UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

GEOLOGICAL SURVEY
W. C. Mendenhall, Director

**Bulletin 904**

# GEOLOGY OF THE SLANA-TOK DISTRICT, ALASKA

BY

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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1938

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - Price 35 cents

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# GEOLOGY OF THE SLANA-TOK DISTRICT, ALASKA

By Fred H. Moffit


## ABSTRACT

The Slana-Tok district includes part of the Alaska Range lying between the headwaters of the Copper River and the Tanana River. This district is commonly and more easily entered from the south or Copper River side, in consequence of which most of it is popularly regarded as belonging to the Copper River region. It was crossed by the old and now abandoned military trail between Valdez, on Prince William Sound, and Eagle, on the Yukon River, and is touched on the southwest by the highway more recently constructed along the north side of the Copper River from Gulkana to the Nabesna River.

The trend of the Alaska Range in this area is approximately northwest, and although the average altitude of the mountains is somewhat less than it is in the western part of the range the relief is nevertheless considerable, reaching a maximum of about 8,500 feet.

The principal streams of the district are the Slana River and Indian Creek, which flow into the Copper River, and three tributaries of the Tanana River—the Robertson River, the Tok River together with its branches, the Little Tok and the Dry Tok, and the Tetling River, which flows through the large Tetling Lake. Although there are few trails within the district, the valleys of these streams give fairly easy access to most of it.

The area is without permanent white inhabitants except the few persons who live on or near the Copper and Tanana Rivers and is also nearly without native inhabitants, for the few families at Mentasta Indian village are the only natives who do not live on the Copper River, at Tanana Crossing, or in the villages of the Tetling Lakes.

The rocks of the district are prevailingly sedimentary but include tuff beds and lava flows and many masses of intruded granitic rocks, most of which are diorite and related types rather than granite. Some of these rocks are highly metamorphic. Others are greatly folded yet not notably altered. The structure is complex and not clearly understood. The rocks range in age from pre-Cambrian or early Paleozoic to late Mesozoic. In places they are concealed by Recent unconsolidated water-laid and glacial deposits.

The oldest rocks are siliceous and micaceous schists, which occupy nearly all the northern half of the district. They are in part altered sandstone and mudrock but probably include altered siliceous igneous rocks as well. Their age is unknown, but they are probably to be correlated with some of the metamorphic rocks of the Yukon-Tanana region, which range in age from pre-Cambrian to early Paleozoic.

The next younger rocks are of Middle Devonian age and include gray and black slate, hard gray siliceous beds, yellowish sandy and gritty beds, limestone, and brown mica schist that is a contact-metamorphic phase of the

sedimentary beds. They occupy only a small area in the southeastern part of the district, yet they attract attention because of the forms into which the limestone weathers. Although they are closely folded they are not greatly altered except in the vicinity of the intrusive diorite.

Permian rocks come next in the stratigraphic sequence. They include both sedimentary and igneous rocks—limestone, sandstone, arkosic and black shale, tuff beds, and lava flows—which make up the Mankomen formation. They are typically developed north of Mankomen Lake near the heads of the Slana and Chistochina Rivers but extend intermittently southeastward along the south face of the mountains to the Nabesna River.

A large area of the district is occupied by slate, conglomerate, and other sedimentary beds that are mainly of Permian age but include an unknown proportion of Middle Devonian and possibly some early Carboniferous rocks.

The youngest of the consolidated deposits consist of an assemblage of Mesozoic slate, argillite, sandstone, conglomerate, and limestone beds that form the mountains of the southeastern part of the district. They are strongly folded but are unmetamorphosed and range in age from Upper Triassic to Lower Cretaceous.

All the sedimentary and volcanic beds so far mentioned are intruded by igneous rocks that are dominantly of the diorite family but include more basic and more acidic rock types. These intrusive rocks range in age from Paleozoic or older to Lower Cretaceous or younger.

The more recent geologic history of the district includes a period of intense glaciation which is not yet ended, although the area occupied by the ice is now only a small fraction of its former extent. This glaciation left evidence of its occurrence in the forms of the mountains and in glacial deposits that in most places are readily distinguishable by their form and composition from the gravel deposited by water.

The Slana-Tok district exhibits many evidences of mineralization by the precious metals, yet thus far no lode mine has been brought to production, although one placer gold-mining operation is established on Ahtell Creek.

## INTRODUCTION

### AREA COVERED

The term Slana-Tok district is used in this report to designate that part of the Alaska Range extending from Mount Kimball southeastward to the Tetling River and including streams that are tributary to the Copper River on the south and to the Tanana River on the north. This area (see fig. 1 and pl. 1) extends 55 miles from north to south and about 72 miles from east to west. Although it includes almost 4,000 square miles of rough mountains and lowland territory, it covers a part of the Alaska Range where the relief is least and where depressions furnish feasible routes between the Copper River Basin and the valley of the Tanana River. The old military trail and telegraph line between Valdez and Eagle, on the Yukon River, the abundance of fur-bearing animals, and the possibilities for mineral production are features that aroused interest in the district at an early time.

## PREVIOUS WORK

The first known visit of white men to this section of Alaska was that of a party of Russians who are believed to have been killed by the natives at Batzulnetas about 1848.[1] The first published references to the district are those of Lt. Henry T. Allen [2] (the late Major General Allen), who crossed it from Batzulnetas to the Indian village on the Tetling River during a notable military expedition in 1885. Prospecting in the district began with the influx of gold seekers who


FIGURE 1.—Map of Alaska showing the location of the Slana-Tok district.

came over the Valdez Glacier in 1898 and during the summer scattered over much of the northern and eastern part of the Copper River Basin. Their activities and the resulting need for topographic and geologic maps led to the first expedition (1902) of the Geological Survey to the headwaters of the Copper River. This expedition consisted of two combined topographic and geologic parties. One, under the leadership of T. G. Gerdine, topographer, mapped an

[1] Moffit, F. H., The Suslota Pass district, upper Copper River region, Alaska: Geol. Survey Bull. 844–C, p. 143, 1933.

[2] Allen, H. T., Report of an expedition to the Copper, Tanana, and Koyukuk Rivers, in the Territory of Alaska, in the year 1885, U. S. War Dept., 1887.

area which includes the southwestern part of the Slana-Tok district. Walter C. Mendenhall was attached to this party as geologist. The second party carried the survey over part of the southeast quarter of the Slana-Tok district and extended it to the Chisana River. The topographic work of this party was done by D. C. Witherspoon; the geologic investigation was carried on by Frank C. Schrader, who also was in charge of the party. Part of the findings of the two geologic investigations, so far as they relate to the Slana-Tok district, were published in 1903 and 1905.[3]

No further topographic or geologic mapping was undertaken by the Geological Survey in the Slana-Tok district till 1929, when the writer revisited the Indian River area and made further geologic investigations in the valleys of the Slana, Dry Tok, and Tok Rivers and the vicinity of Mentasta Pass. Again in 1931 he visited the Suslota Pass and Little Tok River areas. In 1934 and 1935 Gerald FitzGerald made the topographic surveys that are shown on the map of the Slana-Tok district except that of a small area in the southwest which was mapped by T. G. Gerdine in 1902, and a smaller area including the valley of Ahtell Creek and the mountains eastward to the Slana River, which was mapped by C. F. Fuechsel in 1932. While the topographic mapping of 1934 and 1935 was in progress the writer continued areal geologic surveys in the district, in accordance with a plan under which the topographic work was kept a year in advance of the geologic work. In this way the geologic investigation was advanced into the upper Tok and Robertson River sections in 1936, when the last of the field investigations included in this paper were made. Preliminary accounts[4] of part of this later geologic work, beginning with 1929, have already appeared.

## PRESENT INVESTIGATION

From the preceding paragraphs it is apparent that the present investigation is only part of a continuing project that had already been several years under way. This project was conceived with the purpose of extending topographic and geologic surveys along the south side of the Tanana Valley from the Chisana River to the Delta River, thus covering a large area of hitherto unmapped country and at the same time revising and correcting earlier maps made under much less favorable conditions than prevail at present.

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[3] Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: Geol. Survey Prof. Paper 15, 1903. Mendenhall, W. C., Geology of the central Copper River region, Alaska: Geol. Survey Prof. Paper 41, 1905.

[4] Moffit, F. H., The Slana district, upper Copper River region: Geol. Survey Bull. 824-B, pp. 111–124, 1932; The Suslota Pass district, upper Copper River Region: Geol. Survey Bull. 844-C, pp. 137–162, 1934; Upper Copper and Tanana Rivers: Geol. Survey Bull. 868-C, 1937.

The geologic party in 1936 investigated the area mapped topographically by FitzGerald during the preceding year, paying special attention to the possible occurrence of valuable minerals. The party was made up of four men—J. E. Kennedy and Aubrey E. Butters, packers, Barney Dawson, cook, and the writer—and was equipped with 11 horses and the necessary camp equipment and supplies. As in previous years, it was assembled at the Slana Road House, at the mouth of the Slana River, and its members were indebted to the late Mr. Lawrence DeWitt, owner of the road house, for many courtesies. Departure for the field of operations was delayed by the late passage of the act carrying the appropriation for the work, and the length of the working season was somewhat further shortened by early snow, so that it extended only from July 1 to September 11. On the other hand, the summer of 1936 in this district was notable for warm days and clear skies, so that little time was lost on account of unfavorable weather conditions. The principal areas of field work were the valleys of the Slana River, the Dry Tok and Tok Rivers, and the Robertson River, but the Mentasta area and the country between Mentasta Lake and the Dry Tok received further attention also.

## GEOGRAPHY

### RELIEF AND DRAINAGE

The Alaska Range sweeps in a great arc around the valleys of the Copper and Susitna Rivers, extending from the international boundary on the east into the Alaska Peninsula on the west, and separates these two minor drainage areas from the great interior valleys of the Tanana, Yukon, and Kuskokwim Rivers. The Slana-Tok district lies in the eastern part of the range and, as may be seen from the map (pl. 1), is primarily a country of high, rugged mountains trending northwestward and bounded on the northeast and southwest by the lowlands of the Tanana and Copper Rivers. This part of the Alaska Range is cut by many deep valleys, which separate the whole area into irregular-shaped blocks of mountains and give ready although not everywhere direct access to most parts of it. Such mountain blocks, more or less isolated, appear in the area that includes Indian and Ahtell Creeks, the group of mountains north of Mentasta Pass, and especially the group between the Little Tok River and Tetling Lake. Many other minor groups stand out prominently on the map.

The relief of the district is considerable, although less than that of the Alaska Range farther west and much less than that of the Wrangell Mountains, to the south. Slana, at the southward bend of the Copper River, has an altitude of 2,150 feet. This is higher than the Tanana lowland above Tanana Crossing, which has an altitude of about 1,500 feet near the settlement and rises so slowly upstream that near the Tetling River, at the extreme eastern edge of the mapped area, it is still less than 2,000 feet above the sea. The highest point in the Slana-Tok area is Mount Kimball, at its western margin. Mount Kimball also is the highest point of the Alaska Range east of the Delta River. Its altitude is over 10,000 feet but is not known exactly. The next highest point in the district is an unnamed snow-capped mountain near the head of the Tetling River, which is about 9,000 feet above sea level. In the area between the Tetling River and Mount Kimball many peaks reach heights ranging from 6,000 to 7,000 feet, and a few are 8,000 feet high.

The maximum relief of the area, therefore, is approximately 8,500 feet, if considered with reference to the Tanana Valley, or 8,000 feet if reference is made to Slana. The general relief, however, is a little less than 5,000 feet. The four largest bodies of water within the area have the following altitudes: Tetling Lake, 1,567 feet; Mankomen Lake, about 3,000 feet; Mentasta Lake, 2,246 feet; and Suslota Lake, 2,602 feet.

A little less than three-fourths of the area represented on the map of the Slana-Tok district is drained by streams that flow into the Tanana River. The principal streams of the district are the Slana River with its tributaries, of which Ahtell and Suslota Creeks are the largest; the Tok River, including its two tributaries, the Little Tok and Dry Tok; the Robertson River; the Indian River; and the Tetling River, of which Tuck Creek is the largest tributary. All these streams occupy valleys that were once filled with ice, and several now derive much of their water from the melting glaciers of the highland at their heads. In summer the glaciers of the lofty mountains about Mount Kimball supply a large quantity of milky water to the Robertson, Tok, Slana, and Chistochina Rivers. The Little Tok and Tetling Rivers also have small glaciers at the heads of some of their tributaries but are often clear when the ice is not melting rapidly.

Rough measurements of the minor drainage areas within the district give the area of the Slana River basin as 660 square miles, the Tok River 560 square miles, the Little Tok River 75 square miles, and the eastern branch of the Robertson River 265 square miles. The Tetling Lake and Tetling River drainage area includes over 700 square miles.

None of the rivers of the district are navigable by boats other than canoes or like small craft, and the only places where such boats are really practicable are in the meandering lower stretches of the Slana and the Tok and Little Tok Rivers.

The Slana River, from Mentasta Lake to the highway bridge near its mouth, is a tortuous stream flowing through a wide swampy lowland dotted with lakes, ponds, and old cut-off meanders where travel with horses in summer is impossible. It is said that the meaning of the name "Slana," which is a native Indian word, is "Crooked River." A skiff with outboard motor has been used on this part of the stream, and sawlogs have been floated to the small mill at Slana to be cut into bridge timbers and lumber. The gradients of the Tok River from the Tanana River to the mouth of the Little Tok and of the Little Tok River in the lower 7 or 8 miles of its course are much reduced compared with the upstream courses, and the water flows in deep meanders between steep banks, so that fording or swimming with horses is dangerous or impossible in most places because of the difficulty of getting into the water and more particularly the difficulty of getting out. For the most part the larger as well as the smaller streams are swift and loaded with silt. They move great quantities of coarse material in the upper courses and spread it out in wide flood plains over which the channels shift from place to place when the water can no longer carry its load and the sand and gravel that are deposited divert the current to some other course. The flood plain of the Robertson River (pl. 3, *A*) is more than a mile wide in some parts of its valley, as shown on the map, and is bare of timber and other vegetation except on the low benches that border the valley floor. Wide flood plains are formed by the Slana and Tok Rivers also, but on neither of them are the flood plains as extensive as those on the Robertson River. "Braided streams" is a term commonly applied to rivers such as these, with waters flowing through many interlacing channels.

## ROUTES AND TRAILS

The road from the Richardson Highway to the Nabesna River follows the north bank of the Copper River and crosses the Slana River near its mouth, about 1 mile from the Copper River. This is the best and most commonly used route for reaching the Slana-Tok district. An alternative route is the Tanana River, which is used by the traders of Tanana Crossing and Tetling Indian village.

Between Gakona and Slana the road follows in a general way the route of the old military trail from Valdez, on Prince William Sound, to Eagle, on the Tanana River, although most of it was relocated in order to get more suitable ground or to shorten distances in making the change from horse trail to highway.

The Eagle Trail did not go through Slana but bore northeastward from the Cobb Lakes across the end of the ridge on the north to a pass east of the valley of Ahtell Creek and thus reached the Slana

River near Mentasta Lake. From that point it skirted the east shore of the lake, bore eastward through Mentasta Pass to the Little Tok River, and there turned northward to go through the lower Little Tok and Tok Valleys to Tanana Crossing. This trail is still the only established trail within the district, but it has been traveled little since the military trail and telegraph line were abandoned after the completion of the Richardson Highway. Trees had grown up and bridges had rotted down, but the Alaska Road Commission allotted a small sum for repairs in 1934, and the trail was brushed out and reblazed so that now it is in practically as good condition as ever, although there are a few soft spots, and several bridges need replacing. The work done on the trail by the road commission was of much benefit to the Geological Survey parties.

A trail, parts of which can still be followed, formerly connected Mentasta Lake with the Slate Creek district by way of the Slana River Valley. It is the trail by which the first prospectors made their way to the placer diggings of that district but was long ago abandoned. Indian trails, the trails of white trappers, and game trails are encountered here and there. The trail down Timber Creek is a trapper's trail but is suitable for horses, except that care must be taken to avoid the soft ground on the summit north of the lake. This can be done by keeping to the east side of the valley. The south end of this valley between the Slana and Tok Rivers is also soft and has many places where horses are in danger of being mired, especially in rainy weather.

For the most part the traveler must choose his own route, yet travel with horses is not difficult for those accustomed to new mountainous country. The route over the pass between the Tok and Robertson Rivers is not marked by any trail except a short piece up the foot of the hill on the Tok River side. A gulch coming down from the west about 2 miles from the Tok River is the first obstacle and is best crossed at its mouth. The north end of the route is steep, passes through tangled willows and alders, and crosses several slides of angular diorite blocks. In its present state the pass is not easy, but it could be made so, except for the climbing, without great expense if the traffic demanded it.

There are no established trails in the valleys of the Little Tok and Tetling Rivers. Trail Creek, which comes into the Little Tok River east of Mentasta Pass, is a route rather than a trail, for the trail that formerly followed the valley is so blocked with fallen timber and landslides as to be practically useless.

The chief difficulties in traveling with horses in the Slana-Tok district are due to the rivers. In summer the larger streams are likely to be running full and swift because of melting glacier ice, and a ford must be carefully chosen where the channels spread out over the gravel bars. The lower courses of the Tok and Little Tok Rivers offer difficulties of another kind. Their currents are slackened by the lower gradient, and the water flows for miles in a deep channel between cut banks.

## TIMBER AND VEGETATION

Spruce is the common forest tree of the Slana-Tok district and appears everywhere on the valley bottoms and mountain sides up to an altitude of about 3,000 feet, although in favored places it is found considerably higher. In wet, cold soil it grows slowly and produces a trunk of little value for anything except fuel, but on the well-drained gravel terraces bordering the streams and on the lower mountain slopes it flourishes and yields logs suitable for heavy timbers and boards, although it does not compare in quality with the lumber shipped in from Seattle and other outside ports. Bridge timbers and deck lumber to supply material for bridges on the highway were sawed at Slana from logs cut in the Slana Valley. House logs and lumber for building were also sawed. The logs were of good size and were cut near the banks of the Slana River and floated down to the mill. The spruce of the upper Slana Valley, however, is not as large as that below Mentasta Lake and does not grow in such thick stands. Much of it is green and vigorous, with few dead trees, and seems to represent a comparatively recent growth. A fine stand of spruce on the lower slopes of the mountains north of Mentasta Pass was damaged greatly by fires several years ago, and throughout the district the trees have suffered from the ravages of bark beetles.

The lower valley of the Little Tok River contains much fine spruce in the better-drained areas. Timber extends up the valley of the Tok River also and there furnishes some of the thickest stands and finest trees of the whole area. In places the spruce forest of the Tok Valley includes trees that are small and of little value, yet a large part of the timber, especially that of the low gravel benches bordering the flood plains, will be highly valuable for mining or other uses if the need for such material arises. Good timber extends up the Tok River to the upper forks and into the valleys of the Dry Tok and the smaller tributaries from the east. Excellent spruce timber is found on the Robertson River also, although because of the wide flood plain of this river the relative area of timber land is less than in the Tok River Valley.

In addition to spruce the forest areas contain a minor quantity of poplar, aspen, and birch on the ground suited for them. Commonly the poplar grows on the lowland areas near the streams. The aspen and birch, on the other hand, choose the dry ridges and hillsides, but neither they nor the poplars have any present value for lumber. Willows of various kinds are common in the wet ground near streams and springs and wherever the drainage is poor. Alder grows on the mountain sides near timber line. The small black birch with rough crooked stem that commonly goes by the name "buckbrush" is widespread on the flat, well-drained gravel benches and is usually associated with an open stand of spruce.

An examination of the annual rings of the spruce at several localities, particularly on the south side of the Slana Valley near Mentasta Lake and on the north side of the upper Slana Valley above Bone Creek, showed that at these places a vigorous renewal of growth following a long period of slower growth set in about 30 years ago and has continued to the present time. Possibly this stimulation to more rapid growth was due to fires that burned off the moss and brush and allowed the ground to warm up and dry out.

Forage for horses is found throughout most of the area, so that usually the Geological Survey parties have been able to place their camps near the localities where it was desired to work. In general, the most abundant forage grows in the side valleys near timber line, but the broad main valleys also contain an abundance of feed, especially in places that were burned over in former years. Many acres of fine pasture land was thus provided near the west end of Mentasta Lake, and a similar large area of grazing land lies in the vicinity of Gillett Pass, on the heads of the Slana River and the Dry Tok River.

## GEOLOGY

### OUTLINE

The geology of a little-known district often proves to be more complicated after its problems have been examined than it appears to be when the problems are first met. This expresses the experience of the writer in his effort to reach an understanding of the stratigraphy and structure of the rocks of the Slana-Tok district. Few of the puzzling questions that have arisen there are fully answered, yet some of the more outstanding facts are known and a basis for a better understanding of their relations has been laid.

The work represented by the accompanying geologic map (pl. 1) was reconnaissance work in which large areas were examined in a relatively short time, and the map gives only an incomplete and somewhat unbalanced picture of the distribution of the great variety of rocks and their relations to one another. Especially, the time relations of many of them are still unknown and are likely to remain so till more detailed studies have been made in this and other districts where kindred problems arise.

The rocks of the Slana-Tok district are dominantly sedimentary, although some of them are so greatly metamorphosed that their sedimentary origin is difficult to make out. They include conglomerate, sandstone, quartzite, slate, limestone, and tuff, also siliceous and calcareous schist derived from rocks like those first named. Fossils collected from the limestone beds range in age from Middle Devonian to Cretaceous, but many thousands of feet of beds from which no fossils were obtained are possibly if not probably much older than those that yielded fossils.

Besides the sedimentary rocks the district contains extensive areas of extrusive and intrusive igneous rocks, which in addition to the tuffs already mentioned include lava flows and a wide variety of granitic rocks, chiefly diorite and quartz diorite, although finer-grained basaltic and less basic rocks are also present. These igneous rocks show various degrees of alteration, but their age relations are not known further than that some are Permian or older and some are not older than Cretaceous.

In general the schist makes up the north side of the mountain range, and the less metamorphosed rocks the south side. The two are not sharply differentiated, however, for the change from less altered to more altered rocks is progressive from south to north. Areas of schist occur within the area of the less altered rocks, but within the typical schist areas no unaltered beds except intrusives were seen. The schists are believed to be not younger than Middle Devonian and may be much older.

The rocks that are definitely assigned to the Middle Devonian include a small elongated area or wedge of sedimentary beds crossed by the Tetling River and made up of limestone, black and rusty-weathering gray slate, grit, sandstone, graywacke, and rusty schist that is a local phase of the sedimentary rocks near a great mass of intrusive diorite. How much of the sedimentary beds beyond Tuck Creek, north of the intrusive mass, may belong to these Middle Devonian rocks is not known.

Most of the remainder of the Paleozoic sedimentary beds occur in a belt that extends northwestward from the Little Tok River to the Middle Fork of the Chistochina River. This belt includes slate, conglomerate, limestone, tuff and interbedded lava flows, and many intrusive bodies. These rocks are folded and faulted but are not highly metamorphosed and are schistose only near faults and places of exceptional disturbance. Isolated patches of these sedimentary beds appear in the mountain block that includes the Indian River and Ahtell Creek. This group of sedimentary rocks is in part of Permian age, as is shown by fossils collected from the limestones. However, the evidence of some fossil localities also suggests the possibility that part of the beds may belong to an era in the Carboniferous period older than the Permian. This assignment would be more in accord with the character previously ascribed to the Permian rocks in such places as the head of the White River.

Mesozoic rocks form the mountains about the head of the Little Tok and Tetling Rivers. They are chiefly clastic sediments ranging in age from Upper Triassic to Lower Cretaceous and for the most part are of fine grain, though not entirely so. They include slate, argillite, sandstone, conglomerate, and limestone among which argillaceous and sandy rocks dominate. They are strongly folded and faulted but are not metamorphosed, and no schistose phases were seen among them. A characteristic feature of the Mesozoic rocks is the alternation of thin beds of sandstone with slate or argillite. In places individual beds reach a thickness of several feet, but in general the beds are thin, and many hundreds of feet of deposits show few beds more than 2 inches thick.

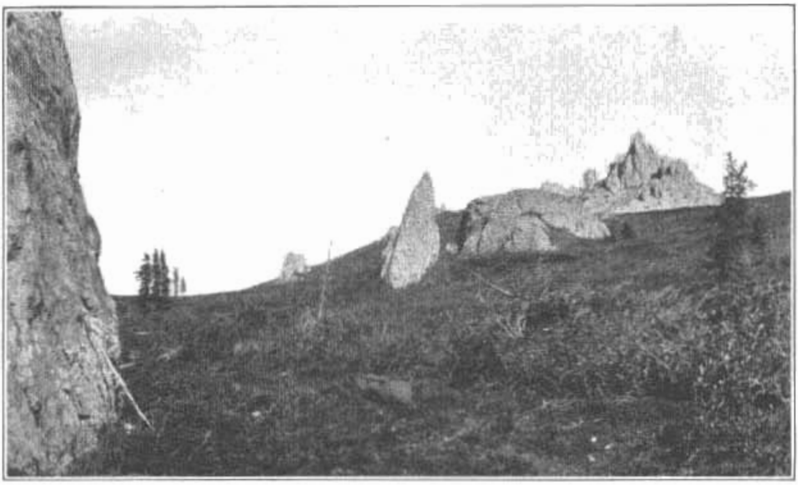
No bedded deposits younger than the Mesozoic have been recognized within the district except the unconsolidated deposits formed by water and ice.

Igneous rocks occupy large areas of the district. They include chiefly lava flows, tuff beds, and granitic intrusives and belong to several periods of extrusion and intrusion, which range in time from pre-Permian to post-Cretaceous. The largest area of igneous rocks includes the mountains about the Indian River and Ahtell Creek, where some of the oldest and probably also some of the youngest of the igneous rocks occur. The volcanic basalts and tuff of this area are thought to belong among the oldest igneous rocks of the district but are associated with coarse-grained dark- and light-gray intrusive granitic rocks that are much younger.

The next largest area of igneous rocks extends from the Little Tok River nearly to the Nabesna River, beyond the boundary of the mapped area, and consists chiefly of light, coarsely granular diorite which in many places contains an abundance of large feldspar crystals and is conspicuous for that reason. Apophyses of this igneous mass extend into the neighboring sedimentary beds as sills, which are especially numerous in the mountains forming the north slope of the Tuck Creek Valley.

The igneous rocks, however, are widespread, and many other areas of them are shown on the map. One belt of volcanic rocks north of Mentasta Pass is of notable extent and forms the highest peak in that vicinity.

The Alaska Range is thought to have been established chiefly in middle and late Tertiary time and to have reached a form approximating that of the present when the beginning of glaciation intro-



*A*. MIDDLE DEVONIAN LIMESTONE OUTCROPS, SOUTH OF THE TETLING RIVER.

*B*. CRYSTALS OF FELDSPAR IN DIORITE FROM THE AREA OF INTRUSIVE ROCKS BETWEEN BUCK AND TUCK CREEKS.

*A*. GRAVEL POINT NEAR THE SLANA RIVER BRIDGE.

*B*. HEAD OF THE EAST BRANCH OF THE ROBERTSON RIVER.
Shows the wide flood plain of the river.

duced the latest spectacular episode in its history. Since then the whole area has been buried under ice, and a complicated glacial story was recorded imperfectly in its mountains and valleys.

## UNDIFFERENTIATED PRE-DEVONIAN SCHIST

### CHARACTER AND DISTRIBUTION

More than half the area shown on the geologic map is made up of metamorphic rocks that collectively may be called schist, although they include a minor proportion of slate or phyllite and crystalline limestone and many less altered bodies of intrusive igneous rock. Roughly these schists lie north of a line extending from the head of the Slana River to the mouth of Tuck Creek and may be said to occupy the Tanana side of this part of the Alaska Range, although they are not restricted to the Tanana River drainage basin and do not occupy all of it. They present a considerable variety in appearance and are believed to be derived in large part from original slate and sandstone beds. Their color ranges from black or gray to silvery white, but the lighter shades dominate, and schist that is really black is rare. The alternation of light and dark schists that is seen in traveling across the strike of the beds is one part of the evidence for their sedimentary origin. Much of the schist is highly siliceous and probably was originally sandstone or quartzite or other quartzose rock, although some of it may be altered granite or some light-colored igneous rock. Sheared quartzite beds with abundant mica flakes developed in shear planes are common and are included here as varieties of the schist. In a few places small areas of black carbonaceous schist are interbedded with the lighter schist.

### THICKNESS AND STRUCTURE

The undifferentiated schist of this part of the Alaska Range represents a succession of closely folded and much altered slate and sandstone beds, together with an unknown proportion of metamorphosed igneous rocks, having a general strike of about N. 70° W., which corresponds to the trend of the range itself. A glance at the geologic map gives the impression that this structural trend is fairly uniform, and the field evidence bears out this impression, although in many places the difference between bedding and cleavage is difficult to determine. Wherever beds and bedding planes were examined it was apparent that the folding is intense. Limestone beds seem to be best adapted to show the folding, and in many places limestone beds are not only closely folded so that the limbs of the minor folds are parallel but they are overturned so that the axial planes of the folds are horizontal. Near the south boundary of the schist area, westward from the Little Tok River, the dip of both bedding and cleavage is prevailingly south and has given rise to some remarkable dip slopes in the siliceous schist north of the Slana River and Gillett Pass. On the other hand, the schist east of the Little Tok River dips northward, away from the platy quartzite that forms the crest of the mountains north of Tuck Creek.

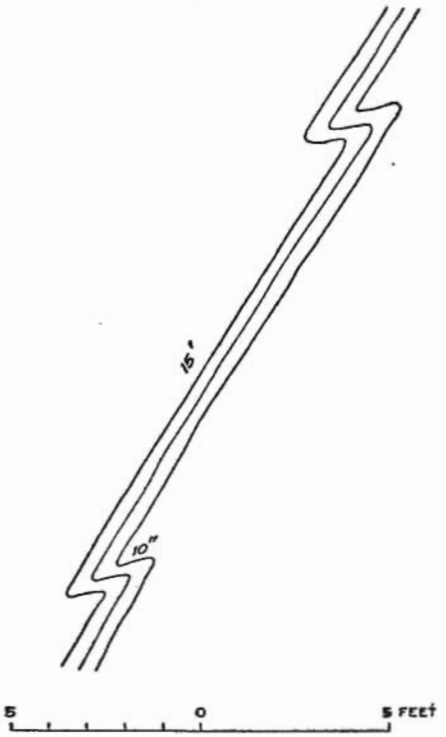



FIGURE 2.—Type of fold common in rocks of the schist area.

Farther away from the south margin of the schist area the bedding and schistosity show more variation in dip and in places are even horizontal. For the most part, however, the cleavage of the schist dips southward. Locally, also, wide variations from the normal strike of the beds occur. A common type of fold in beds that appear at first glance to lack folding is made up of a wide limb followed by a relatively short reverse fold, repeated at fairly regular intervals (fig. 2) and forming a succession of steps, where the beds are horizontal.

Conditions favorable for measuring the thickness of the sedimentary deposits represented by the schist were not found. A succession of isolated yet conspicuous and fairly well alined limestone outcrops paralleling the south margin of the schist area seems to indicate a horizon or horizons that might be traced across the mapped area, but no beds that are recognizable from place to place in crossing the folded strata and would be suitable for horizon markers in making measurements of thickness were recognized. Consequently the only estimate that can be given for the thickness of the schist is that it must be great and is probably thousands of feet.

## AGE AND CORRELATION

The problem of determining the age of the schist has not been solved, although wide limits of age can be set. No fossils have been found anywhere in the schist area, yet the relative degrees of metamorphism of the schist and of the rocks that border it on the south immediately suggest that the schist is the older. To a certain extent the stratigraphic and structural relations suggest the same thing, but their evidence cannot be accepted without question, for the schist of the area east of the Little Tok River overlies the rocks to the south. This relation, however, may be due to faulting. At present the strongest evidence of the age of the schist seems to be the degree of metamorphism, and in contiguous areas such as these this evidence is worthy of greater confidence than would be warranted if the areas were widely separated. The area of less metamorphosed rocks to the south includes limestones of Middle Devonian and Permian ages, and it therefore would follow that the schist is at least as old as Devonian and probably older.

Comparison of this area with the area north of the Alaska Range farther west suggests a correlation of the schist with the Birch Creek schist or with a younger group of metamorphic rocks that occupy large areas in the Tanana-Yukon region. The assignment to the Birch Creek schist was made by Mendenhall [5] for the schist north of the Chistochina drainage basin, although at that time (1902) he called the rocks of this area the Tanana schist of pre-Silurian age, a formation name that has since been abandoned. Farther west, between the Delta and Nenana Rivers, Capps [6] found an extensive area of metamorphic rocks which he regarded as made up mainly of altered sedimentary rocks and assigned to the Birch Creek schist. More recently Mertie [7] has shown that two groups of ancient metamorphic rocks exist in the Yukon-Tanana region. The older consists of the Birch Creek schist and associated altered igneous rocks, of which the Birch Creek schist is considered to be of pre-Cambrian age but not late pre-Cambrian. The associated altered igneous rocks may range in age from pre-Cambrian to early Paleozoic. The second group of metamorphic rocks includes several formations, of which the lowest are considered to be of late pre-Cambrian age. The highest rocks of the second group range upward to the Lower Ordovician. Future study may show that the schist of the Slana-Tok district is equivalent in age to one or more of these groups, but it seems unwarranted to make the correlation with no more evidence than is now at hand.

[5] Mendenhall, W. C., Geology of the Central Copper River region: Geol. Survey Prof. Paper 41, p. 30, 1905.

[6] Capps, S. R., Jr., The Bonnifield region, Alaska: Geol. Survey Bull. 501, pp. 20-22, 1912.

[7] Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: Geol. Survey Bull. 872, pp. 46-47, 1937.

## MIDDLE DEVONIAN ROCKS

### CHARACTER AND DISTRIBUTION

The rocks that are described as Middle Devonian comprise a group of sedimentary beds among which limestone is the most conspicuous, although it makes up only a minor proportion of the total thickness of the group. These crystalline limestone beds are associated with gray and black slate, hard gray siliceous beds, yellowish sandy and gritty beds, and brown mica schist. They are all intruded locally by dikes and sills of dark fine-drained igneous rock. The rocks that appear definitely to belong to the group occupy a narrow belt from 3 to 4 miles wide extending from the head of Buck Creek east-southeastward beyond the limits of the area represented on the map. A small mass of limestone containing corals that are probably Middle Devonian crops out on the ridge west of Suslota Pass. The surrounding rocks are slates and argillites intruded by coarse igneous rocks and are much folded and faulted. The Devonian rocks of this vicinity have not been differentiated from the nearby Permian limestone and associated sedimentary rocks, and their extent is not known. It seems probable also that some of the sedimentary beds north of the Tuck Creek Valley are Devonian, although no fossils were found there, and direct correlation with the Devonian rocks south of the diorite mountains is difficult. The presence of Devonian beds was not suspected when the first work in the vicinity of Suslota Pass and the Little Tok Valley was done, and they are not shown on the earlier preliminary map.[8]

The limestone outcrops that characterize the Middle Devonian beds were seen first near the divide between the head of Buck Creek and the Tetling River, but the limestone and associated sediments are more widely displayed in the valley that lies in line with Buck Creek southeast of the Tetling River and extends to the Nabesna Valley. The limestone owes its prominence to its color and the manner of its weathering. The beds are almost vertical, and exposed parts appear like jagged white teeth or pinnacles (pl. 2, *A*) standing high above the smooth rounded surfaces of the low adjacent hills. Some of these spires are nearly 100 feet tall. The outcrops are not continuous but are isolated from one another, in well-defined rows representing several distinct beds or possibly two or more beds repeated through close folding. At least five such beds and probably six can be recognized in the valley southeast of the Tetling River, where the limestones and associated sedimentary deposits are exposed in a belt occupying the valley between the Mesozoic slates

[8] Moffit, F. H., The Suslota Pass district, upper Copper River region, Alaska: Geol. Survey Bull. 844–C, pl. 2, 1933.

and sandstones on the southwest and the diorite ridge on the northeast. Even at a long distance the trend of the beds is easily recognized by the white limestone outcrops.

The rocks associated with the limestone in most places consist of sandy and grit beds, and slate. The schist is exposed in the vicinity of the great intrusive mass of diorite on the north, and the schistosity increases as the diorite is approached. The number of intrusive dikes and sills in the sedimentary beds is also greater near the diorite ridge. It seems apparent that the schistosity and the development of garnets and metamorphic minerals in the schist are contact features of the Middle Devonian rocks and were produced by the intrusion of the diorite.

#### STRUCTURE AND THICKNESS

A favorable place to study a section of the Middle Devonian rocks in order to determine the sequence of beds and measure their thicknesses was not found, yet it is evident that many hundreds of feet of deposits are present. The beds are so closely folded that the limestone, which is more resistant to weathering and offers better opportunities for observing the bedding than the slate and sandstone, stands on edge in most places. Faulting had undoubtedly occurred extensively but is difficult to recognize. Although the beds are considerably altered chemically as well as physically, schistosity is a local feature, appearing in the vicinity of the great diorite intrusion; and the beds in general are distinctly less metamorphosed than the schist of the Tanana River side of the range.

#### AGE AND CORRELATION

The Middle Devonian limestone is sparingly fossiliferous but has yielded a sufficient number of diagnostic invertebrate species to indicate its marine origin and its age. Since the limestone was deposited it has been subjected to heat and pressure, which have changed its original form and given it a crystalline structure. This change has made it difficult to recognize the fossils in rock that is freshly broken and would have hidden them altogether in most places if weathering had not etched their forms on the exposed surfaces or freed them partly from the enclosing rock. Most of the fossils that were collected were found at the base of limestone beds and not in the middle or top. The fossils were identified by Edwin Kirk and are listed in the table on the following page.

Definite correlation with other Devonian rocks cannot yet be made, but it is desirable to point out that such rocks occur in Alaska, although not certainly in any nearby localities, so far as is known. Middle Devonian rocks are exposed in several areas in the Yukon-

Tanana region and have been described by Mertie.[9] They also occur in the upper Susitna Valley,[10] where a great variety of Middle Devonian sedimentary deposits, including conglomerate, shale, slate, graywacke, quartzite, and thin-bedded and massive limestone, measuring possibly as much as 10,000 feet in thickness, extend diagonally across the Alaska Range from the south to the north side.

*Middle Devonian fossils of the Slana-Tok district*

| | 2690 | 2691 | 2692 | 2693 | 2694 |
|---|---|---|---|---|---|
| Amplexus sp. | × | × | | | |
| Amplexus? sp. | | × | × | | × |
| Cyathophylloid coral, genus uncertain | | | | × | |
| Favosites sp. | | | × | | × |
| Favosites sp. (digitate form) | | × | | | |
| Favosites sp. (massive form) | × | | | | |
| Alveolites sp. | × | | | | |
| Reticularia sp. | | × | | | |

2690. 1½ miles southeast of the small lake at the head of Buck Creek.
2691. Divide between Tetling River (Bear Creek) and a branch of the Cheslina River. Approximately longitude 143°50′ and latitude 62°15′. (See Geol. Survey Bull. 844, pl. 2.)
2692. ¾ mile south of locality 2691.
2693. 2 miles west of the east side of Suslota Pass.
2694. Limestone float from the east slope of the mountain 2 miles west of the east side of Suslota Pass.

Somewhat nearer the Slana-Tok district, on the west side of the Chisana River, about 30 miles east of the southeast corner of the area represented on plate 1, is an assemblage of rocks consisting of conglomerate and slate, which Brooks[11] named the Wellesley formation and referred to the Devonian or Carboniferous period on the evidence of a small collection of fossils. Exact measurements of the thickness of these beds were not made, but they appear to be at least 1,000 feet thick and possibly more. Mertie[12] has presented reasons for regarding the Wellesley formation as Carboniferous rather than Devonian, yet he states that these reasons are not conclusive. The geographic relations of the Middle Devonian rocks of the Slana-Tok district to the possibly Devonian Wellesley formation is suggestive, because the strike of the two sets of beds is the same, but a judgment as to the correctness of this suggestion must be deferred till the age of the Wellesley formation can be more accurately determined.

Middle Devonian rocks are extensively developed in southeastern Alaska and are known in other widely separated parts of the Territory.

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[9] Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: Geol. Survey Bull. 872, pp. 92–93, 1937.

[10] Capps, S. R., The eastern portion of the Mount McKinley National Park: Geol. Survey Bull. 836, pp. 251–255, 1933.

[11] Brooks, A. H., A reconnaissance in the Tanana and White River Basins, Alaska: Geol. Survey 20th Ann. Rept., pt. 7, maps 24, 25, pp. 470–472, 1900.

[12] Mertie, J. B., Jr., A geologic reconnaissance of the Dennison Fork district, Alaska: Geol. Survey Bull. 827, pp. 25–26, 1931.

## PERMIAN ROCKS

### CHARACTER AND DISTRIBUTION

The Permian rocks of the Slana-Tok district were first described by Mendenhall,[13] who found them well displayed in the mountains north of Mankomen Lake and named them Mankomen formation. Some of the beds of the Mankomen formation, like Permian beds in other parts of Alaska, are highly fossiliferous and furnish the evidence for the age assignment. Beds bearing the same fauna are exposed on Indian Creek, north of lower Ahtell Creek, near Suslota Pass, and in some of the rocks described below as undifferentiated Middle Devonian and Permian rocks, but in none of these places are they as extensive areally or as thick stratigraphically as at the head of the Slana and Chistochina Rivers.

In its type locality the Mankomen formation includes between 6,000 and 7,000 feet of marine sedimentary beds—sandstone, shale, and limestone—together with interstratified tuff and igneous sheets. According to Mendenhall the formation may be separated into two divisions, a lower part over 2,000 feet thick, which consists prevailingly of arenaceous and tuffaceous rocks, and an upper part including more than half the total thickness, which is prevailingly calcareous. A section of beds measured by Mendenhall in the valley of Eagle Creek and on the ridge east of it is shown in figure 3. The measurements were calculated from barometer readings and probably will require correction if more exact measurements are made, yet they doubtless give an adequate representation of the succession and relations of the beds. The base of the section appears to be near the foot of the mountain between Eagle Creek and the Slana River and is made up of thin limestones and red calcareous shales with intrusive diabase. An altered red porphyritic rock which lies a little lower on the slope to the south is regarded by Mendenhall as possibly the base on which the Permian rocks rest. The spur above and to the north shows about 2,000 feet of feldspathic sandstone, tuff, shale, limestone, and intrusive rocks, with the tuff beds more numerous and coarser in the upper 1,000 feet. Exposures are poor on top of the ridge northward for some distance, probably equivalent to a thickness of 2,000 or 3,000 feet of strata, but south of the high gap between Eagle Creek and the Slana River a prominent white limestone crops out and is underlain by several hundred feet of "dark thin-bedded limestones, sandy limestones, quartzites and sandstones, and some thin beds of black shale." The white limestone is exposed also on the west side of Eagle Creek, above the forks, and is overlain by several hundred feet of black shale, which in turn is overlain by about 600 feet of thin-bedded fossiliferous limestone and this again by black shade.

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[13] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Geol. Survey Prof. Paper 41, pp. 40–51, 1905.

The valley of Eagle Creek is one of the best places to study the rocks of the Mankomen formation but was not visited by the writer, who examined only the Slana River side of the area, collecting fossils at several places from limestone and tuff beds. Several limestone beds, the chief ones appearing on the crest and east slope of the mountains, are shown on the geologic map but are not mapped as extending to Eagle Creek and the mountains west of it, because information about their position is lacking and not because they do not continue west into that area.

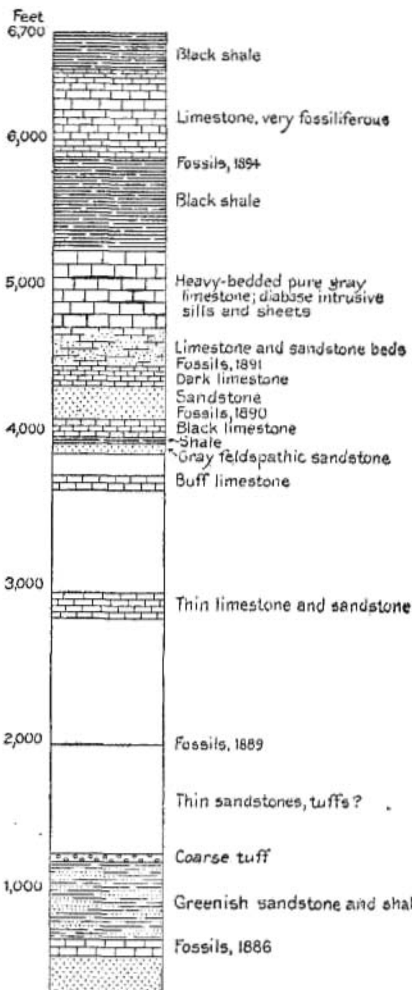


FIGURE 3.—Section of Permian sedimentary rocks north of Mankomen Valley as measured by Mendenhall. For locality numbers, 1894, 1891, etc., see list of Mendenhall's fossils (p. 26).

The rocks east of the Slana River and the Mankomen area offer a problem in correlation not yet solved. They include volcanic and intrusive rocks and are in strike with the Mankomen formation to the west, but they seem to correspond in no way to the Mankomen formation. A possible explanation is that faulting brought the rocks on the two sides of the Slana Valley to their present position, although other evidence to support this suggestion was not found.

A small patch of Permian sedimentary rocks, less than 1 square mile in area, occupies the highest part of the ridge between the two main branches of Indian Creek, about 6 miles north of the place where these two branches come together. The lower part of the section is dark-gray calcareous grit containing scattered crinoid stems and a few fragments of thick-shelled brachiopods. On this rests about 50 feet of light bluish-gray crystalline limestone, locally containing abundant crinoids and brachiopods. These beds rest on igneous rocks, chiefly a porphyritic granitoid rock of varying degrees of coarseness containing feldspar, hornblende, and a little quartz, and are overlain in places by a thin covering of igneous rock. Their thickness is between 100 and 200 feet, and they are only moderately folded, appearing nearly horizontal in most places. On the evidence of the fossils the beds are correlated with the Mankomen formation.

The crystalline limestone that crops out in several exposures east of lower Indian Creek did not yield fossils, and its appearance is so different from that of the beds just described that the two are not shown on the geologic map as the same.

A third and larger area of Permian rocks includes part of the mountain block east of the old Eagle Trail between Ahtell Creek and Mentasta Lake. The rocks of this area are dominantly beds of volcanic tuff and lava flows but include also clastic and calcareous sedimentary deposits. A section of these rocks on the east side of Porcupine Creek, 2½ miles south of the little lake in the low pass leading to upper Ahtell Creek, shows more than 500 feet of beds that include coarse sandstone or grit, fine conglomerate, argillite, shale, coarse rough black conglomerate with tuffaceous base, calcareous grit, and limestone, interstratified with dark fine-grained igneous rocks that represent lava flows or intrusives. The beds of this locality strike N. 25° E. and dip 30° ESE. The highest part of the section, near the top of the ridge, is coarse brown sandstone or grit overlain by a 6-foot bed of limestone on which rest limy shale beds. These limy beds form the crest of the north-south ridge for nearly a mile. They, as well as some of the beds lower in the section, are fossiliferous. A bed of limestone 10 feet thick crops out on the mountain side about 1 mile north of the ridge but is associated with tuff beds and a little shale and lacks the associated sandstone and grit of the locality just mentioned.

North of Ahtell Creek and 3 miles southwest of the point where the section was examined is a notch between a low knob and the mountain north of it. The notch was formed by faulting and the weathering of soft gray sandstone and gray shale interbedded with tuff, dark fine-grained basalt, vesicular lavas, and volcanic breccia or agglomerate. No fossils were found in the sedimentary beds, but they doubtless belong among the Permian rocks, like the heavy tuff beds in the canyon of Ahtell Creek.

Other areas of Permian rocks are known within the Slana-Tok district for they have yielded fossils that are identified as belonging to the Permian fauna of the Mankomen formation, but except the limestones they have not been distinguished on the geologic map. Only limestone beds have yielded fossils so far. The associated

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argillaceous and sandy beds predominate and are certainly Permian in part, but it has not been possible with the information at hand to differentiate some of the Permian beds from the Middle Devonian beds and other rocks that may be older than Permian. Areas of Permian limestone are shown within the areas designated on the geologic map as undifferentiated Middle Devonian and Permian rocks and indicate that the Mankomen formation is more widespread than appears from the areas mapped as Mankomen. These beds receive further consideration in the section on undifferentiated Middle Devonian and Permian rocks.

#### THICKNESS AND STRUCTURE

An estimate of the thickness of the Mankomen formation has been given incidentally and is the best estimate now available, but this estimate may not include the thickness of all the beds that will eventually be included in the formation. Mendenhall's section [14] on Eagle Creek (fig. 3) gave a measured thickness of 6,700 feet for the beds in a locality where conditions for measurement are more favorable than at any other locality known to the writer. The section of 100 to 200 feet on Indian Creek and the section of 500 feet in the mountains east of the Eagle Trail probably represent only part of a much greater thickness of beds that were there at one time but have been removed by erosion.

It will be impossible to measure the thickness of the Permian beds in the undifferentiated area until the Middle Devonian rocks are distinguished from the Permian. In general the undifferentiated beds differ from the rocks of the type Mankomen section in having a greater proportion of argillaceous deposits and less tuff, and any correlation of individual beds will be difficult unless paleontologic evidence for the correlation can be found. At present it is not known whether the beds of the undifferentiated area can be correlated with any part of the type section. Nevertheless it seems probable that the section on Eagle Creek does not represent the full thickness of Permian rocks in the district.

According to Mendenhall [15] the area of Permian beds between the Middle Fork of the Chistochina River and the Slana River has the structure of a rather simple tilted block of beds striking N. 60° or 70° W. and dipping northward at angles that are generally low near the south side of the block and grow greater toward the north side. Furthermore, he regarded this block as having been brought into contact with the schist mass of the high mountains north of the

[14] Mendenhall, W. C., op. cit., p. 40.
[15] Idem, p. 46.

valley connecting the heads of the Middle Fork and the Slana by a great fault and did not find evidence of southward-dipping Mankomen strata near the fault in the localities he visited on the Middle Fork and westward.

As seen from the Slana River Valley the Mankomen formation on the west side of the valley and south of the mouth of the stream coming from Gillett Pass dips northward. An observation on beds at a place 4½ miles east-northeast of the mouth of Mankomen Lake gave the strike as N. 55° E. and dip as 25°–30° NW. This observation suggests the possibility that the Mankomen formation west of the river may overlie the volcanic rocks east of it, rather than that the two are offset by faulting, as suggested on page 20.

The beds on the south side of the upper Slana River between the Gillett Pass stream and the first glacier appear either to dip southward or to be nearly horizontal in places, contrary to Mendenhall's conclusion, yet it is probable that the contact of these beds with the schist north of the valley is a fault contact. At any rate, this valley is a place of abundant intrusion by igneous rocks, which are made conspicuous by the iron stains produced by weathering.

The structure of the Permian rocks at the Indian Creek locality is simple, for they are practically horizontal. Near the Eagle Trail they overlie igneous rocks and dip moderately to the southeast, probably forming a shallow syncline, although the rocks of the southeast side of this area are concealed and their structure is not known.

The structure of the Permian rocks of the undifferentiated area is considered in connection with the description of the rocks there.

### AGE AND CORRELATION

Wherever Permian rocks have been found in Alaska it has usually been true that notably fossiliferous beds were discovered in some part of the section. Most commonly the fossils are found in limestone or limy grit or tuff beds in which the organic material most likely to catch the eye first is the fragment of a crinoid stem. In many places, however, sections of the thick-walled shells of one of the most numerous of the Permian brachiopods stand out on a weathered surface or on a joint plane of the enclosing rock. In many places corals are conspicuous. For the most part, successful collecting depends on finding places where just the right degree of weathering to free the fossil from the enclosing calcite crystals or grit has taken place.

Fossils were collected from the Mankomen formation by Mendenhall and from limestone beds in the Suslota Pass area by Schrader in 1902. Since then they have been collected from some of the same localities and from other localities by the writer. The earlier determinations were made by Charles Schuchert, and the later ones by George H. Girty, who also has reviewed the earlier collections and is in essential agreement with the original identifications, although the present terminology is somewhat changed from that of earlier reports. All the fossil forms so far identified in the more recent collections are shown in the following table, together with a description of the localities from which they came. It seems best, however, to retain Mendenhall's list of fossils from the type Mankomen area as he gave it originally, for it could hardly be included in the larger table without extensive revision of the older names.

*Permian fossils from the upper Copper River district*

| | 29AM-F1 (6755) | 31AM-F1 (7046) | 31AM-F2 (7046a) | 34AM-F9 (7439) | 35AM-F1 (8012) | 35AM-F2 (8013) | 35AM-F3 (8014) | 35AM-F4 (8015) | 35AM-F5 (8016) | 35AM-F6 (8017) | 35AM-F7 (8018) | 35AM-F8 (8019) | 35AM-F9 (8020) | 35AM-F10 (8021) | 35AM-F11 (8022) | 35AM-F12 (8023) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyathaxonia suggested | | | | × | | | | | | | | | | | | |
| Triplophyllum sp | | | | | | | | | | | | | | | × | |
| Zaphrentis sp | | | | | | | × | | | | | | | | | × |
| Cyathophyllum sp | | × | | | | | | | | | | | | | | |
| Aulophyllum sp | | × | × | | | | | | | | | | | | | |
| Lithostrotion sp | | | | | | | | | × | | | | | | | × |
| Lithostrotion? sp | | | | | | | × | | | | | | | | | |
| Lonsdaleia sp | | × | | | | | | | | | | | | | | |
| Cladochonus? sp | | | | | | | | | | | | | | | | × |
| Crinoid stems (columns) | × | | | × | | | | | | | | × | | | | |
| Tabulipora sp | | | | | × | × | × | × | | | | | | | | |
| Batostomella sp | | | | | | | × | | × | | | | × | | | |
| Bryozoan, probably belonging to Batostomella or Leioclema | | | | × | | | | | | | | | | | | |
| Phyllopora? sp | | | | | | | × | | | | | | | | | |
| Polypora sp undet | | | | × | | | | × | | | | | | | | |
| Rhombopora sp | × | × | × | | | | | | | × | | × | | | | |
| Rhabdomeson sp | | | | | | | × | | | | | | | | | |
| Fenestella sp | | | | | | | | | × | | | | | | | |
| Enteletes? sp | | | | | | | | | × | | | | | | | |
| Orthotichia aff. O. morganiana | | × | | | | | | | | | | | | | | |
| Schizophoria aff. S. resupinoides | | | | | | | | | | | | | | | | × |
| Derbya or some cognate form | | | | × | | | | | | | | | | | | |
| Streptorhynchus? sp | | | | | | | | × | × | | | | | | | |
| Streptorhynchus pearyi? | | | | | | | | | | | | × | | | × | |
| Chonetes aff. C. flemingi | | | × | | | | | | | | | | | | | |
| Chonetes aff. C. granulifer | | | | | | | × | × | × | × | | | | | | |
| Chonetes sp | | | | | | | × | × | | | | | | | | |
| Productus (Productus) aff. P. gruenewaldti | | | | | | | × | × | × | × | × | × | | | | |
| Productus (Echinoconchus) aff. P. fasciatus | | | × | | | | × | × | × | | | × | | | | |
| Productus (Horridonia) aff. P. timanicus? | | | | | | | | × | × | | | × | | | × | × |
| Productus (Horridonia) sp | | | | | | | | | | | | | | | × | |
| Productus (Linoproductus) aff. P. cora | | | | | | | | | × | | | | | | | × |
| Productus (Linoproductus) aff. P. koninkianus | | | | | | | | × | | × | | | | | | |
| Productus (Pustula) aff. P. pseudaculeatus | | | | | | | × | | | | | | | | | |
| Productus (Pustula) wallacianus | | | × | | | | | | | | | | | | | |
| Productus (Avonia?) aff. P. tuberculatus | | | | | | | | | | | | | | | | × |
| Productus (Waagenoconcha) aff. P. humboldti | | | | | | | × | × | | | | | | | | |
| Productus (Waagenoconcha) aff. P. irginae | | | | | | | | | × | | | × | | | | |
| Productus (Buxtonia) aff. P. porrectus | | | × | | | | × | × | | | | | | | × | |

*Permian fossils from the upper Copper River district*—Continued

| | 29AM-F1 (6755) | 31AM-F1 (7046) | 31AM-F2 (7046a) | 34AM-F9 (7439) | 35AM-F1 (8012) | 35AM-F2 (8013) | 35AM-F3 (8014) | 35AM-F4 (8015) | 35AM-F5 (8016) | 35AM-F6 (8017) | 35AM-F7 (8018) | 35AM-F8 (8019) | 35AM-F9 (8020) | 35AM-F10 (8021) | 35AM-F11 (8022) | 35AM-F12 (8023) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Productus (Productus) semireticulatus group | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Productus apparently related to P. (Buxtonia) peruvianus | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Productus with fine striae | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Productus sp. | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- |
| Marginifera aagardi? | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | × | ---- | ---- | ---- | ---- |
| Marginifera aff. M. cristobalensis | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- |
| Marginifera aff. M. involuta | ---- | ---- | ---- | ---- | ---- | ---- | × | × | × | ---- | ---- | ---- | ---- | ---- | × | ---- |
| Marginifera aff. M. timanica | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Marginifera aff. M. typica var. septentrionalis | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- |
| Marginifera? sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- |
| Camarophoria aff. C. mutabilis | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- |
| Camarophoria? sp. | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Rhynchopora aff. R. nikitini | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | × | ---- | ---- | ---- | × |
| Rhynchopora sp. | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Rhynchopora? sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Dielasma aff. D. truncatum | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Dielasma sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × |
| Heterelasma sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × |
| Spirifer aff. S. fasciger | × | ---- | ---- | ---- | ---- | ---- | × | × | × | × | ---- | ---- | ---- | ---- | ---- | ---- |
| Spirifer aff. S. ravena | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × |
| Spirifer aff. S. schellwieni? | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- |
| Spirifer sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- |
| Spirifer several sp, fragments | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Spiriferella arctica? | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Spiriferella aff. S. saranae | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- |
| Squamularia aff. S. perplexa | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × |
| Squamularia sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | × | ---- | ---- |
| Squamularia? sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- |
| Martinia? sp. | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Spiriferina aff. S. laminosa | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Spiriferina sp. | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | × |
| Aviculipecten sp. | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Aviculipecten? sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Streblopteria? sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Pleurotomaria sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Pleurotomaria? sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Paraparchites sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | × | ---- | ---- | ---- | ---- | ---- | ---- | ---- |

6755 (29AM–F1). Top of mountain, 6½ miles north-northeast of the forks of Indian Creek. Same locality as 1863 and 1864 of Mendenhall's collection. Fred H. Moffit, 1929.

7046 (31AM–F 1). 3 miles north-northeast of Suslota Lake. Same locality as 5875. Frank C. Schrader. 1902.

7046a (31AM–F 2). 3 miles north-northeast of Suslota Lake. Fred H. Moffit, 1931.

7439 (34AM–F 9). 6½ miles N. 83° E. of the mouth of Suslositna Creek. Fred H. Moffit, 1934.

8012 (35AM–F 1). Northeast tributary of lower Suslositna Creek, 3¾ miles north of the north end of Suslota Lake. Fred H. Moffit, 1935.

8013 (35AM–F 2). Fossil Creek, 3 miles N. 20° E. from the north end of Suslota Lake. Fred H. Moffit, 1935.

8014 (35AM–F 3). 3⅓ miles N. 15° E. from the north end of Suslota Lake, ½ mile north of locality 7046. Fred H. Moffit, 1935.

8015 (35AM–F 4). On mountain side ¼ to ½ mile east of Fossil Creek and locality 7046. Fred H. Moffit, 1935.

8016 (35AM–F 5). Head of Fossil Creek, near locality 8014. Fred H. Moffit, 1935.

8017 (35AM–F 6). 4 miles N. 35° W. of Suslota Pass. Fred H. Moffit, 1935.

8018 (35AM–F 7). ¼ mile east of locality 8017, or about 4 miles N. 35° W. of Suslota Pass. Fred H. Moffit, 1935.

8019 (35AM–F 8). Limestone ledge 8½ miles S. 70° E. from Mentasta Indian village. Fred H. Moffit, 1935.

8020 (35AM–F 9). 10 miles S. 67° E. of Mentasta Indian village. Fred H. Moffit, 1935.

8021 (35AM–10). On Eagle Trail, Porcupine Creek, 3 miles from Ahtell Creek. Fred H. Moffit, 1935.

8022 (35AM–11). 5½ miles N. 4° E. from the mouth of Ahtell Creek. Fred H. Moffit, 1935.

8023 (35AM–12). Top of ridge above gulch where lot 8022 was collected, 3.7 miles N. 8° E. from the mouth of Ahtell Creek. Fred H. Moffit, 1935.

*Permian fossils collected by Mendenhall in the Copper River basin, Alaska*

| | 1894 | 1891 | 1890 | 1889 | 1886 | 1881 | 1864 | 1863 |
|---|---|---|---|---|---|---|---|---|
| Goniocladia sp. | | × | | | | × | | |
| Orthotichia sp. | | | | | | | | × |
| Orthothetes sp. | | | | | | × | | × |
| Chonetes cf. C. uralica Moeller | | | | | | | | |
| Chonetes cf. C. granulifer Owen | | | | | | × | | |
| Productus sp. 4 (group of P. multistriatus) | | ? | | | | × | | |
| Productus semireticulatus var. | × | × | × | | × | × | | |
| Productus sp. 7 (group of P. semireticulatus) | | | | | | × | | |
| Productus sp. 9 (group of P. cora) | | | | | | × | | × |
| Productus sp. 11 (group of P. cora) | × | | | | | | | |
| Productus sp. 15 (group of P. undatus) | × | | | | | | | |
| Productus sp. 17 | × | | | | | | | |
| Productus sp. 18 (group of P. humboldti) | | | | × | | | | |
| Productus sp. 20 (group of P. humboldti) | | × | | | | | | |
| Marginifera sp. 1 | × | | | | | | | |
| Marginifera longispinus (Sowerby) | | | | | × | × | | |
| Camarophoria near C. pinguis Waagen | | × | | | | | | |
| Camarophoria sp. 2 | × | | | | | | | |
| Rhynchopora near R. nikitini Tsch | × | × | | | | | | |
| Reticularia cf. R. lineata (Martin) | × | | | | | | | |
| Martinia sp. 1 | | | | | | × | | |
| Martinia sp. 2 | | | | × | | | | |
| Spirifer sp. 1 (group of S. striatus) | × | | | | | × | × | × |
| Spirifer sp. 6 (group of S. striatus) | | | × | | | | | |
| Spirifer sp. 3 (group of S. arcticus) | | × | | | | | × | |
| Spirifer sp. 3a (group of S. arcticus) | | | | | | | × | |
| Spirifer sp. 4 (group of S. supramosquensis) | | × | | | × | | | |
| Spirifer sp. 5 (group of S. supramosquensis) | | | | | | × | | |
| Spirifer sp. 7 (group of S. supramosquensis) | | × | | | | | | |
| Spirifer sp. 7a (group of S. supramosquensis) | × | | | | | | | |
| Spirifer sp. 8 (group of S. alatus) | × | | | | | | | |
| Spiriferina sp. 1 | | × | × | | | | | |
| Straparollus sp. undetermined | | | | × | | | | |
| Total | 12 | 9 | 3 | 3 | 3 | 11 | 3 | 4 |

**1863–1864. 100-foot limestone bed on upper Indian Creek; same locality as 6755. Walter C. Mendenhall, 1902.**
**1881. Near base of spur between Mankomen and Slana Valleys. Walter C. Mendenhall, 1902.**
**1886. Top of buff limestone, 700 feet above locality, 1881. Walter C. Mendenhall, 1902.**
**1889. Thin dark limestone near top of spur between Mankomen and Slana Valleys. Walter C. Mendenhall, 1902.**
**1890. Upper part of ridge between Eagle Creek and Slana Valley. Walter C. Mendenhall, 1902.**
**1891. Top of ridge between Eagle Creek and Slana Valley. Walter C. Mendenhall, 1902.**
**1894. Base of upper limestone, west of Eagle Creek. Walter C. Mendenhall, 1902.**

Permian rocks are widely distributed in Alaska and contain a fauna that is more closely related to that of Asia than to that of most of North America. In many places, as in the Mankomen formation at its type locality, they include a large proportion of tuff beds and lava flows, and in some places, such as the vicinity of Skolai Pass [16] between the White River and Nizina River Valleys, they contain a preponderating proportion of volcanic material.

A section of Permian rocks that may be regarded as one of the outstanding Permian sections of Alaska is exposed on the Yukon River just above the mouth of the Nation River. This section is notable for having yielded a larger Permian fauna than any other Alaskan locality, rather than for containing a typical assemblage of Permian beds. It consists essentially of limestone, but its lower part contains beds of fossiliferous conglomerate, sandstone, and

[16] Moffit, F. H., Geology of the Chitina Valley and adjacent area, Alaska: Geol. Survey Bull. 894, in press.

shale. The formation name "Tahkandit limestone" was given to these beds by Mertie,[17] who measured the section and found it to contain 527 feet of sedimentary deposits, of which 373 feet is limestone. However, the top of the section was not recognized. Furthermore, the measurement may be subject to some modification because of faults that were not recognized when it was made.

## UNDIFFERENTIATED MIDDLE DEVONIAN AND PERMIAN ROCKS

### CHARACTER AND DISTRIBUTION

The rocks that are described in this section occupy a wedge-shaped area extending from the head of the Slana River to the southeast corner of the area shown on the map, separating the undifferentiated schists on the north from the Permian and other rocks on the south. They are dominantly marine sedimentary rocks but include extrusive and intrusive igneous rocks, which are widespread, although more conspicuous in the southeastern part of the district.

The prevailing rocks of the group are slate and argillite, but conglomerate, quartzite, grit, graywacke, and limestone are also present. Locally some of the members of the group show metamorphism and are schistose. Although fossils were found only in a few of the limestone beds, it seems probable, from a consideration of the collections made at different places, that a large part of the rocks of this group will eventually prove to be Permian rather than Devonian, for fossils identified as Middle Devonian were obtained from only one small limestone mass within the undifferentiated area.

The main area of these undifferentiated rocks, westward from the Little Tok River, consists chiefly of beds that were originally mud but are now slate and argillite. The original sediments included gravel and sand also, but typical sandstones and quartzites are not found with the slate, although conglomerate made up of pebbles rather sparsely scattered through a sandy, slaty matrix were seen at various places. A notable feature of the rock distribution that appears on the geologic map is the alinement of limestone outcrops, which may originally have been continuous beds that have since been separated through faulting and folding or which possibly were discontinuous limestone deposits originally. At the west end of the undifferentiated area the rocks are chiefly black slate and limestone.

The group of mountains northeast of the valleys of Tuck Creek and the Little Tok River is separated from the mountains to the southwest by a wide gravel-floored valley which obscures the relations of the rocks on the two sides of the valley. The southwest face of this group is made up of slate and schist or phyllite, quartzite,

[17] Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: Geol. Survey Bull. 872, pp. 146–153, 1937.

and an occasional thin limestone bed, interlarded with sills of dark-gray or greenish fine- to medium-grained igneous rock that in different localities may be described as basalt, diabase, basic diorite, or even some more basic rock type. The sills commonly do not exceed 50 feet in thickness and are separated by 10 to 50 feet of sedimentary beds. This arrangement gives rise to a striking feature of the topography, for the hard, resistant sills stand in relief on the mountain slopes and are separated by smooth grassy surfaces that indicate the softer slate and phyllite. Such rocks are to be seen from the Tetling River to the mouth of Trail Creek, and it is at least suggestive that they are close to the great diorite intrusive mass to the southwest. The rocks that have been called schist or phyllite lie mostly in the vicinity of these intrusives, and most of them probably owe their alteration to the intrusion.

The highest member in the succession of beds that form the mountains north of Tuck Creek and are included in the undifferentiated Devonian and Permian area is a platy quartzite or sandstone, which extends from the Tetling River to the south branch of Trail Creek and forms the crest of the mountains for a distance of about 14 miles. Its greatest thickness is near the Tetling River, where at least 1,000 feet of quartzite is exposed in the end of the ridge. The thickness decreases toward Trail Creek, and beyond that creek the quartzite was not recognized.

The diorite mountains south of Tuck Creek resulted from the intrusion of a great mass of melted rock into sedimentary beds that are necessarily older than the diorite. All the rocks of the valley south of these mountains are designated Middle Devonian, because the limestone beds contain Middle Devonian fossils. Not much lithologic resemblance was seen between these beds and the sedimentary beds of the mountains north of Tuck Creek, and no basis of correlation was discovered, yet the possibility remains that the rocks of both localities may be Middle Devonian. There is also a possibility that the Middle Devonian area may contain some Carboniferous rocks.

### THICKNESS AND STRUCTURE

The undifferentiated Middle Devonian and Permian rocks include a great but unknown thickness of sedimentary deposits. Doubtless, however, the thickness of these deposits is to be measured in thousands rather than hundreds of feet. The mountains north of Tuck Creek include at least 5,000 feet of sedimentary beds and intruded sills, and the black slate at Gillett Pass is probably as thick. These two sections may or may not be equivalent, but they do not include all the beds that must be taken into consideration, although they suggest the magnitude of the thickness involved.

All the beds of this area are strongly folded and faulted, and their structure is complex. At the head of the Slana River, in the vicinity of Gillett Pass, the structure seems to be that of a synclinal trough with its axis occupying the valley. The black slate on the north side overlies the silvery mica schist and dips steeply south. It is greatly disturbed, however, for it is filled with quartz veins and is intruded by dikes and sills of igneous rock. The black slate and limestone south of the pass dip north.

Southeastward from the head of the Slana River the area widens, and the folding is more complicated, although the synclinal structure may persist at least as far as the Little Tok River. Throughout this distance the beds bordering the north side of the undifferentiated beds are black slate, as at Gillett Pass, and the dip is north. On Station Creek a variety of sedimentary beds, chiefly schist and slate of the undifferentiated schist area, are overlain by undifferentiated Middle Devonian and Permian beds that, from the forks of the creek to the Mentasta Valley and from the bottom to the top, include black slate, basaltic (?) intrusives or lava flows, schist and slate, sheared conglomerate, limestone, brown-weathering and gray slates, and intrusive granite. These beds all crop out along the creek for a distance of 3½ miles and all dip south, but the structure is complicated by faulting.

North of Tuck Creek, from the Little Tok River to the Tetling River, the beds dip uniformly northeast, in sharp contrast with those west of the Little Tok River, described above. The meaning of this change of dip on the border of the area is not yet clear.

The nature of the contact of the undifferentiated beds with the beds of the schist area on the north presents a problem which cannot yet be definitely solved, for the observations were not sufficient to give the solution. Probably the Middle Devonian and Permian beds overlie the schist unconformably, although the present relation may have resulted from faulting.

### AGE

Fossils were found in the limestone beds at several localities within the area under consideration. Most of them are correlated at least provisionally with the Permian Mankomen fauna, and the limestone that yielded them is shown as Permian on the geologic map. The forms identified are included in the table of fossils on pages 24–26. Fossils were not found in the limestone on either side of the valley of Mentasta Pass nor in the limestone areas north of the Slana River, although careful search was made for them.

One locality 2 miles west of Suslota Pass yielded a small collection of fossils that were identified as Middle Devonian. The collection was obtained from a mass of much folded and faulted limestone within a mile of one of the principal localities of Permian fossils. It is the only collection of Devonian fossils found outside the Tetling River area and is the chief reason for using the term "undifferentiated" in describing the beds of this area. How extensive the distribution of Devonian rocks may be here cannot be stated, but it is believed to be small.

A further factor of uncertainty connected with the undifferentiated beds is a measure of doubt regarding the age of some of the fossils designated Permian. Apparently the collections from some localities are not sufficiently diagnostic to eliminate the possibility of their belonging to a part of the Carboniferous earlier than Permian, yet until more conclusive evidence is obtained it seems best to include all the collections in the Permian.

## MESOZOIC ROCKS

### CHARACTER AND DISTRIBUTION

The mountains southeast of Suslota Pass, in which the Little Tok and Tetling Rivers rise, are made up almost wholly of banded and thin-bedded argillite and fine sandstone, with which conglomerate is interbedded locally and in which a few thin beds of limestone are found. These rocks occupy the northwest end of a trough of Mesozoic marine sedimentary deposits which extends southeastward beyond the limits of the mapped area, almost if not quite to the international boundary. The width of this trough between the heads of Buck and Suslota Creeks is a little more than 10 miles, but it increases toward the southeast and is about 15 miles in the interval between the Nabesna and Chisana Rivers. For the most part the beds are dark and weather rapidly, so that they give a somber aspect to the mountains and produce topographic forms that are distinct from those of the areas of the older sedimentary deposits, schist, and igneous rocks.

Probably the most characteristic feature of the Mesozoic rocks is the banding produced by the alternation of dark slate or argillite beds and lighter fine-grained sandy beds. The two layers grade into each other, but the change from one pair of beds to the next is distinctly marked. In places hundreds or possibly thousands of feet of such banded rocks in which beds 2 inches thick are uncommon and beds less than 1 inch thick dominate were deposited. Thinly banded rocks of this kind prevail at the west end of the Mesozoic syncline. Along the mountains to the area between the Tetling and Nabesna Rivers the thickness of the individual beds increases, and the gradation of coarser material into finer material within the pairs of beds disappears. The mountains shown on the map east of the head of the Tetling River consist of thin-bedded argillite and arkosic sandstone in which few of the sandstone beds reach a thickness of 2 feet, although one or two much thicker beds were seen. A thick bed of conglomerate interstratified with the argillite and sandstone crops out at one locality and is made up of well-rounded pebbles of fairly uniform size, which, however, vary from place to place, so that the rock appears as a coarse grit with pebbles as much as a quarter of an inch in diameter or as a coarse conglomerate with pebbles as large as 4 inches. Some of the conglomerate contains many well rounded pebbles of granite, and some of it is made up largely of limestone pebbles. Both the conglomerate and the arkosic sandstone beds are stained brown by weathering. Limestone was found in the stream wash and must be present in the section but was not seen in place.

The Mesozoic rocks north of the head of Suslota Creek are banded but less distinctly thin-bedded than the argillite and sandstone of the Tetling River area. They include beds of slate, a few thick sandstone beds, and thick beds of conglomerate in which the pebbles are sparsely scattered through a slaty sandstone. One bed of coarse conglomerate contains boulders as much as 18 inches in diameter. Pebbles and cobbles of limestone form a large part of some of the conglomerate. A block of limestone 5 feet long and 10 inches thick was seen in a mass of conglomerate that rolled down from a cliff. Well-rounded pebbles of granite or diorite are also present in some of the conglomerate. Calcareous beds and thin limestone beds containing a few fossils were seen in the mountains between Suslota Creek and the Little Tok River.

Intrusives are less common in the Mesozoic rocks than in any of the older rocks, although dikes or sills were found here and there, and fragments of such dikes appear in the stream wash.

### THICKNESS AND STRUCTURE

The Mesozoic rocks occupy a great synclinal trough in which the beds are strongly folded but are not so highly metamorphosed as to become schistose. They have not been examined thoroughly and have not yet furnished a section of beds from which the thickness and the details of the structure can be determined. Three periods of Mesozoic time are represented in the area, although the beds corresponding to them have not been differentiated. It is probable that the structure is complex and may involve two or more unconformities within the stratigraphic section, as well as an unconformity at its base. In general the structure is that of a broad syncline made up of minor folds, strongly compressed and in places overturned. The total thickness of beds is undoubtedly many thousands of feet.

### AGE AND CORRELATION

The rocks of the undifferentiated Mesozoic area are only sparingly fossiliferous and so far have yielded few forms from localities within the area being considered here. Most of the fossils that have been found were in thin beds of limestone or limy grit, although a few came from slate. Fortunately, most of the collections are diagnostic, even if poor in number of species, and from them and from collections made in areas adjacent to the territory covered by the geologic map, it has been found that Upper Triassic, Upper Jurassic, and Lower Cretaceous faunas are present in this area. The collections of fossils were submitted to John B. Reeside, Jr., for identification and are listed in the following table:

*Mesozoic fossils from the Slana-Tok district*[1]

| | 16085 | 16086 | 16259 | 16260 | 16261 | 16262 | 16264 | 16265 | 16266 | 16267 | 16268 | 16269 | 16921 | 16922 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Astrocenia, n. sp., identified by J. W. Wells as not older than Triassic | | | | | | | | | t | | | | | |
| Dielasma? n. sp. | | | | | | | | | t | | | | | |
| Terebratula, 2 sp. probably new | | | | | | | | | t | | | | | |
| Conucardia, n. sp. | | | | | | | | | t | | | | | |
| Dimyopsis, n. sp. | | | | | | | | | t | t? | | | | |
| Cyrtina? n. sp. | | | | | | | | | t | | | | | |
| Spiriferina cf. S. yukonensis Smith | | | | | | | | | t | | | | | |
| Spiriferina, n. sp. | | | | | | | | | t | | | | | |
| Spiriferina? n. sp. | | | | | | | | | t | | | | | |
| Cassianella? sp. | | | | | | | | | t | | | | | |
| Monotis sp. | | | | | | | | | t | | | | | |
| Pseudomonotis subcircularis Gabb | | t | | | | | | | | | | | | |
| Buchia (Aucella) crassicolis Keyserling) | c | | c | | | | | | | | | | | |
| Buchia (Aucella) cf. B. pallasi (Keys) | | | | | | | | | | | | | j | j |
| Aviculopecten? sp. | | | | | | | | | t | | | | | |
| Omphaloptycha sp. | | | | | | | | | t | | | t? | | |
| Entolium sp. | | | | u | | | | | | | | | | |
| Phillipiella sp. | | | | u | | | | | | | | | | |
| Pelecypod fragments | | | | | | u | | | | | | | | |
| Turbo? sp. | | | | | | | | | t | | | | | |
| Gastropod fragments | | | | | | u | | | | | | | | |
| Spherical organism, unidentified | | | | | t? | | t? | t? | | t? | t? | t? | | |

[1] The letter c stands for Lower Cretaceous; j for Upper Jurassic (Naknek); t for Upper Triassic; u for age undetermined.

16085 (31AM–F9). Head of Lost Creek, latitude 62°36.0′, longitude 142°59.0′.
16086 (31AM–F16). Head of first large creek west of Lost Creek, latitude 62°35.5′, longitude 143°19.0′.
16259 (31AM–F4). Talus near head of west tributary of first large stream southwest of Buck Creek.
16260 (31AM–F5). Tributary of Suslota Creek, about 5½ miles east of Suslota Lake.
16261 (31AM–F6). South side of pass between Suslositna Creek and west branch of large creek southwest of Buck Creek.
16262 (31AM–F7). Threeway Pass, same as 16261.
16264 (31AM–F10). Lost Creek.
16265 (31AM–F11). Lost Creek; same as 16264.
16266 (31AM–F12). Head of Lost Creek.
16267 (31AM–F13). Head of first large creek west of Lost Creek, tributary of Jack Creek.
16268 (31AM–F14). Same as 16267.
16269 (31AM–F15). Same as 16267 and 16268.
16921 (34AM–F3). 2¾ miles east of lake on Suslositna Creek.
16922 (34AM–F4). Gravel bar at camp 6, near head of Tetling River (Bear Creek).

Although the number of localities included in the table is small, the fossils have some unusual features, especially those from locality 16266, of which Reeside says: "This fauna is wholly new and of a facies not recorded in North America before. It seems surely to be

Triassic and probably Upper Triassic, but none of the familiar species are present." The fact that typical Upper Triassic fossils were collected nearby, at locality 16086, and have been collected at other places in the area of Mesozoic rocks outside the limits of the area included on the map is a further reason for assigning the lot from locality 16266 to the Upper Triassic, notwithstanding its unusual character.

## IGNEOUS ROCKS

Igneous rocks are widespread in the Slana-Tok district but are far more abundant in its southern part than in the schist area to the north, as is immediately apparent from a glance at the geologic map. They are of many varieties and of different ages, but their petrographic characters have not been studied carefully, and their relative ages have been determined in only a few localities. They include both extrusive and intrusive types, which in many places occur in close relation to each other. The two types of igneous rock are only partly differentiated on the geologic map (pl. 1), especially in those places where both types are common, for the separation would be difficult even if ample time were available for careful detailed mapping. Two principal areas of light-colored coarse-grained intrusive rock are shown. One makes up the high mountains adjacent to the lower Slana River on the southwest. The second forms the mountains between Buck and Tuck Creeks. These intrusives are mainly diorite or quartz diorite but locally include more basic types. In addition to the two large areas several smaller areas of similar rocks appear north of the Slana River, near Mentasta Pass, and in the mountains west of the upper Little Tok River.

Small areas of intrusive rocks that in general are finer-grained and darker-colored than those just mentioned are common in the schist area, more particularly near its southern border, where many high peaks and prominent hills terminate in masses of igneous rock that is more resistant to weathering than the schist into which it was intruded.

The principal area of volcanic rocks, which include lava flows and tuff beds, is in the southwestern part of the district. This area, however, includes also a large proportion of intrusive material, chiefly medium-grained gray diorite, andesite, and dark fine-grained basaltic rock, too intimately associated with the volcanic rocks to be separated in reconnaissance mapping.

Future work may show that more of the metamorphic rocks of the schist area were derived from igneous rock than is realized at present. This possibility was recognized during the field work, yet it was believed that most of the schist represents metamorphosed sedimentary deposits.

### INTRUSIVE ROCKS

The area of granitic rocks forming the mountains on the southwest side of the Slana River is about 20 miles long and 5 miles wide and contains the highest mountains of the group in which Indian and Ahtell Creeks rise. Its southern boundary as represented on the geologic map is only approximately correct, for it was not traced accurately. The rocks are coarse-grained light-colored diorite and quartz diorite, which are in strong contrast with the darker rocks of the mountains to the south and north. Surfaces that have long been exposed to the weather are covered with a black lichen, which is often a sufficient indication for distinguishing the diorite from other rocks. On disintegration, however, the diorite yields a white wash made up of rounded boulders and gravel that make every creek bed stand out distinctly against the dark vegetation of the mountain slopes. The rock shows an even granular rather than porphyritic texture and thus differs from the diorite of the mountains north of Buck Creek. In this larger area near Buck Creek the rocks seem to be somewhat more basic. They are diorite rather than quartz diorite, and a porphyritic texture is common. Perhaps the most striking feature of the diorite is the common occurrence of phenocrysts of feldspar (pl. 2, *B*) in the form of chubby twinned crystals (carlsbad twins) ranging in greatest diameter from less than 1 inch to 2 inches in rare examples. The twinned crystals are readily distinguished by the reflection of the sunlight from the cleavage planes. They are not present in all of the diorite but were seen at many places from the Little Tok River to the mountains south of the Tetling River.

This intrusive mass brought about marked changes in the sedimentary beds which it invaded, altering them to schist filled with garnet and other contact minerals. The altered zone is adjacent to the intrusive mass and is most noticeable along the south boundary, for the other side facing Tuck Creek is largely concealed by unconsolidated deposits.

### UNDIFFERENTIATED EXTRUSIVE AND INTRUSIVE ROCKS

The principal area of extrusive rocks is the area that is drained in large part by Indian and Ahtell Creeks but extends northward across the upper Slana River and eastward into the mountains between the Slana River and Suslota Lake and those south of Suslota Creek. A low hill 3 miles northwest of Mentasta Lake is made up of lava flows and tuff, and the highest mountains north of Mentasta Pass are in a belt of dark basaltic rock that extends from Mineral Lake to Bone Creek and may consist in part of intrusive rocks.

The volcanic rocks of the Indian Creek area are intimately associated with dark granitic intrusive rocks and a minor proportion of siliceous argillite and limestone. The volcanic rocks are dark basaltic flows and beds of tuffaceous material, somewhat altered chemically but not schistose. They predominate in the western and northern parts of the area and are subordinate to the granitic intrusives in the Ahtell Creek Valley and eastward. Careful detailed mapping would be necessary to separate the intrusive rocks from those poured out or blown out on the surface.

The intrusives include dark-gray medium-grained diorite and dark andesitic rocks that may be finer-grained, more quickly cooled phases of the diorite.

The lava and tuff beds north of the upper Slana River are conspicuous because of the bright coloring that comes from the oxidation of pyrite or other iron minerals. They dip northward and may underlie the tuff and limestone beds at the base of the Permian Mankomen formation (p. 23).

## AGE

The igneous rocks of the Slana-Tok district represent several periods of igneous activity extending through a great range of geologic time. They include metamorphic rocks that may be older than Paleozoic and little-altered dikes and sills that cut the Mesozoic sedimentary beds and may be of Mesozoic or later age, as well as rocks of intermediate age. In the nearby Wrangell Mountains lava flows that are of Recent origin are exposed. Unfortunately definite age assignments cannot yet be made for most of the igneous rocks of the district.

The igneous rocks of the schist area belong to not less than two periods, for in part they are as highly metamorphosed as the associated sedimentary beds and in part are much less so. The many small isolated areas of igneous rock forming mountain tops north of Trail Creek and the Tok River belong to the younger period, but the age limits of this period are not known.

More definite statements can be made as to the igneous rocks associated with the Permian sedimentary beds. It is evident that the interbedded tuff beds and lava flows are contemporaneous with the limestones and other fossil-bearing beds that reveal the age of the Mankomen formation and are therefore Permian. However, the intrusive rocks that cut the Mankomen formation are necessarily younger, although their upper age limit is undetermined. The Permian epoch was a time of exceptional volcanic activity in Alaska, and the Permian rocks nearly everywhere are characterized by tuffaceous beds and lava flows.

The large masses of light-colored diorite northeast of Buck Creek and along the southwest side of the Slana River Valley intrude Middle Devonian and possibly Permian rocks. Presumably they all belong to the same period of intrusion, although they differ somewhat in lithologic character, for they seem to show little alteration or about the same degree of alteration. A probable upper limit of age for these intrusive masses does not appear from the evidence at hand, for they are nowhere in contact with Mesozoic rocks. Mountain building that affected the whole Pacific coast line of North America took place in Jurassic or Cretaceous time and was accompanied by the intrusion of vast bodies of granitic rock, including diorite, granodiorite, monzonite, and other rock types. It is suggested that the two large masses of diorite may have been intruded during this period of mountain building, although no direct evidence to support such an assignment is at hand.

The oldest of the lava flows that are so widely displayed in the Wrangell Mountains were extruded in Tertiary time and in places overlie fresh-water deposits containing plant remains that have been identified as Eocene.[18] However, the extrusion of lavas did not stop then but has continued to Recent time, as is shown by the lavas that cut unconsolidated deposits of the Chitina Valley. The lava flows of the Wrangell Mountains do not extend to the Slana-Tok district, yet it may be true that some of the dikes cutting the Mesozoic beds of the district are equivalent to them in age.

## UNCONSOLIDATED DEPOSITS

The most recent consolidated sedimentary deposits of the Slana-Tok district are the Mesozoic beds of the mountains in the southeastern part of the district. Throughout the area, however, unconsolidated deposits that are geologically young and in fact are still being formed occupy the valley floors, concealing the underlying bedrock and protecting it for the time from further erosion. They include deposits of gravel, sand, and silt laid down by streams or in lakes, the more or less unsorted material deposited by glacial ice and the water associated with it, and the angular, practically unsorted debris on the hill slopes that is formed by the action of frost and rain, and the other processes of weathering. This last-mentioned material calls for little comment except that it is present wherever bedrock is exposed to attack by the elements and represents the first state of most of the deposits formed by water and ice. Gravel, sand, and morainal deposits are the subject to which attention is chiefly directed in this section, and they are shown on the geologic map

[18] Moffit, F. H., Notes on the geology of the upper Nizina River, Alaska: Geol. Survey Bull. 813, p. 160, 1930.

(pl. 1) without any attempt to differentiate between the deposits of different origin.

No gravel deposits or unconsolidated deposits of any kind that were present when the ice took possession of this district have been recognized in it. Apparently all loose material was swept away by the ice as it advanced from the highland areas to the lowlands, and all the present unconsolidated deposits except some of those in the Copper and Tanana Valleys were formed after the waning of the glaciers began.

A large proportion of the unconsolidated deposits could at some time have been classified as glacial material, even some that now are clearly stream deposits, for either they have been contributed to the streams by ice moving out from the mountain valleys or they are reworked glacial deposits. Streams that issue from active glaciers carry much fine material in suspension and move great quantities of gravel and coarser material along the bottoms of their channels. Commonly they move the coarser material by stages, depositing it at some point temporarily but later removing and redepositing it as their carrying power varies and their channels shift.

Morainal deposits are finely displayed in some parts of the district and are easily recognized by their topographic form where they are not concealed by timber. The valley of the Slana River from the vicinity of Mentasta Lake to Mankomen Lake is one of the best localities for seeing what may be accomplished by ice in its work of transporting rock debris. The wide valley floor is occupied by masses of unsorted material, which was brought from its original source by a great ice stream that carried the debris on its surface and within its body and finally left it in confused heaps where the ice melted. Although the Slana River shifts its channels over a wide gravel flood plain and has removed some of the debris left by the ice, the old moraines still occupy most of the valley from the margin of the flood plain to the lower mountain slopes, 400 to 500 feet above the river, and appear as a confusion of irregular rounded hills and deep kettle holes with no order or system of arrangement. Lakes and ponds are numerous, yet most of the unconsolidated material is sufficiently porous for the water to drain out of the kettle holes gradually, leaving moist soil in the bottoms, where grass grows luxuriantly.

Morainal deposits are not confined to the Slana Valley. They are present throughout the lowland areas but are not everywhere so conspicuous, especially if they are timber-covered. Only where they are above timber line or have been burned over is their topographic form readily made out. The conspicuous glacial deposits are in the lowland areas and valley bottoms, but erratic blocks and well-rounded stream wash are present on mountain tops high above the valleys and give evidence that the ice once hid everything but the highest peaks. Such high gravel can be seen in many places. In the Indian Creek Valley water-worn pebbles and cobbles are scattered over the flat-topped mountains 2,000 feet above the stream. On both sides of lower Ahtell Creek erratic boulders and gravel were found at an altitude of 4,500 feet, or 1,800 feet above the creek, and contain fragments of vesicular lava that doubtless came from the Wrangell Mountains.

Glacial ice also produced a form of terrace deposit made up of material that is commonly well rounded and much better sorted than the typical glacial deposits, which was deposited in water along the margin of the ice and probably, in places, in water impounded by the ice. Excellent examples of this type of deposit are presented by the high gravel benches at the forks of Ahtell Creek, where gravel deposits more than 200 feet thick were accumulated. It is clear from the evidence of this place and other places on Ahtell Creek that the glacial history of the valley is complex and that reversal of the direction of the main ice flow must have taken place at least once, for the glacial deposits contain material from widely separated sources toward the north and far to the south.

Another example of water-laid deposits contributed directly by the ice but distributed in part by water can be seen at the head of the small tributary to Suslota Creek 5 miles east of Suslota Lake. Here immense quantities of gravel were deposited near a former border of the glacial ice, opposite the west end of the narrow pass leading eastward to the Little Tok drainage area. Furthermore, the glacial water spilled northwestward from the head of this little creek and northward through the next pass on the west into the head of Suslositna Creek, whence it made its way through Suslota Pass to the Little Tok River, leaving a fine northward-sloping bench of gravel 2 miles long on the east side of upper Suslositna Creek.

The gravel point near the Slana Bridge, where Ahtell Creek and the Slana River join, is still another prominent example of the deposits formed by glacial ice and water. This gravel point (pl. 3, *A*) stands nearly 300 feet above the valley floor and is a conspicuous feature of the upper Copper River Valley because of its light color and isolation, which make it visible for miles from many directions. The exact way in which this mass of partly assorted rock debris came to its present position is difficult to determine. Possibly the deposit accumulated at the margin of an ice mass, or possibly it is part of an outwash train that has been encroached upon by the currents of the Slana River and Ahtell Creek.

Stream gravel, with which the low bench-gravel deposits adjacent to the flood plains may be included, is present on all the streams.

In large part the stream wash is of local origin, but in many places it contains rock fragments from a foreign source. In some places this foreign material was contributed directly to the stream by the glacial ice; elsewhere it was derived from morainal deposits or from old gravel deposits laid down by former streams that flowed away from the ice.

The flood plains of the larger rivers, such as the Copper, Slana, Tok, and Robertson (pl. 3, *B*), contain immense quantities of rock debris in all stages of reduction from angular blocks and rounded boulders to fine silt. The material of this flood-plain gravel is not stationary but is gradually moving downstream under the action of the swift currents, especially those of the high water of spring flood time or the warm days of summer, when the snow and glacial ice of the headwater tributaries is melting rapidly. The depth of the flood-plain gravel is not known but doubtless varies considerably with the irregularities of the bedrock floor, distance from the valley walls, position on the stream, and other conditions. The character of the bedrock and the varying capacity of the glacial ice to erode bedrock doubtless produced irregularities in the valley floor that are now hidden by the unconsolidated deposits.

Peculiarities of the topography appear to indicate that the gravel deposits of the lower Tetling River and the Tanana Valley are relatively deep, for the isolated hills on the lowland rise abruptly from the gravel plain without the usual gradual steepening as if they had been partly buried under a great quantity of gravel deposited around them by the streams flowing from the west and south. The depth of gravel in the Tanana Valley at Tanana Crossing and above may have been influenced also through the obstruction of the river channel at Cathedral Rapids, from which it resulted that the grade of the river above was lessened, and the slower currents deposited the load of material that they could no longer carry.

## GEOLOGIC HISTORY

Only a brief and imperfect outline of the geologic history of the Slana-Tok district can be constructed from the evidence now available. This history covers an enormous length of time and involves many great changes, all traces of which have been removed, so that some of them can only be guessed at from facts that have been learned in other places and some will never be known. The record is written in ancient rocks, and, as is true of all records of historical events, the more distant in the past the event is the less legible the record is likely to be.

The oldest rocks of the Slana-Tok district are the metamorphosed sedimentary deposits of its northern part. At present they are schist, but originally most of them were mud, sand, and limy deposits laid down in a Paleozoic or possibly a pre-Paleozoic sea. Surmise as to the time of their formation is based on scant evidence and will remain uncertain till it is known whether the rocks are to be correlated with some part of the Birch Creek schist or with younger metamorphic rocks of the Yukon-Tanana region.

What happened in the interval of time between the deposition of these older rocks and the deposition of the Middle Devonian beds is imperfectly known. Probably the older rocks were buried deeply under early Paleozoic rocks, intruded by igneous rocks, folded and metamorphosed, and then subjected to erosion after having been raised above sea level. The cycle of submergence and elevation may have been repeated not once but many times before the final submergence that preceded the deposition of the Devonian sediments.

The sequence of events between the deposition of the Middle Devonian and the Permian beds is also unknown except that not far away, in seas that occupied areas which are now parts of the Copper, Chitina, and Tanana Valleys, early Carboniferous beds were laid down and igneous rocks were intruded. The oldest rocks that have been identified as Permian overlie igneous rocks. Furthermore, they are interstratified with lava flows and tuff beds and are intruded by igneous rocks, so that almost every section of the Permian beds contains a large proportion of igneous material. The Slana area and other areas, especially that which includes the heads of the White and Nizina Rivers, show that Permian time in this part of Alaska was a time of exceptional volcanic activity. During the Permian epoch great quantities of melted rock were poured out on the land or on the bottom of the sea. These outpourings were accompanied by the ejection of fragmental material blown from volcanoes. Some of this loose material fell on the land, and some settled in the sea, where it mingled with other sediments and formed beds of tuff. Such beds make up a large part of the Mankomen formation.

The Permian beds of the Nizina and White River areas were folded, raised above sea level, and eroded before the earliest of the Mesozoic beds were deposited. Evidence for the unconformity between these two systems of beds has not been found in the Slana-Tok district, yet it is reasonable to suppose that a series of events similar to that which occurred in the Nizina area, where the unconformity is well shown, took place here also.

The three epochs of the Mesozoic era represented in the southeastern part of the Slana-Tok district account for only a small part of Mesozoic time—the Upper Triassic, the Upper Jurassic, and the Lower Cretaceous—but they suggest three distinct periods of sedimentation and subsequent erosion. Probably the Upper Triassic rocks were raised above sea level and subjected to erosion before they were depressed again and covered by the Upper Jurassic beds; and the Upper Jurassic beds in their turn probably experienced a repetition of this sequence of events before the Lower Cretaceous rocks were laid down on them.

Toward the end of Cretaceous time a period of mountain building began in which all the rocks were folded, the land was raised above the sea, and vigorous erosion of the highlands was started. This appears to be the time when the Alaska Range came into existence in essentially its present form. Since the end of Cretaceous time Alaska has been a land mass, continuously above the sea, as is known from the absence of younger marine deposits anywhere except near the present seacoasts. Erosion continued in early Tertiary time, and fresh-water coal-bearing deposits were laid down on the land surface over a wide area. The coal-bearing Tertiary deposits are not known in the Slana-Tok district but are represented in the nearby Wrangell Mountains by thin beds of conglomerate and clay containing fossil leaves and coal, lying beneath a great mass of lava flows which began to accumulate in Tertiary time and have continued to be outpoured from local vents almost to the present day. Tertiary beds are present also at the head of the West Fork of the Chistochina River, west of the Slana-Tok district.

The forces that folded the older rocks and gave rise to the Alaska Range were brought into play again after the coal-bearing beds were deposited, for in places these beds are moderately folded and tilted. Yet no such mountain-building activity as that of the late Cretaceous or early Tertiary has occurred since then.

The more recent and better-known geologic history of the district has to do with glaciation. When glaciation began the mountains and valleys were probably much as they are today except that the topographic forms were those that are produced by normal stream erosion, unmodified by the work of moving ice. It is evident that the glaciation began as the result of climatic changes which brought about the precipitation of more snow in winter than was melted in summer, that the accumulation of snow and ice continued till a maximum was reached, and that another climatic change finally reversed the process and the ice gradually disappeared. Accumulation probably began in the high mountains, whence the ice fronts advanced slowly down the valleys and out into the lowland areas. At the maximum the Copper River Basin was completely filled with ice, which reached a thickness of several thousand feet and covered all but the higher peaks of the surrounding mountains. Probably both the advance and the retreat of the ice were intermittent and made up of many minor movements, forward and back, even when the general movement was in one direction. Many thousand years was required to complete this cycle of events, and many local centers of accumulation contributed to the first advance, maintained the retreat, and remain as centers even to the present day.

The Wrangell Mountains were one center where ice accumulated, but practically nothing is known about the advance of the ice from this and other centers except that whatever unconsolidated material, sand and gravel, may have been present in the mountain valleys was swept away. Of more significance in producing changes in the appearance of the land, however, is the modification of the forms of the valleys that came about through erosion by moving ice. The most outstanding expression of such erosion appears in truncated spurs, straightened valley walls, and the U-shaped cross sections of the valleys themselves (pl. 4, *A*).

In a few places on the rounded hills overlooking Tetling Lake the schist country rock has weathered into unusual forms (pl. 4, *B*) which suggest the possibility that this part of the range may have escaped the intense glaciation that took place on the Copper River side. Such unstable masses of rock could hardly have withstood the force of a large body of moving ice, and they appear too old to have been developed since the more recent ice was present in the Copper River Valley.

When the rate of accumulation of snow fell below the rate of melting, gradual disappearance of the great ice mass began, and other topographic expressions of glacial activity came into existence in the bodies of unsorted debris left by the melting of the ice and the gravel and silt beds deposited by the streams of water that flowed away from it. These deposits form the moraines and gravel benches that have been described and already are partly destroyed through the attacks of present-day streams.

A belief is common that the "ice age" in Alaska is definitely a thing of the past. This belief is not necessarily true. A view that more nearly represents the facts is that Alaska is still in an ice age. It seems probable that for the time being the Alaskan glaciers as a whole are diminishing rather than increasing, yet the present recession may be only a temporary recession in a general advance. The movement of an ice front, whether that of a great continental glacier or that of a small valley glacier, is not steadily forward or backward but consists of alternating advances and retreats which make the dominant movement difficult to recognize.

## MINERAL RESOURCES

The Slana-Tok district possesses geologic features that are commonly looked on as favorable for the occurrence of mineral deposits, and it has been a field for prospectors since the days of 1898, although the number of prospectors engaged there in recent years has been small. Many small veins containing one or more of the minerals galena, tetrahedrite, stibnite, sphalerite, iron sulphides, magnetite, gold, silver, copper, and possibly others have been found, as well as gravel deposits that have yielded native copper, silver, and gold. So far, however, no productive lodes have been discovered, and only one placer mine is now in operation. A little exploratory work has been done on lode prospects in many parts of the district. Most of the work was done in the earlier days, but as the showings did not offer much encouragement at that time the work was discontinued, and most of the prospects were abandoned. The more favorable conditions of recent years, however, together with the higher price for gold, have brought a revival of interest in them, and several have been restaked and had further exploratory work done on them. A prospect in the upper Tok Valley and several on Ahtell and Indian Creeks merit consideration, as they represent types of mineralization and may prove to have value.

## LODE PROSPECTS

### TOK RIVER

The prospect in the Tok Valley is on a tributary of the river flowing in from the north and joining it 7 miles above the mouth of the Dry Tok, or 2½ miles above Shindata Creek. This tributary stream has two branches, which come together about 1 mile above its mouth. On the south side of the eastern branch, nearly half a mile from the forks, an old prospect hole was driven in a mass of stibnite cropping out in the canyon wall at the edge of the gravel bar.

The country rock is chiefly metamorphosed sedimentary deposits which are nearly everywhere siliceous and have been folded, faulted, and cut by granular intrusive rocks, now considerably altered. Near the forks of the creek soft gray or black schist that plainly lies in a zone of faulting forms a high wall on the south. It dips southwest and is underlain by the siliceous schistose beds, which show some differences in appearance from place to place and extend up the creek beyond the tunnel. The siliceous schist appears to be a succession of altered quartzite beds but presents phases that possibly indicate altered siliceous intrusive rock. Exposed surfaces of the schist commonly show a fine banding caused by alternating thin layers or lenses and sheets of granular quartz and brownish mica. The appearance of a clean surface is striking and at a short distance suggests a sheet of white or gray paper ruled with straight, closely spaced, parallel lines. At the tunnel the banded schist is interrupted by a finer-grained siliceous rock with rusty weathering on exposed surfaces and joint faces, which appears to be a silicified sedimentary bed but possibly is an altered fine-grained intrusive. It is 100 feet thick, strikes N. 67°–73° W. and dips about 50° S. Like the other rocks of the vicinity, it is much faulted and is filled with veins of glassy bluish-gray and white quartz.

The ore body forms the base of a projecting ledge or spur of the silicified rock about midway between the two schist boundary lines (fig. 4) and lies mostly in a single bed or block about 8 feet thick, which is more massive than the adjacent rock and makes the nose of the spur. Stibnite that occurs chiefly as a granular mass but in

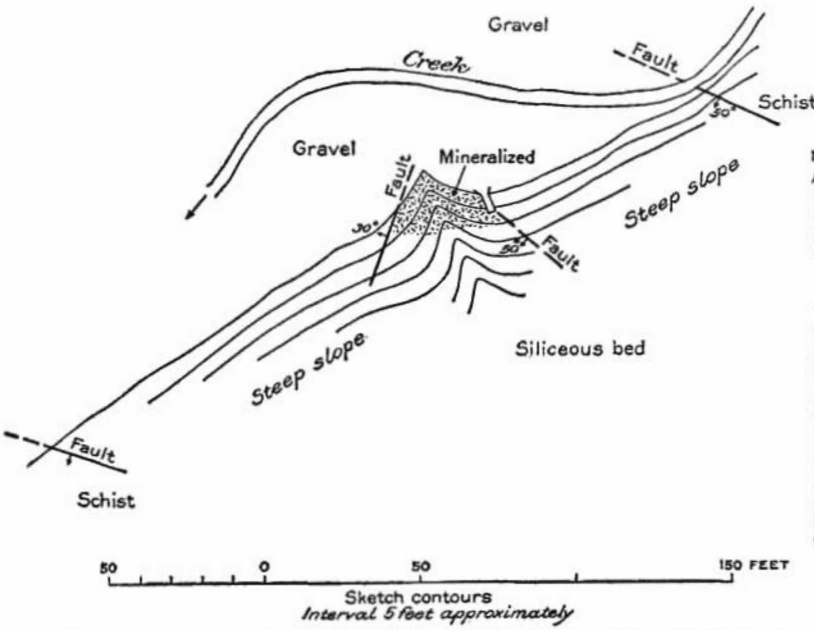


FIGURE 4.—Sketch map showing the relation of the stibnite deposit in Tok Valley to the creek bars and the canyon wall.

part in coarse shining crystals replaces the siliceous rock completely in the lower part of the deposit. Elsewhere it partly replaces the country rock, is disseminated through it, or cuts it in well-defined veins. This mineralized block shows a triangular face about 25 feet high and 20 feet across the base at the gravel bar.

The floor of the short tunnel is 5 feet above the gravel bar and follows a small vein of stibnite in or near a fault in loose caving ground. It shows much less of the ore body than is exposed on the surface below and west of it, and this fact and the general appearance of the mineralized part of the spur suggest that the continuation of the mineralized body may be below the level of the bars rather than up the canyon wall.

*A*. TRUNCATED SPURS OF THE MOUNTAINS SOUTH OF UPPER ROBERTSON RIVER.

*B*. WEATHERED LEDGE OF SCHIST ON A LOW, ROUNDED HILL NORTH OF THE HEAD OF TRAIL CREEK.

The original owner of the property has done nothing on it for many years and was not available for consultation regarding his findings, but recent assays show that the ore contains a little gold.

This mineral deposit is in a narrow canyon where space for mine buildings and equipment is small. Timber ends at the forks of the creek, so that none for mine uses is available near at hand, although a plentiful supply of excellent timber grows on the bars of the Tok River not more than a mile away.

### INDIAN CREEK

Several mineralized veins were discovered on tributaries of Indian Creek. One of them that seemed to have particular merit was prospected by several open cuts, which, however, did not disclose any commercial ore bodies, and the work was discontinued. This prospect is on a small tributary of the eastern branch of Indian Creek, near the top of the ridge dividing the Indian and Ahtell Creek Valleys, and is 13 miles in direct line from the highway bridge over Indian Creek. The writer [19] visited the prospect in 1929 and described it as follows:

> The vein is at the head of the tributary, near the top of the ridge dividing this tributary from the next small tributary on the west. The country rock is quartz diorite, which shows wide variations in texture but at the place where the vein was found is coarsely granular and contains large phenocrysts of feldspar. At this place the diorite is cut by a number of vertical fracture planes extending east and west and distributed over a distance of 100 or 200 feet from north to south. About 75 feet below the top of the ridge, which is 1,800 feet above Indian Creek, a quartz vein stands more than 6 feet above the ground and is at least 10 feet wide, although its boundaries are not exposed. Broken-down ledges and float show that this vein extends down the hill several hundred feet, but it does not hold the same width and where it crosses the ridge is reduced to about 18 inches. The quartz is cavernous and iron-stained and evidently contained iron sulphides, which have been leached out, leaving the more resistant galena.
>
> Between 100 and 200 feet south of this vein are two open cuts on similar quartz veins, but they were caved, so that the veins could not be seen. Almost directly west of these open cuts and 300 feet lower on the mountain slope are two other open cuts on the east side of a small gulch. The southern one is about 15 feet higher than the other. The diorite between them is crossed by numerous parallel fracture planes, which are vertical, trend east, and contain mineralized quartz in veins from a fraction of an inch to several feet thick. The largest of the quartz veins exposed in the gulch is about 7 feet thick but was not wholly in view, for the gulch was still partly filled with snow at the time of visit. Moreover, the character of the vein varies within a short distance, for a few feet above in the gulch half of the thickness of solid quartz is replaced by smaller parallel veins. The quartz is mineralized with galena, chal-

[19] Moffit, F. H., The Slana district, upper Copper River region, Alaska: Geol. Survey Bull. 824, pp. 123–124, 1931.

copyrite, and probably pyrite. It is cavernous and iron-stained from the weathering of iron sulphide and in places is stained with copper. A small vein about an inch thick in the lower open cut shows a larger proportion of galena distributed with considerable regularity throughout a gangue of quartz, but the larger vein of the cut to the south contains galena and a little chalcopyrite somewhat more unevenly distributed. Between the outcrop and the open cuts near the top of the ridge several exposures of quartz vein matter were seen, but because of loose material on the surface it was not possible to tell whether they are part of a continuous vein or fracture zone. The development work on the claims consists of open cuts, mostly on the west side of the ridge, and a trail which climbs the mountain side from the rock slide at the head of the valley to the upper cuts, a vertical distance of 400 feet. There is also an open cut on the east side of the ridge which was not examined because of a snow comber on that side.

Another vein, which has not been thoroughly explored, was found on a tributary of the west branch of Indian Creek 3½ miles northwest of the prospect just described. The ridge between the two main branches of Indian Creek is broken in this vicinity by a depression that provides fairly easy access from one branch to the other. The vein referred to is on the east branch of the little creek that drains the mountain north of this depression, nearly 2 miles northeast of the summit of the pass. It consists of galena-bearing quartz cutting the diorite country rock and showing great similarity to the vein just described. Although several open cuts have been made on the outcrop, they were so badly caved at the time the locality was visited that none of the vein matter could be seen in place, and it was not possible to tell whether the loose pieces of mineralized quartz on the hillside below the open cuts were there when the vein was discovered or whether they were dug from the cut.

### AHTELL CREEK

The recent placer-mining operations on Grubstake Creek, a small eastern tributary of Ahtell Creek, brought prospectors into the Ahtell Valley who carried on a spasmodic search for other gold-bearing gravel and for lode deposits. They found no new lode deposits but relocated two abandoned lode prospects on which work had been done in former years. These prospects are on a small stream locally known as Silver Creek, which joins Ahtell Creek 3 miles below Grubstake Creek, and on the west branch of Ahtell Creek, which comes in to the main stream nearly 3 miles above Grubstake Creek. Silver Creek is 1 mile below the much larger tributary of Ahtell Creek known locally as Flat Creek.

The Silver Creek prospect is on the north side of the creek, near its head and scarcely a mile from the highway. The country rock is mainly medium-grained gray diorite and a dark basaltic-looking rock that probably is igneous, although it resembles a silicified sedimentary bed seen on Grubstake Creek. About 1 mile from the mouth of the creek the country rock is crossed by a fault zone, at least 30 feet wide and probably much wider, showing many minor steeply dipping faults that strike N. 45°–70° W. The fault zone shows many veins of mineralized quartz.

An old tunnel near the creek is now caved, but the dump nearby shows quartz vein matter containing zinc blende, a little pyrite or chalcopyrite, galena, and copper staining. Nearly 100 feet higher than the tunnel, on the hill to the north, is an inclined shaft, 15 feet deep, driven in a mass of crushed vein matter about 4 feet thick and highly stained with iron oxide. Veins and knots of quartz with conspicuous blue copper stain contain granular tetrahedrite, sphalerite, and pyrite or chalcopyrite. An open cut 25 feet northeast of the shaft and a little lower exposes a vein of quartz 30 inches thick, mineralized in the same way as that at the shaft. Another caved shaft 25 feet lower and 50 feet to the southwest shows similar mineralization of the vein matter on its dump.

Although the tunnel, shafts, and many open cuts are caved or buried in slide rock, sufficient evidence is at hand in this locality to show that the faulting and crushing were severe and the mineralization extensive. Any silver present is probably associated with the tetrahedrite, as is true of the silver-bearing tetrahedrite of the Kotsina River in the Chitina Valley. Whether the ore contains gold was not determined.

The second prospect mentioned as occurring in the Ahtell Creek valley is at the base of the mountain north of the west branch of Ahtell Creek, about 200 feet higher than the creek and 1½ miles from the place where the two branches join each other. At this prospect a shear zone striking N. 30° E. and dipping steeply west cuts a fine-grained intrusive rock, which is a phase of the diorite that forms the mountains of this vicinity. A short tunnel, now partly caved because of the failure of old timbers, was driven in a fractured zone from 7 to 8 feet, where veins of quartz with a maximum thickness of 8 inches were encountered. The quartz contains galena and iron sulphides and is highly colored with the blue and green stains of copper. No work had been done on this prospect for several years when it was visited in 1935, but the ground had recently been restaked by other prospectors who were not the original owners. The prospect is near the upper limit of timber in this valley and is easily reached from the trail to Grubstake Creek.

The lower part of the valley of this west branch of Ahtell Creek is filled with gravel deposits through which the creek has cut a deep canyonlike channel, removing a large quantity of gravel and producing conditions such as would be favorable for the reconcentration of gold if the original gravel deposits carried any. On the other hand, the creek bed is filled with large boulders, which would cause difficulty in placer-mining operations if gold were found and an attempt were made to recover it.

## PLACER MINING

Prospecting for placer gold in the Slana-Tok district began in 1898 and led to the discovery of the gold placers of Slate Creek, Miller Gulch, and other streams at the head of Chistochina River, just west of the district, but prospecting within the district was less successful, although many of the streams were examined, at least superficially. However, a little placer gold was found at several places in those early years and at still other places in more recent years. These places include Ahtell Creek, Grubstake Creek, the northern tributary of Flat Creek locally known as Hidden Creek, Granite Creek, a small stream southeast of Mentasta Lake, and probably other streams unknown to the writer. Out of this list Grubstake Creek is the only stream that has produced sufficient gold to encourage continued mining and the only one where mining is now carried on.

### GRUBSTAKE CREEK

Grubstake Creek is one of the streams that were prospected in the earlier days without yielding satisfactory returns. It is a small eastern tributary of Ahtell Creek, draining part of the ridge between Ahtell Creek and the valley traversed by the old military trail to Eagle, and is reached from the highway by a trail about 5 miles long that begins not far from mile 61.

The stream is barely 2 miles long as measured from the crest of the ridge to Ahtell Creek and is formed by two small branches which come together about 1¼ miles above its mouth. The two branches occupy high open valleys, but after uniting they flow for half a mile through a narrow V-shaped valley between high pointed mountains and then for an equal distance over a wide alluvial fan that contains the loose material brought down from the upper valley by the creek and extends from the mouth of the Grubstake Valley to Ahtell Creek.

The country rock is dominantly igneous and includes dark fine-grained lava flows and coarsely granular diorite intrusives, together with dark-gray silicified rocks derived from detrital sediments such as graywacke or slate. Some of the country rock contained an abundance of pyrite, which weathers readily and stains the surfaces with iron oxide. Faults and crushed rock are widespread and in places are associated with dikes of light-gray diorite. The course of Grubstake Creek below the forks was probably determined by a zone of faulting that trends N. 75° W. through the diorite bedrock.

The greatest accumulation of unconsolidated material took place near the forks of the stream, where the valley narrowed and the creek was choked. The deposits include rounded stream gravel, glacial debris, and angular slide rock from the mountain sides. This material is poorly sorted and contains less of the stream gravel than of the other constituents. Much of it consists of boulders and other rock fragments that are clearly foreign to the valley and were derived in part from the mountains of upper Ahtell Creek. The deposits lower on the creek are smaller and include a greater proportion of boulders, for the finer material was removed by the swift current.

The heavy minerals magnetite, ilmenite, native copper, silver, and gold are recovered from the sluice boxes, and other heavy minerals would probably be discovered if the concentrates were examined thoroughly. Magnetite is abundant and occurs as sand, pebbles, and much larger pieces. Boulders of magnetite and of dark-green rock cut by veins of magnetite were seen in the cut. Ilmenite is not abundant, but pieces are occasionally found when the gold is being cleaned. Copper is present in considerable quantity and occurs both in well-rounded pieces and in flattened pieces. Copper oxidizes so easily, however, that it is difficult to tell how much battering the copper nuggets received in the movement of the gravel. Silver makes up a large proportion of the two valuable minerals recovered from the gravel. Both the silver and the gold show little abrasion and battering by the pounding rock fragments and must have come from a bedrock source not far distant from where they are now. Pieces of gold and of silver of dendritic form and many pieces that look as if they had been squeezed out of their original matrices under great pressure are found in the clean-ups. Another feature of the placer deposits that suggests a local origin for the gold and silver is the absence of these metals in the gravel above a well-defined point on the creek, which would seem to indicate that the source of the metals was below that point.

Grubstake Creek was rediscovered by Charles Swanson and M. G. Olson after it had been abandoned by earlier prospectors. These men began mining in a simple way in 1934 and, meeting with encouraging results, brought Gus F. Johnson and Lawrence DeWitt into the enterprise to assist them in developing the property, which now includes a group of lode and placer claims on Grubstake Creek, Ahtell Creek, and Quartz Creek, the first small stream north of Grubstake Creek. A trail was built to connect Grubstake Creek with the highway, also a cabin for headquarters at the mouth of the creek and another for living quarters on the working ground at the forks of the creek. The equipment now includes pipe for sluicing, sluice boxes, and a caterpillar tractor, which is used for both transportation and power plant.

The water of the two branches of Grubstake Creek is not sufficient for continuous piping. It is therefore impounded behind a dam and is released automatically from time to time as the pond fills, thus supplying water for short periods of sluicing, between which the boulders uncovered are rolled out of the cut by hand. In the first season of mining a cut was made on the north branch of the creek just above the forks, without reaching bedrock. It was 16 feet deep at its upper end, and the gold was distributed through the gravel from the grass roots to the bottom of the cut. During the second year, with 700 feet of pipe available for carrying water under greater head, a cut was made below the forks, but work in it was stopped in late summer by a shortage of water, in consequence of which the remaining time before the freeze-up was devoted to prospecting gravel on the lower part of the creek. Mining was continued in 1936 but was handicapped, as in the previous year, by insufficient water.

The experience of these three working seasons has shown that water supply presents an important problem for solution before efficient mining can be done. Several solutions or partial solutions have been suggested, including a ditch line to divert the upper part of Quartz Creek into the Grubstake Valley, a tunnel or ditch to tap a small lake on the divide between Quartz Creek and Grubstake Creek, and a long ditch to bring water from upper Ahtell Creek. This last-named proposal involves a large expenditure of money and can hardly be undertaken till the ground has been more thoroughly prospected. Grubstake Creek is favorably situated with relation to the highway. A bridge over Ahtell Creek and the conversion of 5 miles of trail into road would provide a way for hauling freight by motor truck at the time when it is needed and at less expense than by the present methods. As the difficulties of road construction are no more than the usual difficulties of this region, the improvements mentioned would not be unduly costly. Timber suitable for most mining purposes is available on Ahtell Creek but not on upper Grubstake Creek, for the forks of that stream are several hundred feet higher than timber line.

#### OTHER STREAMS

Gold has been found in gravel deposits on several other streams in the Slana-Tok district, but not in large enough quantities to be mined profitably. The two short streams that flow eastward from the divide at the head of Grubstake Creek into Porcupine Creek carry sufficient gold to encourage prospecting. Hidden Creek, which flows southward and joins Flat Creek a quarter of a mile below the lake, has gold-bearing gravel in its valley and was prospected in the earlier days, as is shown by the remains of old placer-mining equipment. It was restaked after mining began on Grubstake Creek. Granite Creek is a tributary of the Slana River, with two branches, one heading against the north branch of Ahtell Creek and the other against the west branch of Indian Creek. It carries placer gold, in consequence of which prospectors have spent several seasons there in recent years. Placer gold is also reported from one of the small streams flowing into the Slana River east of Mentasta Indian village, where a little work was done in former years but did not disclose pay dirt.

In 1936 prospecting was in progress on Ahtell Creek near the lower end of the canyon, 2 miles from Slana Bridge. Gravel deposits have been formed in the bends of the canyon and at its mouth and are probably composed chiefly of material of local origin—that is, of the Ahtell Valley. They contain gold, but the quantity of gravel within the canyon is relatively small, and mining would be difficult unless adequate provision for controlling the creek were made. It has not yet been shown whether the deposits can be worked profitably.

## SUGGESTIONS TO PROSPECTORS

Several suggestions, prompted by the consideration of the descriptions of geologic conditions that have been given, may be of interest and value to prospectors. In the first place, the failure of past prospecting to produce the results desired is not in itself evidence that no favorable results can be obtained. In support of this statement, the discovery of gold on Ahtell Creek after it had once been abandoned may be cited, or the Nabesna mine, which was not found till more than 25 years had been spent in the search for gold and copper in its vicinity. Most geologists now hold to the belief that veins carrying gold, silver, copper, and many other metals are produced as a consequence of or an accompaniment of the intrusion of igneous rocks. Mineralization does not necessarily accompany such intrusion but often does, and therefore an area like the Slana-Tok district, where intrusive masses of igneous rock are widespread, merits attention. The fact that mineralized veins have been found is proof that mineralization took place in some measure.

In the search for gold placer deposits it is well to remember that when glaciation began in this area weathering and erosion had probably been attacking and reducing the surface of the land for a much greater time than has elapsed since the period of maximum glaciation. Great quantities of gravel, sand, and finer material had been produced, some of which must have been present as stream and lake deposits. As the ice accumulated in the highlands and gradually moved down into the lowlands these deposits were swept away from the mountain valleys and for the most part were carried into the great open valleys like the Copper River Basin and the Tanana Valley or were moved still farther to the sea. In places, however, other deposits, some of large size, were laid down as the ice wasted and its boundaries withdrew into the mountainous area again. Wherever these younger gravel deposits contained gold and were cut by present streams, conditions were created that were favorable for the reconcentration of gold that was too thinly scattered through the gravel to be recovered with profit into enriched deposits that may be of value. Such reworked gravel deposits are worthy of examination.

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