THE MINERAL RESOURCES OF THE KOTSINA AND CHITINA VALLEYS, COPPER RIVER REGION.

By Fred H. Moffit and A. G. Maddren.

INTRODUCTION.

The four best-known and most promising copper-bearing regions of Alaska are the Kasaan Peninsula region of southeastern Alaska, the Prince William Sound region, the region included within the drainage area of Kotsina and Chitina rivers, and the region of upper Copper, Tanana, and White rivers. Of these four only Kasaan Peninsula and Prince William Sound have yet produced copper commercially and at the present time they furnish the entire production of Alaska, which in 1906 amounted to 8,685,646 pounds of blister copper—an increase of more than 3,500,000 pounds over the output of the previous year.[a]

The mines of these two regions are all located either at tide water or within comparatively easy reach of it, so that the matter of transportation does not present so great an obstacle to development as in the interior of Alaska, and they thus possess an advantage that has enabled them to reach the productive stage more rapidly than otherwise would have been possible.

The two remaining regions, each of which is sometimes referred to as the Copper River region, although the name is more often applied to the Kotsina-Chitina area (Pl. III), are really one, but are distinguished from each other because they lie on opposite sides of an almost impassable mountain range. They are situated in the interior, north of the high mountains forming the Coast Range, and can be reached only by long, hard journeys over trails which, although their value to the prospector and traveler can hardly be overestimated, still leave much to be desired. The cost of supplies and the time and labor required to carry them into the country have been

[a] Graton, L. C., The production of copper in 1906: Mineral Resources U. S. for 1906, U. S. Geol. Survey, 1907.

so great that little more than the assessment work required to hold claims or to obtain patents has been done. The whole of the interior region may be said to be still in the prospecting stage and must remain so until means are provided by which supplies and equipment can be brought to it more cheaply and by which the ore, when produced, can be taken out.

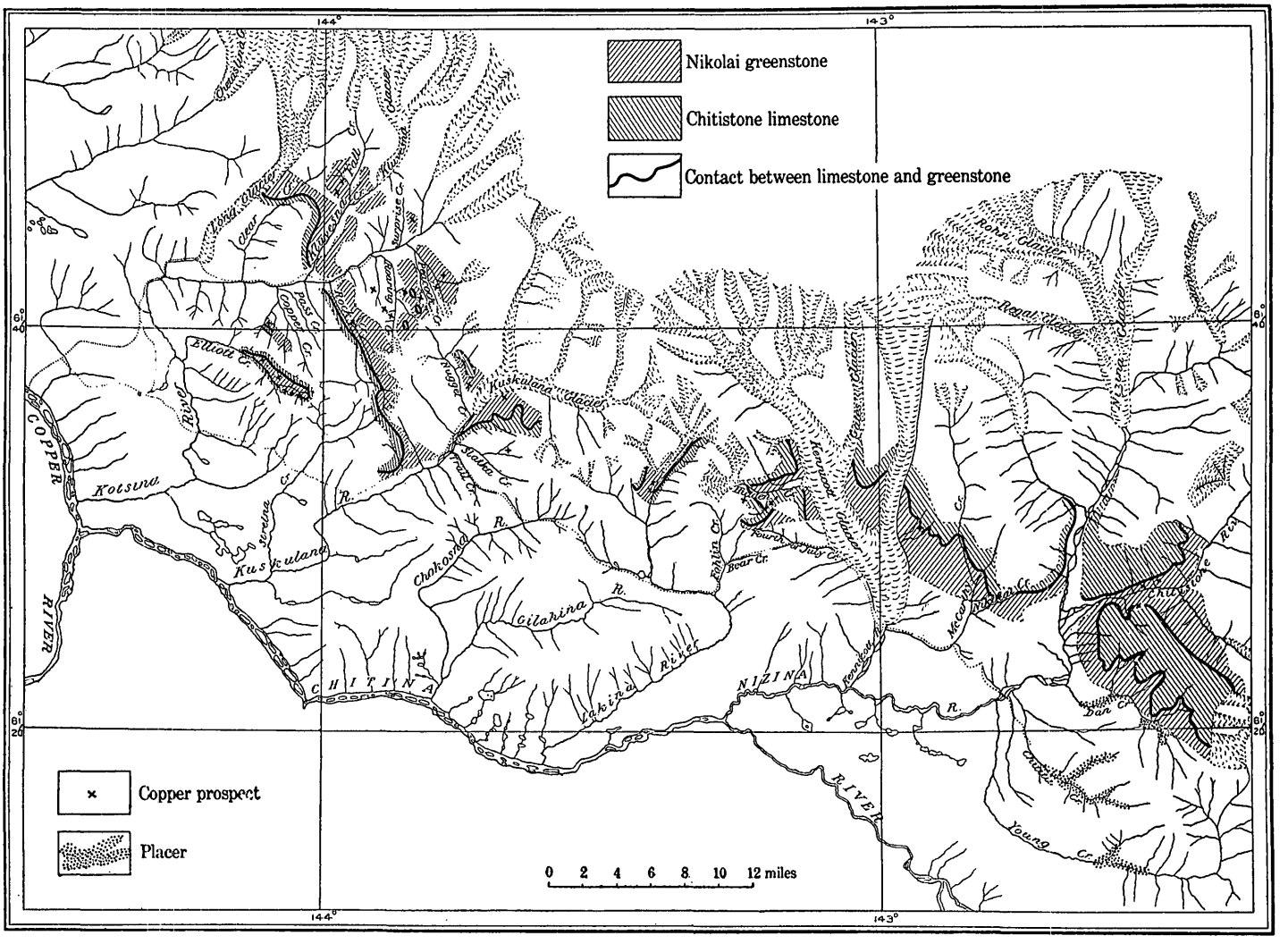
The first study of the copper deposits of Chitina Valley by members of the Geological Survey was made by F. C. Schrader and A. C. Spencer[a] in 1900. At the same time a topographic map of the region, including Hanagita Valley on the south and lower Copper River as well, was made by T. G. Gerdine and D. C. Witherspoon. Prospecting was then just beginning and very little work had been done on any of the claims, yet some of the important facts concerning the ores were established. Two years later (1902) W. C. Mendenhall[b] visited the west end of the area, including Kotsina River and Elliott Creek, but after that time no further work in the region was undertaken by the Survey till 1907, when public interest made it desirable to send another party into the field.

In this paper, which embodies the principal results of last season's work, the copper deposits of the Kotsina-Chitina region are described. Only enough of the general geology is introduced to give a clear idea of the relation existing between the copper ores and the rocks with which they are associated, as it is desired to lay emphasis on the economic side of the subject and to avoid confusing this with descriptions of formations and their relations that may more properly be taken up in another place. It is hoped that the facts observed are here presented impartially and in such a way as to give a proper idea of the type of ores occurring in this region and of the progress in developing them since they were last visited by members of the Survey.

Those seeking information in regard to the commercial value of the deposits here described may be disappointed in finding no definite statements in regard to values. It has become the established practice in the Alaskan investigations not to treat this subject, for it evidently falls within the province of the mining engineer who investigates a particular property. In the short time available for their study it would obviously be impossible for the Survey geologists to sample the deposits visited, and it also appears unwise to publish the results of assays furnished by property owners, because it is not always possible to learn how a given sample was taken.

[a] The geology and mineral resources of a portion of the Copper River district, Alaska, a special publication of the U. S. Geol. Survey, 1901.

[b] Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905.



MAP OF KOTSINA-CHITINA COPPER BELT.

GENERAL DESCRIPTION.

LOCATION.

The principal copper deposits to be described in this paper lie east of Copper River, within an area included between the watershed of the Wrangell Mountains on the north and Chitina River on the south and extending eastward from Kotsina River and Long Glacier to the meridian passing through Skolai Pass, a distance of approximately 75 miles. (See Pl. III.) This description, however, gives an exaggerated idea of the extent of the copper-bearing rocks, which, although they are found from one end to the other of the area indicated, occupy but a small part of the whole. Geographically this area crosses diagonally, from northwest to southeast, the quadrangle bounded by meridians 140° 20′ and 144° 20′ west longitude and parallels 61° 10′ and 61° 50′ north latitude.

TRAILS AND TRANSPORTATION.

The region is reached by a trail from Valdez, the distance from Valdez to Kotsina River being not far from 125 miles. In summer the Government trail via Tonsina is used, but in winter supplies have in some years been taken in by way of Tasnuna and Copper rivers. The ice on Copper River furnishes excellent sledding and it is possible to haul very heavy loads over it, but the violent winds that sweep down the Tasnuna and Copper valleys often prevent traveling for days at a time.

In summer Copper River is crossed by boats. An Indian named Billum has a ferry license and transfers travelers with their equipment in two small boats at a place about 1½ miles above the mouth of Tonsina River, called Copper River Crossing. There is a road house here on the west side of the river. Horses swim the river, but this is a somewhat dangerous undertaking because of swift currents and quicksand, and it is not an uncommon thing for one to be lost.

Travelers for Kotsina and Chitina rivers follow the same trail eastward from Copper River Crossing for 8 miles to Horse Creek, where the trail divides, one branch going northeastward to Willow Creek and the upper Kotsina, the other southeastward up the Chitina Valley. From Willow Creek the northerly trail follows the right (west and north) bank of Kotsina River and crosses the lower end of Long Glacier. There is a bridge over Kluvesna Creek and another over Kotsina River near the mouth of Rock Creek, so that it is not necessary to ford these streams. The Hubbard-Elliott Company has built a bridge over Kotsina at the mouth of Willow Creek,

on the trail to Elliott Creek. A bridge was recently built by the Government over Kotsina River at the point where the lower or Chitina trail crosses it, doing away with a dangerous ford at that place. From the Government bridge the trail continues eastward along the foothills of the Wrangell Mountains, crossing Kuskulana River 3 miles below the glacier and reaching the head of Chokosna River and the Lakina by way of Kuskulana Pass. Ascending Fohlin Creek, it leads through Kennicott Pass and down Fourth of July Creek to Kennicott Glacier and Kennicott River, which is crossed on the glacier ice. A good trail leads to the Bonanza property from the lower end of the glacier. Another trail follows McCarthy Creek for 4 miles and, crossing the ridge known as Sourdough Hill, extends to Nizina River, from which Chititu Creek, Dan Creek, and Chitistone River are easily reached. Nizina River must be forded—a task that may be difficult, if the water chances to be high. There are no bridges east of Kotsina River, and most of the streams, being of glacial origin, are very cold, but the only ones likely to cause trouble are the Kuskulana, Lakina, and Nizina.

It is a common thing for prospectors in the Nizina country to come out in the fall by way of Chitina and Copper rivers, either leaving the Copper at Tasnuna River and going overland to Valdez, or following the river to the coast and landing at Eyak or Orca. Several days' work is needed to whipsaw the lumber and build the boat, but the river trip is even then much quicker and easier than the overland trail. The distance from the mouth of Young Creek to Tasnuna River, over 115 miles, has been made in less than twenty running hours. A skillful boatman would meet with little or no difficulty on the Copper or Chitina, but the canyon at the lower end of Nizina River is dangerous, particularly at low water, and a number of persons have been drowned in trying to run through it.

In July, 1907, a small steamboat called the *Chitina* made her first run from Tasnuna River to Copper Center on Copper River and to the mouth of Nizina River on Chitina River. The material for her construction was hauled over the snow from Valdez during the previous winter, and she was completed early in July, but after the trip up the river was hauled out on the bank for the winter. She draws very little water, but will probably be unable to run after the middle of summer because the river is much lower in the fall than during spring and early summer. Boats can not descend Copper River farther than Abercrombie Rapids, 25 miles below Tasnuna River, and any freight the *Chitina* may carry up the river must be delivered to her either at the rapids or at Tasnuna River.

The building of a railroad from a point on the coast to the interior Copper River country is of prime importance in the development of the copper resources of the region. During the last few years vari-

ous companies have been formed with this object in view, and railroad surveys have been made from Katalla, from Orca, and from Valdez by both the Tasnuna and the Tonsiña routes. Construction work has been done in all these routes, but, except the Copper River and Northwestern Railroad and the Alaska Pacific Railway and Terminal Company, none of the companies were making progress last summer, although the Alaska Home Railway laid a few miles of track at Valdez.

The Copper River and Northwestern Railroad has its coast terminal 28 miles west of Copper River on the east side of Prince William Sound at Eyak, or Cordova Bay, as it is frequently called. The terminal was changed from Katalla to Eyak late last fall, probably because of the great difficulty experienced in lightering freight at Katalla and the expense and time that would be required in building a breakwater for the protection of ships while discharging cargoes. Eyak has a protected harbor and can be approached at any time. A wharf and a few miles of railroad embankment from Eyak village to Glacier River had already been constructed by another company, but were purchased by the Copper River and Northwestern. It is proposed to use the Katalla branch, which will join the main line in the vicinity of Childs Glacier, as a means of reaching the Controller Bay coal fields. Considerable work on this branch, originally intended as the main line, has been done at Katalla and in that vicinity. In October, 1907, construction trains were running between Katalla and Martin Point, a large part of the rock work along the coast from Martin Point to Softuk Bar was done, and most of the piling in the low ground on the east edge of Copper River delta as far north as Camp Seven, 7 miles from Palm Point, had been driven. Location surveys have been made up Copper, Chitina, and Nizina rivers to Kennicott River. Just how soon this railroad will reach the interior is difficult to say, in view of the progress during the last two years.

The Alaska Pacific Railway and Terminal Company starts from the coast at Katalla and contests the right of way through Abercrombie Canyon with the Copper River and Northwestern Railroad. In 1907 a trestle connecting Martin Point with the nearest of the Martin Islands was built, and when filled in with rock will be used as a breakwater behind which ships may be unloaded. Other work done by the company was directed largely toward the construction of a line to connect Katalla with the Bering River coal field.

The Alaska Home Railway is a railroad project started at Valdez in midsummer, 1907. This road was planned to connect Valdez with the Copper River region. It was to ascend Lowe River and reach the Copper River basin by way of Thompson Pass, whence it was expected to continue to Tonsina by practically the same route as the Government trail. Its motive power was to be electricity. A steam

locomotive and some rails were shipped to Valdez, and a short stretch of track was laid, but work was soon suspended owing to lack of funds.

WORKING SEASON.

Inadequate and expensive transportation facilities have been the chief obstacle in developing the copper resources of Chitina River. Another adverse condition, which, however, affects prospecting more than it will mining, is the short summer season. Up to the present time practically all supplies have been taken in during the winter with sleds drawn by horses. In the earlier days dogs or man power were sometimes used, but of late years horses have been employed almost entirely. Sufficient feed to last till the grass starts in the spring is carried, but after that most horses "live on the country." The early snows begin about the end of August, so that a horse can not be expected to find his own feed longer than from about the first of June till the first of September. Grass is always abundant on the mountains near the timber line in June, July, and August, and good pasture is usually found at lower elevations after the timber has been burned off for a number of years. Some of the prospectors have provided their stock with fine feed by following this practice. In the timbered valley bottoms horses frequently have difficulty in finding enough to eat, even in midsummer, yet in the fall, after frost has killed the grass higher up, the river bars afford an excellent forage plant known as "pea vine," of which they are very fond. Since most prospectors use at least one or two horses for packing in summer, as well as for hauling supplies in winter, it is obvious that the matter of horse feed has an important influence in determining the number of available working days. The prospecting season is still further shortened owing to the fact that in the high mountains, where most of the copper ores have been found, snow often remains till the first or even the middle of July.

GENERAL GEOLOGY.

The major geologic features of the copper region may be briefly described as follows:

The geologic succession as determined by Schrader and Spencer, to confine the description to the rocks most closely associated with the copper prospects and gold placers, consists of four formations. These, named from the lowest to the uppermost, are the Nikolai greenstone, the Chitistone limestone, the Triassic shales, and the Kennicott formation. With these are associated igneous intrusives.

The basal formation of this succession—a slightly altered eruptive mass—is made up of a series of basaltic flows and is known as the Nikolai greenstone. It is conformably overlain by the Chitistone lime-

stone, a massive limestone ranging in thickness from 200 feet on the Kotsina to 2,000 feet on Chitistone River and now known to be of Triassic age. Conformably overlying the Chitistone limestone is a succession of sedimentary beds whose lower part consists of banded limestone and shale, but whose upper part is made up almost entirely of shales. This limestone-shale series has a maximum thickness possibly greater than 4,000 feet and from fossil evidence is considered to be of Triassic age also. In places it was entirely removed by erosion before the deposition of the unconformably overlying Kennicott formation. Kennicott is the name applied to a body of rocks consisting of conglomerates, sandstones, limestones, and shales present in a few relatively small but widely distributed areas throughout the copper region. It is of Upper Jurassic or Lower Cretaceous age. These four formations and, more particularly, the lower three have been folded and extensively faulted. Some of the faults are of considerable displacement and horizontal extent, but readjustment, accompanying movements of the rocks, seems to have been brought about more by crushing and frequent faults of small displacement than by single movements of great amount.

In addition to the four formations thus briefly described, some small areas of coal-bearing rocks and the Pleistocene gravels should be mentioned. A thin bed of coal was seen not far west of the Kennicott Glacier, but a much greater amount is present near the head of Chitistone River. No fossils were collected from the coal-bearing rocks, but they are probably much younger than the Kennicott formation. Extensive Pleistocene gravel deposits occur along Chitina and Nizina rivers and extend into the valleys of their larger tributaries. Except on Dan and Chititu creeks they have nowhere proved of economic importance.

Igneous rocks other than the Nikolai greenstone are only locally abundant, but are found throughout the Chitina region. They include gabbro, diorite, porphyritic intrusives, and Tertiary volcanics. Of these the diorite and porphyritic intrusives are most closely associated with the copper-bearing rocks, and though of less areal extent, concern the present discussion more than the others. The largest diorite area is situated on the north side of Kotsina River near its head. It is surrounded by greenstone and has an areal extent of about 10 square miles. Dikes of the same material are found on the south side of the valley also. Light-colored porphyritic intruded rocks cut the Nikolai greenstone in a number of localities, but were not seen in the Chitistone limestone. They are most abundant in the Triassic shales of the eastern half of the copper belt and more particularly in the vicinity of Kennicott Glacier.

Because of the close and constant relation between the copper ores, on one hand, and the Nikolai greenstone and Chitistone limestone,

on the other, it is necessary to give some further description of these two lower members of the rock series. The Nikolai greenstone, as mapped by Schrader and Spencer in 1900, includes a succession of basic lava flows of basaltic character, which, however, do not form a homogeneous whole, but show decided differences of texture and appearance in their vertical section. A flow or bedded structure is seen at many places and at first glance might suggest a sedimentary origin for the rock. This apparent bedding is much more evident in some localities than in others, and is most readily seen in the large cliffs which, in some places, constitute half a mountain side.

Directly beneath the limestone the Nikolai greenstone has much the same appearance wherever it was observed. It is a rough massive green rock whose individual crystals are generally too small to be distinguished by the naked eye. Lower down in the flow series the greenstone is usually found to be closer grained and denser, much of it with a fracture resembling that of quartzite. Amygdaloidal flows are numerous and the previously existing cavities are now filled with quartz or with dark minerals which in some specimens have been determined as chlorite and serpentine. Most of these flows are green in color, but a reddish hue is seen here and there, possibly the result of alteration or weathering. There is no evidence at hand to determine definitely the relation of the Nikolai greenstone to the more altered and probably older rocks occurring south of Chitina River, and so far as its age is concerned, we know only that it is older than the Chitistone limestone.

The Chitistone limestone is best developed in the vicinity of Chitistone River, where it attains its greatest thickness and is well exposed. Its outcrops, nearly always appearing as cliffs high up on the mountain, extend westward, however, all the way to Elliott Creek and Kotsina River and constitute one of the most conspicuous features of the topography. From a freshly broken fragment the color is seen to be bluish gray. A weathered surface, on the other hand, is light gray or dirty white, a fact which accounts in large measure for the striking appearance of the outcrops and in many places makes it possible to distinguish the limestone from associated rocks even at a long distance. Except where covered by talus from the limestone cliffs or by the unconformably overlying Kennicott formation, the contact of the Chitistone limestone and Nikolai greenstone can usually be traced without difficulty.

In the report of Schrader and Spencer the Chitistone limestone was tentatively correlated with limestone east of Skolai Pass, which at that time was considered to be of upper Carboniferous (now called Permian) age. Mendenhall, in a later paper, gave reasons for believing it to be still younger, probably Triassic, and his contention is established by fossil evidence collected last summer.

ECONOMIC GEOLOGY.

GENERAL OUTLINE.

The copper ores of the Chitina Valley are associated with the Nikolai greenstone and Chitistone limestone. In the western half of the copper-bearing area the copper minerals, with one exception, were seen only in the greenstone, and most of the prospects are at no great vertical distance below the limestone contact, yet this is not an invariable rule. In the eastern half of the area, on the other hand, the largest and most valuable copper deposits known are either at the limestone-greenstone contact or immediately above the contact, in the limestone. There are deposits of copper in the greenstone here also, similar to those farther west, but so far as they are now known they are of less importance than those associated with the contact.

A large number, perhaps a majority, of the copper prospects examined during the summer have a form which Mendenhall has described as "bunch deposits." This term, though an unsatisfactory one in some ways, probably describes as closely as any single term can the form of ore body most common in the Chitina Valley. A smaller number of the deposits occur as fairly well defined veins. The term "bunch deposit" does not necessarily refer to a mass of ore composed of copper minerals only, as most of the ore bodies to which the term could be applied are not such masses, but it does indicate that the length, breadth, and thickness of the body do not differ from one another greatly.

The copper minerals are chalcocite, bornite, chalcopyrite, native copper, and the oxidation products, malachite, azurite, and cuprite. The ores, as they appear on the surface, are chiefly chalcocite and bornite. Chalcopyrite is not as common as either of the other two sulphides, but forms an important part of the ore at several prospects. Native copper is present in the greenstone of all parts of the Chitina region and is surprisingly abundant in some of the stream gravels. Masses of several hundred pounds and one of more than 2 tons have been discovered. Wherever native copper was observed, it is associated with amygdaloid beds of the greenstone and consequently is some little distance below the limestone. More extended observation, however, might show that this is not always the case.

No considerable bodies of oxidized ores have been found in the Chitina region. Malachite and azurite, the green and blue carbonates, are merely surface alterations on the other copper minerals, and cuprite, the red oxide, is a common oxidation product. Azurite is the prevailing carbonate accompanying the copper sulphides associated with the heavy limestone or in veins with a calcite gangue. Malachite gives the green stain usually seen in the ores in greenstone.

The copper ore is composed in many places of country rock and copper minerals without any accompanying gangue. The copper sulphides fill fractures in the rock and also occur as a replacement of the rock. Where the country rock is greenstone, a careful examination is usually necessary to determine the limits of the impregnation, which is not marked by any definite boundary, the replacement becoming gradually less with increasing distance from the center of impregnation. In limestone areas, on the other hand, the transition from copper sulphides is abrupt and the bounding surface is more readily determined.

Faulting, as has already been pointed out, is a phenomenon observed at many localities in the rocks of the Wrangell Mountains. Zones of crushing and shearing show the same result as has been accomplished at other places by fault movements, the disturbing forces that produced them having led to a circulation of mineral-bearing waters through the rock. Most of the channels were exceedingly variable in form and direction, and this fact explains the rarity of definite, regularly formed, and clear-cut veins in the region. This is particularly evident from an examination of the ores in greenstone. Where the more regular vein deposits occur they are usually connected with fault planes and some of them are accompanied by other minerals, as calcite and quartz. Calcite is nearly always the predominating gangue mineral where such minerals are present, and is particularly prominent near the limestone-greenstone contact. The basic greenstone could furnish only a small amount of quartz to circulating waters, but calcite was supplied abundantly from the overlying limestone. The wide distribution of copper minerals in the Nikolai greenstone wherever it occurs has led to the belief that the greenstone itself is the source from which the copper was derived and that the ore deposits as they now exist have resulted from the concentration of copper minerals disseminated in small quantity through the rock.

Copper prospecting in the Chitina region is carried on from a few central localities, of which those receiving most attention are Kotsina River (including Elliott Creek), Kuskulana River, Kennicott River, and Chitistone River. These centers are named from west to east, the order in which they were visited, and the prospects will be described in the same way.

KOTSINA RIVER BASIN.

Kotsina River receives a large part of its water from snow fields and glaciers on the south slopes of Mount Wrangell and joins Copper River 2 miles above the Chitina. Much of the drainage area is occupied by Nikolai greenstone, but the limestone, shales, and conglomerate are all present. Prospecting is most actively carried on in the upper part of the basin and on Elliott Creek. The upper tributaries include Peacock Creek, Surprise Creek, Roaring Creek, Ames

Creek, Rock Creek, Kluvesna Creek, and Copper Creek. No work has been done here which can properly be called mine development, as there is no place where sufficient work has been done to demonstrate the presence of a mine.

KOTSINA RIVER.

Practically the only prospecting on the Kotsina itself is that done by the Great Northern Development Company. This company is the largest one carrying on operations on the Kotsina, to which, however, its interests are not confined. The headquarters of the company are on Kotsina River at the mouth of Roaring Creek, and its equipment includes a sawmill and telephone connection with the Government telegraph line at Tonsina. Probably 100 men were employed during the summer. The prospects on the river include five short tunnels, the nearest one of which is about one-half mile below the camp. They are within a short distance of one another on the south side of the river and almost on the same level as its broad gravel floor. No one of these tunnels had been driven farther than 20 feet in August, 1907. At the first a porphyritic dike 10 feet thick cuts a fine-grained greenstone. Its course is N. 30° W. and it is bounded on both sides by fault planes. A little copper-bearing pyrite was deposited along the faults in the fractured rock. At the second tunnel, a few hundred feet to the west, a quartz vein ranging from 4 to 6 inches in thickness contained a little copper pyrite. The vein has a strike S. 50° W. and cuts the greenstone in a perpendicular direction. At the other three tunnels a little pyrite is present in the greenstone. Its oxidation gave the brown stain by which the tunnels were located.

AMES CREEK.

Ames Creek is the first creek below Roaring Creek on the south side of Kotsina River. It is a small creek in a hanging valley and, like nearly all the tributaries of this river, owes the broad, round cross section of its valley to the work of glacial ice. The copper prospects include three tunnels, the property of the Great Northern Development Company, known as tunnels 6, 7, and 8.

Tunnel 6 is on the west side of Ames Creek and is at an elevation of 1,400 feet above its mouth. Early in August, 1907, it had been driven for 50 feet in a southwesterly direction in frozen slide rock from the hill above. Country rock in place had not been reached. One hundred feet above the tunnel a little pyrite is seen in a dense, hard, faulted greenstone.

On the east side of Ames Creek, and 50 feet higher than tunnel 6, is tunnel 7, which runs N. 30° E. for 70 feet through loose slide rock before reaching the undisturbed greenstone, which here is fine grained and stained with iron from the oxidation of pyrite.

Tunnel 8 is also on the east side of Ames Creek, one-fourth mile south of tunnel 7. It had been driven for 30 feet in amygdaloidal greenstone, but no copper had been found.

ROCK CREEK.

Rock Creek is one of the largest southern branches of the Kotsina and heads against Strelna and Nugget creeks, tributaries of Kuskulana River. A horse trail crosses the divide from Rock Creek to Strelna Creek and furnishes the shortest road from upper Kotsina River to the Chitina Valley. Active prospecting was confined to Lime Creek, a tributary of Rock Creek, which joins it from the east. The Warner prospect at the mouth of Rock Creek, which was visited and described by Mendenhall in 1902, is now patented and no further work has been done on it. Lime Creek flows near the limestone-greenstone contact, and the copper deposits, although mostly northeast of the creek on the opposite side from the southwestward-dipping limestone, are not far from it. The prospects are near the point where the Rock Creek trail crosses Lime Creek. In July, 1907, a tunnel was being driven in the greenstone just below the limestone, only a few feet above the creek, but no ore had been found at that time.

Several feet up the hill to the northeast was a tunnel 20 feet in depth, in jointed greenstone. The principal copper mineral is bornite, which occurs as lenses or irregular lumps in the greenstone, having diameters up to 1 inch or more. These patches, so far as the surface shows, appear to be unconnected. Bornite also fills fractures in the rock and forms small lenticular veins, but it appears principally in joint planes on whose surfaces it forms a veneer in places an eighth of an inch or more in thickness. There are small veins of calcite and quartz.

About 50 feet farther east is an open cut showing similar rock and ore, although here the ore is in greater amount. The bornite occurs in sheared greenstone cut by small faults striking N. 35° E. and dipping 60° S., and forms a lens-shaped mass 2 feet thick. The greenstone has nearly all been replaced by bornite.

At a point 200 feet still farther north and 100 feet higher is an open cut in amygdaloidal greenstone. The cavities are now filled with quartz or with a dark mineral, possibly chlorite. Several faults with gouge and zones of crushed rock up to 1 foot in thickness cut the greenstone with a strike of N. 15° E. and a dip ranging from 60° to 70° E. A little copper stain was seen along the crushed rock, but no other copper minerals, although bornite is found in the slide rock near by.

ROARING CREEK.

Roaring Creek is a southern tributary of Kotsina River, which it joins a short distance above the main camp. It heads in a small glacier and flows through an open valley several hundred feet higher than the level of the Kotsina. The country rock, with the exception of one small limestone area on top of the ridge between Roaring Creek and Peacock Creek, is greenstone, yet the greenstone is not of uniform character, for slaty beds and hard, fine-grained cherty-looking beds are intermingled with amygdaloidal flows. Most of the prospects are in the upper part of the valley.

The Great Northern Development Company has several prospects on Roaring Creek. One of these is located on the south side of a small gulch west of Roaring Creek, near the camp known as camp 3. A tunnel was started in gray and black mottled slates near a fault plane which separates them from the greenstone mass. The strike of the slate cleavage and of the fault plane is the same, N. 20° W., and the dip is high. The tunnel is perpendicular to the strike. There is some brown iron stain resulting from pyrite alteration, but no copper ore had been found.

Another tunnel was being started on the east side of Roaring Creek about half a mile above the tunnel just mentioned, but not enough work had been done to show the presence of ore. A piece of greenstone picked up near this place contained small particles of native copper.

Above camp 3 on the west side of Roaring Creek a tunnel 50 feet long had been driven by the California-Alaska Mining and Development Company. This tunnel is 2,600 feet above the mouth of Roaring Creek and at least 1,500 feet above camp 3. The country rock is greenstone and the ore consists of small calcite-quartz veins containing native copper and azurite. In a little gulch a few feet north of this tunnel, but some distance below it, a nugget of native copper, which from measurements was estimated to weigh between 500 and 600 pounds, was found in the slide rock.

The Kotsina Mining Company holds several claims on Roaring Creek. Among them is the Sky Scraper claim, located near the small limestone area previously mentioned. Several open cuts and short tunnels have been made and in July, 1907, the company was starting a tunnel on an exposure of copper minerals 350 feet below the base of the limestone at the north end of the area. This cut exposed a lenticular mass of chalcocite 6 inches thick and 3 feet long, as seen on the face, lying horizontally in the rough, coarse-grained greenstone that occurs immediately below the Chitistone limestone. In the vicinity there are several greenstone exposures in which chalcocite forms small patches or lenses. They are seemingly in no way related to one another.

PEACOCK CREEK.

Peacock Creek joins Kotsina River about 2 miles below the more southerly of the several large glaciers from which the river receives its water supply. There are two branches of the stream, one extending toward the east and the other toward the southeast. The eastern branch originates in a small glacier and the valleys of both branches were formerly occupied by glaciers. Greenstone is the country rock, with the exception of the limestone mass on the ridge between Roaring Creek and the more southerly branch of Peacock Creek. Dikes of diorite cut the greenstone, probably apophyses of the diorite mass on the north side of Kotsina River. The copper prospects of Peacock Creek are owned by the Alaska Kotsina Copper Company.

Rose claim.—The Rose claim is located on the point of the ridge between the two branches of Peacock Creek. It is a little more than 2,000 feet above the valley of Kotsina River. The greenstone is cut by a perpendicular fault striking N. 25° E. This fault is easily traced for a distance of nearly 400 feet and is indicated by a zone of crushed greenstone with a maximum width of about 12 feet in which the copper minerals are seen. Bornite, glance, chalcopyrite, and a small amount of native copper, with malachite and a little red oxide as alteration products, comprise the minerals associated with the fault.

White Dog and Mint claims.—Two claims on the west side of the more southerly fork of Peacock Creek have been partly prospected. The first of these, called the White Dog, is approximately 2,500 feet above Kotsina River. The country rock is greenstone and is cut by a fault plane striking N. 40° E. and dipping steeply westward. A crushed zone of rock along the fault ranges from $3\frac{1}{2}$ to $4\frac{1}{2}$ feet in width. The walls are well defined and clay seams show where the principal movements have taken place. An open cut 25 feet long has been made in the crushed rock. Chalcopyrite or copper-bearing pyrite is scattered through the crushed rock and clay seams and has strongly colored them with iron oxide. Green copper carbonate occurs as a surface stain, but the bornite and glance were not seen here. The fault is plainly marked along the steep mountain side for several hundred feet.

Two hundred feet above the White Dog and a little to the north is a claim called the Mint. A small fault with a strike of N. 15° W. and a dip of 60° W. cuts a grayish greenstone having amygdaloidal phases. The rock adjacent to the fault is broken and crushed, giving a zone with a thickness of 6 inches to 1 foot, which besides the greenstone includes a little quartz and calcite accompanied by bornite and glance. Chalcopyrite was not observed, but a heavy stain of iron oxide would indicate that either this mineral or pyrite had formerly been present. There is a parallel fault 4 feet from this main fault,

and both are cut perpendicularly by a third poorly defined fault having the same strike and carrying a little bornite. The main fault was traced for a distance of 500 feet.

Mountain claim.—The Mountain claim is one of several on the north side of the east fork of Peacock Creek. It is about 2,600 feet above Kotsina River and consequently is at a greater elevation than the other claims described. In August, 1907, almost no work had been done on it and only a few small stringers of copper sulphides were exposed.

SHOWER GULCH.

A small stream joining Kotsina River a short distance below the glacier in which its southern branch originates is called Shower Gulch, from the waterfall near its lower end. Native copper is found near this fall in the amygdaloidal greenstone that forms the country rock. Copper occurs as thin leaves or films in fractures of the greenstone and as grains and small slugs in the greenstone and in the seams of the amygdules. It is in places associated with secondary quartz, filling irregularly shaped veins or cavites. Several claims have been staked on Shower Gulch, but little prospecting has been done.

SURPRISE CREEK.

Surprise Creek is a northerly tributary of Kotsina River and heads in the high mountain southeast of the lower end of Kluvesna Glacier. Most of its bed is cut in the diorite mass previously referred to and in a rude way follows the contact between the diorite and the greenstone on the east. It has a small easterly tributary, Sunshine Creek, which lies mostly in the greenstones. Tin is reported to have been found in the diorite of Surprise Creek, but such specimens of the supposed tin-bearing rock as were examined contained no tin and no reliable assay tests of the rock are known to the writers. All the copper prospects are in the greenstone east of Surprise Creek. They are the property of the Alaska Kotsina Copper Company.

Laddie claim.—Between Surprise and Sunshine creeks is a steep gulch running down from the north. On the west side of this gulch and nearly 3,000 feet above Kotsina River is the Laddie claim. A very close grained grayish "greenstone" forms the country rock and is cut by a fault striking N. 20° to 30° E. and dipping about 45° NW. Along the fault is a zone of crushed country rock ranging in width from 2 to 3 feet, in which is a quartz vein 18 inches thick. Besides quartz there is a small amount of calcite. The vein carries glance accompanied by a little bornite and chalcopyrite. In places the percentage of copper minerals in the vein is high, but they are not distributed uniformly through it. A line of prospect holes extends along the vein for a distance of 200 feet.

Sheehan claim.—At the Sheehan claim, 200 feet higher than the Laddie and a little farther east around the mountain side, the greenstone is cut by a fault striking N. 45° E. and dipping 45° NW. This fault resembles the Laddie fault in being accompanied by a zone of crushed rock, but the zone is here somewhat wider, ranging from 3 to 4 feet. A small quartz vein is exposed in which the copper minerals are glance, bornite, and a little pyrite. The small veins of glance cutting the quartz are in places half an inch thick.

Hubbard claim.—About 300 feet east of the Sheehan claim and a little higher on the mountain the vein of the Hubbard claim is exposed in two open cuts The vein is almost perpendicular and strikes N. 40° E. In the more southerly open cut there is a vein of white quartz ranging in thickness from 4 to 8 feet and carrying the copper minerals glance, bornite, and pyrite, which are named in the order of their abundance. A strongly marked fault with 3 inches of clay seam defines the north wall of the vein. Eight feet from the vein on the southeast is a second vein or lens of quartz 10 inches thick and also carrying glance. Between the two veins is crushed greenstone. Nearly 200 feet to the northeast along the strike an open cut 40 feet long and 25 feet deep has been made across the vein. The fault is seen again along the north wall, but the single large quartz vein exposed in the other cut is here represented by many smaller veins of lenticular form up to 12 inches in thickness. Glance and bornite are the copper minerals. Nearly 1,000 feet farther northeast a well-marked fault with a zone of sheared greenstone crosses the ridge between Kotsina River and the Hubbard claim and is said to extend as far as the glacier from which this branch of the Kotsina springs. There is little doubt that this fault is the continuation of that crossing the Hubbard claim.

KLUVESNA CREEK.

Kluvesna Creek and its tributary, Fall Creek, are the only streams besides Surprise Creek coming into Kotsina River from the north on which any prospecting or assessment work was done last summer. Kluvesna Creek drains the main lobe of Kluvesna Glacier, and the smaller western fork known as Fall Creek originates in a minor lobe of the same ice mass coming down from the snow fields of Mount Wrangell. The valley floor is a broad gravel flat and was once occupied by glacier ice, which has since retreated to its present position 7 miles from the river's mouth. The country rock is greenstone except that the Chitistone limestone forms the top of the ridge west of the southern part of the river and descends to the Kotsina River valley near its junction with that of Kluvesna Creek. Dikes of light-colored eruptive rock, mostly dioritic in character, cut the greenstones locally.

On the east side of Kluvesna Glacier, nearly three-fourths of a mile from its south end, copper minerals have been found in the greenstone several hundred feet above the ice. Three open cuts show a light-colored rock—possibly altered greenstone—cut by irregularly branching quartz veins. The light-colored rock contains chalcocite and chalcopyrite scattered through it in specks rarely larger than a pin head. There are besides this small veins of chalcopyrite. The greenstone country rock locally contains small particles of chalcopyrite, a fact that may have some bearing on the origin of the richer copper-sulphide ores.

West or a little southwest of the mouth of Fall Creek and nearly 1,800 feet above it is a short tunnel, the property of the Kotsina Mining Company. This tunnel is on the north side of a small gulch running down to Kluvesna Creek and is located at the contact of a fine-grained greenstone and a grayish amygdaloidal greenstone. The contact is parallel with several prominent fault planes cutting the country rock, strikes N. 35° to 45° W., and dips 50° SW. The fine-grained greenstone is much shattered and requires timbering to make it stand in the tunnel. Native copper appears as small particles in the amygdaloidal greenstone, both in the apparently unaltered rock and in portions that have been partly leached. It is also associated with small quartz and calcite veins in the greenstone. At many places where native copper is found there is a little red copper oxide. Several pieces of native copper and quartz weighing 20 or 30 pounds were piled on the dump, but nothing like them was seen in the tunnel or in the open cut above the tunnel.

A number of small open cuts and short tunnels in which copper minerals were seen, on Fall Creek or its tributaries, were examined. These small branches flow into Fall Creek from the west within the lower 2 miles of its course. Less than half a mile from the mouth of the most northerly one there is a short tunnel on the south side of the stream driven along a north-south fault in amygdaloidal greenstone. The greenstone is crushed and contains small veins of quartz and calcite. A green stain of malachite appears on the surface, but within the crushed country rock both green and blue copper carbonates are found in a way that suggests them to be the alteration products of some earlier copper mineral deposited along the fault. Between the rock fragments along the fault there is in places a soft black carbonaceous filling with which the copper carbonates are mingled. Very little copper is exposed by the tunnel.

South of this creek on the second tributary a short tunnel about 6 feet under cover was made along a perpendicular north-south fault plane in amygdaloidal greenstone. This tunnel is only a few feet above the creek and on its north side. The greenstone is cut by many small light-colored, fine-grained porphyritic dikes containing abun-

dant grains or crystals of quartz. A very little bornite is associated with quartz veins in the greenstone.

Up the hill to the south and 1,375 feet above the short tunnel just mentioned is another tunnel 40 feet long, also in amygdaloidal greenstone. Here too the perpendicular north-south faulting is to be seen and green copper stains appear on the surface of the fractured rock. The tunnel was driven to strike the supposed downward extension of an outcrop of greenstone containing native copper exposed on the ledge 25 feet above the tunnel and about that distance to the south, but had not yet reached it. Bornite and copper carbonates in small amount were seen in a number of shallow open cuts a short distance southeast of this tunnel.

COPPER CREEK.

Copper Creek is the most westerly tributary of Kotsina River on which prospecting was done last summer. It drains a portion of the ridge between Kotsina River and Elliott Creek and joins the Kotsina 2 miles below Kluvesna Creek. All four of the geologic formations already named are present in the upper part of the basin—the Nikolai greenstone, Chitistone limestone, Triassic shales, and Kennicott formation. Their relations, however, are not simply those due to folding, for extensive faulting has accompanied the folding.

There are two principal branches of Copper Creek, but the westerly branch also forks at a point about 2½ miles from Kotsina River. Near this fork the limestone-greenstone contact crosses the two branches in a northwest-southeast direction and good exposures of the limestone are found between the branches as well as on each side of them. The greenstone, however, is not exposed on the slope from the fork to the limestone outcrops between the branches.

The workings of the Mullen claim are between the branches, about 1,000 feet from the place where they separate and 275 feet above it. Three open cuts have been made along the foot of a limestone cliff. The strike of the limestone at this place is difficult to determine accurately but is nearly north and south. It dips 45° W. In the northernmost open cut, which is 20 feet long and 10 feet in depth from front to back, a fault plane parallels the bedding and forms the west wall of the cut. The limestone is much broken, particularly near the fault, forming a zone of broken rock with a maximum width of 3 feet. In places the limestone is almost completely replaced by bornite and chalcopyrite. The best ore forms a poorly defined vein ranging in thickness from 12 to 18 inches but does not outcrop on the surface. Azurite is more abundant than malachite where the copper minerals are oxidized, and in places the bornite is completely altered to azurite. Small calcite veins are numerous, especially in the brecciated rock near the fault, where the fragments have been cemented

together with calcite. There are minor faults or joint planes in which a green copper stain is seen, but this appears to be derived from the copper of the main vein.

About 75 feet south is another open cut where the fault planes are not prominent but where the limestone is much jointed. Bornite occurs in isolated bunches in the limestone.

A large open cut and shallow pit have been made 75 feet still farther south. Several faults may be seen here, but the most prominent ones strike east and west and dip at a high angle to the south. The north-south faults are present but are not continuous for more than short distances. Patches of crushed rotten rock stained with iron oxide and copper carbonates lie adjacent to the faults and joints. There are also small masses of high-grade bornite replacing the limestone and forming bunch deposits in the country rock. These deposits were probably connected by the joints and faults with the channels carrying the mineral solutions, but this is not evident at the surface. A little chalcopyrite and both malachite and azurite are present with the bornite. Malachite is the surface stain, but below the surface azurite is the alteration product of the copper minerals. The bornite is cut by many thin veins of azurite and in places contains small cavities lined with iron oxide or with azurite crystals. More work has been done in this place than in the first open cut, yet less ore seems to have been taken out, to judge by the amount piled near by.

ELLIOTT CREEK.

General description.—Elliott Creek is a tributary of Kotsina River and joins it approximately 17 miles above the mouth of that stream, or 12½ miles almost directly east of the Copper River crossing. It is reached by a trail which leaves the Kotsina trail at Willow Creek and crosses Kotsina River by a bridge about half a mile above the upper end of the canyon. This trail passes over the southwestern spur of Hubbard Peak and reaches an elevation of approximately 2,700 feet before the descent to Elliott Creek begins. A second trail, used for the first time during the summer of 1907, leaves Elliott Creek (at Five Sheep Creek) about 6 miles above its mouth and, crossing the west end of the ridge to the south, leads to the Nizina trail not far east of the new Government bridge.

Elliott Creek is approximately 10 miles long and throughout most of that distance flows in a direction about N. 30° W., but makes a sharp southerly bend before joining Kotsina River. More than 2 miles of the lower portion is through a narrow rock-walled canyon, but the upper part, along which the claims extend for a distance of 4½ miles, lies in a narrow V-shaped valley. Between the upper cabin,

situated about midway between the upper and lower ends of the claims, and the lower cabin, a distance of 2⅛ miles, the creek descends 759 feet, or approximately 360 feet per mile. Above the upper cabin this gradient increases as the head of the stream is approached. Elliott Creek is fed in a large measure by melting snow, and although the stream is not a large one, with the head available it is capable of furnishing considerable power.

The lowest and the only one commercially important of the rock formations exposed in the Elliott Creek valley is the Nikolai greenstone. All the copper prospects so far discovered here are associated with this rock. The massive bluish-gray Chitistone limestone is conformably overlain in some places by the black and gray Triassic shales and thin-bedded limestones cut by light-gray porphyritic dikes and sills, and in other places is succeeded unconformably by coarse conglomerate of the Kennicott formation.

In an ascent of Elliott Creek the greenstone and overlying limestone appear for the first time on Magpie Creek and continue eastward from that locality to the head of the valley. These two rock formations form a great anticline, whose axis is approximately parallel with the course of Elliott Creek. It pitches under the younger rocks at the east and west ends and dips into the ridges on either side of the creek. North of Elliott Creek and at its upper end the Chitistone limestone forms a very prominent topographic feature. With the exception of the Copper King and Mineral King, the claims described are on the north side of Elliott Creek, and are owned chiefly by the Hubbard-Elliott Copper Mines Development Company. The description of the claims is given in the order of their location from east to west.

Copper King and Mineral King claims.—The Copper King and Mineral King claims, often spoken of as "the Kings," are the most easterly claims on Elliott Creek. They are located along the limestone-greenstone contact, at an elevation of over 4,000 feet above the sea.

On the Copper King claim there is an open cut in the greenstone a little more than 100 feet below the base of the limestone cliff, 1,390 feet above the upper cabin. The copper minerals are found along a shear zone in the greenstone. Bornite is the principal copper ore and is seen along fractures and between them replacing the country rock. Calcite veins are not so numerous as might be expected near the limestone contact. The shear zone, which so far as can be determined at this exposure runs parallel with the base of the limestone N. 60° to 70° E. and dips to the south, is mineralized for a thickness of about 10 feet, though the copper-bearing solutions have penetrated the country rock for a greater distance, as is shown by a slight alteration of the greenstone. There is some pyrite in the ore,

and besides malachite a blue coating of copper sulphate appears in protected places. This open cut is reached by climbing over a steep rock slide.

The two open cuts on the Mineral King are reached by another hard climb over a steep snow-covered talus slope. These cuts are about 800 feet northeast of the cut in the Copper King. The lower one was filled with snow at the time of visit, but the ore piled up at one side consisted of bornite replacing greenstone. The second cut, 50 feet higher and about 100 feet farther west, is almost at the same elevation as the Copper King cut. The ore was found on the steep face of the cliff and consists of chalcocite with a small amount of bornite replacing the greenstone along a fault or shear zone. Numerous close perpendicular joints running approximately N. 60° E. cut the greenstone, and there are a number of fault planes which strike N. 35° E. and dip 30° S. The trend of the disturbed zone is the same as that of the faults mentioned. The best ore has a thickness of about 6 feet and is traced for a distance of 25 to 30 feet along the strike, although the boundaries and extent of the ore body are somewhat indefinite. On the south, however, a fault plane makes a fairly well-defined wall. There is some rich ore at this exposure, but the development work is not yet sufficient to determine whether or not the ore body has any considerable extent.

Claim at the head of Queen Creek.—On the claim at the head of Queen Creek a small open cut has been made in the greenstone about 50 feet below the base of the limestone and shows small veins of calcite and a little quartz containing copper.

Van Dyke claim.—Two open cuts on the Van Dyke claim were visited, one 15 and the other 25 feet below the base of the limestone. The greenstone is stained with the oxidation products of iron and copper and contains also a small amount of pyrite, but the cut shows very little copper.

Copper Queen claim.—The open cut on the Copper Queen claim is about 50 feet west of Kings Creek. It has an elevation of 965 feet above the upper cabin. The cut is nearly filled by the caving of the bank above, so that the face of the greenstone was not exposed. A large mass of the rock, however, which lay at one end was filled with a great number of tiny intersecting veins of iron and copper sulphide, either pyrite and chalcopyrite or, more probably, copper-bearing pyrite. The greenstone fragments were covered with the green copper coating.

Marmot claim.—A large open cut has been made on the Marmot claim, at the base of the limestone between 200 and 300 feet west of Pouch Creek. The greenstone is much broken, and slickensided surfaces are numerous. The most prominent fault planes strike approximately N. 60° W. and are nearly perpendicular. Small calcite

veins carrying a small amount of copper-bearing pyrite occur along some of the openings. A malachite coating was seen on the greenstone, but is not prominent along the main fault planes. Bornite was not observed.

Louise claim.—The Louise open cut is on the east side of Rainbow Creek and 50 feet above it, or 390 feet above the upper cabin. The country rock is greenstone and is cut by faults and joints. Slickensided surfaces are common. The best-developed fault planes strike about N. 20° W. and dip 45° to 50° W. Small calcite veins, having a thickness in general not greater than 2 inches and containing a little quartz, cross the country rock in all directions. Such veins are more numerous here than in most of the other workings examined. Bornite and chalcopyrite are the copper minerals present, and of the two bornite is the more abundant. They appear in the calcite veins and disseminated through the greenstone. The ore is best developed, however, in the calcite veins and the greenstone adjacent to them. It is difficult to give any definite statement of the thickness of the mineralized zone. The ore extends parallel with the creek for a distance of about 30 feet horizontally.

Above the cut on the steep hill slope green copper stains can be traced for a distance of 150 or perhaps 200 feet. Such an exposure as this may be the surface indication of an ore shoot, but the rich ore can not be traced for any considerable distance on the surface, usually not more than 25 feet and rarely as much as 50 feet.

Lizzie G. claim.—The open cut of the Lizzie G. claim is in the bed of Rainbow Creek only a short distance from the Louise. The greenstone at this place is sheared and plicated, but many of the resulting openings have been filled by infiltration of quartz and calcite. Quartz veins reach a thickness of 2 inches and carry considerable chalcopyrite. Calcite filling is, however, the more abundant and in places the rock consists of about equal amounts of sheared greenstone and calcite similar to the knotty masses of schist and quartz in many regions where metamorphism has been greater than in this area. These calcite-greenstone veins, if such they may be called, carry a considerable amount of bornite and chalcopyrite and make a fine-appearing copper ore, but the open cut does not show how great a quantity may be present.

Goodyear and Henry Prather claims.—Directly opposite the Louise open cut, about 40 feet west of Rainbow Creek and 340 feet higher than the upper cabin, an open cut has been made in the claim known as the Goodyear. The amygdaloidal greenstone is cut by faults and is much jointed. The most prominent of these faults strike north and south and dip about 40° W. Another set of less well-developed faults has a more easterly strike and a lower dip to the northwest. Between two of the north-south faults is a mass of rock

lighter in color than the greenstone outside the faults. This lighter rock is sheared or sheeted parallel with the faults and is filled with a great number of thin calcite veins containing chalcopyrite or copper-bearing pyrite and bornite, something like the leaves of a book made of coarse paper. In the lower part of the cut this ore body is between 4 and 5 feet thick and forms a lenticular mass about 20 feet long bounded by two north-south faults and a northeast fault. The upper north-south fault is not continuous, but the lower foot-wall fault extends to the north for some distance. On the south this body of ore is much crushed and is filled with iron oxide. It can not be traced farther in that direction than the limit of the cut. Besides the thin veins of copper minerals in the sheeted rock, there are small veins of calcite and ore throughout the mass.

Along the strike a short distance to the north, and a few feet higher, the light-colored copper-bearing rock reappears, but the upper boundary of the mass is the fault which forms the lower boundary of the lower body. The ore body has a maximum thickness here of not less than 8 feet. An irregular branching calcite vein containing small horses of the light rock or main ore body reaches a thickness of 14 inches and contains chalcopyrite and bornite. This body of ore continues for a distance of 50 or 60 feet toward the north. These two bodies are portions of a single ore body included between two north-south faults and cut by later faulting.

Almost directly above the Goodyear, on the hill slope to the west and not more than 100 feet away, is the open cut of the Henry Prather. Here a north-south fault dips 60° W. and is intersected by two parallel faults striking N. 40° E. and dipping 30° to 35° W. These faults inclose a lenticular mass of rock 30 feet long and 5 feet wide, whose weathered surface is lighter in color than the inclosing greenstone and which is similar in all respects to the ore body of the Goodyear. This lighter-colored rock is impregnated in a similar manner with copper sulphides, and through it runs a vein of coarsely crystalline calcite carrying chalcopyrite and bornite, very rich in places. The calcite vein has an irregular thickness, ranging from 8 to 12 inches, and in two places is offset by small faults for a distance of 10 inches.

The main north-south fault may be traced to the north for about 75 feet and shows much green stain and some sulphides, but the large calcite vein and main ore body end, apparently having been faulted off. Almost 50 feet from the ore body the large fault is intersected by a northeast fault. This also shows copper stain and both contain small calcite veins with the sulphides.

Although no direct proof was obtained, the similarity in character and appearance of these two ore bodies of the Goodyear and Henry Prather suggests that they are faulted portions of one mass.

Elizabeth claim.—The Elizabeth claim lies north of the upper cabin and has received more attention in the way of development work than any other claim on the creek. This work consists of a tunnel and one or two open cuts. The tunnel is located in a narrow gulch a little more than 1,000 feet above the cabin. It has been driven into the greenstone in a northeasterly direction for a distance of 250 feet, and some ore has been uncovered, but it is not believed that the main ore body which outcrops on the hill above has been reached, and the work is to be continued. About 75 feet from the entrance the first copper appears in some lenticular veins of calcite and quartz, but there is only a small amount of this. In the face of the tunnel the greenstone is impregnated with bornite and chalcopyrite. Small veins of calcite also are present and carry the copper minerals. These small veins follow joint and slip planes in the greenstone and are rarely over half an inch thick. There is no well-defined master vein; the mineral waters appear to have followed a zone of fracture and faulting that runs, as closely as it is possible to determine at the tunnel face, in a nearly north-south direction. The greenstone has undergone considerable movement and slickensided surfaces are numerous. The slip planes and joints follow no definite general direction or, at least, this direction was not determined, if they do. At present the tunnel does not reveal the thickness of the ore-bearing zone nor even its direction with certainty.

In the gulch directly above the tunnel to the north and about 100 feet higher is an open cut exposing the copper-ore-bearing fault zone, which the tunnel is expected to cut. The greenstone is much shattered and shows a number of fault planes, the most prominent of which range in strike from N. 10° W. to N. 30° W. Movement along some of these planes has been very marked, and the rock is greatly crushed. Bornite and chalcopyrite are present in small calcite veins and also impregnating the greenstone in and adjacent to the fault zone. The green stain due to oxidation is prominent here, as it is in all places where the copper minerals occur, and makes it possible to trace the copper-bearing zone from the open cut in a direction N. 12° W. for several hundred feet up the hill, where several other small open cuts have been made.

Marie Antoinette claim.—Copper ores are exposed in the Marie Antoinette claim in two open cuts on the top of a narrow ridge adjoining the Elizabeth claim on the northwest. These cuts are within less than 100 feet of each other and show shattered greenstone stained with the oxidation products of iron and copper. There are a number of faults which strike in different directions, and in the open cut on the west brow of the ridge a crushed vein of variable thickness, consisting of calcite and a small amount of quartz, is exposed. The greenstone also contains veinlets of calcite which follow joint

or slip planes and carry copper and iron sulphides. The larger vein strikes approximately N. 30° W., a direction which would take it somewhat to the south of the other open cut. Near it a small perpendicular dike of fine-grained diorite from 2 to 2½ feet thick cuts the greenstone.

Albert Johnson claim.—The Albert Johnson claim and the Guthrie claim described below adjoin each other end to end and lie parallel to the greenstone-limestone contact, but slightly below it. Deception Creek crosses their common end line at an angle of about 45°. Some open-cut work has been done, and a tunnel has been driven on the Albert Johnson about 100 feet east of Deception Creek. The tunnel is 30 feet under cover and is not over 150 feet below the base of the Chitistone limestone exposed to the north in the creek.

Small, nearly horizontal faults cut the greenstone, and the rock is otherwise broken by joints, giving it a blocky character. Calcite veins are present, but not abundant. Copper ore is exposed in the tunnel and in the open cuts. When a piece of the copper-bearing greenstone is broken, bornite and chalcopyrite are found to be the copper minerals, the bornite predominating. The fault zone in which the copper sulphides occur can be traced by the green stain in a nearly horizontal plane almost around to the Guthrie tunnel, so that these two appear to form parts of one ore deposit.

Guthrie claim.—The tunnel of the Guthrie claim is on the hill slope west of Deception Creek, directly opposite the Albert Johnson tunnel and about 200 feet from it, but 10 or 15 feet higher. Above the tunnel for a distance of 40 or 50 feet the surface of the country rock has been cleaned off, exposing small veins of calcite in shattered greenstone; these veins carry the sulphides bornite and chalcopyrite. The freshly broken greenstone adjacent to these small veins is also seen to be impregnated with the sulphides. There is no well-defined vein, but the jointing or faulting has permitted the mineral-bearing waters to circulate through a shattered zone in the greenstone. The tunnel is not more than 100 feet below the base of the heavy limestone as it is exposed in the creek to the north, which would account for the considerable amount of calcite present in the greenstone.

Leland and Lawton claims.—The Leland and Lawton claims are located in the saddle between the heads of Five Sheep and Deception creeks, which here has an elevation of more than 2,500 feet above the lower cabin. They lie north of the main body of the Chitistone limestone, whose scarp forms the prominent cliff on the southern brow of the spur to the south. This unusual location apparently above the limestone is due to faulting, which brings the greenstone up against the Kennicott formation or, rather, against the large porphyritic dike which here separates these two formations. On the Lawton claim a

fault which strikes N. 30° W. and dips 50° to 60° S. is seen between the greenstone on the south and the porphyry dike on the north. The dike here shows a thickness of 30 to 35 feet. Several open cuts have been made in the greenstone and show small amounts of pyrite and chalcopyrite impregnating the rock adjacent to joint or fault planes. Green copper stain and also copper sulphate were seen in a number of other places. The copper minerals where observed were all within a few feet of the porphyry dike, but any other relation between the two was not evident.

Cliff claim.—The Cliff claim is on the west side of Deception Creek. Two open cuts have been made at an elevation of 600 feet above the mouth of this stream. The greenstone is cut by numerous fault planes and slickensided surfaces are abundant, but perhaps the most prominent of the planes of movement strike nearly east and west and dip about 45° N. The green copper carbonate and the oxide of iron stain the greenstone. Small amounts of the copper sulphides also are exposed along joint planes, but no considerable exposure of ore has been made.

Chance claim.—The Chance is the most westerly of the patented claims and includes the prominent point of the limestone cliff which is seen on entering the valley. A small open cut only a few feet below the base of the limestone shows the green copper stain and a little bornite in the greenstone.

KUSKULANA RIVER BASIN.

GENERAL DESCRIPTION.

Kuskulana River receives its greatest supply of water from Kuskulana Glacier, an ice stream made up by the union of four principal branches coming down from the southwest side of Mount Blackburn. The river is a little over 21 miles long and in the upper half passes through a broad gravel-floored glacial valley between high, rugged mountains. After leaving the mountains it flows for more than 10 miles, most of the way in a narrow rock-walled canyon, across the broad valley of Chitina River and joins that stream 10 miles above Copper River. Strelna Creek is the largest tributary of Kuskulana River. It rises in the mountains about the head of Elliott Creek and joins the Kuskulana 3 miles from Chitina River, thus having a length of 12 miles.

Most of the copper prospects are in the vicinity of Kuskulana Glacier, where the Nikolai greenstone and Chitistone limestone are well exposed. There are, besides these two formations, some rocks of doubtful identity in the vicinity of Nugget Creek, a western tributary joining Kuskulana River just below the glacier. These rocks are probably the same as some at the head of Kotsina River which

have been included with the Nikolai greenstone, but may be older. Triassic shales and limestones are well developed east of the Kuskulana and are also represented in a small area west of it.

The best-known copper properties of this area are on Nugget Creek, but there are other prospects on one or two neighboring streams tributary to the main river on the west side and in the vicinity of the glacier on the east side as well as on Slatka and Trail creeks. There are also a few prospects on the head of Strelna Creek.

NUGGET CREEK.

General outline.—Nugget Creek drains the southeast side of the mountain mass whose northwest side is drained by Peacock, Roaring, and Rock creeks of the Kotsina basin. Several of its branches are fed by small glaciers. The stream is about 6 miles long and joins Kuskulana River less than a mile below the glacier.

The country rock includes amygdaloidal greenstones and other greenish rocks which differ somewhat in appearance from typical exposures of the Nikolai greenstone and might be separated from it on closer study. A small area of Chitistone limestone outcrops on the mountain slope east of the upper part of Nugget Creek, and near it along the creek bed is a small exposure of gabbro.

Most of the copper prospects, of which there are a considerable number, are situated in the lower or southern part of Nugget Creek valley. Collectively they constitute the Alaska Consolidated Copper Company's properties, only a part of which were examined by the writers. The claims on which most work has been done are located on the small rounded hill between the lower end of Nugget Creek and Kuskulana Glacier. It was not possible in the short time available to visit any other properties than those on this hill, so that no description of claims in the Nugget Creek valley north of the hill or west of the stream can be given. A good trail leads from the creek's mouth to the camp, where several very comfortable cabins have been built.

Valdez claim.—On the south slope of the rounded hill referred to above is a claim called the Valdez. It is crossed by a fault or set of parallel perpendicular faults running N. 65° E., along which the ore is deposited. The continuation of the fault or faults for a distance of several hundred feet is shown by a line of test pits, but how much farther they extend was not learned. A tunnel run in toward the north and 30 feet under cover gives a cross section of the deposit. At the mouth of the tunnel is greenstone separated by a fault from a large calcite vein on the north. The calcite vein has a width of 24 feet, as measured along the tunnel wall. This wall, however, is not exactly perpendicular to the course of the faults. After passing

through the calcite vein the tunnel penetrates a close-grained dark-gray rock, possibly one phase of the greenstone series, for a distance of 5 feet. This rock and the vein are separated by a fault, along which is a seam of blue and yellow clay, ranging from 2 to 3 inches in thickness and containing small crystals of chalcopyrite. All of the calcite vein as exposed in the tunnel is ore. Bornite is the principal copper mineral and is accompanied by chalcopyrite in minor amount. Movement has taken place along both faults since the ore was deposited, and the country rock as well as the vein matter is jointed and crushed. The greenstone is sheeted parallel to the fault, but the harder close-grained rock in the face of the tunnel was more resistant and broke in angular blocks. The calcite vein is also much broken and in places granulated.

A prospect hole or crosscut a short distance northeast of the tunnel did not expose the vein, but 300 feet still farther northeast an open cut shows greenstone faulted against a light-colored rock consisting chiefly of calcite and quartz, much shattered and impregnated with bornite and chalcopyrite.

Thirty feet to the southwest along the vein from the tunnel mouth is a shaft which in August, 1907, was partly filled with water, but was said to be 30 feet deep. The shaft is sunk in the vein matter, but here the vein has a thickness of only 8 or 9 feet. On the north side is greenstone, much sheared and containing thin calcite veins accompanied by bornite. It is not evident from the exposures why the position of the greenstone with reference to the calcite vein is here reversed. The ore is similar to that in the tunnel. No traces of the vein or fault were seen on the grassy hill slope southwest of the shaft nor were they expected since no test pits had been dug and the country rock was not exposed.

One Girl claim.—The One Girl claim is on the west slope of the hill between Nugget Creek and the lower end of Kuskulana Glacier. A tunnel called the "mud tunnel" has been driven on the south side of a small gulch and extends into the hill for 100 feet in a direction S. 75° W. Of this tunnel 91 feet is in frozen slide rock and is reported to have caved in sometime during the early fall. The remaining 9 feet of the tunnel is in amygdaloidal greenstone, the cavity fillings being calcite. No ore was observed in the face, but the tunnel had not been extended far enough to encounter the mineralized body of rock seen on the hill, nearly 300 feet higher than the tunnel, toward the southeast. This "lead" is amygdaloidal greenstone country rock impregnated with fine particles or grains of chalcocite in association with small calcite veins and epidote. Several open cuts extending along a line from southwest to northeast show the same copper-bearing greenstone, but no work has been done to indicate the width of the zone or any of its other dimensions.

This ore, if the copper content is sufficient to warrant the use of the term under the conditions prevailing in Alaska, is similar in many respects to that of the Copper Queen claim north of the Nugget Creek camp.

Nugget Creek received its name from the large mass of native copper found in the creek bed a short distance above the camp. This nugget is estimated to weigh between 2 and 3 tons and is too heavy to be removed economically by means of transportation now available. It is 7 feet in its greatest dimension, 3 feet 2 inches wide in the middle, and has a maximum thickness of 12 inches, but the average thickness is probably less than 6 inches. Many smaller nuggets ranging in size from shot to pieces of several ounces or pounds are found in the gravels of the creek, but their bed-rock source has never been discovered.

STRELNA CREEK.

The copper prospects of Strelna Creek are of interest chiefly as showing the close relation between copper deposition and the limestone-greenstone contact. The Chitistone limestone forms numerous cliffs in the upper part of the creek, particularly on the branch leading to the Elliott Creek pass.

About a mile southeast of the Elliott Creek pass a small area of Chitistone limestone caps the greenstone of the ridge south of Strelna Creek. The north contact of the two formations is here a fault contact. From 6 to 8 feet of the decomposed greenstone along the fault is heavily mineralized with pyrite, weathering to brown iron oxide. Along with the pyrite is a little copper, as is shown by the green stain of malachite. In the heavy overlying limestone, but not over 10 to 20 feet above the contact, thin veins of copper-bearing pyrite were seen in the limestone. Stringers and small bunches of ore are not uncommon in the underlying greenstone at various places on the creek.

LAKINA RIVER.

Lakina River rises in an area of glacial drainage of minor importance lying between the much more extensive basins of the Kuskulana Glacier on the west and the Kennicott Glacier on the east. The Lakina is not as large nor as turbulent a glacier stream as the Kuskulana or the Kennicott.

The trail regularly traveled through this region reaches Lakina River about 6 or 7 miles below the lower ends of the two glaciers from which the river emerges. This portion of the valley of the Lakina differs somewhat from those of Kuskulana and Kennicott rivers where they flow from their glacial sources, in that it has a more basin-like expansion in its lower half. This basin-like expanse,

which is about 2 miles wide along the trail and gradually narrows into a mountain gorge valley one-half mile wide toward the head of the river, as the glaciers are approached, is floored with deposits of gravel, sand, and mud.

In an ascent of Lakina River from the main trail, the first bed rock to present itself along the margins of the flat gravel floor of the valley is the Nikolai greenstone. This rock appears on both sides of the valley where it begins to become more restricted, about 3 miles below the glaciers, and rises in steep mountain slopes on both sides. Above the greenstone the Chitistone limestone presents its characteristic cliff-like faces, and above the Chitistone limestone a series of shales and thin-bedded limestones form on the east side of the valley bare slopes that are also present, though not so evident, on the heights west of the river.

The camps of two prospecting parties are located within a few hundred yards of each other on the west side of the Lakina, about a mile below the glaciers from which the river flows. The copper prospects occur at comparatively low elevations above the river, in the greenstones that form the steep western side of the valley at this place.

The prospect farthest up the river is about 250 feet up the mountain side from the upper cabin. A short open cut, about 6 feet deep, has been made on a shear or minor fault plane that strikes N. 30° W. and dips 70° SW., into the country rock of amygdaloidal greenstone, which, at this place, is weathered to a reddish-brown color. The walls of this plane are separated at this opening for about 2 feet, and the space thus formed contains a filling of crushed and slickensided slabs and fragmental pieces of the country rock, the whole being cemented together by the deposition of quartz in the interstices. The quartz in one place is somewhat continuous along one of the walls for a few feet and has a thickness of 1 to 2 inches. Most of the filling, however, is crushed country rock. A small amount of native copper in the form of specks and scales occurs within this filling. The amygdaloidal greenstone country rock just north of this filled space is checked with thin veinlets of quartz and contains some scattered chalcopyrite in specks and films. The small size of the opening makes it impossible to give any idea of the extent or amount of mineralization at this place.

The second prospect of this vicinity is similarly located on the lower slopes of the mountain side only a few hundred yards south of the one just described. At this locality the natural exposure of the rocks is good enough to exhibit the so-called pseudobedding that the Nikolai greenstone shows in many localities. Here this bedlike structure of the greenstones strikes N. 70° E. and dips 45° SE. Apparently there has been some shearing or movement along a major plane of pseudobedding or faulting, as well as movements along

joint or other pseudobedding planes parallel to the principal one. This is shown by clean block or slab spalling for a distance, on the strike and dip above recorded, of 500 to 600 feet. This well-exposed face extends up the mountain side to the west and above the camp in a diagonal direction. The surface of the exposure is a natural dip slope along the major pseudobedding plane, offset somewhat by parallel bedding or joint planes. Slickensided surfaces may be observed along the joints or planes, and a tendency toward plication, indicative of shearing movements, is present. A small stream flows down over the surface of this rock incline. Along the major pseudobedding plane at this locality there is a somewhat continuous sheetlike filling of rock that does not look very different from some phases of the country rock at this locality and elsewhere. This sheetlike filling ranges from 1 to 6 or 8 inches in thickness and, as the surface of the rock incline is now exposed, this material lies in patches as a veneer over the surface of the country rock. It does not appear to be so markedly siliceous as the filling in the prospect several hundred yards to the north. It is this filling that contains the native copper in specks, flakes, slugs, and nugget-like lumps. No pieces of native copper of large size were observed, the largest pieces seen being about 2 inches by half an inch in area, and the size of these, as they are exposed on the surface, is due to the flattening and spreading to which they have been subjected by the impact of material carried down over this steeply inclined rock surface by the stream. The surface exposure of this sheet of native copper-bearing material, which lies bare over an area of about 400 by 20 to 30 feet, has been well picked over for specimens, and most of the larger pieces of copper originally present have been removed. For this reason it is impossible to give an estimate of the quantity of native copper that a given volume of the sheetlike filling along this sheared pseudobedding plane may have originally contained. No work has been done in opening up the locality to show how extensive or persistent the deposit may be in any direction, and there appears to be no evidence to justify an assumption that there is a mass of native copper-bearing rock 20 to 40 feet wide extending into the mountain in a direction perpendicular to the strike of the pseudobedded structure.

High up on the mountain side, 2,400 feet above and three-fourths of a mile west of the camps on the river, some surface stripping has been done that exposes a fault in shattered amygdaloidal greenstones. This fault strikes N. 15° E. and dips 75° W. The walls are 18 inches apart and the space is occupied by what appears to be a gouge of crushed country rock, the 6 inches of material adjacent to the hanging wall being essentially earthy and the remaining 12 inches on the foot wall being cemented by a quartz filling. Apparently just enough copper-bearing mineral matter is associated with this cemented gouge

to stain the surface of the 18 inches exposed with green carbonate films. Apparently no other copper minerals were present, although there may be such finely disseminated through the cementing material. A very little bornite in specks and stringers not over one-eighth inch thick was observed in a piece of loose material at this place.

KENNICOTT RIVER BASIN.

ROUTE.

The summer trail that leads through the mountains east of Lakina River to the Kennicott Glacier follows the banks of the Lakina to Fohlin Creek, a tributary flowing from the north. The trail then ascends Fohlin Creek about 2 miles to its first large tributary from the east, locally known as Bear Creek, and continues up the valley of Bear Creek to Kennicott or Fourth of July Pass. From this mountain gap the trail descends Fourth of July Creek to the western margin of the Kennicott Glacier, along which it continues to Kennicott River.

HIDDEN CREEK.

Hidden Creek is a tributary to Kennicott Glacier on its west side, about 4 miles northeast of the mouth of Fourth of July Creek. It presents a feature of lateral valley drainage that is unique in a way, yet also characteristic of many glacial valleys that are tributary to larger glacial valleys where the main ice stream still flows past and completely dams the mouth of the smaller valley. Considered by itself, the valley of Hidden Creek presents all the features of larger glacial valleys. The head of the valley comprises ample cirque basins for the accumulation of snow and its transformation into the ice of the comparatively small glaciers that now exist at its head. These glaciers flow from their basins and terminate well down toward the valley level, but do not extend into its flatter main portion. From them issue small streams that within a short distance join to form a good-sized creek that flows down over the gravel-floored part of the valley. At its lower end the valley of Hidden Creek is completely dammed by the Kennicott Glacier, which ponds back the waters of the stream so as to form a lake which occupies the entire lower valley. This body of water is known as Icy Lake. It is one-half mile across and extends 1½ miles up the valley to a point where the gradually ascending gravel floor rises above its surface. This gravel floor continues as bare flats to the foot of the slopes of the cirque basins, from which the small steep glaciers occupying the head of the valley descend. The stream flowing over it from the glaciers at its head to the lake at its foot is about 2 miles long and has been well named Hidden Creek, as its existence is not to be suspected and it can not be seen

until the valley is actually entered. About half a mile above Icy Lake, on the south side of the valley, a small stream that heads near Fourth of July Pass flows out of a steep mountain gorge. This stream is locally known as Glacier Creek.

The steep walls of both the north and south sides of the valley of Hidden Creek expose on the lower halves of their slopes the Nikolai greenstone, above which rise practically inacessible cliffs of the massive Chitistone limestone. A number of lode claims have been located along the contact of the greenstone and overlying limestone, where in places a little evidence of copper mineralization is to be seen. Most of these locations were made in 1906, and during the summer of 1907 assessment work was performed on them with a view to prospecting the ground.

The Great Northern Development Company had in this neighborhood for part of the season a crew of men who expended most of their labor in making a trail to the valley by following the steep mountain that bounds the western side of the Kennicott Glacier for a couple of miles south of Hidden Creek. This trail was not completed.

The only actual work on claims located in the Hidden Creek valley was done by the Valdez Exploration Company. This company packed its supplies with horses up a trail over the western lateral moraine of Kennicott Glacier to the Hidden Creek valley, thence, by a hazardous route across the ice that dams that valley, to the north side, and thence up the northern shore of Icy Lake to its head. The camp was located 500 feet above the bed of Hidden Creek, on a small area of bench ground, about 4,100 feet above sea level, that still remains in the fork formed by the junction of Hidden and Glacier creeks. During the summer season of 1907 five or six men were employed by the company in prospecting a group of twenty-five lode claims, more or less, some of which are located on the greenstone-limestone contact that extends along the south side of the Hidden Creek valley above Glacier Creek. About half a dozen claims extend from this group along the contact to the west and across the course of Glacier Creek into an area of greenstones. Another chain of claims has been located up the valley of Glacier Creek and across the divide at its head into the headwater drainage area of Fourth of July Creek.

Most of the work on Hidden Creek is on its south side about a mile above the camp, and consists of open cuts in the greenstones about 300 to 400 feet below their contact with the overlying limestones. All the work done during 1907 was necessarily in the form of open cuts because of the difficulty of getting supplies into the place, especially timber for tunnel work, necessitated by the condition of the rock. No timber of any kind grows near Hidden Creek. Five

open cuts were seen on claim No. 3 at this locality, at an elevation of 4,800 to 4,900 feet above sea level, in much-sheared greenstones, the shattered blocks and fragments of which are tightly keyed into one another. The displacements that the greenstones have undergone at this place have been severe enough to obscure their pseudobedded structure to a large extent. The mineralization through and between these keyed shatter blocks consists of irregular and disconnected stringers of bornite, with lumps of the same mineral, some of which may weigh as much as 20 to 30 pounds. There is no continuity to the mineral deposits. They appear to be scattered erratically through the greenstones in an irregular zone for a width of 25 to 75 feet, and by far the greatest amount of this material is only shattered country rock.

GLACIER AND FOURTH OF JULY CREEKS.

Nebraska claim.—About three-fourths of a mile up Glacier Creek, at an elevation of approximately 4,800 feet above sea level, an open pit 8 feet square and 8 feet deep has been sunk, on what is called the Nebraska claim, in a shattered mass of the greenstone that forms a low knoll in the valley. This knoll appears to be a slide mass from the mountain side on the east. Green copper-carbonate stains, specks of bornite, and one speck of chalcopyrite were observed in some of the pieces of rock that came from this pit, but nothing more was revealed. There is said to be a surface showing of chalcocite, on which no work has been done, in the greenstones about 400 feet below the limestones on the southeast side of Glacier Creek opposite the camp.

Bekka and Eli claims.—Above the Nebraska claim the Chitistone limestone dips southward under thin-bedded limestones and shales. But the stratigraphic continuity of the rocks that occupy the headwater areas of Glacier and Fourth of July creeks is disturbed by a line of major faulting that passes in an east-west direction through the head of Fourth of July Creek. This fault throws the heavy-bedded Chitistone limestone to the surface again on the divide between Glacier and Fourth of July creeks, where it is exposed for a thickness of about 600 feet. There is probably a minor fault that passes across Glacier Creek north of and parallel to the major displacement on Fourth of July Creek. Over this faulted area the Bekka and Eli claims extend, crossing the divide to the head of Fourth of July Creek, where the major fault brings the thin-bedded limestones and shales against the greenstones. In the greenstones at the head of the creek, about 200 feet below the massive Chitistone limestone, is a bed of crystalline rock about 30 feet thick that has the attitude of a sill. Above the sill-like rock at this place is typical amygdaloidal greenstone that does not appear to be altered from its usual texture in any

way. Along the contact between this crystalline rock and the overlying amygdaloidal greenstone are a few thin seams of chalcopyrite, and there are also specks of this mineral within the amygdaloid a few inches from the contact. Bornite occurs associated with this chalcopyrite in very small quantities, and the presence of a small amount of chalcocite is suspected by its presence in a piece of rock float picked up below.

Realgar.—About one-third of a mile farther down Fourth of July Creek there is an occurrence of realgar (sulphide of arsenic). The mineral fills small spaces in a crushed zone in thin-bedded limestones. Some of the spaces are filled for a width of 1 to 2 inches with well-formed crystals, but other seams contain the realgar in a more impure earthy form. The rest of the shatter spaces of the limestone are largely filled by thin seams of calcite. No considerable amount of realgar appears to be present at this place.

Coal.—On the divide between Fourth of July and Bear Creeks to the north of the pass crossed by the trail, at elevations of 5,800 to 6,000 feet, is a small patch of coal-bearing shales and flaggy arkosic sandstones covering an oval-shaped area of about 20 acres. The thickness of these beds is probably not over 50 feet. They are partly covered by more recent andesite lava that occupies a smaller area and stands at its highest point as a pinnacle about 50 feet thick. These rocks, which may be provisionally assigned to the Tertiary, appear not to have been involved in the major fault that is well exposed on the head of Fourth of July Creek, which brings the Nikolai greenstone and Chitistone limestone, to the north, against the thin-bedded limestones and shales, to the south. The Tertiary coal-bearing beds seem to lie in a nearly horizontal position on top of the inclined beds of the older series. The coal was not seen in place, its presence being indicated only by small weathered fragments mixed with the disintegrated shales. It is probably not of workable thickness, and even though it were, the small amount and its inaccessibility would prevent it from becoming of commercial importance.

BONANZA CREEK.

The Bonanza, the most valuable known copper deposit of the Chitina Valley, is situated at the head of Bonanza Creek about 1½ miles east of Kennicott Glacier and 7 miles north of the glacier's southern extremity. It is the property of the Kennicott Mines Company and is the only property visited during the season that gives promise of shipping ore in a commercial way in the near future. Two other groups of claims, known as the Jumbo and Independence groups, are situated in the near vicinity and are owned by the same company.

Bonanza Creek is about 3 miles long and heads on the west side of the high mountain ridge running north and south between Kennicott Glacier and McCarthy Creek. Its general course is to the southwest. The company's main camp and office, however, are located at the mouth of National Creek, almost 4 miles by trail from the mine. A new trail, sufficiently wide for a wagon road, is nearly completed and leads from the lower camp to the upper one, and a second trail of easy grade and good width leads down the east side of the glacier to the Kennicott River crossing.

South of National Creek the high north-south ridge between the glacier and McCarthy Creek is made up of Triassic shales and limestones intruded by large masses of a light-gray quartz porphyry. These Triassic rocks and the intrusive are separated by a great fault from the greenstone and overlying Chitistone limestone on the north. The strike of the limestone is northwest and southeast, and its dip averages between 25° and 35° NE. It therefore cuts diagonally across the main ridge and appears at the glacier's eastern edge nearly 9 miles north of the head of Kennicott River. The limestone here has a thickness of more than 1,000 feet. Still farther northeast the Triassic shales conformably overlying the heavy limestone reappear, but they do not occur within the area of the copper-bearing rocks. Bonanza Creek and the other creeks where copper claims have been located lie wholly within the greenstone-limestone area.

The Bonanza mine is situated on the west side of Bonanza Creek on a spur running down to the southwest from the main ridge. This spur divides Bonanza Creek from a small southwestward flowing tributary heading just west of the mine and is crossed by the greenstone-limestone boundary about one-half mile southwest of the main ridge. On the axis of the ridge this boundary has an elevation of approximately 6,000 feet above sea level, or 3,800 feet above the mouth of National Creek, where the ore bins are to be built. To the southwest the spur is greenstone; to the northeast it is limestone, rising to an elevation more than 1,000 feet greater than that of the contact.

The base of the limestone consists of not less than 40 feet of coarse gray limestone rock filled with cylindrical bodies which look like worm borings or seaweed. Over this is a few feet of impure shaly limestone, which in turn is overlain by dark and light-gray massive beds which carry the ore bodies. The ore is chalcocite, with which is associated, as an alteration product, in some places at least, considerable quantities of azurite. The limestone is broken by numerous faults and fracture planes, the most prominent of which are nearly perpendicular and range in direction from N. 40° E. to N. 70° E. Another set of faults runs in a northwesterly direction, and in several places striations on the slickensided surfaces or the clay seams show that the movement was horizontal. Horizontal fault surfaces are

also present. None of the faults observed give evidence of any very great displacements, but, together with the numerous joints, they gave opportunity for ore-bearing solutions to enter the limestone. The principal fault planes—those running from northeast to southwest—form what may be described as a sheeted zone in the limestone. In this sheeted zone are the principal ore bodies. In places numerous closely spaced parallel fractures which contain thin veins of copper ore may be seen, especially near the north end of the deposit. This sheeted zone is not very conspicuous in the limestone beds and greenstone southwest of the main ore body, nor does it extend in a well-developed form for any considerable distance northeast of it.

The copper ores are chalcocite and azurite. The chalcocite is in veins of solid ore up to 5 or 6 feet in thickness and in large, irregularly shaped masses. On the surface two principal veins are seen. They stand almost perpendicularly, 12 to 15 feet apart, and strike N. 41° E., forming the comb of the sharp ridge, but crossing it at a slight angle, as the ridge at this place has a more nearly north-south direction than the veins. In places the precipitous west face of the ridge is a mass of solid chalcocite for a distance of 50 or 60 feet vertically below the top. Azurite appears on the surface of the glance and also as a lining of small vugs in the glance, but it is present chiefly as thin veins that form a network in the limestone and probably are due to the alteration of original chalcocite veins, for much of the azurite has an inner core of chalcocite. Azurite is more conspicuous than chalcocite in the northern 150 feet of the ore body, but chalcocite forms the great mass of the remainder. The ore bodies formed along the northeast-southwest faults of the northern part of the deposit are not the direct continuation of the large chalcocite veins at the south, but lie in nearly parallel veins which cut the ridge at a greater angle, their strike being about N. 60° to 70° E. The very rich ore can be traced on the surface for a distance of about 250 feet. It ends abruptly on the south in a nearly vertical limestone wall, but on the north gives place to the lower-grade ores, consisting of small veins of azurite and chalcocite, with scattered masses of chalcocite, some of them weighing several tons. This lower-grade ore shows on the surface for a distance of at least 150 feet northeast from the high-grade ores, and small scattered azurite veins extend still farther in that direction. The ore, as it shows on the surface, therefore, extends northeast and southwest along the strike for a distance of 400 feet. The thickness, however, is more indefinite, but the very rich ore, with its included limestone, as seen at the surface, has a width of approximately 25 feet, although the thickness of ore sufficiently rich to be mined may be greater.

Two crosscuts have been driven in the ore body in a direction N. 33° W. They are therefore not exactly perpendicular to the ore

body. The longer of these crosscuts starts on the east side of the ridge, 75 feet below its top. It is 180 feet in length and extends through to the west side of the ridge. The richest ore, consisting of large masses of chalcocite with some included limestone, is encountered at a distance of 90 feet from the tunnel's mouth and continues for a distance of 21½ feet, as measured in the roof. There are smaller bodies of chalcocite, however, for a distance of 10 or 15 feet on either side of the main ore body. About 115 feet from the entrance to the tunnel a winze 30 feet deep was sunk in the ore, and from the bottom a drift, which cuts some rich ore and also some of the lower-grade azurite-chalcocite limestone body, zigzags to the northward.

About 120 feet southwest of this tunnel is a parallel tunnel driven from the west side of the ridge and 50 feet lower than the little saddle above it. This tunnel starts in a face of solid chalcocite and extends S. 33° E. for 50 feet. The ore, which is chalcocite with a small amount of azurite, extends for 34 feet along the tunnel, but is interrupted by horses of limestone. The remainder of the tunnel shows limestone cut by small azurite veins and in places containing a small amount of chalcocite.

From the description that has been given, it will be seen that there is little on the surface or in the tunnels by which to determine whether the ore body has a greater extension from southwest to northeast than about 400 feet or, at most, 450 feet, or whether it extends down into the basal beds of the Chitistone limestone. It is evident, however, that the Bonanza is an exceedingly rich and unusual body of copper ore.

JUMBO CREEK.

From the Bonanza mine the Chitistone limestone continues northwestward in a succession of lofty cliffs as far as Kennicott Glacier. The base of these cliffs is at the greenstone contact and in many places contains veinlets and stringers of azurite or chalcocite. In at least two places the quantity of these two minerals, especially of the chalcocite, is such as to make the deposits of commercial importance.

The ore body of the Jumbo claim is 4,600 feet northwest of the Bonanza, at the head of Jumbo Creek, and is located in limestone just above the greenstone-limestone contact on a small southwestward-projecting spur or angle of the limestone cliff. South of it and nearly 200 feet below is the glacier in which Jumbo Creek heads and which must be crossed to reach the ore body. The Jumbo and Bonanza ore bodies are at practically the same elevation above sea level, approximately 6,000 feet.

The limestone at the Jumbo is made up near the base of slightly cherty beds, ranging in thickness from 8 to 12 inches. The strike is

N. 65° W.; the dip 35° N. A tunnel 12 feet long was started on the south face of the ridge, 10 feet above the greenstone. The limestone is jointed or cut by minor faults parallel to the bedding and is crossed by veins of calcite from 1 to 2 inches thick. Thin veins of chalcocite and azurite accompany them and fill some of the fractures. Seven feet above the tunnel mouth is the east end of a large chalcocite mass which is well exposed on the axis of the ridge. As indicated on the surface, this body of ore is a mass of solid chalcocite, 30 feet long, 6 feet by 4 feet 6 inches at the west end, and tapering to a diameter of 1 foot at the east end. It is a rudely conical body, but has irregularly shaped protuberances, as may be seen at the west end, where the steep west face or slope of the spur gives a cross section of the ore body.

A little way east of the Jumbo tunnel is a second tunnel in limestone a short distance above the greenstone. The tunnel runs nearly north or slightly to the northeast, in limestone that strikes N. 65° W. and dips 25° N. In the tunnel, which is 12 feet long, the limestone is crushed and jointed. Small veins of calcite and azurite up to 2½ inches in thickness fill joint cracks, especially a set of perpendicular minor faults or slip planes running N. 70° W. No chalcocite is exposed in the tunnel, but it is believed that the azurite indicates its former presence. Fifty feet below the tunnel a lenticular vein of chalcocite, 3 inches thick at its widest part and 3 feet long, was found in the limestone.

OTHER CLAIMS.

Northwest of the Jumbo claim and nearer Kennicott Glacier is another chalcocite body of similar character that is said to be larger than the Jumbo. This property was not visited by the Survey party, nor was the Independence group of claims, which lies just below the top of the ridge between Bonanza and McCarthy creeks, on the McCarthy Creek side. The vein of the Independence is in greenstone and is described by Mendenhall[a] as being a fairly persistent fissure vein from 6 to 8 inches wide and trending obliquely to the limestone-greenstone contact. The ore is essentially bornite, but is associated with a small amount of chalcopyrite. The gangue is calcite and crystalline quartz, but a considerable part of the ore is without gangue and is relatively pure. The walls of the vein are fairly well defined, but the ore is observed to gradually fade away into the country rock on the eastern side of the gulch in which the vein is exposed.

The Nikolai mine on Nikolai Creek, a tributary of McCarthy Creek emptying into Kennicott River a short distance below the glacier,

[a] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1906, p. 104.

was not visited by the Survey party, as no work has been done there since the claim was patented, and the shaft was reported to be filled with snow and ice.

CHITISTONE RIVER BASIN.

MAIN STREAM.

Chitistone River is a southwestward-flowing tributary of the Nizina and joins that stream approximately 30 miles above its mouth. It heads in the glaciers which cover the divide between Copper and White rivers, and its valley is one of the routes by which prospectors reach Skolai Pass and the White River Glacier. Between the lower end of the Chitistone Glacier and Nizina River the stream has a length of 18 miles, but the copper properties on which most work has been done are situated within the lower 10 miles of the valley. Within this lower 10 miles of its valley Chitistone River flows over a broad gravel-covered flat, ranging in width from one-half mile to 1 mile. The largest tributaries are Glacier and Toby creeks, both flowing in a northwesterly direction and joining the main stream within 2 miles of each other. The mouth of Glacier Creek, the more westerly of the two tributaries, is 7 miles from Nizina River. The larger tributaries, including two or three besides the two named, have broad gravel-covered valley floors similar to that of the Chitistone itself, but much narrower and with higher gradients. The smaller tributaries tumble down steep rock-walled gulches.

For more than half its length the valley of Chitistone River is cut in Nikolai greenstone and the overlying heavy Chitistone limestone. In this vicinity the limestone reaches the maximum thickness observed, at least 2,000 feet. South of the river it dips gently northward, forming a conspicuous cap on the greenstone that may be seen for many miles to the southwest and everywhere lies at least 1,000 feet above the valley floor. On the north side of the river, between the Nizina and Glacier Creek, the whole mountain mass, with the exception of 200 or 300 feet at the base, is Chitistone limestone extending to an elevation of more than 4,000 feet above the valley. On the west side of Nizina River the limestone dips to the north at about 30°, so that the great thickness on the east side represents the central low-lying portion of a large syncline. Farther up the valley Triassic and other younger rocks with granular intrusions and included coal beds appear.

Copper is found on Chitistone River in both the greenstone and the limestone, but in 1907 development had not revealed any considerable ore bodies. On the Chitistone itself most of the work had been done by the Houghton Alaska Exploration Company and by

the Alaska United Copper Exploration Company, the first-named company directing its efforts to prospecting claims north of the mouth of Glacier Creek on the north side of the river and claims on the south side of the river about 4 miles below Glacier Creek, and the second to prospecting ground on Contact Gulch opposite the mouth of Toby Creek. A large number of claims have been staked, including practically all of the limestone-greenstone contact, but some of them show nothing but the green carbonate stain.

Glacier Creek, among the tributaries of Chitistone River, is at present the area of greatest promise. Native copper is the ore chiefly found.

The property of the Houghton Alaska Exploration Company west of Glacier Creek on Chitistone River on which most work has been done lies at the limestone-greenstone contact 1,225 feet above the river valley. A tunnel 20 feet deep follows a fault in the limestone, running S. 30° E. and dipping 70° to 80° E. This tunnel lies just above the greenstone contact, at the top of a large limestone talus slope. Fifteen feet higher and 20 feet farther east is a slope about 25 feet long driven on the dip of a fault parallel to the bedding, which strikes N. 60° E. and dips 35° S. There is a fault zone of crushed country rock which has a thickness of 4 feet on the west side of the slope but diminishes to 2 feet on the east side and practically dies out at a short distance from the mouth. It can be followed for 15 feet westward and is then cut off by a cross fault, giving it a lenticular cross section with a maximum thickness of 4 feet and a length of about 25 feet. The limestone is further cut by many small calcite veins. The fault zone is heavily impregnated with blue and green copper carbonate, accompanied by epidote. Iron oxide also is abundant in the crushed zone. The copper minerals penetrate the country rock, coating the joint planes with green carbonate, but azurite is almost restricted to the crushed zone.

The central camp of the Alaska United Copper Exploration Company is at the mouth of Contact Gulch, opposite Toby Creek, and most of the summer's work was done in that vicinity, although the company owns many other claims. A large part of the season was consumed in the construction of a cabin and trails by which the prospects, situated over 2,000 feet above the mouth of Contact Gulch, may be reached. Bornite in greenstone is the principal ore, but not enough development has yet been done to reveal any large body of it.

GLACIER CREEK.

Native copper is found on Glacier Creek in a small gulch about 1 mile above the lower end of the glacier, or 6 miles above the mouth of the creek. This copper was known to the Indians, who broke out

fragments from the bed rock. The outcrop is on the northwest side of a steep gulch 625 feet above the glacier and less than half a mile from it. The gulch is reached by a trail over a high rock cliff, by going along the north side of the glacier between the ice and the bank or by crossing diagonally from the south side of the glacier. Traveling along the glacier's side is dangerous because of almost continuous rock slides and is not possible at all in some seasons.

The country rock is a series of bedded amygdaloidal greenstone flows, and the copper is seemingly restricted to a particular one of these beds. Nearly 75 feet above the creek, on the claim known as the Chiti, the greenstone is cut by a fault running N. 10° E. and dipping 40° W., almost parallel to a bed of greenstone filled with black amygdules and cut by small veins of the same material. Above and below this bed, whose maximum thickness is 8 feet, is greenstone with quartz amygdules and only a small amount of the black mineral. In the main open cut the fault appears at first glance to form the hanging wall, but there is a small thickness, not over 2 feet, of the black amygdaloidal greenstone just above it. Thirty feet farther north along the strike the fault is at the foot wall, and here the black amygdule rock has its greatest thickness, 8 feet. The main fault changes its direction here and strikes more nearly east and west. It is cut by minor faults and slightly displaced. The black amygdule rock is covered by slide rock 50 feet south of the largest cut, but continues with decreasing thickness northeastward for about 200 feet. The large fault, however, is easily traced for not less than 300 feet.

Copper is present as malachite, native copper, chalcocite, and cuprite. Masses of native copper weighing several pounds are found, but it is present chiefly as small specks in the greenstone and the black amygdules and as thin sheets or leaves of about the thickness of paper and small stringers in the greenstone. The larger masses occur in sponge or net-like form inclosing country rock. The largest one seen in place was not over 8 inches in diameter, but a quartz vein 300 feet north of the main cut yielded a mass weighing about 60 pounds. The fault with traces of the black amygdaloidal rock and some copper are reported to be found still farther northeast, but were not followed.

DAN CREEK.

Dan Creek is the first tributary to Nizina River below the Chitistone, from which it is separated by a mountain mass made up of Nikolai greenstone capped by gently northward-dipping Chitistone limestone. On the northern side of this mountain mass the limestone-greenstone contact at its lowest point is only a few hundred feet above Chitistone River. On the southern or Dan Creek side, however, it ranges from 2,000 to 4,000 feet above the stream. A further descrip-

tion of the geography and geology of Dan Creek is given in the account of its gold placers, a few pages beyond.

Just below the contact, north of Dan Creek, the greenstone in many places is stained with copper green and contains small stringers and bunches of copper minerals, chiefly bornite. This is said to be particularly true of a zone of greenstone extending for a long distance along the contact and situated about 30 feet below it.

At the head of Boulder Creek, which joins Dan Creek below the canyon, is a claim called the Westover, belonging to the Alaska United Copper Exploration Company. The exposed ore is a mass of bornite at or just above the limestone-greenstone contact. This ore body is entirely in the limestone and is unusual in that the other known similarly situated copper deposits of the eastern portion of the Chitina copper region are chalcocite rather than bornite. The surface exposure has a length, in a horizontal direction, of 30 feet and a maximum width of 8 feet. At one end the ore consists of nearly pure bornite whose boundaries with the inclosing limestone are rather sharply defined. At the other end it gradually fades into the country rock. No development work has been done other than to clear away the face of the exposure.

THE NIZINA GOLD PLACERS.

LOCATION AND HISTORY.

The Nizina placer district, as now known, embraces in a general sense the drainage areas of Dan, Chititu, and Young creeks, which flow into Nizina River from the east and south. Young Creek empties into the Nizina about 20 miles above its mouth, Chititu Creek comes in about 1 mile above Young Creek, and Dan Creek flows into the main river about 4 miles farther upstream.

The discovery and location of these placers in 1902 has been described by Mendenhall and Schrader.[a] After passing through the stampede stage of exploration, the Nizina district relapsed into a period during which great many of the claims as originally located were worked only on small scale in an unprofitable manner. From one cause or another much of the better ground was soon involved in lawsuits that have taken until last year to settle in a way to justify systematic work necessitating an investment of capital.

GEOLOGIC SKETCH.

The bed-rock floor of this area is, so far as known, made up of a series of shales with a few thin limestones that are rather commonly intruded by dikes and sheets of light-colored porphyry. This bed rock on Chititu and Dan creeks is for the most part a dark, fine-

[a] Mineral resources of the Mount Wrangell district, Alaska: Prof. Paper, U. S. Geol. Survey No. 15, 1903, pp. 59–61.

grained homogeneous shale in which there is very little limestone. These shales are hard and closely jointed and have been intricately folded and contorted. They have also been subjected to faulting, some of which is very recent, as it has occurred since the unconsolidated Pleistocene bench gravels that lie unconformably upon the shales were deposited. It is probable that this shale bed rock is the floor upon which rests the thick sheet of bench-gravel deposits that, so far as known, appear to extend from the northern slopes of the valley of Dan Creek along the gently sloping mountain sides that form the eastern side of the Nizina Valley to and probably beyond Young Creek. Schrader and Spencer represent the higher mountains to the east to be made up of this series of shales and thin-bedded limestones.

The unconsolidated deposits of the region that concern this paper include bench and stream gravels. Of these two the bench gravels are of less present commercial importance, although in amount they greatly exceed the stream deposits. The general distribution of this thick gravel terrane appears to correspond to the benchlike surface feature that extends along the eastern side of the Nizina Valley from Dan Creek to Young Creek and beyond in a southwesterly direction. The gravels apparently have their upper eastward limits about the middle altitudes of the mountain sides. They gradually slope down toward the west to an elevation of about 3,000 feet above sea level, where the surface descends more abruptly for several hundred feet and thence continues on to the west for 2 to 6 miles as a gradually sloping valley floor to Nizina River, where the elevation is about 1,400 feet.

It is not known to what extent the configuration of the surface of the rock floor buried by this thick mantle of gravels may influence their distribution, but there are undoubtedly considerable irregularities both in slope of surface and in surface forms, as ridges, valleys, and hills such as would be presented by a rolling topography of moderate relief, that have been controlling factors in the original distribution of the gravels. This consideration of the older rock-floor topography is especially important in studying the Nizina placers for the reason that at the present time all the evidence points toward the bench gravels on this older land surface as being the source from which the supply of gold in the present stream or creek gravels is chiefly derived.

The view that the easily worked creek gravels of the present streams have received their gold from a source in the higher bench gravels is amply substantiated by the fact that the presence of gold in the bench gravels has been established. On Chititu Creek the bench gravels have been prospected rather carefully and systematically at several localities by digging tunnels into their lower part

along their contact with the underlying shale bed rock, and it has been found that gold is present in no inconsiderable amount and that although the values are naturally highest on or near bed rock, yet there is a considerable amount of gold distributed in the gravels for some distance above bed rock. Under present conditions, however, it does not seem that the bench gravels can be worked profitably for their gold content. When supplies and labor can be obtained at lower cost, it may prove profitable to mine these bench gravels by tunnel and drift methods along the bed-rock surface or possibly by hydraulicking on a large scale. These bench gravels are not frozen, as are similar deposits in some parts of Alaska; consequently in working them by tunnels and drifts it is necessary to timber the workings thoroughly, an item of expense that increases the cost of such operations. It is by no means improbable that there may be old channels in the rock floor underlying these gravels, where placer gold has been concentrated in amounts large enough to pay for mining by timbered tunnels and drifts. It may also be found that over some areas the bench gravels are not too thick to be profitably worked by hydraulic methods, even if a considerable thickness of barren overburden should have to be removed to reach the pay ground. It is possible that a systematic and thorough sampling of large areas by drilling test holes is the best manner by which this problem of the bench gravels may be approached.

The present stream gravels of Dan, Chititu, and Young creeks are the deposits in which gold was first discovered and on which active operations are now being conducted. They are in part derived from the bench gravels and in part by the cutting of the streams in their own bed-rock channels. These deposits are more fully described in connection with the individual creeks.

The suggestion that the present auriferous creek deposits were evidently derived from the thick mantle of bench gravels leads to the question as to the source of the bench gravels and the placer metals they contain. Greenstone bowlders, cobbles, and pebbles form a characteristic percentage of the material of the bench gravels. Another characteristic feature is the presence of considerable native copper in the form of nuggets. A few of these copper nuggets weigh more than 100 pounds, but most of them run about 1 or 2 ounces. The nearest known source for the greenstone and native copper of these gravels is on the north side of the valley of Dan Creek and thence northward in the area of Chitistone River. Here there are areas of greenstones in which some small amounts of native copper are known to occur, but no gold has been reported from these rocks. The following statements are quoted from the report by Mendenhall and Schrader:[a]

[a] Mendenhall, W. C., and Schrader, F. C., Prof. Paper U. S. Geol. Survey No. 15, 1903, p. 61.

The rocks throughout the greater part of the district are reported by Schrader and Spencer to be the black shales and thin limestones of the Triassic, but in the northern part of the basin of Dan Creek the Nikolai greenstone and the overlying heavy-bedded Chitistone limestone outcrop. There is a doubtful region about the head of Young Creek where these older rocks may also be found.

The black Triassic shales are reported to be intruded in this region, as they are known to be in other localities, by abundant porphyritic dikes, and the gold may be found to be genetically connected with these intrusives.

So far no facts have been brought to light to show whether the porphyry dikes in the Triassic shales may be a possible source of gold or not. On the other hand, it has been reported by a prospector that placer gold occurs in the conglomerates of the Kennicott formation in this region. This formation has been assigned to the Upper Jurassic or Lower Cretaceous, and at present the only rocks of this age known to occur in the Nizina placer area lie south of Young Creek. There is also an area on the west side of Nizina River, opposite the mouth of Chitistone River. The Kennicott formation as now known occurs in isolated areas, of no very great extent, distributed from Kotsina River to the mountains south of Young Creek. It lies unconformably upon the Triassic shales and limestones and older greenstones. This series of conglomerates was no doubt formerly very much more widely distributed than it is at present. Extensive deposits of it have probably been entirely carried away by erosion, and if they were gold bearing in part or as a whole it can easily be seen how such a source might have supplied the present bench gravels in the Nizina district.

CHITITU CREEK.

The stream gravels of Chititu Creek and its tributaries are the deposits that have received the most attention in this district. The upper half of Chititu Creek occupies a comparatively narrow valley that is excavated to a depth of 200 to 400 feet through the thick deposits of bench gravels to the shale rock floor beneath. In this shale bed rock the stream has carved a trough that conforms in slope to that of the surface of the rock floor. In width this trough ranges from 200 to 700 feet and its depth is from 10 to 50 feet. It is well filled to a depth of 8 to 16 feet throughout its length and width by recent stream gravels. These gravels have been mostly derived and concentrated from the bench gravels in which the creek valley has been excavated. In brief, the whole process has been that of a natural ground sluicing of the bench gravels down to the grade of the shale rock floor, in which a natural bed-rock flume has been cut. This bed-rock flume has been paved with the bowlders and larger cobbles of the bench material and has thus afforded a natural set of riffle blocks that have served to catch and hold the gold and copper which make up the metal values.

Only one of the original locators of claims on Chititu Creek has developed his holdings along conservative and consistent lines from the time of their discovery. On claim No. 11 above Discovery open-cut work was begun with pick and shovel. This was facilitated the next season by the use of canvas hose, and finally a small hydraulic plant with giants was installed. This plant has been improved from year to year and the results obtained have been increasingly satisfactory to the owner.

In 1907 active development work was begun on a group of claims that includes the major portion of the placer ground on Chititu Creek. A complete hydraulic plant, supplemented by a well-equipped sawmill run by water power and an electric-lighting plant to aid in night work during the latter part of the open season, was during the winter taken over the snow and ice to Chititu Creek from Valdez, a distance of 200 miles, by means of horses and sleds. This winter method of transportation is the only way by which any considerable quantity of materials can be conveyed into the Copper River region at the present time. Even when economically conducted, on a large scale involving quantities of 100 tons or more, such transportation from Valdez to the Nizina district has never cost less than $130 per ton. On small amounts of supplies the cost may be as much as $400 per ton.

The greater part of the open season of 1907 was spent in installing this plant on the lower eight claims on Chititu Creek. The sawmill was erected on claim No. 4 above Discovery to supply lumber for flumes, buildings, and other purposes. A large amount of hydraulic pipe was riveted together from the separate sheets, and as the season progressed the whole plant with dam and head-gates on claim No. 8 above, the flume and pipe lines, lighting plant, etc., was assembled in working order so that by the close of the season all arrangements were completed for beginning active mining on claim No. 1 with the opening of the season of 1908.

DAN CREEK.

Dan Creek in point of size is the first important tributary to Nizina River above Chititu Creek and, as has been previously stated, is also the first one below Chitistone River. Its general course is west-northwest and it joins the Nizina at the point where that stream, flowing southward from the Skolai Mountains, abruptly changes its course to the west. The drainage area of Dan Creek covers approximately 45 square miles and is nearly as broad as it is long.

The stream for a distance of nearly a mile below the place where it emerges from the mountains flows across the gravel floor of the Nizina River valley, but is raised slightly above it by the broad, low, fan-shaped deposit of gravels it has brought down from above. The

valley above this portion of the stream presents three different topographic features. For nearly 2 miles Dan Creek has cut its way through the deep bench gravels bordering the Nizina Valley and has excavated a shallow trough in the country rock. In this narrow trough the stream gravel is laid down. Above this portion the channel is in a narrow box canyon, which finally expands into the more open, basin-like upper valley. Two principal branches unite above the canyon to form the main stream. The northern branch retains the name Dan Creek; the other is known as Copper Creek.

The bed rock as naturally exposed or as uncovered by mining operators along the lower part of Dan Creek is made up of Triassic shales intruded by light-gray porphyritic and greenstone dikes. These shales, so far as is now known, occupy most of the area south of Dan Creek to Chitina River. North of Dan Creek is the Nikolai greenstone, overlain by a heavy capping of Chitistone limestone that forms the top of the mountain mass between Dan Creek and Chitistone River. The unnatural position of the Triassic shales south of the stream with reference to the greenstone north of it is believed to have been brought about by a great fault extending through the valley from southeast to northwest and removing from view the Chitistone limestone, which normally should be present between the greenstone and shales. This fault continues northwestward at least as far as Lakina River.

Placer mining is at present restricted to the regions above and below the canyon. Above the canyon the most work has been done on Copper Creek. This part of the stream is difficult to reach with supplies and only a few men were at work there in 1907. Most of them were doing nothing but assessment work, and yet a few thousand dollars in gold have been produced during the several years since work began. The creek claims below the canyon are under one control, and though the gold production has not been large, owing to the difficulty of working the ground, prospecting has shown that gold is present.

Placer gold is associated with two classes of deposits—the present stream gravels and the older and much more extensive bench gravels. Mining or prospecting has been carried on in both of these. Undoubtedly a great part of the gold in the present stream is a concentration from the benches through which the creek has cut its channel. Whether any part of it has been brought by the present stream directly from its original source or a source other than the higher unconsolidated bench gravels to the place it now occupies is a question whose answer was not determined.

The first claim below the canyon is No. 7 and the numbers decrease down stream. Near the camp a cut approximately 400 feet long and as wide as the shovelers could work at one setting of the boxes was made in the creek gravels of claim No. 5. Directly above is a larger

cut, nearly as long and averaging about 75 feet in width. The bed rock is hard, close-jointed shale cut by dikes of light yellowish-gray porphyry and of greenstone. The gravel and its slight soil covering range in thickness from 8 to 12 feet. The gravel consists in part of shale fragments and contains a large percentage of greenstone and porphyry. Some of the bowlders in the large cut have diameters as great as 4 feet, and many of them average 10 or 12 inches in maximum diameter. All of this material has been more or less rounded by stream action. It is poorly bedded and spruce logs and fragments of wood are buried in it. The large cut was made by piling up a wall of bowlders along the gravel face, thus forcing the creek water to undercut the bank and causing it to cave. Bed rock was then cleaned by hand. Such work is expensive, as it requires several handlings of all the larger material. A third cut, 300 feet long and one box wide, on claim No. 6, showed gravel and bed rock of the same character.

The width of the stream gravels is not great, in places not over 100 or 200 feet, but increases as the creek is descended. On either side benches of gravel close to the stream rise to a height of several hundred feet. Tunnels in these benches have demonstrated that they carry gold. One of these tunnels on the upper end of No. 6 or the lower end of No. 7 had a length of 72 feet. It was driven along the rock floor upon which the gravel rests and is 10 feet higher than the present stream. In other words, the creek here has cut 10 feet into the bed rock since the present drainage was established. The tunnel was driven in winter as a prospect and yielded good values in gold.

The Dan Creek gold from the gravels below the canyon is coarse and smooth. Most of it is flat, and the heaviest of it is found either on bed rock or within 2 feet of it. It is accompanied by placer silver and placer copper. Nuggets of silver and copper, such as are called "half breeds" in the Lake Superior region, are frequently found here, and on Chititu Creek also. Copper is associated with both the creek and the bench gravel, in pieces ranging from the size of shot to masses of 100 pounds or more. It is only recently that any effort has been made to secure the copper, as it is of no value with the present means of transportation. Most of the operators are now saving it, however, and when railroad transportation is available the returns from the copper may be found to reduce considerably the cost of mining.

The gold from Dan Creek above the canyon differs from most of that below in that it is generally rough and not flattened, indicating that it has not been hammered out and worn so much by moving bowlders.

Surveys for a hydraulic plant on the lower end of Dan Creek have been made, and it is expected that the plant will be installed during the summer of 1908.

NOTES ON COPPER PROSPECTS OF PRINCE WILLIAM SOUND.

By FRED H. MOFFIT.

The copper prospects of Prince William Sound were examined by U. S. Grant and Sidney Paige in 1905 and a short account describing the general geology of the region and the occurrence of the copper ores was published.[a] Since that time the region has not been visited by members of the United States Geological Survey, but the statements here made concerning later developments have been procured from sources that are believed to be reliable. A small map of the region (fig. 2) is here reproduced without change from Grant's preliminary report.

During the two years since 1905 two mines have made regular shipments of ore to the smelter, several promising prospects have been partly developed, and further prospecting has been carried on in all parts of the sound. The search for copper has been active on Knight Island, Latouche Island, and in the vicinity of Copper Mountain and of Orca. Attention has been directed most strongly toward Knight Island and considerable money has been expended in the endeavor to prove the presence of ore bodies of commercial value, but it can not be said that a copper mine has yet been developed there. Shipments of ore have been made from prospects in various parts of the sound, but most of them must be regarded merely as smelter tests and give no indication of the ability of the prospects to produce ore regularly and in quantity. This statement is made because one or two companies are said to have purposely endeavored to misrepresent the state of their development work or the value of their ore deposits by reports of this kind.

As described by Grant, the geology of the region may be briefly summarized. The rocks of Prince William Sound are in part sedimentary, in part igneous. The sedimentary rocks consist essentially of graywackes and slates, the graywackes in places approaching arkoses and sandstones or even quartzites. The color of both gray-

[a] Grant, U. S., Copper and other mineral resources of Prince William Sound: Bull. U. S. Geol. Survey No. 284, 1906, pp. 78–87.

wackes and slates is dark gray or black, the slates being the darker. Limestones are few and inconspicuous.

Granite, aplite dikes, basic dikes, and basic lava flows constitute the igneous rocks. Only the basic lava flows are of special importance in connection with the copper deposits. These flows are more or less altered and in places are schistose. They are usually referred to as greenstones.

Sedimentaries and interbedded lava flows are much folded so that

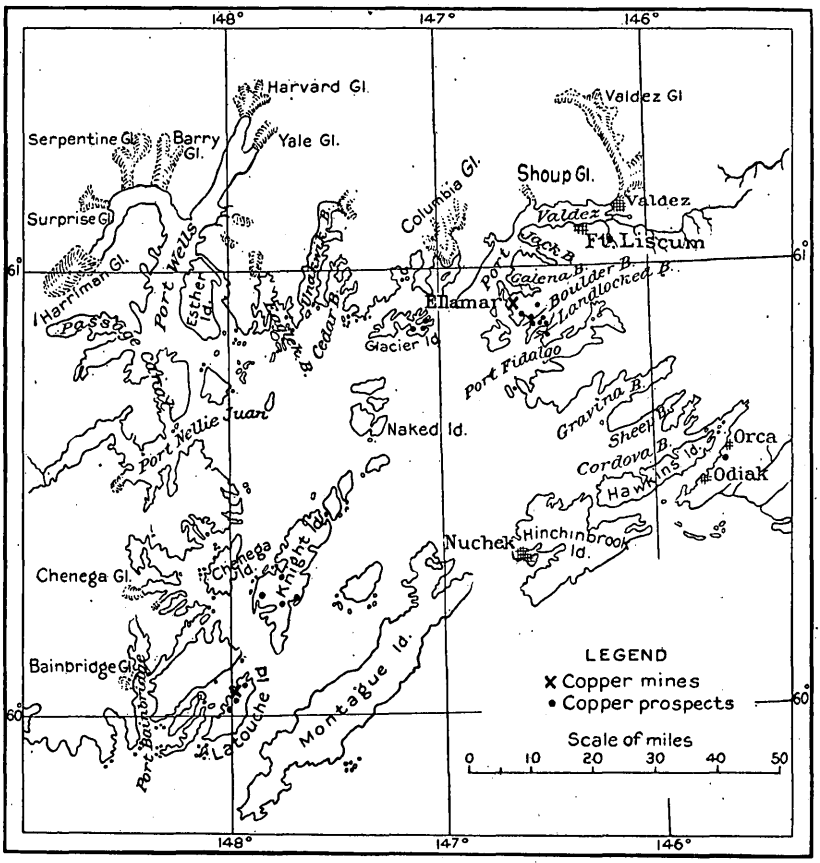


FIG. 2.—Sketch map of Prince William Sound. By U. S. Grant, 1905.

bedding and cleavage are in most places parallel. The sedimentary rocks of Prince William Sound consist of two series of nearly similar beds that have been given the names Valdez and Orca. Of these the Orca is more widespread and differs from the Valdez in being a little less metamorphosed and in containing much black slate, conglomerates, and many interbedded lava flows.

The copper ores are chiefly chalcopyrite, generally associated with pyrrhotite and less commonly with pyrite and marcasite. It occurs

in many places in shear zones in greenstone, and this association of copper ore with greenstone is so pronounced that the copper is believed to be derived from the greenstone. Native copper and chalcocite have been found in the vicinity of Orca in sufficient amount to indicate a possibility of their commercial importance.

Among the older and better-known properties that at Ellamar was partly idle during the summer, it is said because of labor troubles. The shaft was sunk to the 600-foot level and 650 feet of drift was made. At Galena Bay an aerial tram 5,000 feet long, from the mine to the beach, was begun and ore bunkers were being constructed at the beach. Only a small amount of work was done at Boulder Bay, most of it by the Reynolds-Alaska Development Company, which extended its main tunnel. Some small shipments of ore were made from Landlocked Bay and a tramway and wharf were built.

The Beatson property at Latouche, known as the Bonanza, but not to be confused with the Bonanza mine on Kennicott River, in the Chitina region, was the only property of western Prince William Sound to make regular shipments. A crosscut tunnel 900 feet long was driven, cutting the ore body at a level 90 feet below the old tunnel. The Reynolds-Alaska Development Company has erected a wharf, electric-light plant, trading store, and a number of houses on its property at Horseshoe Bay, on the west side of Latouche Island. A shaft was sunk on one of the claims and a small amount of ore was shipped. East of the Bonanza mine, on the Barrack claims, active development work was in progress. A wharf, ore bunkers, and a tramway were under construction and a little ore was shipped.

A great many claims have been staked on Knight Island, but most of the locations were made within a year or two so that development work is not as far advanced as on some of the older properties. Among those most actively engaged in prospecting is the Hubbard-Elliott Company, whose property is located at Drier Bay, on the west side of the island. A tramway with other equipment was installed during the summer and a small shipment of ore is reported.

Prince William Sound properties enjoy a great advantage over those of the interior in that nearly all of them are within comparatively easy reach of tide water and their development is not dependent on expensive railroad construction or hindered in the same degree by the severity of the winter.