THE ALATNA-NOATAK REGION.

By PHILIP S. SMITH.

INTRODUCTION.

In the open season of 1911 a party from the Geological Survey visited the Alatna-Noatak region (see Pl. XV) and obtained the information concerning the mineral resources of the region presented in this report. A more complete account of the geology, based on a more thorough examination of the notes and specimens collected, is in preparation, but will not be published for a year or more. No productive mining has yet been done in the region, so that deductions concerning the future of this industry must be based mainly upon analogies with known productive camps elsewhere in northwestern Alaska.

GEOGRAPHY.

RELIEF AND DRAINAGE.

Alaska has been divided by Hayes, Brooks, and others into four large geographic provinces which, from south to north, have been called the Pacific Mountain system, the Central Plateau region, the Rocky Mountain region, and the Arctic Slope region. The Alatna-Noatak region lies almost entirely within the limits of the Rocky Mountain system. Although mainly of mountainous topography the region is so diversified by highlands and lowlands that in places the reason for assigning the country to the Rocky Mountain system would not be evident to a traveler contemplating only the immediate details without regard to their larger relations.

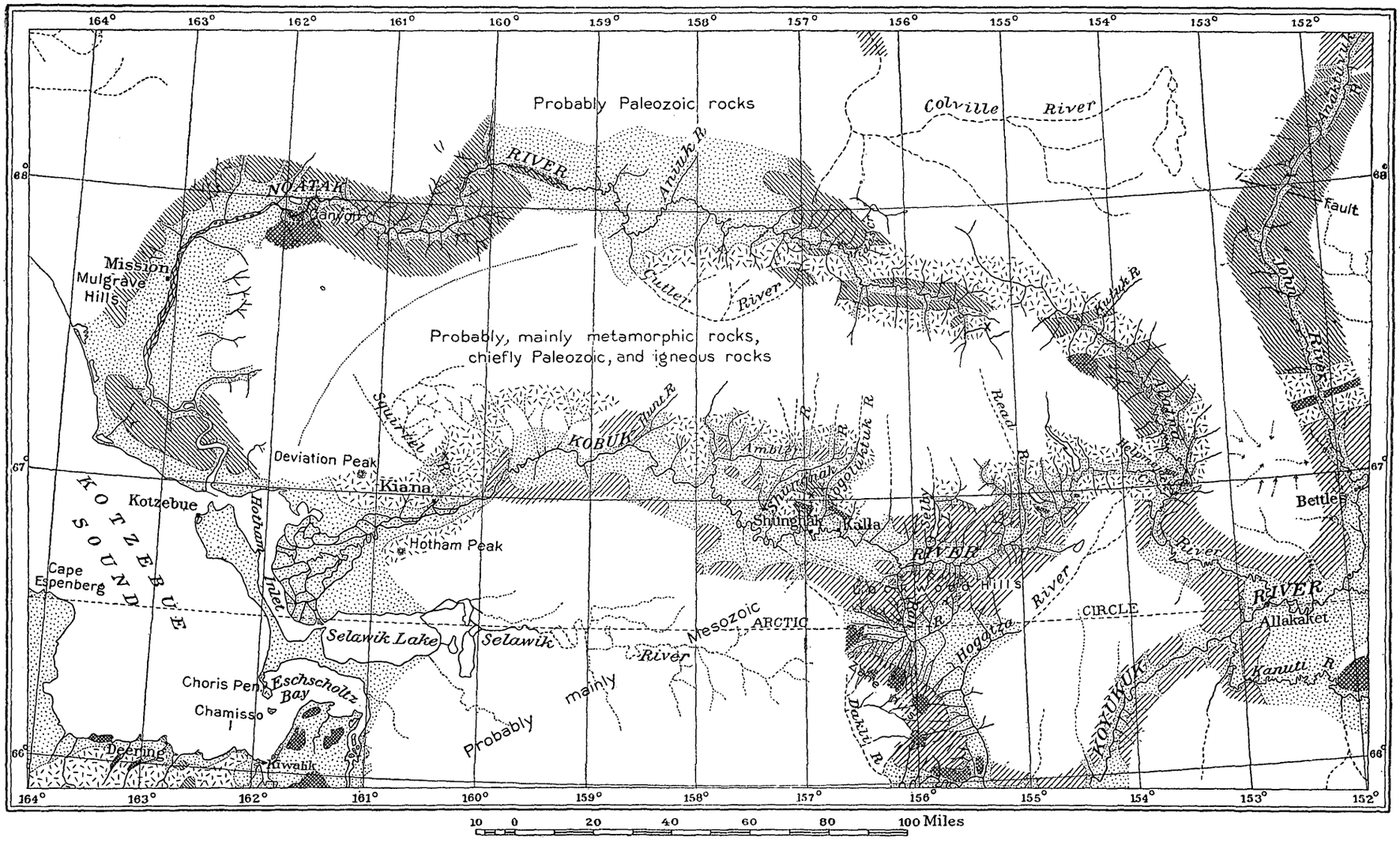
The Alatna River valley has a general northwest-southeast trend. It is about 140 miles long and is somewhat narrow in proportion to its length. This basin consists of two topographically rather distinct parts—a southern, carved in relatively weak rocks, having subdued topographic features, and a northern, carved in more resistant rocks, characterized by rugged mountains. In the southern part the valley floor is a wide gravel-filled lowland in which the stream, from

one-quarter to one-eighth mile in width, meanders extensively. Here and there rocks outcrop on either side of the river, but although the current is too strong to allow rowing there are no obstructions to navigation for shallow-draught boats.

The mountain province extends northward from Helpmejack Creek. In the part of its course that lies in this province the river flows on a flood plain that ranges in width from 1½ miles in the southern part to only a few feet in the northern, the stream itself reaching in places a maximum width of one-eighth mile. For 40 miles north of Helpmejack Creek the course of the river is very sinuous, although the valley is straight. Farther up the stream meanders less and the course of the valley is nearly straight. Under ordinary conditions the river is navigable by canoes as far as camp July 23, but in its upper 25 miles its gradient is so steep that it is an almost continuous succession of riffles. Several rather large tributaries that drain the unexplored country to the east and west enter the Alatna in this province. A stream in one of these valleys in the central part of the mountainous region was ascended to its head and was found to have its source in several small glaciers. None of the glaciers was more than 2 miles long, but all of them appear to be the shrunken remnants of more extensive glaciers that once occupied much of the Alatna Valley.

The slopes from the streams to the top of the ridges are everywhere steep; in the smaller, newer valleys they are the result of normal erosion, but many of the slopes of the larger valleys have been oversteepened by glaciation. The detritus that has fallen from the cliffs above or has been deposited by agencies formerly operative is a prominent feature on the lower slopes. Higher on the hillsides this mantle becomes thinner until on the steeper slopes exposures of bedrock dominate. The ridges are narrow and range in elevation from 4,000 to 8,000 feet. The crests are undergoing rapid degradation by erosion, so that they nowhere preserve any considerable area of an earlier topography.

The Noatak Valley in the main trends east and west, though in its lower part it makes an abrupt bend and has a nearly north-south course. One of the most notable features of the region adjacent to the Noatak is the succession of highlands and lowlands through which the river flows. At the headwaters of the Noatak there is the same mountainous region as at the head of the Alatna. This province is about 75 miles long and is characterized by lofty mountains, many small glaciers, and steep slopes. The river, which is about 300 feet wide, has cut a meandering channel through ancient gravels in a flood plain that is about 2 miles wide at its western end. Farther downstream the mountains gradually recede from the river, which in this lower stretch flows through a lowland 70 miles long and 10 to 35



QUATERNARY

Silts, sands, and gravels of fluviatile, glacial, and marine origin

MESOZOIC AND TERTIARY

Sandstones and conglomerates of Upper Cretaceous age, some Lower Cretaceous sandstones, shales, and tuffs, and Tertiary sandstones and conglomerates

PALEOZOIC

Limestones, sandstones, and quartzites, practically unmetamorphosed though greatly deformed. Fossiliferous portions mainly Devonian and Carboniferous

METAMORPHIC SEDIMENTARY ROCKS

Schists, slates, thin limestones, all much metamorphosed. Numerous small quartz veins. Age undetermined, probably early Paleozoic or older

IGNEOUS ROCKS

Granite, andesite, greenstone, and basalt Paleozoic to post-Mesozoic in age

x Placer prospect

GEOLOGIC SKETCH MAP OF ALATNA-NOATAK REGION.

miles wide. Still farther downstream the mountains on the north and south again converge, and the river flows in a rather narrow valley through a range of hills from 3,000 to 4,000 feet high. This mountainous topography extends along the river for about 60 miles. The western end of this part of the river valley is marked by a narrow canyon, 600 to 800 feet deep, with rock walls on both sides of the stream. Below this canyon the hills again recede, and the river flows through another lowland, 50 miles long and 20 to 30 miles wide. This nearly flat lowland rises only a few hundred feet above the river and bears innumerable lakes on its surface. On the south this lowland abruptly terminates against a range of hills, 1,500 to 2,000 feet high, which form another distinct topographic province. The Noatak cuts through this range in a narrow gorge, 400 to 600 feet deep, the bedrock jutting into the river in fantastic pinnacles. These hills trend in general east and west and are from 10 to 15 miles wide. South of the hills the country near the river is low, in few places rising more than 200 feet above the sea and at its southern margin being submerged by the waters of Kotzebue Sound during periods of high water.

Throughout its course as far as camp July 28 the Noatak is navigable by canoes, and in this distance has few dangerous places. In the upper part of its course the stream has washed out of the gravel deposits through which it flows many large bowlders that make riffles which require careful watch. In the lowland north of the mountains near the mouth the stream splits up into so many channels that the depth of water in any one is not always sufficient to float a boat and therefore the course must be selected with care. Except at the very mouth of the river the current is so strong that little or no progress can be made upstream by rowing or sailing. Good tracking can usually be found, though the numerous meanders, with cut banks, make frequent crossing from side to side necessary.

Passes from the Noatak to the Colville on the north, to the Alatna on the east, and to the Kobuk on the south are known and have been traversed. One pass to the Colville lies between longitude 156° and 157°. (See map, Pl. XV.) At this place the divide is about 2,000 feet above and 7 miles distant from the Noatak, and floating water could probably be reached by a portage of not over 13 miles. Other passes, by way of Aneyuk River, may also occur, but they have not been examined. The pass used by the Survey expedition in crossing from Alatna River to the Noatak is about 13 miles in an air line between floating water, and the divide was 1,000 feet high, with small lakes on the summit. Another pass, farther up the Noatak, leads into a stream joining the Alatna about 8 miles below the one just described. It is much longer and more difficult and therefore not to be recommended. Opposite the higher pass of the Noatak there is a

pass to the upper Reed River of the Kobuk drainage and another pass to the same stream is reported by way of the southern fork of the Noatak. Both of these are steep and difficult, but prospectors say that horses can be taken over them. Natives report that the valley of the large stream coming in from the south about 12 miles above Midas Creek affords a good pass into the Kogoluktuk and is much used by hunting parties. Other passes into the Kobuk farther downstream undoubtedly occur but have not been explored.

CLIMATE.

Instrumental climatic observations have not been made in the Alatna-Noatak region except at Allakakat, at the mouth of Alatna River. The records at this place show that the mean annual temperature is about 15° F. This temperature, however, is probably higher than that of the Alatna-Noatak region as a whole, for the observations were made at an elevation of only 500 feet and nearly a degree farther south than the greater part of the region considered in this report. As a result of this low temperature the country is icebound nearly nine months of the year, so that it is almost impossible to reach it from the United States much before the first of July. Ice in the lakes at the head of the Yukon basin prevents passenger boats from running until nearly the middle of June and from reaching the Alatna much before the first of July. The last boat down the Koyukuk usually leaves the head of the river by the first week in September. Approach to the region by Bering Sea and Kotzebue Sound is even later than by way of the Koyukuk, for Kotzebue Sound usually does not open before the first week or so in July and is likely to close before the end of September.

The annual precipitation at Allakakat is from 10 to 15 inches, which is probably less than that in the region as a whole, for, other things being equal, a low region like that near the recording station does not receive so much precipitation as highlands. Although precipitation in the region is small, much of it comes in summer and the traveler therefore gains an impression that it is greater than the actual amount. In 1911, for instance, 37 out of 64 days were partly rainy, but the rainfall on many of these days consisted of small showers, during which only 0.01 inch of rain fell. Much of the precipitation is snow, which may be expected during practically every month of the year in the hills and the higher mountains. In 1910 snow covered the high hills between the Kobuk and Noatak on July 14, and in 1911 the hills opposite the Alatna-Noatak pass were snow-covered on July 26. The snow that fell during these storms, however, remained only a few days.

POPULATION AND SETTLEMENTS.

The main settlement in the region is at Kotzebue. The Noatak mission, about 50 miles above the mouth of Noatak River, and Allakakat, on the Koyukuk, at the mouth of the Alatna, are the only important villages. Kotzebue is normally the home of a missionary and family, three or four traders, a few boatmen, and a settlement of natives, but after the breakup of the ice in the spring many whites and natives from the neighboring rivers and coast towns congregate there for trading and fishing, and a thousand or more people are camped along the beach or in the town. Mail service is maintained by boat every 10 days during the summer and by dog team once a month during the winter. The nearest telephone station is at Kiwalik, 80 miles to the south, and the nearest telegraph office is at Nome, 200 miles to the southwest. Travelers from Nome can reach Kotzebue in summer by the mail boat, a gasoline schooner. The trip takes about 3 days, as stops are made at way points, and the charges in 1911 were $25 apiece for passengers and $20 a ton for freight. Large vessels from the States can not approach Kotzebue nearer than Cape Blossom, an unprotected headland about 12 miles distant, because the channel is so narrow, crooked, and shallow that it can not be navigated by boats drawing more than 6 feet. Supplies of good quality and in sufficient quantities to meet the demand can be obtained in Kotzebue at prices but little higher than those in Seattle plus the freight charges.

Allakakat is the name of the mission of St. John in the Wilderness, on the Koyukuk, directly opposite the mouth of Alatna River, and Marsans, about a mile downstream, is the trading post. The two together form practically one settlement. At the mission is the missionary and the Government school-teacher and a small settlement of natives; at Marsans is the store and a few natives. The post office is at Bettles, but mail is delivered along the route. In summer communication is by boat and in winter by dog sledge that leaves the Koyukuk near the mission and reaches the Yukon near the mouth of the Tanana. The nearest telegraph station is at the Government post at Fort Gibbon.

The Noatak mission is on the west bank of the Noatak, on a gravel terrace. The settlement consists of a church, schoolhouse, and several well-built cabins belonging to whites and natives. It was practically deserted when visited by the Survey geologists, as the inhabitants spent the summer at Kotzebue. Farther downstream, however, the Survey party passed nearly a score of boats loaded with families bound for their homes at the mission.

It is almost impossible to estimate accurately the population during the summer, for many of the people are away on trading or hunt-

ing trips, but it seems fairly certain that less than 100 white people live in the basin of either the Alatna or the Noatak, including the settlements at Allakakat and Kotzebue. The general impression was that the total number of natives in the basin of the Alatna and the Noatak was not over 250. This would indicate that the total population is therefore not more than one person to 50 square miles of territory.

ANIMALS.

At the headwaters of both the Alatna and the Noatak game was fairly plentiful. In the mountains sheep were numerous, and natives make annual hunting trips from distant points to this region. In the low country in the Noatak basin, just west of the mountains, caribou are fairly numerous and are sought not only by natives from farther downstream but by those from the Kobuk as well. In this same region many signs of fox, wolf, and martin were seen along the banks of the river. Bear tracks were particularly plentiful along the bars north and east of the Noatak Mission as far as the canyon and evidently were made by large bears. In the central part of the Alatna Valley evidences of bear were observed, but they were not plentiful and only small black bears were seen. On the lakes and sloughs at the lower part of the Noatak hundreds of ducks, geese, cranes, and other birds were seen. Water birds are reported to be numerous also near the mouth of the Alatna. Flocks of ptarmigan were seen in the central part of the Alatna Valley and in the Noatak Valley near its mouth. From the number of animals seen it is believed that they could be relied on as food by prospectors.

Fish are abundant in the Alatna and probably also in the Noatak. Salmon are reported in the lower Alatna, and some were seen on native drying frames at the Noatak Mission. It is said that they run up as far as the Aneyuk. Most of the Noatak natives, however, go to Kotzebue for salmon fishing, as the fish are better in salt water than they are after they have gone a long distance in fresh water. Grayling and white fish are caught in the Alatna and the Noatak. The members of the 1911 expedition shot several pike in Lake Takahoola in the Alatna River basin. Although few of the streams were actually tried for fish, their similarity to other streams in northwestern Alaska that have been tested leads to the belief that prospectors and travelers could probably get enough fish for ordinary needs in most of them.

VEGETATION.

The vegetation of the Alatna-Noatak region is typically Arctic and sub-Arctic. In the lowlands, near the river, bushes are common, but toward the higher regions the vegetation gradually disappears until,

on the steep slopes and the crest of the ridges, even grasses are practically absent. Spruce is found in the Alatna basin to within 3 or 4 miles of the stream leading to the Noatak portage. The trees in the southern part of the basin average 10 to 12 inches in diameter and extend up the slopes to an elevation of 1,000 to 1,500 feet, but the diameter and the elevation of the upper border of the tree zone gradually decreases upstream until at the irregular bend 13 miles below camp July 23 the diameter of the spruce is from 6 to 8 inches, and even the scattered trees do not extend more than 500 to 600 feet above the river. The northern limit of spruce is decidedly abrupt.

In the Noatak Valley the most eastern locality where spruce is found is about 10 miles east of the canyon. At this place spruce 8 inches in diameter appears as a narrow fringe along the well-drained banks of the river. Farther downstream spruce grows almost everywhere in the immediate vicinity of the river down to a point midway between the most southern hills and the mouth of the river, where it is again absent. Over much of the swampy lowland back from the streams, on the hill slopes, and in the entire area east of the canyon spruce is absent. This absence of timber is a decided handicap to development, for all lumber used in mining or in constructing cabins must be brought into the region.

The grass in the valley is sufficient for pack animals that are traveling, but not sufficient for the permanent pasturage of a large number of animals. Red-top grass is particularly abundant around old cabins and settlements, but although it grows luxuriantly it does not appear to afford as much nourishment as the tougher, smaller, less abundant grasses that grow on the lower hill slopes. Caribou moss is plentiful in the better drained lowland areas, especially those near Aneyuk and Cutler rivers, and on the hill slopes a short distance back from the coast. These hill slopes have been used as the feeding ground for the herd of reindeer that was introduced by the Government and that ranges between the mouth of the Noatak and Cape Kruzenstern.

Berries are generally plentiful in the low areas and form an important part of the local food supply of both the natives and whites. Blueberries, cranberries, currants, and salmon berries are the most abundant, and owing to the cold climate those picked in summer can be kept throughout the year without deterioration. It is said that the natives collect many berries after they have been frozen on the bushes, as they can then be knocked off with sticks and can be more easily cleaned of twigs and leaves.

DESCRIPTIVE GEOLOGY.

DIVISIONS OF THE ROCKS.

Most of the Alatna-Noatak region is still so little known that data are not available for a final statement of its geology, but certain general facts seem to have been sufficiently defined to warrant a general description. The rocks may be divided into three main classes—sediments, igneous rocks, and veins. The sedimentary rocks have been further divided into metamorphic rocks, Paleozoic sediments, Mesozoic and Tertiary rocks, and unconsolidated deposits. The igneous rocks have been divided into the metamorphic and non-metamorphic rocks, and the veins might also be similarly grouped. Each of the larger groups has been indicated on the geologic map (Pl. XV), with the exception of the veins, which are too small to be shown. The four divisions of the sedimentary rocks have been distinguished by separate patterns, but all the igneous rocks have been shown in a single pattern.

SEDIMENTARY ROCKS.

METAMORPHIC ROCKS.

Metamorphic schists were seen only in the middle and upper parts of the Alatna and in the headwater part of the Noatak. The physical character of these rocks indicates that they are the equivalents of the Nome group of Seward Peninsula. This view is shared by Mendenhall, who studied similar rocks in the Kobuk region, to the south, for he says: "The rocks here described are regarded in a general way equivalent to those described by the writer in a previous paper[1] as the metamorphic series."[2] These rocks are the oldest in the region and have been deformed during at least two periods of mountain building.

Lithologically the metamorphic rocks are quartzose schists containing an abundance of chlorite, some muscovite, practically no biotite, and in many places considerable calcite. In color they range from greenish gray to nearly black. The green color is due to chlorite; the black color is usually caused by carbonaceous material. Here and there the schists have a brown, iron-stained appearance, due to the weathering of the iron sulphides that are disseminated through the rock. These sulphides appear to be of later origin than the schistose structure, for well-developed cubes, entirely unsheared and otherwise undeformed, were found in the schists at many places. The pyrite in the schist occurs not in veins but in cubes that are

[1] Mendenhall, W. C., Reconnaissance in Norton Bay region, Alaska, in 1900: Special publication U. S. Geol. Survey, 1901, pp. 109–204.

[2] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 31.

scattered irregularly throughout the rocks. In addition to the disseminated sulphides there are others, closely associated with the quartz veins, which are everywhere numerous in the schist members and are described on pages 18–19.

Although the schists are dominantly quartzose in the lower part of the section they become more calcareous as they approach the thick overlying Paleozoic limestone. The relation of the schists to the overlying limestone has not been satisfactorily demonstrated. The much more deformed character of the schists suggests that an unconformable relation exists between the two groups, but the considerable difference in resistance to dynamic metamorphism of the two rocks makes other interpretations possible. Perhaps the fact that raises strongest doubt as to the unconformity between the schists and the next younger rocks is the notable increase in the calcareous content of the schists toward the top of the section.

No fossils have been found in the schists and consequently paleontologic evidence as to the age of these rocks is wanting. The apparent greater metamorphism and the stratigraphic position of this series warrants its assignment to the lower part of the geologic column. No known fact precludes the assignment of the schists to the early Paleozoic, but, on the other hand, nothing is known that would prevent their assignment to the pre-Paleozoic.

PALEOZOIC ROCKS.

Although it is possible that the metamorphic schists may be Paleozoic, it seems advisable to differentiate as Paleozoic a great thickness of sediments, ranging in lithology from shales and sandstones to limestones, which are much less metamorphosed and seem, on the whole, to be younger than the schists. These rocks have not been nearly so much sheared and metamorphosed, yet they present structures that are by no means simple but that have been so deformed that the series as outlined on the map may include representatives of both higher and lower horizons that have been infolded or infaulted. The delimitation of this series, as a whole, however, marks the areas of less metamorphosed sediments that overlie the schists.

The oldest part of the Paleozoic rocks recognized on Alatna River consists of the very thick limestones that form a belt about 20 miles wide in the central part of the basin. Throughout this distance the rock is almost uninterruptedly a bluish-white limestone, though it includes some dark carbonaceous phases. Many specimens of the limestone show evidence of recrystallization and brecciation. Bedding is usually difficult to discriminate, and although at a distance the structure appears to be relatively simple, close examination shows that it is complex. The general trend of this limestone is east-west,

but the dip changes from north to south so frequently that numerous reduplications must occur.

In the Alatna River region no paleontologic evidence as to the age of this limestone was obtained, but a similar series of limestones on John River, which Schrader called the Skagit formation, yielded fossils that indicated that the rocks were not older than upper Silurian and not younger than lower Carboniferous.[1]

This is probably the same limestone that was seen on the headwaters of the Noatak and that forms some of the high, rugged peaks in the eastern part of the divide between Noatak and Kobuk rivers. It is also probably present near the gorge of the Noatak and in the hills near the mouth of the river, but fossils were not found in it at these places, and the correlation rests mainly upon the stratigraphic position and lithologic similarity.

In the vicinity of the Noatak canyon a dolomite forms part of the country rock south of the river. The fossils from this place were not diagnostic, but the dolomitic composition of the rock suggests correlation with the only dolomite horizon known in Seward Peninsula, which is of upper Silurian age, is widespread throughout Alaska, and is everywhere dolomitic. Dolomite is also exposed in the lower gorge of the Noatak where the stream crosses the range near the coast. It is underlain by calcareous schists whose contact with the dolomite is but poorly exposed. This dolomite is a compact, rather dense rock showing few of the solution markings that are common on the other limestones. It is usually whiter than the limestones and rarely contains fossils. At many localities it is brecciated, and at the outcrops near the canyon, where it occurs near intrusives, it exhibits some cherty phases.

Another important part of the series which is included here with the Paleozoic rocks but which on subsequent study will probably be differentiated from the other members is the sandstone, quartzite, and limestone series in the central part of the Noatak basin, from the western part of the lowland near Aneyuk River westward to the canyon. These rocks are less metamorphosed than the other Paleozoic rocks, but have been much deformed and closely appressed, and show overturned folds and thrust faults. Although cleavage and jointing have been produced by the forces to which these rocks have been subjected, the bedding has in few places been entirely obliterated, and as a result most outcrops clearly show both bedding and cleavage.

The rocks are dark grayish to green on fresh exposures, at a distance appearing almost as light as some of the limestones. Some

[1] Schrader, F. C., A reconnaissance in northern Alaska across the Rocky Mountains, along Koyukuk, John, Anaktuvuk, and Colville rivers, and the Arctic coast to Cape Lisburne, in 1901; Prof. Paper U. S. Geol. Survey No. 20, 1904, p. 57.

shales that form part of this series are nearly coal black and others are light green. The prevailing tone, however, is dark, and the rocks can not be readily recognized at any great distance either by their color or by their physical characters. Generally speaking, however, the rocks are hard and form many of the higher hills in the area in which they occur.

Fossils have been collected from these rocks at several places, and the paleontologic determinations show that they are Carboniferous, probably Mississippian. This determination is of interest, as it shows that the rocks reported by Collier[1] in the Cape Lisburne region and by Schrader in the John River basin also occur in the intervening country.

Some shales and slates have been provisionally assigned to the Paleozoic rocks because of their interrelation with known fossil-bearing limestones and other rocks. These shales and slates differ from the schists in that they are not so highly metamorphosed and their original structures are better preserved. The thickest series of these rocks examined was found in the vicinity of Midas Creek. They are dark green in color, rather fine grained, and have well-developed slaty cleavage. They contain many small faults and probably some larger ones, which escaped detection because faulting brought like rocks into juxtaposition. However, even with due allowance for reduplication through faulting, a thickness of several thousand feet must be assigned to this division.

MESOZOIC AND TERTIARY ROCKS.

It is highly probable that some members which might on more detailed study be placed elsewhere have here been included in the Paleozoic. In fact, it is by no means certain that there was a decided stratigraphic break at the top of the Paleozoic, and therefore correlations based mainly on long-range observations and general stratigraphic sequence would fail to note faunal breaks unassociated with marked lithologic or structural discordances. Although some younger sediments may have been inadvertently included in the Paleozoic, the main representatives of the Mesozoic to which attention will be directed in this section are the Cretaceous sandstones and associated sediments, recognized in the region under discussion only on the lower part of Alatna River.

These rocks are entirely unmetamorphosed, although compact, well indurated, and so deformed that dips of 45° or more are common. A few thin conglomerates appear in the section, but the series as a whole consists of dark greenish-gray sandstones, with thin shaly beds.

[1] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: Bull. U. S. Geol. Survey No. 278, 1906.

The conglomerate phase becomes more pronounced toward the border of the basin, and Mendenhall notes that about the mouth of Helpmejack Creek, near the former Cretaceous shore line, the basal portion of the formation consists almost exclusively of conglomerate containing pebbles of the older formations to the north.

Although this series of rocks has been classified as Mesozoic by Mendenhall and as Cretaceous(?) by Schrader, both of whom called it the Bergman series, its age was not determined on paleontologic evidence. Mendenhall[1] states that it contains indistinct plant remains, but it has yielded no determinable fossils. The rocks are certainly younger than the Paleozoic rocks to the north and their greater induration shows that they are probably older than the Tertiary deposits of Dall River. Their lithologic similarity to the rocks extending from Nulato to Seward Peninsula, specimens of which, collected by the writer in 1909, yielded Cretaceous fossils, indicates that they are of Mesozoic age.

UNCONSOLIDATED DEPOSITS.

The purpose of the present paper is not so much to describe all the different deposits examined as to point out the general types recognized. Three main types of unconsolidated deposits were distinguished—marine, glacial, and stream gravels. All three are shown in one pattern on the map (Pl. XV).

MARINE GRAVELS.

The recognized marine deposits occur mainly along the Arctic seacoast and the lower portion of the Noatak. These deposits are only in part marine, for in places there were alternations of marine and fluviatile action, such as are now seen in the delta of the Noatak. The deposits at such places therefore present features characteristic of both agencies. None of the marine deposits have been prospected and consequently the history of the gravels has not been made out, but they have probably accumulated in the same manner as the coastal plain gravels in parts of Seward Peninsula.

No sections of the typical marine gravels along this part of the Arctic coast have been examined, and it is not definitely known whether or not the deposits are permanently frozen. From analogy with similar deposits elsewhere it is believed that the more recent marine gravels are not frozen, but that the older ones, which occur at some elevation above the sea, are probably permanently frozen. The presence or absence of permanent frost in the ground has a decided influence on the cost and method of mining, so that a determination of the physical character of the gravels is economically important.

[1] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by way of Dall, Kanuti, Allen, and Kowak rivers: Prof. Paper U. S. Geol. Survey No. 10, 1902, p. 40.

GLACIAL DEPOSITS.

The glacial deposits may be roughly divided into two main classes—those of distinct ice-laid origin and those which have been in part handled by glaciers but whose dominant features were determined by running water. Deposits of the first class are relatively uncommon and even the most distinctive may merge into the second class, so that no sharp line of demarcation between them can be drawn.

The distinctly ice-laid deposits are most notable in the mountain valleys near the heads of the Alatna and Noatak. Even at the present time there are small glaciers in the highlands in this part of the region, and they are transporting and depositing débris and forming glacial moraines. In the past, however, these glaciers were much more extensive and formed deposits that may still be recognized. It is not yet possible to state the limit of these ancient glaciers because their deposits merge into deposits of glacio-fluviatile origin and, furthermore, in the time that has elapsed since the glaciers reached their maximum extent their deposits have been so much modified by later processes that their character or origin has been obscured.

Glacio-fluviatile gravels are widespread throughout both the Alatna and Noatak valleys. In the Alatna Valley ice-transported blocks have been found on divides 2,000 feet above the present valleys and at least 5 miles from their nearest outcrop. Washed gravels up to an elevation of 2,300 feet above the Alatna were noted on the hillsides below Lake Takahoola. Not only are there high-level glacio-fluviatile deposits but numerous outwash deposits, lying not more than 100 to 200 feet above the river, formed by the same agency, were also found. The glaciation in the Alatna Valley, however, was distinctly of the valley glacier type. No evidence of regional glaciation was observed and the known facts preclude the probability of such glaciation.

In the Noatak Valley glacio-fluviatile deposits are even more conspicuous and widespread. Although it was not possible to determine the elevation of the upper limit of outwash deposits at many places, gravel was observed to an elevation of 900 feet above the river near Midas Creek, to an elevation of 800 feet above the river at the canyon, and to at least 600 feet above the river west of camp August 23. These high-level deposits, however, are relatively thin and have but slight topographic expression. The lower outwash deposits, on the other hand, form large areas and are prominent features. They rise from 100 to 200 feet above the river and the river flows through them in narrow gorges, exposing good sections. Much of the material thus exposed exhibits water rounding and many of the sections show stratification. That these deposits are not merely gravels of the former Noatak is shown by the occurrence in them of many large

angular blocks of rock derived from regions relatively remote from the places where they now occur. Some of these bowlders are 10 feet or more in longest dimension. These large bowlders are washed out from the gravel deposits through which the river flows and they form rapids, so that they are particularly conspicuous.

The surface of these outwash deposits is not smooth and even but is marked by depressions, some of which are occupied by lakes of irregular form and extent, which do not simulate abandoned river channels or other normal river features. Evidence of drainage modifications, such as is seen in the neighborhood of the canyon, show that blocking of the normal discharge must have been effected by an agent that has subsequently disappeared—probably ice. This obstruction may have formed lakes in which deposits were laid down. In other words, the late Pleistocene history of the region shows that a complex series of deposits was formed under a variety of conditions and by different processes. The material of all these deposits, however, was acquired mainly by the action of ice, and, although handled by ice or water, or both, it was not so much disintegrated, decomposed, and sorted as if it had been carried to its present position by running water alone.

STREAM GRAVELS.

Little need be said here of the gravels that are distinctly stream deposits. The stream gravels merge, on the one hand, into the marine gravels and, on the other, into glacio-fluviatile deposits. The deposits that are solely of stream origin show by the form, size, arrangement, and lithology of the pebbles their difference from the glacio-fluviatile deposits. The stream-laid gravels, however, are found chiefly in the smaller streams and, except where they are preserved beneath outwash material in protected places, are relatively uncommon in the valleys of the larger streams.

Many of the present streams have been developed in and are eroding the unconsolidated deposits of the preceding geologic period and are therefore really forming typical stream deposits. To the placer miner, however, these do not represent the ordinary single-cycle streams or even streams reworking former stream deposits or benches, for the distribution of the valuable minerals would be far different had they been deposited by one process. It is therefore believed that deposits formed solely by streams are to be sought only in the smaller valleys or in the larger ones where other erosion has been least active. In either class the deposits are likely to be small or discontinuous.

IGNEOUS ROCKS.

GRANITES.

For the purpose of this report the igneous rocks of the region may be divided into two main groups, the granitic and the basaltic. Igneous rocks of the granitic type were recognized in place only in the central part of the Alatna Valley and 20 to 30 miles westward, at the head of the Noatak. There are probably large areas of granite in the unexplored hills between the Kobuk and the Noatak on the south and, possibly, between the Noatak and Colville on the north. The granitic rocks show many phases, ranging from massive, even-grained, moderately fine textured granite to porphyritic gneissoid rocks. The granites cut the limestone of the central Alatna Valley, but contacts were not examined in detail. Granite pebbles found in the basal Cretaceous conglomerate indicate the upper age limit of the granitic intrusives, and if analogy with Seward Peninsula granite intrusives that cut fossiliferous limestones may be accepted, the lower limit of the intrusive period is Carboniferous. The determination thus reached roughly fixes the period of the intrusion between Carboniferous and Cretaceous time.

Topographically the granites form high, rugged peaks having strong relief, which is in a measure due to the character of the rock but is also produced by the glacial sculpturing that centered in the high ranges where the granites occur. The granites have not been closely studied petrographically, so that their mineral composition and lithologic character have not been determined. It is significant, however, that they contain few sulphides and that the surrounding rocks show no pronounced mineralization which was coincident with their intrusion.

BASALTIC ROCKS.

Basaltic igneous rocks were seen at several places in the Alatna-Noatak region. These rocks may be divided into two main groups—an older and a more recent one. The rocks of the older group can not yet be described mineralogically for the lack of microscopic study but are greenstones of medium fine texture, dark-green color, and relatively weak resistance to weathering. It is highly probable that there was more than one period of greenstone intrusion, as certain dikes appear to have been much metamorphosed and others are practically unaffected. This difference, however, may be explained by assuming that the metamorphism affected only rocks near to planes or zones of movement and that the unmetamorphosed greenstones were remote from such planes.

Most of the exposures of greenstone show a compact, rather dense rock. Here and there an amygdaloidal phase was seen which seems to correspond to the igneous greenstone schists which Schrader found in the Totsen group on John River and interpreted as old basaltic flows. Although some of these greenstones may have been of extrusive origin the evidence tends to show that the greenstones occur mainly as intrusive dikes and sills.

The later basic igneous rocks were seen in place mainly in the vicinity of the canyon of the Noatak. They occur as large stocklike intrusions from which apophyses extend into the adjacent sedimentary rocks. In the immediate contact the igneous rocks have locally metamorphosed the other rocks, but the effect does not seem to be widespread. Near the lower end of the canyon some ellipsoidal basalt appears to mark a special phase of this intrusion. The only minerals recognized in hand specimens were plagioclase feldspar and ferromagnesian minerals.

Topographically the later basic igneous rocks weather into numerous pinnacles. They are irregularly distributed and lack the definite trend usual in stratified rocks. Their color is dark, but at a distance is not distinctive enough to differentiate them from the other rocks of the region, except the limestone.

The age of the intrusion of these rocks was not definitely determined. They cut the Carboniferous rocks and are therefore younger than that series, but the absence of later rocks in the neighborhood of the intrusions prevents closer correlation. From analogy with other regions it is believed that they are earlier than the Upper Cretaceous, but final statement of their age must await fuller investigation. The later basic igneous rocks are apparently in no way connected with the recent basaltic flows of Seward Peninsula and parts of the Yukon drainage basin but are much older and are essentially intrusive rather than effusive.

In addition to the two types of basaltic igneous rock that were seen in place, float of a coarsely granular hornblendic rock was found in the stream and bench gravels at several points along Noatak River. Some of the hornblende needles are over an inch long and form nearly three-fourths of the entire rock. Float of this sort was found near Aneyuk River and at the canyon, so that in the hills away from the river there are undoubtedly other intrusives, the extent and relations of which are not yet determined.

VEINS.

The veins of the region may be roughly divided into two main types—quartz and calcite veins. The quartz veins are the most abundant and are economically the most important. They are further divisible into many smaller groups, based on differences in

age or in mineralogic composition. How many periods of quartz vein formations there were is not known, but at least two have been recognized. The older veins appear to have been formed before the metamorphism of the lower schists and to have been afterwards deformed and sheared. As a result, they are much distorted and form discontinuous strings and lenses. These veins lack almost any other visible filling than quartz. Assays of similar veins in Seward Peninsula suggest that at least some of the veins in the Alatna-Noatak region carry gold. Although the gold tenor and the discontinuity of these veins preclude their being mined, they were probably the main sources of the placer gold in the streams.

These deformed and shattered quartz veins appear to be limited to the older schists, and if they are so restricted this fact will help to indicate where placers may be found.

The quartz veins that were formed after the main period of metamorphism are widespread. They occur in all the groups studied in this field, but are seldom found in the limestone, except near its contact with other rocks. The later quartz veins are mostly gash veins, formed by the fracturing of the rocks through deformation. The quartz in these veins seems to have migrated from the adjacent rocks, under such conditions that the chances of finding any economically valuable minerals in them are not good. None of these veins have been sampled, so their presumptive value is based mainly on the theoretical interpretation of the mode of filling. Sulphides or metallic minerals have not been recognized in veins of this type.

There are, however, other later quartz veins which seem to have had a deep-seated source and probably contain minerals of economic importance. Although these veins have not been so thoroughly metamorphosed as the older veins, they are more or less faulted and discontinuous. Many, however, show the typical comb structure usual in veins which have not been completely recrystallized. Some of these veins contain sulphides in small amounts, and if the evidence afforded by veins of similar type in Seward Peninsula is applicable to veins in this region, they may carry free gold. These veins were not large enough to warrant exploitation as lodes, but where processes of concentration have been effective they undoubtedly contribute some gold to placers.

Although veins of this type have been found at many places throughout the Alatna-Noatak region, they are more abundant in the schistose rocks than in the overlying limestones. In fact, it is relatively unusual to find quartz veins extending far into the limestones. Their absence is probably due not to the fact that the higher rocks were deposited after the formation of the veins but rather to the fact that extensive fissures could not be maintained in a rock that flows so easily under pressure as a limestone.

Calcite veins are confined almost exclusively to the limestone areas and rarely extend into the schists for more than a short distance from the contact. As a rule, they are similar to the quartz veins of the gash type and, like those veins, are believed to have been formed by the filling of fissures produced during the deformation of the region, their material being derived from the rock in their immediate vicinity. Calcite is practically the only mineral filling these veins. A few contain also a small amount of quartz but no sulphides. One calcite vein in Seward Peninsula carries free gold, but it is the only one of its kind known in the region. It is believed, therefore, that the calcite veins in the Alatna-Noatak region not only do not warrant exploitation as lodes but also did not afford material for productive placers.

So far no connection has been traced between any of the veins of these types and the igneous intrusions. The absence of definite proof, however, does not preclude the possibility of such a relation, but this can be determined only by more detailed investigation. The source of the vein filling in the two types of veins known to carry minerals of commercial value—the metamorphic quartz veins and the younger quartz fissure veins—is yet undetermined. The greenstones and associated schists show some sulphide mineralization of a disseminated type that may have been brought in during or immediately after the intrusion of this rock. The amount of mineralization from this source, however, seems to have been relatively slight. Sulphides are found also in the gabbro at the Noatak Canyon but only in grains scattered throughout the rock, and their mineralizing effect does not seem to have extended far beyond the contact. In the regions occupied by granite a very little disseminated sulphide mineralization was observed, but it was so slight that the rocks show practically no iron stains on weathered surfaces.

ECONOMIC GEOLOGY.

The region covered by this report is practically unprospected for metalliferous resources. A few prospectors have passed rapidly through certain parts, but have done no permanent development work. Probably not more than a hundred prospectors have traversed the 10,000 square miles covered by the Survey party in 1911, and it is doubtful whether at present there are half a dozen white men even intermittently engaged in prospecting in the region. Prospecting has been done in two main regions, the Alatna Valley and the Noatak Valley.

ALATNA RIVER REGION.

During the excitement of 1898 many prospectors reached the Kobuk and Koyukuk valleys and some disappointed ones essayed the Alatna. They found little of value, however, and some strikes elsewhere

caused them to abandon their holdings and leave for more promising camps. In the Alatna Valley, where the schists form the bedrock, a little placer gold was found, and some sulphide-bearing veins were staked and held for many years awaiting a boom. Practically no work was done to open up the leads, and when the place was visited in 1911 a few insignificant pits driven on quartz stringers were the only visible traces of this early work.

In this same general belt of rocks, but farther east, on a small tributary of Malemute River called Mecklenburg Creek, a prospector reports having found colors of gold in the creek gravels. This locality was not visited, and nothing of importance was learned of the occurrence and no workable deposits have been developed. The gold is in small particles, rarely flaky, and is of a reddish color. No black or rusty gold was reported. In the concentrates magnetite is very abundant, but garnets are only sparingly found.

Some prospecting has also been carried on north of the larger limestone belt, where the dark slates form the country rock. Two prospectors have found sufficient prospects on the Kutuk to cause them to continue exploration, but they have uncovered no gravels of workable value. Work at this place has been carried on only in the shallow gravels of the present stream. It is believed that the gold has been derived from quartz stringers and veins in the slate. Magnetite is abundant in the concentrates, but garnets are practically absent.

Schrader notes that in 1902–3 prospectors reported lode deposits carrying gold and copper in the divide between the Alatna and Noatak. The veins were said to consist essentially of quartz with pyrite and chalcopyrite, but some specimens contained stibnite also. The location of the veins was given very indefinitely and they were not seen in 1911. The fact, however, that the highest assays made by the Survey of the specimens brought out by the prospectors carried less than $2 a ton in gold, as well as the fact that no work has been done recently in the region, shows that the tenor was not sufficient to warrant development under the high costs prevailing in the upper Alatna Valley.

NOATAK RIVER REGION.

Within the Noatak basin gold has been found mainly in the headwater region. Even there, however, only two small areas have been reported to afford placer ground and of these only one, that near Lucky Six Creek, has produced as much as a hundred dollars worth of gold.

INDEFINITELY LOCATED PROSPECTS.

In this region, as in others, reports of lost prospectors finding enormously rich deposits are common. Unfortunately, however, these "finds" can not be located when subsequently sought and the less

that is known about them the more their reported value tends to increase. An instance of this sort was the reported discovery of rich gold quartz in the vicinity of Mount Kelley, a hill about 40 miles north of the southward bend of the Noatak, west of the canyon. On attempting to learn about this gold quartz it was found that the locality was stated in an extremely indefinite way, varying from the Igichuk Hills, near the mouth of the river, to the region beyond the Noatak drainage. Gold-bearing quartz may have been found in the Noatak basin, but when its location is given so indefinitely it is not possible to discuss the significance of the reported discovery.

Gold quartz has also been reported in the hills south of the river, a short distance east of the canyon. A prospector from Squirrel River, of the Kobuk basin, with pack horses, spent part of the fall and winter of 1910 in the hills north of Squirrel and Salmon rivers and returned with numerous specimens of quartz, some showing free gold. It was not possible to obtain a description of this trip at first hand and consequently most of the information is indefinite. That the prospector was satisfied with the indication of mineralization is shown by the report that he intends to return and carry on further exploration during the winter of 1911–12. Presumably the country rocks in this region are schists and metamorphic limestones, a ground that has elsewhere generally proved auriferous.

A short distance below the canyon a prospector's cabin, which evidently had been occupied during the previous winter, was visited. A well-worn trail led to a near-by creek, and there were indications that placer prospecting had been in progress. No information concerning the results of this work could be obtained. The geology in the neighborhood does not indicate a near-by source of gold, and the abandonment of the claims suggests that the returns were probably small.

In addition to gold, veins carrying copper and silver ores are also reported in the Noatak region. The silver ore is said to occur on the north side of the Kobuk-Noatak divide, between the Reed and Mauneluk River portages. Nothing was learned of the geology or of the mode of occurrence. The same prospector[1] reports that farther west, on the Noatak side of the pass from Kogoluktuk River, there is a considerable deposit of copper ore, and float of native copper is found in some of the streams. This place is probably in the headwaters of Ipmilouik River, a tributary of the Noatak above Midas Creek. Assays are stated[1] to have shown 9.81 per cent copper and 27.73 per cent lead, but the samples were not representative, being selected specimens. This ore is said to carry also some gold and silver. An assay of ore from what is supposed to be a continuation of the same vein on the Kobuk side of the divide is reported to have

[1] Lloyd, L., unpublished letter.

yielded gold and silver to the value of $1.24 a ton. No work has been done at this place; in fact, it was only discovered and a few samples taken during a hurried trip from the Kobuk to Lucky Six Creek.

LUCKY SIX REGION.

The only place where placer gold has been produced in the Noatak basin is on Lucky Six Creek, a stream joining the Noatak from the east about 12 miles in an air line south of the mouth of the stream heading in the mapped pass to Alatna River. Gold was discovered on this stream in 1898 and from time to time since that date small parties of prospectors have visited the region. This place is so inaccessible, however, that men have spent only a few days there. Not only is the region inaccessible, but it is also difficult to prospect, for lack of timber. It is reported that the planks used for making sluice boxes were whipsawed by hand on Reed River (a tributary of the Kobuk) nearly 30 miles away and hauled by dogs and men to Lucky Six. There were no logs for cabins and consequently the prospectors lived in tents. Although it is now known that spruce can be obtained in the Alatna Valley not more than 12 miles in an air line from the mouth of the creek, yet the labor of transporting lumber even this distance and over a divide at least 1,000 feet high is a great tax on time and energy. Even wood for fuel is scarce and is mainly green alder and willow.

The Lucky Six basin was not surveyed by the Geological Survey party, but the general geology was learned from a study of the stream to the north. This creek, known as Twelvemile Creek, is not more than 10 to 12 miles long. For about half a mile above its mouth the stream meanders on the outwash gravel plain of the main Noatak. Farther up in the hills the stream flows in a narrow, precipitous gorge incised in bedrock and early glacial deposits. In this stretch it is not more than 50 feet wide, even during times of high water, but it is a roaring torrent and its bed is full of huge bowlders that make crossing difficult. Still farther upstream the gradient of the valley decreases, but in the headwater region it again increases.

The Lucky Six region presents many geologic problems, for it contains various groups and kinds of rocks in intricate relations. The larger part of bedrock appears to have been originally a sediment that was subsequently metamorphosed. No large masses of granite were seen in place, though they are reported by prospectors and may exist in the more remote parts of the valley, which were not explored. Limestones form a considerable part of the divide north of Twelvemile Creek and appear to have a general east-west trend. The direction of the structure in the schists, however, is not constant, though it, too, appears to strike east and west and to dip north.

Gravel and partly rounded morainic material extend to an elevation of 1,500 feet above the creek, or 4,000 feet above the sea. It is reported that the gold was found not in this material but in the cracks and crevices of the bedrock in the creek or in the very shallow present-day creek gravels. All the gold is said to be notably coarse, fine flaky pieces being extremely rare. It is described as shaped like "pumpkin seeds," has a reddish color, and assays about $19.20 an ounce.[1]

While the members of the Survey party were in this region in 1911 they met three prospectors who intended spending the winter there. These prospectors had started up Alatna River in a light-draft steamboat with supplies for two years, but about 40 miles above the mouth their boat had been stopped by low water. They therefore decided to make a rapid reconnaissance of the region and await the freeze up before moving their supplies to the Noatak. Consequently the men, with supplies for a month, visited the headwater region and did a little prospecting. Their work was decidedly surficial, and it is understood that the returns were not sufficient to induce the men to hold to their original plan of wintering at this place.

MIDAS CREEK REGION.

From these same prospectors, one of whom had been in the headwater region of the Noatak in 1904, it was learned that placer gold had been obtained on Midas Creek, a tributary from the north joining the main stream near camp August 2. The gold found was reported to be in small particles, all of which were rather well worn. In 1911 the Midas Creek region was again visited by these prospectors and, although their work was superficial, they obtained certain significant results in connection with the geologic observations made by the survey party. It seems that disseminated gold in fine particles was found in the creek and ancient gravels of the Noatak, both north and south of the river, but the gravels of the tributaries of Midas Creek that are derived entirely from the hills north of camp August 2 are not auriferous. The geologic study of the rocks forming these hills indicates that they differ from the metamorphic schists in that they are younger and belong to the group described as the Paleozoic sediments. (See p. 13.) The older rocks that are more likely to be mineralized apparently form the bedrock to the south and underlie those forming the hills in which Midas Creek rises. It is therefore believed that the gold reported to have come from Midas Creek was derived either from the older rocks forming the southern part of the basin or may have come from outwash gravels that have been transported for long distances. These ancient gravels have been recognized up to an elevation of 1,000 feet above the

[1] Lloyd, L., unpublished letter.

mouth of Midas Creek and are believed to have been mainly of glacial origin.

Some prospecting has also been done on the south side of the Noatak opposite Midas Creek. Although it is reported that small colors of gold were found at many places, the abundance of large bowlders in the streams makes prospecting difficult without numerous appliances not easily procurable in this remote region. The bedrock south of the Noatak appears similar to that usually present in gold-bearing regions, although where the limestones form the hills the probability of productive placers seems slight.

CONCLUSIONS REGARDING FUTURE MINING DEVELOPMENT.

The foregoing account of the meager amount of prospecting done in the Alatna-Noatak region shows that conclusions regarding the economic resources of the region must be little more than tentative. It has seemed worth while, however, to state certain observations and the deductions made from them, in order that the available information and theory concerning this little-known region may be at the disposal of the prospector and of the investor.

From what has been said of the general geography it is evident that in a region so remote and so difficult of access, and having a climate so severe the costs of transportation, supplies, and labor are necessarily high and will not materially decrease in the near future. Fish and game may be sufficient for the needs of the prospector for short periods, but there is no adequate local food supply. Even wood for fuel is absent throughout a large part of the region, and timber for use in mining can be procured only in a very restricted area.

Although the commercial conditions will in large measure determine the future development of the Alatna-Noatak region, the present paper deals primarily with geologic facts and emphasis has here been placed upon these. The basis of the first mining development in the region will probably be gold-placer deposits rather than gold lodes or veins of the other metals. It is believed, therefore, that the regions most worthy of prospecting are those in which the metamorphic schists form the country rocks. From the geologic map it may be seen that these rocks are most widely distributed in the country between the Noatak and Kobuk and are almost absent north of the Noatak. The intricate structure of the region and the small scale of the map preclude the representation of all the details, so that the map should be regarded as indicating only the larger geologic features rather than detailed facts having but local significance.

Another geologic fact of importance that requires study is the history of the mineralized region. In the past much of the highland

area of the Alatna-Noatak region was covered with snow and ice and many of the valleys were occupied by glaciers, producing conditions under which effective sorting ceased, and whatever detritus existed was swept away by the ice. This material was so mixed with glacially eroded material that there was little or no gravitative separation. On reaching the limits of glaciation the heterogeneous débris was deposited as the ice melted and was distributed by streams. This condition was dominant in the Noatak Valley. In the region where deposition was taking place, however, concentration was not pronounced, for the dominant process was aggradation. As a consequence, although a large amount of material was being dumped by the ice and spread out by the streams, deposits were building up. It should also be noted that the ends of the glaciers were not stationary, but almost continually advanced and retreated, so whatever processes of concentration took place at the front were weakened by being dissipated over a considerable area.

It is therefore believed that in the distinctly glacial deposits extensive rock placers are but little to be expected or would be so irregularly distributed that they would be difficult to mine systematically. Here and there, even in the glaciated areas, possibly some auriferous preglacial material may not have been eroded. Such auriferous deposits, however, would be distinctly local. Some areas of this sort may also be preserved in protected places under the mantle of outwash material. These may be of value, but would be difficult to find and to mine.

With the close of the period of greatest glaciation and accompanying outwash the streams intrenched their courses in the earlier gravels and now flow at many places in rather narrow trenches a hundred or more feet below the surface of these deposits. In this process concentration of these glacio-fluviatile deposits has been effected, but whether it has formed placers can be determined only by prospecting. From the assumed distribution and amount of gold in the outwash deposits it is probable that except under particularly favorable conditions this secondary concentration would not produce very rich placers. The places to be examined by prospectors are those where this later sorting has affected deposits formed by a long-continued stand of the ice in one place or where reconcentration of material from deposits subsequently buried by outwash is actively in progress.

In spite of the difficulties that handicap immediate development and forbid large enterprises dependent on quick returns on their investment, it is believed that there is a large area of unknown country between the Noatak and the Kobuk that warrants investigation by observant prospectors equipped with inexpensive outfits.