggest that they belong to two formations.

Upon the basal Cretaceous sandstones were deposited a thick series of black and red shales in which was intercalated a few beds of limestone and sandstone. These in turn were buried under many feet of coarse conglomerate, arkosic sandstone, and sandy shale—the youngest sedimentary rocks in the district and probably the last of the Cretaceous sedimentary deposits.

IGNEOUS INTRUSIONS.

All the sedimentary rocks of the district except the conglomerates and sandstones at the top of the Cretaceous section are cut by igneous rocks. These igneous rocks may have been intruded at several different periods, but the younger intrusions probably occurred during the period of elevation and folding that followed Cretaceous deposition. The quartz diorite porphyry intrusive rocks of Young Creek are younger than similar rocks on Kuskulana River, where the basal conglomerate of the Upper Jurassic section contains pebbles derived from the underlying quartz diorite, and they may be younger than the much larger masses of quartz diorite in the upper Chitina Valley, which probably belong among the Jurassic or Cretaceous intrusives of the Coast Range, whose age is not yet definitely determined.

TERTIARY EROSION.

The conglomerate, sandstone, and shale that cap the mountains about Young Creek are the youngest rocks known in the district and are believed to have been deposited before the present mountain systems of Alaska were uplifted and therefore to have been subjected to erosion during the long period of emergence that, as indicated by evidence found in other parts of Alaska, occupied a part of early Tertiary time. This erosion brought the surface of the land to general low relief and was characterized in many parts of Alaska by the formation of wide areas of fresh-water and other inland deposits, including thick coal beds.

Deposition of the Tertiary coal beds was followed by the elevation of the existing great mountain systems of Alaska, which marked the beginning of the present topography and was followed by the most recent great event in the geologic history of the district—that is, its glaciation.

GLACIATION.

Glacial ice gave to the Chitina Valley some of its most prominent topographic characteristics. When the glacial epoch began nearly all the drainage lines had doubtless already been established in essentially their present positions. The valleys were narrow and their cross sections V-shaped, like those produced in mountainous regions by normal stream erosion. The hills between tributary streams projected as spurs into the main valleys, and the valley walls were less steep and straight than now.

Snow and ice accumulated in the high mountains and gradually crept down into the smaller valleys and out into the larger valleys till they filled them completely, only the tops of the high mountains remaining uncovered. The great trunk stream of ice in the Chitina Valley, moving westward toward Copper River, united with other glaciers coming from the Wrangell Mountains and overrode the mountains on the south. All of Alaska south of the Alaska Range was one great ice field.

How long this glaciation continued is not known, but the climate after a long time underwent a change and the ice withdrew from nearly all the area it had occupied, though slowly and with many periods of interruption during which the glaciers remained stationary or even advanced for a time. The effects of the action of the ice on the topography were widespread and notable. Projecting spurs of the interstream area were cut away, leaving triangular mountain faces. (See Pl. IV, *B*, p. 10.) Valley walls were straightened and made steeper. Immense quantities of morainal material were spread out over the valley floors by the streams from the melting ice. Old drainage courses were in places changed. These and other less prominent features, brought about by the action of the ice, but modified in some degree by postglacial erosion, all united to change the preglacial surface forms in this district and to give it its present aspect.

Capps[1] has shown that at least two glacial stages are indicated for the Wrangell Mountain district. The earlier, and possibly the less extensive, glaciation is expressed in a series of sheets of till, some indurated, some unconsolidated, separated by outwash gravels and other sediments and by lava flows. These deposits are exposed in a section over 3,000 feet thick at the head of White River. They have been folded and subjected to erosion, and are overlain by till beds belonging to the last great stage of glaciation. This second stage is that whose effects in the Chitina Valley have been described. According to Capps,[2] the greatest extension of ice in this latest stage was contemporaneous with the Wisconsin continental glaciation, which, in conformity with the estimate of Chamberlain and Salisbury, may have taken place between 20,000 and 60,000 years ago. Some idea of the movement, or lack of movement, in a glacier is furnished by the timber that grows on the débris overlying the foot of the Chitina Glacier. D. W. Eaton, of the Boundary Survey party, informed the writer that he cut a spruce tree on the end of the Chitina Glacier that showed 193 rings of growth. The débris and moss are commonly not over a foot or two thick, so that evidently the underlying ice has moved very little in many years.

Glaciation, although still effective in the higher parts of the district, may be regarded as the last great event in the geologic history of the upper Chitina Valley. The withdrawal of the ice, however, merely allowed weathering to begin a new cycle of events that will eventually destroy all the work of the ice.

ECONOMIC GEOLOGY.

GENERAL FEATURES.

The following account of the mineral resources of the upper Chitina Valley is based entirely on what was learned during the brief geologic reconnaissance made in 1915 and can not be checked or extended by facts furnished by a mining industry in the course of development or already established, for no such industries exist in the district.

The gold placers of Dan and Chititu creeks are not considered here. They have been described in earlier publications[3] of the United States Geological Survey and belong in the Nizina district rather than the upper Chitina Valley. Young Creek, however, although a tributary of Nizina River, receives some attention. (See pp. 74–76.)

[1] Capps, S. R., Two glacial stages in Alaska: Jour. Geology, vol. 23, pp. 748–756, 1915.

[2] Capps, S. R., An estimate of the age of the last great glaciation in Alaska: Washington Acad. Sci. Jour., vol. 5, pp. 108–115, 1915.

[3] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 98–108, 1911.

The only minerals yet found in this district that may be of possible economic importance are copper, gold, and molybdenum. No copper ore has been mined nor is any likely to be mined in the near future, for practically no work has been done on the copper deposits except the assessment work necessary to hold a few claims. The present price of copper, however, should stimulate the search for that metal in this district.

A little gold has been produced, but it is doubtful if the quantity recovered has been sufficient to pay more than a small part of the cost of production. What gold has been obtained came from the gravels of Young Creek and Kiagna River and was taken out while the gravels were being prospected. At present Kiagna River appears to be abandoned. Young Creek, on the other hand, although yielding no gold now, gives some promise of future production.

The work done in the district was only a reconnaissance survey and did not furnish sufficient data to permit the designation of areas where special mineralization has taken place. In a broad way, however, the mineralization appears to be definitely related to certain rock formations. The copper minerals on the north side of Chitina River, so far as they have been examined in place, are restricted almost entirely to the altered lava flows and the associated tuffaceous beds, which represent the eastward extension of the Nikolai greenstone but which may include also lava flows and tuffs that have not been correlated with the Nikolai. (See Pl. III, in pocket.)

The copper occurs as sulphides, such as chalcocite, bornite, and chalcopyrite, and as native copper in shear zones and along fault and fracture planes in the greenstones (the altered lava flows and tuffs). Excellent specimens of copper ore were obtained from a shear zone or fault zone near the contact of greenstone and limestone, but no copper minerals were seen in the massive limestones. Apparently the occurrence of copper minerals is the same as in the Nikolai greenstone of the Wrangell Mountains.

Evidence as to the distribution of gold is furnished solely by the gold-bearing gravels, for, so far as the writer knows, no gold lodes have been discovered in the district. Gold has been found only in areas of shales and slates that have been intruded by porphyritic dikes and sills closely related to granite and to the vicinity of the contact of such sedimentary rocks with granitic masses. Possibly some gold is contained in veins in the granites themselves. The known gold-bearing areas are those occupied by shale and slate on Young Creek and Kiagna River. Gold is reported from a stream on the south side of Chitina River near the glacier, but the report has not been confirmed. So far as known the bedrock of this stream is all granite.

place outside of the Young Creek valley. Not enough prospecting has yet been done to show clearly the distribution of copper and silver, and it is not known whether these metals occur in the gravels at the head of Young Creek or not. If they are found there, their quantity will doubtless be less than on the lower stream, and probably they will not be found on the west fork.

A large part of the work done in prospecting stream gravels is quickly effaced by the stream. Though assessment work has been done for many years on the claims along Young Creek, most of the stream gravels and low-bench gravels show little evidence that they have been disturbed by miners. Such work was done at various places in 1915. Three miles below Calamity Gulch a small area of bench gravel about 2 feet above the creek was sluiced off and found to contain a little gold and a great many small concretions of marcasite, derived from the black shales in which the canyon is cut. A tunnel driven into the high-bench gravels at this place some years ago revealed many boulders inclosed in gravel and glacial silts and some gold. It is said that more gold was found in the roof of the tunnel than on the bedrock.

About a mile below Calamity Gulch work was done on a shale bench within the canyon, about 25 feet above the level of the creek. The gravel deposit was formed when the canyon was intrenched and is older than the lower benches adjoining the creek, which here flows in a shallow canyon within a canyon. A little gold, together with silver and copper, was recovered from the gravels, but not enough to make mining profitable—in fact, the work was done only as a means of prospecting the ground.

A little prospecting was carried on near the head of Calamity Gulch, which is a deep gash in the black shale on the north side of Young Creek. The stream in the gulch is loaded with all the débris it can carry by rapid erosion of the country rock, and though gold is found in the gravel, its recovery is difficult because of the small quantity of water in the gulch.

On the rest of Young Creek little attempt was made to do more than the work necessary to hold the claims. The bedrock in Young Creek valley is the same as that on Chititu Creek, including Rex and White creeks, but the gravel deposits are different. Only on the lower part of Young Creek, below Calamity Gulch, can any enrichment of the stream gravels by the concentration of gold that is scattered through the bench deposits be expected, for all such gravels that may have once been present in the upper valley were swept out by the ice and were not replaced when the ice retreated.

Young Creek is favorably situated with regard to transportation, being only a short distance from the railroad, and has the further advantages of good supplies of timber and water.

KIAGNA RIVER.

Kiagna River, a southern tributary of Chitina River, which it joins 30 miles below the Chitina Glacier (see Pl. VI, p. 12), heads in the high mountains between Chitina River and Granite Creek. It is formed by the union of three principal branches, which receive most of their water from melting snow and ice, and it occupies a typical glacial valley—straight, steep walled, and heavily timbered. Its east and west branches are inclosed by high mountains, but its smaller middle branch flows from a glacier, part of whose drainage is diverted by a tributary to Granite Creek. It thus provides a route from the Chitina Valley to Granite Creek, a westward-flowing stream about 20 miles south of the Chitina, which occupies an interior basin in the ice fields of the Chugach Range and has no known outlet. The prospectors who have explored it, however, believe that it drains westward into Copper River, possibly flowing out beneath Miles Glacier.

Most of the prospecting for placer gold in this district has been done on and near the middle and east branches of Kiagna River. Kiagna River was first explored by prospectors who ascended the stream from Chitina River, probably about 1904, after gold had been discovered on Dan and Chititu creeks. They staked ground but seem to have done little mining. In 1906, or possibly 1905, James Barkley and J. B. Miller crossed the ice field between Yakataga beach and Granite Creek and made their way to the head of the Kiagna. They saw evidence that the Indians knew this route to the coast and they found the stakes of the former prospectors on the Kiagna. After a short stay they returned to Yakataga by the route over which they had come. In 1907 Barkley, accompanied by William Jefferies, made the trip again, but they went around the east end of Granite Creek, and instead of going back to Yakataga they descended Chitina and Copper rivers to the coast. Since then others have visited the district from time to time. In the fall and winter of 1914–15 there was a miniature stampede to the district. Nothing appears to have come of this, however, for the men who took part in it found little to encourage them and abandoned the field.

The rocks exposed on Kiagna River are reported to include black shale or slate, schist, greenstone, and granite. Both the granite and the shale are much disturbed and are cut by veins of quartz. Granite Creek lies wholly in an area of granite, and was therefore so named. The Kiagna is on the strike of the sedimentary gold-bearing rocks of Bremner River, a fact that suggests that the sedimentary beds of the two areas may be equivalent. This, however, is no more than a conjecture.

There is no record of the quantity of gold taken from the gravels of Kiagna River, but it was too small to encourage the miners to continue the work.

A large vein of sulphide minerals that crosses the branches of the Kiagna was staked as iron ore, but no work has been done on it.

OTHER PLACER PROSPECTS.

Gold has been found in the gravel bars at the mouth of Canyon Creek, where unsuccessful attempts were made to sink a shaft to bedrock, and also on the rims of the channel within the canyon. It is said to be coarse, but the difficulty of doing any mining within the canyon has prevented prospecting there. This gold is probably derived from the black porphyry-intruded shales between Canyon and Young creeks.

Placer gold has been reported also from the first creek below Chitina Glacier on the south side of the river, but the report lacks confirmation.

COPPER.

The greenstones that extend southeastward from the head of Canyon Creek to the north side of the Chitina Glacier contain copper minerals in numerous places, at some of which claims have been staked and assessment work has been performed. At no place, however, so far as the writer knows, has enough work been done to give a better idea of the occurrence of the copper minerals than may be had from the surface exposures.

At an exposure on Erickson Gulch, a small gulch on the east side of Canyon Creek, a little below the pass from the east fork of Young Creek to Canyon Creek, the copper sulphides occur in a shear zone in greenstone about 500 feet above the creek. The ore can be traced to its source by the float in the talus slope below the ledge. The property was staked many years ago and is in the hands of the original owner. Only enough work has been done on it to retain the claims.

Another group of claims is on the north side of Chitina River, east of Canyon Creek, on the west side of the Hawkins Glacier near its foot and possibly 1,500 feet above it. The high mountain west of the glacier is greenstone and includes tuffaceous beds as well as lava flows. A vein that carries chalcopyrite in places cuts the greenstone. Near by in the greenstone some native copper was found.

Greenstone carrying chalcopyrite and possibly bornite was found on the mountain slope between Hawkins and Barnard glaciers. The country rock here is much disturbed by faulting and includes intruded masses of lighter-colored igneous rock.

Specimens of chalcocite associated with galena were collected from the mountain in the angle between Chitina River and Barnard

Glacier at an elevation of about 4,000 feet above the glacier. The country rock includes greenstone, limestone, and granitic intrusive rocks, all considerably disturbed. The limestone and greenstone stand vertically and strike northwestward. At an elevation of about 6,000 feet, near the top of the ridge, a body of the granite porphyry that makes up a large part of the lower mountain mass is succeeded on the northeast by several hundred feet of greenstone. Then follows about 10 feet of limestone-greenstone breccia, a thin bed of greenstone, and, finally, a few feet of limestone containing quartz pebbles. This limestone, which is much weathered and near its contact with the greenstone is stained here and there with malachite, is overlain by horizontally bedded sandstone, which caps the mountain.

Fresh surfaces of the limestone stained with malachite show chalcocite and galena, which also occur in small amount in stringers cutting the limestone and as grains disseminated through it. The mineralized outcrop is on a sharp ridge with precipitous sides, so that only a small part of the limestone-greenstone contact could be examined. Claims were staked in this locality several years ago, but the assessment work required to hold them has not been done.

Copper stains were seen on the greenstones at many other places, and small veins of chalcopyrite and stains of copper were observed on numerous boulders along the streams in this district.

MOLYBDENUM.

A vein of molybdenite is reported by a prospector who spent part of the summer of 1915 in the upper Chitina Valley. The vein, which is about 8 miles from the lower end of the largest of the Canyon Creek glaciers, is in granite and is reported to be 8 feet wide and to consist of quartz and molybdenite. The molybdenite forms a solid vein, 12 inches thick, between the quartz and the hanging wall and occurs in stringers and bunches through the quartz and in disseminated flakes in the quartz. There is no timber near the property, and the best source of supply would be Young Creek, which is separated from Canyon Creek by a low, flat divide that could be easily traversed. Sleds afford the only method of transportation now available in winter, and any ore produced from the vein will have to be brought out over the glacier ice to Canyon and Young creeks and carried thence to the railroad at McCarthy.

ECONOMIC CONDITIONS.

Most of the conditions that would influence the development of the mineral resources of the upper Chitina Valley have been mentioned, but a brief summary of the more important among them will be given.

The district is favorably situated as to transportation, for a branch of the railroad could be built to it without encountering unusual engineering difficulties and at relatively small cost if the traffic should become sufficient to warrant the expenditure for its construction. If, on the other hand, traffic were not sufficient to support a railroad a wagon road could be built without great expense. The principal obstacle to either a railroad or a wagon road is the crossing of Nizina River—and of Chitina River, if that were necessary.

The trails now used in going to and from the Chitina are either steep or very soft and wet in many places. Traveling along the river is difficult and dangerous where glacial streams have to be forded at times of high water. Traveling away from the main valley is difficult because of the extremely rugged topography and the presence of glaciers in nearly all the tributary valleys. The climate, however, is more favorable to mining than that of many other parts of interior Alaska, for the summer is longer than in less protected places. There is excellent timber for many years' use, and the bars of Chitina River afford pasture for stock.

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