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THE MOUNT EIELSON DISTRICT ALASKA

BY

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Investigations in Alaska Railroad belt, 1931
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ILLUSTRATIONS

INVESTIGATIONS IN ALASKA RAILROAD BELT, 1931

FOREWORD

By Philip S. Smith

To help the mining industry of Alaska and to assist in the development of the mineral resources of the Territory have been the prime motives of the Geological Survey's investigations in Alaska during the past 35 years, in which nearly one half of the Territory has been covered by its reconnaissance and exploratory surveys. It was natural, therefore, that the Alaska Railroad, when it undertook intensive consideration of the problem of finding tonnage that would increase its revenues, should look to the Geological Survey to supply technical information as to the known mineral deposits along its route and to indicate what might be done to stimulate a larger production of minerals and induce further mining developments and prospecting that would utilize its service. Realization of the need for this information had long been felt by the officials responsible for the operation of the Alaska Railroad, and the need had been partly supplied by the Geological Survey, but funds to carry through an extensive inquiry of this sort had not been available until 1930, when a special committee of the Senate, composed of Senators Howell, Kendrick, and Thomas, visited Alaska, studied some of the railroad's problems, and successfully urged Congress to grant it $250,000 for investigations of this kind.

On the invitation of the Alaska Railroad the Geological Survey prepared various plans and estimates for the investigations that appeared to be most likely to contribute the desired information as to the mineral resources. Selection of the problems to be attacked proved difficult, because the choice necessarily was hedged about with many practical restrictions. For instance, each project recommended must give promise of disclosing valuable deposits—a requirement that was impossible to satisfy fully in advance, as it involved prophecy as to the unknown and undeveloped resources. Then, too, it was desirable that the search should be directed mainly toward disclosing deposits which if found would attract private enterprises to undertake their development in the near future. Finally, some of the deposits that might be worked profitably did not appear likely to afford much tonnage to be hauled by the railroad. Under these limitations it should be evident that the projects that could be recommended as worth undertaking with the funds available by no means exhausted the mineral investigations that otherwise would be well justified. In a large sense, all of Alaska may properly be regarded as indirectly contributory to the welfare of the railroad, but even in that part of Alaska contiguous to its tracks there are large stretches of country that are entirely unexplored and large areas that have had only the most cursory examination. Although areas of this sort might well repay investigation, they were excluded from the list of projects recommended because they were not known to contain mineral deposits of value, and it therefore seemed better to make the selection from other areas that had been proved to hold promise. Furthermore, several areas within the railroad zone were excluded because their value was believed to lie mostly in their prospective placers, which would not yield much outgoing tonnage; others because their lodes carried mainly base metals, for which development and the recovery of their metallic content in a readily salable condition were relatively expensive; and still others because their resources consisted mainly of granite, building stone, or some other product for which at present there is only a small local demand.

After careful consideration ten projects were selected, and the funds required for undertaking them were made available. The projects that were selected involved the examination of two areas principally valuable for their coal (Anthracite Ridge and Moose Creek), five areas likely to be principally valuable for gold (Fairbanks, Willow Creek, Girdwood, Moose Pass, and Valdez Creek), and three areas whose lodes consisted mainly of mixed sulphides (the Eureka area in the Kantishna district, Mount Eielson, formerly known as Copper Mountain, and the head of West Fork of Chulitna River). The general position of these different areas is indicated on the accompanying diagram (fig. 1). A general study of the nonmetalliferous resources of the entire region traversed by the railroad was included in the projects to be undertaken, but the results obtained were not such as to permit adequate determination of their extent at this time.

Examinations were made in the field in each of the selected areas, all the known prospects and mines being critically examined and sampled so far as time and other conditions permitted. The records thus obtained, together with all other information bearing on the problems, were then subjected to further study in the laboratory and office, in the course of which other Geological Survey specialists whose knowledge and experience could be of assistance were freely consulted. The outcome of all these lines of analysis has been the reports which make up this volume. Although each chapter is presented as embodying the latest and most authoritative information available regarding the districts and properties described up to the time field work in them

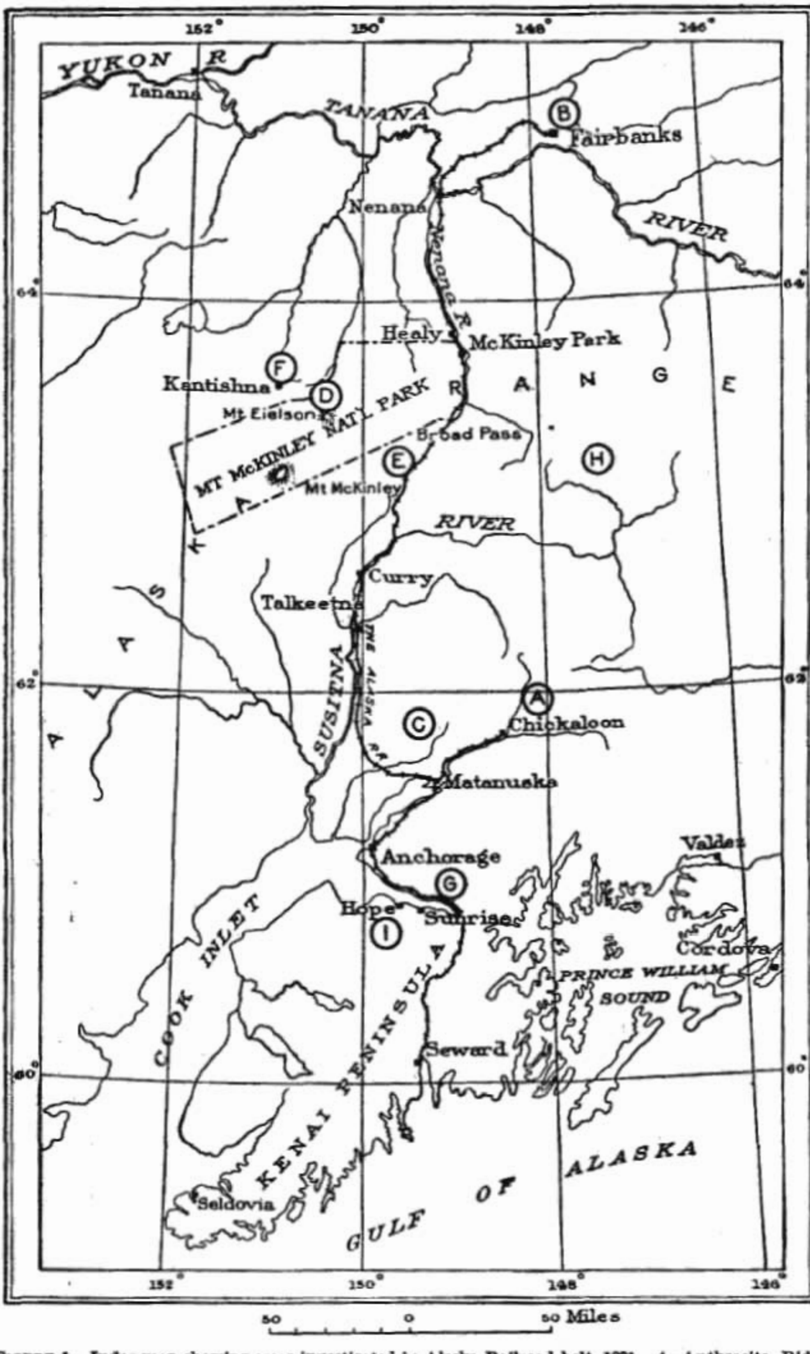

FIGURE 1.—Index map showing areas investigated in Alaska Railroad belt, 1931. A, Anthracite Ridge B, Fairbanks; C, Willow Creek; D, Mount Eielson; E, West Fork of Chulitna River; F, Eureka and vicinity; G, Girdwood; H, Valdez Creek; I, Moose Pass and Hope.

was finished, the authors make no claim that all the results they have presented are to be regarded as final nor as solving all the problems that have arisen. Actually none of the mines have been developed to such an extent as to furnish all of the evidence desired to solve the problems involved. At none of the properties is any considerable quantity of ore actually "blocked out" in the engineering sense of that term, so that instead of specific measurements as to the quantity and grade of ore the different camps will yield, the Survey geologists and engineers have necessarily had to make numerous assumptions and be content with estimates and generalizations as to the potential resources. Furthermore, the work was planned so as not to invade the proper field of the private mining engineer in the valuation of individual properties, but rather to occupy the open field of considering the districts as a whole.

In two of the districts, Anthracite Ridge and Moose Creek, whose value lay in their prospective coal resources, the examinations that could be made by ordinary geologic means were not adequate to arrive at a final judgment of the resources of the area but pointed to the desirability of further tests by drilling. As a consequence additional exploration of these districts by means of diamond drilling was authorized, and this work was undertaken in the season of 1932. The results of these tests were not available at the time the manuscripts of the other reports were completed, and rather than delay their publication until the later reports could be finished and incorporated in the volume these reports have been omitted here and will be published later elsewhere.

This is not the place to summarize the detailed findings of the geologists as to the merits of the different districts, as those findings are explained in detail and summarized in the respective chapters. Suffice it to say here that on the whole the principal purpose of the investigations was carried through satisfactorily and that while the studies in some of the districts indicate that they hold little promise of extensive mineral development in the near future, others appear to encourage development under existing conditions, and still others seem to be worth development when some of the existing factors such as transportation or price of base metals are improved. That conditions which are now temporarily retarding the development of some of the deposits will become more favorable cannot be doubted. The entire region is becoming more accessible each year, and as a result costs are being lowered and experience is being gained as to the habit of the various types of deposits, so that the conclusions expressed in this volume as to the resources of the different districts should be reviewed from time to time in the light of the then current conditions.

THE MOUNT EIELSON DISTRICT

By John C. Reed

ABSTRACT

The Mount Eielson district lies in south-central Alaska, on the north side of the Alaska Range, about 30 miles east of Mount McKinley. The most widely distributed rocks of the district include a thick series of thin-bedded limestone, calcareous shale, and graywacke of Paleozoic, probably Devonian, age. These sediments are cut by a mass of granodiorite which forms most of Mount Eielson and which was intruded probably in late Mesozoic time. The intrusive has sent a multitude of dikes and sills into the associated sediments.

Material given off by the granodiorite has permeated the enclosing sediments and selectively replaced them with minerals of the epidote group and to a somewhat lesser extent with sphalerite, galena, chalcopyrite, and pyrite. South of Mount Eielson the regional strike is about N. 55° E., and the dip is low toward the southeast. North of the mountain the strike of the sediments conforms in general to the curve of the base of the mountain and is about N. 65° W. on Bald Mountain and north of the eastern peak of Mount Eielson, nearly east north of the central peak, and about N. 50° E. on the northern slopes of Copper Mountain. In most places the dip is steep toward the north. A normal fault of large displacement abruptly terminates the granitic area on the south.

An ore-bearing zone can be definitely traced for about 4 miles along the north side of the granodiorite mass. Its width on the surface is not uniform, but its thickness is about 2,000 feet. Sphalerite is the most abundant sulphide and is several times as abundant as galena. Chalcopyrite is present in minor quantities. The small amount of silver in the ore appears to be irregularly distributed.

INTRODUCTION

ARRANGEMENT WITH THE ALASKA RAILROAD

In the spring of 1931 funds from a special appropriation to the Alaska Railroad became available to the Geological Survey for the geologic investigation of certain areas tributary to the railroad which were considered of potential economic importance. The principal object was to determine to what extent each of the several areas might become a source of ore tonnage for railroad haulage. The investigation of nine areas was undertaken, of which the Mount Eielson area was one.

NATURE OF FIELD WORK

As there was no adequate map of Mount Eielson and vicinity a topographic party in charge of S. N. Stoner was organized to make a topographic map to be used as a base for the geologic work. The writer accompanied the topographic party as geologist. The personnel of the party, in addition to the topographer and the geologist, consisted of a topographic assistant, a packer, and a cook. Seven horses were used as pack and saddle animals.

The party reached the district on June 16 and left on September 8. About 14 square miles was mapped, both topographically and geologically, on a scale of 1 to 24,000; and about 70 square miles, partly surrounding and including the smaller area, was mapped topographically on a scale of 1 to 48,000. Most of the larger area was also mapped geologically, but a few of the more remote parts could not be covered in the time available. A 50-foot contour interval was used throughout.

ACKNOWLEDGMENTS

The writer gratefully acknowledges the many helpful courtesies which were extended by the Alaska Road Commission, particularly by M. C. Edmunds and Ben Cleary; by Harry J. Liek, Lou Corbley, and Grant Pearson, of the National Park Service; and by O. M. Grant.

SUMMARY OF PREVIOUS WORK

The first geographic and geologic observations in the Mount McKinley region, of which the Mount Eielson district is a small part, appear to have been made by members of Brooks' party [1] in 1902, during that remarkable trip from Cook Inlet across the Alaska Range through Rainy Pass, northeastward along the face of the range to the Nenana River, down that river to its mouth, and thence to Rampart. Since then several geologic investigations have been made in areas near Mount Eielson, and the reports have been published. Some of the regions covered included all or parts of the Mount Eielson area, but the maps accompanying the reports were all on a much less detailed scale than the map accompanying the present report. In 1906 Prindle [2] made a brief examination of the Bonnifield and Kantishna regions, but no geologic map accompanied his report. Capps [3] spent the field season of 1910 in the Bonnifield region, and his report

[1] Brooks, A. H., The Mount McKinley region, Alaska: U.S. Geol. Survey Prof. Paper 70, 1911.

[2] Prindle, L. M., The Bonnifield and Kantishna regions, Alaska: U.S. Geol. Survey Bull. 314, pp. 205–226, 1907.

[3] Capps, S. R., The Bonnifield region, Alaska: U.S. Geol. Survey Bull. 501, 1912.

includes a geologic map on a scale of 1 to 250,000. In 1911 Capps[4] mapped part of the Yentna district on the same scale. The Broad Pass region was studied and mapped by Moffit[5] in 1913, and in 1917 Capps[6] made a hasty geologic examination of the upper Chulitna region. The mineral deposits of the Kantishna region were studied by Capps[7] in 1916, and his report includes a geologic map of the area covered on a scale of 1 to 250,000. The southern part of the area covered by this map includes a little of the northern part of the Mount Eielson area. Brooks[8] visited the Kantishna region in 1921 and in his report made the first mention of the mineral deposits of Copper Mountain (Mount Eielson) and gave a brief picture of their geologic setting. P. S. Smith visited Mount Eielson in 1922, and Capps[9] mapped a large area on the north flank of the Alaska Range in 1925. The scale of Capps' published sketch map is about 8 miles to the inch. The area covered includes all of the Mount Eielson district. Capps[10] and Moffit[11] have also studied and mapped a large area including the Mount Eielson district.

GEOGRAPHY

LOCATION AND EXTENT

The area discussed in this report is included between parallels 63°17′ and 63°28′ north latitude and meridians 150°9′ and 150°31′ west longitude. (See fig. 1.) It lies less than 10 miles north of the crest of the Alaska Range, and the western boundary is about 26 miles east of the top of Mount McKinley, the highest point on the continent. All of the area is within the Mount McKinley National Park. Mount Eielson was named for Lieut. Carl Ben Eielson, one of Alaska's pioneer aviators. It is one peak of a conspicuous mountain group of the vicinity, and its name has been chosen to designate the district herein discussed. The area is rhombic in outline and has a northeast-southwest dimension of about 11 miles and a north-south dimension of about 7 miles. In detail the boundaries are very irregular. The district includes about 70 square miles.

[4] Capps, S. R., The Yentna district, Alaska: U.S. Geol. Survey Bull. 534, 1913.

[5] Moffit, F. H., The Broad Pass region, Alaska: U.S. Geol. Survey Bull. 608, 1915.

[6] Capps, S. R., Mineral resources of the upper Chulitna region: U.S. Geol. Survey Bull. 692, pp. 207–232, 1919.

[7] Capps, S. R., The Kantishna region, Alaska: U.S. Geol. Survey Bull. 687, 1919.

[8] Brooks, A. H., The Alaskan mining industry in 1921: U.S. Geol. Survey Bull. 739, pp. 36–38, 1923.

[9] Capps, S. R., The Toklat-Tonzona River region, Alaska: U.S. Geol. Survey Bull. 792, pp. 73–110, 1927.

[10] Capps, S. R., The eastern portion of Mount McKinley National Park, Alaska: U.S. Geol. Survey Bull. 836, pp. 219–300, 1932.

[11] Moffit, F. H., The Kantishna district, Alaska: U.S. Geol. Survey Bull. 836, pp. 301–338, 1932: Mining development in the Tatlanika and Totatlanika Basins, Alaska: U.S. Geol. Survey Bull. 836, pp. 219–300, 1932.

ROUTES OF APPROACH

Before the completion of the Alaska Railroad, which now connects Fairbanks with salt water at Anchorage and Seward, the strip of country adjacent to the north face of the Alaska Range, particularly the part of it that lies in what is now Mount McKinley National Park, was relatively isolated. Some of the difficulties met with in approaching the region through the range from the south are described in the accounts of several expeditions[12] which entered, or attempted to enter, from that side. It was much easier to approach the range from the north by ascending the headwaters of the Kantishna River and thence proceeding overland, but only a few of the mountaineering expeditions[13] came that way.

The completion of the railroad in March 1923 greatly increased the accessibility of the region. McKinley Park station is on the north side of the range, on the Nenana River. It is 348 miles by rail from Seward and 123 miles from Fairbanks. Mount Eielson lies approximately 48 miles in a direct line west-southwest of McKinley Park station, but it is about 70 miles from the station by road and trail. The Alaska Road Commission is now building a road from the station through a series of low passes along the front of the range to the vicinity of Mount Eielson. The plan is to continue the road northwestward to Kantishna. In the spring of 1931 trucks could go as far as the Toklat River, which is about 20 miles from Mount Eielson. By fall the road was passable, except at times of very high water, as far as Stony Creek, about 10 miles nearer Mount Eielson, and ground had been broken to the west end of Thorofare Pass, just above Copper Mountain Bar. The road probably will not be kept open in winter. Winter travel in the region is done principally by dog team. Mount Eielson can be reached by airplane from Fairbanks or from Savage Tourist Camp in summer, or from Fairbanks in winter. Copper Mountain Bar provides a natural landing field.

TOPOGRAPHY

RELIEF

The Alaska Range[14] reaches its greatest height between Muldrow Glacier and the Tonzona River, and in that stretch the mountains

[12] Brooks, A. H., The Mount McKinley region, Alaska: U.S. Geol. Survey Prof. Paper 70, 1911. Dunn, Robert, The shameless diary of an explorer, Outing Publishing Co., 1907. Cook, F. A., The top of the continent, Doubleday, Page & Co., 1908. Browne, Belmore, The conquest of Mount McKinley, G. P. Putnam's Sons, 1913.

[13] Brooks, A. H., op. cit., pp. 29–30 (account of trip of James Wickersham). Thompson, W. F., First account of conquering Mount McKinley (from narrative by Thomas Lloyd): New York Times, June 5, 1910. Stuck, Hudson, The ascent of Denali, Charles Scribner's Sons, 1914.

[14] Capps, S. R., The Toklat-Tonzona River region, Alaska: U.S. Geol. Survey Bull. 792, pp. 77–78, 1927.

rise abruptly from the Kantishna-Kuskokwim lowland on the north without any intermediate belt of foothills; east of Muldrow Glacier the range is bordered on the north by a considerable foothill belt. This belt [15] is crossed by broad eastward-trending structural basins of low relief, which separate the foothill ranges from one another and from the higher mountains to the south. Capps [16] says:

> The Alaska Range proper succeeds the foothills on the south. Between Nenana River and Muldrow Glacier the range is about 20 miles wide from its north front to its crest and consists of a number of rugged ridges which extend from north to south and are separated by valleys of closely spaced, northward-flowing streams. These ridges gradually become higher toward the crest of the range, and many peaks rise to elevations between 6,700 and 8,000 feet and are the gathering ground for glaciers.

The northward-flowing streams after leaving the range proper traverse the foothill belt and cut the eastward-trending structural basins at nearly right angles.

Mount Eielson rises abruptly just southeast of the northern great bend of Muldrow Glacier and just south of the eastward-trending structural depression that separates the range proper from the foothill belt. Thus the mountain belongs to the range and forms the angle where the range narrows along Muldrow Glacier to continue westward with a narrower but higher and steeper northern scarp. Mount Eielson's position in this angle, facing the Kantishna-Kuskokwim lowland to the northwest and the north and the foothill belt to the northeast, accounts for its topographic prominence, for relatively it is not a high mountain.

The Mount Eielson district (see pl. 21) as here defined includes parts of two of the north-south rugged ridges of the Alaska Range and a small part of the abrupt portion of the range west of Muldrow Glacier, the west end of one of the eastward-trending structural depressions, a fractional part of the foothill belt lying north of the depression and a small area west of Muldrow Glacier which, although inconspicuous, should be grouped with the foothills, a narrow strip of the Kantishna-Kuskokwim lowland east of the glacier and a smaller area of lowland west of the glacier, and a considerable area occupied by Muldrow Glacier itself.

The structural basin is the one that separates the mountains from the foothills. It forms the series of low passes through which the road enters the district. Within the Mount Eielson area it occupies a strip from half a mile to a mile wide near and parallel to the northern edge of the area. The elevation of the depression at the eastern edge of the district is 3,625 feet; at the low divide in Thorofare Pass, 3,760 feet; and at the west end of the pass, 3,150 feet.

[15] Capps, S. R., The Kantishna region, Alaska: U.S. Geol. Survey Bull. 687, p. 4, 1919.
[16] Idem, p. 14.

Near the west end of the pass the Thorofare River enters the depression from the south between the mountain ridges, and its alluvial flat, Copper Mountain Bar, occupies the depression from that point westward to Muldrow Glacier, where the elevation of the bar is 2,900 feet.

A mountain belonging to the foothill belt lies north of Thorofare Pass. Its crest line parallels the pass and has an elevation of 5,634 feet at the highest point. Only part of this mountain is included in the district. On the west it gives way to the Kantishna-Kuskokwim lowland, a small part of which appears within the area as a narrow strip just north of Copper Mountain Bar. The elevation of this part of the lowland is about 3,060 feet.

On the west side of Muldrow Glacier, directly in line with the depression forming Thorofare Pass and containing Copper Mountain Bar, there is a small valley which has some of the characteristics of a structural depression such as the one just mentioned. It may represent the continuation of the same depression, but there is some evidence that it does not. The north side of this valley constitutes the extreme northwest portion of the district and, in spite of its relatively great elevation, seems to belong to the lowland province. The hill north of the valley reaches an elevation of 4,250 feet. South of the valley the foothill province is represented by a rugged ridge whose east end (4,634 feet high) lies just within the district.

Just west of the limits of the area the upper boundary of the lowland province bends around this foothill ridge and touches the glacier again a mile south of the east end of the ridge. The lowland belt here has an elevation of 3,500 feet and is less than half a mile wide. It is succeeded on the south by the lower slopes of the main range.

Muldrow Glacier traverses the area near its western border from south to north. It crosses the southern boundary at an elevation of about 3,900 feet and is there 2 miles wide. At the northern edge of the district the glacier is 3 miles wide and lies at an elevation of about 2,950 feet. Its surface is rough and is almost entirely covered by a moraine blanket.

One of the striking topographic features of the area is the bench that occurs above the present gradients of all the larger streams. This bench has a distinct slope both parallel with and at right angles to the directions of the streams. The bench levels are concordant across any particular stream valley. Obviously the streams have entrenched themselves below former broad valleys. Along any individual stream there may be benches at more than one level above the stream, but the lowest one, which in most places is not over 100 feet above the stream, is by far the most conspicuous. The longitudinal gradients of the lowest bench projected downstream merge with the surface of the lowland province. Collectively the surfaces of the lowest bench form a considerable proportion of the Mount Eielson district.

The bench just described is well represented just south of Copper Mountain Bar, where it is about half a mile wide. The elevation of its upper limit in this vicinity varies somewhat, but 3,500 feet is roughly an average. Mount Eielson itself rises steeply above the bench to culminate in three peaks at elevations of 5,720, 5,861, and 5,602 feet. The crest line of the mountain is a knifelike ridge with an east-west trend; the highest peak is in the middle, and the lowest on the west end. The northward-facing slope of the mountain is deeply dissected by two cirques, thus leaving three spurs projecting northward from the main east-west ridge. The southern slope is a steep, straight face.

A narrow serrate ridge extends southward from the eastern peak of Mount Eielson to the southern border of the district. The saddle at the head of Contact Creek separates the mountain from the ridge. There are several conspicuous peaks on this ridge, one of the most striking of which is Castle Rock, 5,765 feet above sea level. West of the north end of the ridge and south of Mount Eielson is a lower, shorter, relatively inconspicuous ridge which trends about parallel to the crest of Mount Eielson. It is 5,123 feet high at its east end and 4,814 feet high at its west end, three quarters of a mile away.

The southern part of the Castle Rock Ridge forms the eastern wall of a northward-facing cirque that lies on the north side of Sunset Peak. Between the western wall of the cirque and Muldrow Glacier is a rough area with several peaks that reach elevations between 4,000 and 6,000 feet. This region is really part of the northern slope of the mountain that culminates in Sunset Peak.

The east end of Mount Eielson and the eastern slope of the Castle Rock Ridge form the west side of the upper valley of the Thorofare River.

The remaining portion of the district east of the Thorofare River is rugged. A high north-south ridge defines the eastern edge from the structural depression near the northern boundary to the southern boundary. On the east, outside the district, the surface descends steeply to the heads of Stony Creek and the Toklat River. On the west side, however, several minor ridges branch from the main one and extend northwestward toward the Thorofare River and Thorofare Pass. Elevations of prominent points lie between about 4,500 and 6,385 feet, which are the highest points in the area shown on the geologic map.

South of the Mount Eielson district the Alaska Range attains greater elevations and is much more rugged than within the district.

DRAINAGE

The Mount Eielson district lies entirely in the drainage basin of the Kantishna River. The water from all but a very small part of the district reaches the Kantishna by way of McKinley Fork, which flows around the west end of the Kantishna Hills. Stony Creek, which drains several square miles in the northeastern part of the district, flows into the Toklat River, and that river in turn empties into the Kantishna after circling the east end of the Kantishna Hills.

Most of the streams in the part of the district west of Muldrow Glacier drain into the glacier; but the most easterly tributary of Clearwater Creek, is an exception; it runs westward from the glacier from the middle of the western part of the district. Part of the water from the melting of Muldrow Glacier probably escaped by this stream in the not very distant past, for even now the top of the ice is in places higher than the adjacent level of the stream. Clearwater Creek flows into McKinley Fork about 12 miles below the front of the glacier. The main flow of McKinley Fork is derived from the melting of Muldrow Glacier, whose lower end is about 5 miles west of the northwest corner of the district.

The great bend of the glacier northwest of Mount Eielson almost completely dams the lower end of Copper Mountain Bar. Glacier Creek and the Thorofare River, which drain all of the district except those parts in which the drainage has already been described, meet at the lower end of the bar, and the combined stream escapes through the notch at the northwest corner of the bar, and flows in a canyon, confined between the side of the glacier on the south and a wall of rock and, in places, an old moraine on the north, and farther downstream between a lateral moraine of the glacier on the south and an old moraine on the north until it joins McKinley Fork on McKinley Bar, some distance below the front of the glacier.

Glacier Creek rises in the mountains south of the central part of the district. It flows along the east side of Muldrow Glacier from the southern to the northern boundary. Its tributaries drain the west end of Mount Eielson and all the country between the Castle Rock Ridge and the glacier. Its main tributaries are Crystal Creek and Intermittent Creek. Intermittent Creek has a small drainage area which includes part of the southern slope of Mount Eielson and the northern slope of the minor parallel ridge south of Mount Eielson. Crystal Creek is formed by the melting of two small glaciers that occupy the cirque north of Sunset Peak. The lower part of the valley of Crystal Creek is an alluvial flat that broadens to include the lower end of the valley of Intermittent Creek.

Grant Creek rises in the western cirque of Mount Eielson, drains much of the northern slope of the mountain, and crosses the bar to join Glacier Creek and the Thorofare River near The Notch.

The Thorofare River is the main stream of the area. With its tributaries it drains the eastern slope of the Castle Rock Ridge, the northeastern part of Mount Eielson, the western part of Thorofare Pass, and all the country between the ridge that defines the eastern border of the district and the river. Its main flow comes from the melting of Sunset Glacier, whose terminus lies in the district. It has few tributaries from the west, as the drainage area on that side is small; one of them is Granite Creek, which comes from Mount Eielson's eastern cirque. Several large tributaries enter from the east, among which are Sunrise and Gorge Creeks. Sunrise Creek rises in Sunrise Glacier, at the southeast corner of the area. It flows northwestward to join the Thorofare River northwest of Bald Mountain. Gorge Creek rises in several small glaciers north of the middle of the eastern part of the district and with one of its tributaries drains the west end of Thorofare Pass.

The lower courses of Crystal Creek and Intermittent Creek are braided across an alluvial flat. Clearly they are held at a temporary baselevel by the glacier. The lowest elevation of the alluvial plain is just a little less than 3,300 feet.

A similar condition, on a larger scale, accounts for Copper Mountain Bar, whose lowest point is at The Notch, about 2,925 feet above sea level. At the end of the glacier, 5 miles below The Notch, the elevation of McKinley Bar is about 2,400 feet.

Capps [17] in writing of the Toklat-Tonzona River region, of which the Mount Eielson area is a small part, states:

> All the larger streams within this area head in the glaciers of the Alaska Range and therefore are supplied in large part by waters flowing from the melting of ice fields. As a consequence the volume of stream discharge is extremely variable, being lowest in the winter and greatest on the long warm days of summer or during warm rains, when the melting of the glaciers and snow fields is most rapid. In the winter stage of low flow the streams run clear, being fed mainly by springs. In summer, by contrast, when the glacial discharge is active, the streams are turbid from a heavy load of gravel, sand, and silt.
>
> As a consequence of the heavy load of glacial debris which they carry and of their great daily and seasonal variation in volume the glacial streams tend to build up extensive valley-floor deposits of gravel and sand, and they generally flow over these deposits in many braided channels. These glacial-outwash deposits consist of coarse boulders near the glaciers, but their materials become progressively finer downstream, and as a result the valley flats narrow, and there is a tendency for the streams to break into smaller channels.

Rock cliffs from 50 to 100 feet high bound the alluvium-floored valleys in most places. Thus the streams are apparently at grade as regards downward cutting; but they are still capable of actively cutting their banks laterally wherever the constantly changing channels bring them against the cliff faces.

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[17] Capps, S. R., The Toklat-Tonzona River region, Alaska: U.S. Geol. Survey Bull. 792, p. 76, 1927.

In addition to the topographic trends imposed by the two north-south valleys occupied by Muldrow Glacier and by parts of the Thorofare River and Sunset Glacier, and the structural depression containing Copper Mountain Bar and Thorofare Pass, there is a distinct expression of some northwest-southeast control, as is witnessed by the directions of Crystal Creek, Sunrise Creek, Thorofare Creek, the crest line of Mount Eielson, the crest line of Bald Mountain, and the ridge between Sunrise and Gorge Creeks. The northward-trending divides between the Toklat River and Stony Creek and the Thorofare River and between the Thorofare River and Muldrow Glacier are each strikingly nearer the valley that lies to the east.

CLIMATE

Climatologically the Mount Eielson district belongs with the Tanana and Yukon Valleys, but it lies so close to the southern edge of that province and so close to some of the highest parts of the Alaska Range that the climate is greatly modified by the range.

In general the winters are long and cold and the summers are moderate. The light precipitation is concentrated mostly in the summer and therefore falls as rain. Although a negligible part of the Mount Eielson district is above the permanent snow line, which is about 7,000 feet in this region, much of the district is high enough to receive fresh snow during the summer, while the lower parts are receiving rain. About the middle of June 1931 fresh snow fell on Mount Eielson itself at least as low as 4,000 feet, and by the middle of September several inches lay in Thorofare Pass down to 3,500 feet.

Accurate climatic data are lacking for the whole northern slope of the Alaska Range and consequently for the Mount Eielson district. Incomplete observations are on record for Broad Pass for 3 years, 1923 to 1925, for McKinley Park from 1922 to the present time, and for Wonder Lake from 1925 to 1929. Broad Pass is about 35 miles east-southeast of Mount Eielson and is south of the crest of the range, where in general temperatures are more moderate and precipitation much greater than north of the range. However, the record seems to show that Broad Pass climatologically is not much different from McKinley Park. McKinley Park station, although about 50 miles from Mount Eielson, has a comparable geographic position with respect to the Alaska Range, and climatic comparisons should be reasonably accurate. Wonder Lake is about 16 miles west-northwest of Mount Eielson and must have a very similar climate, although it is somewhat farther away from the crest of the range.

The graphs in figure 34 and the following tables show some of the available data which, except for the monthly means, are quoted from the annual publications of the United States Weather Bureau.[18]

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[18] Climatological data, Alaska section, U.S. Weather Bureau.

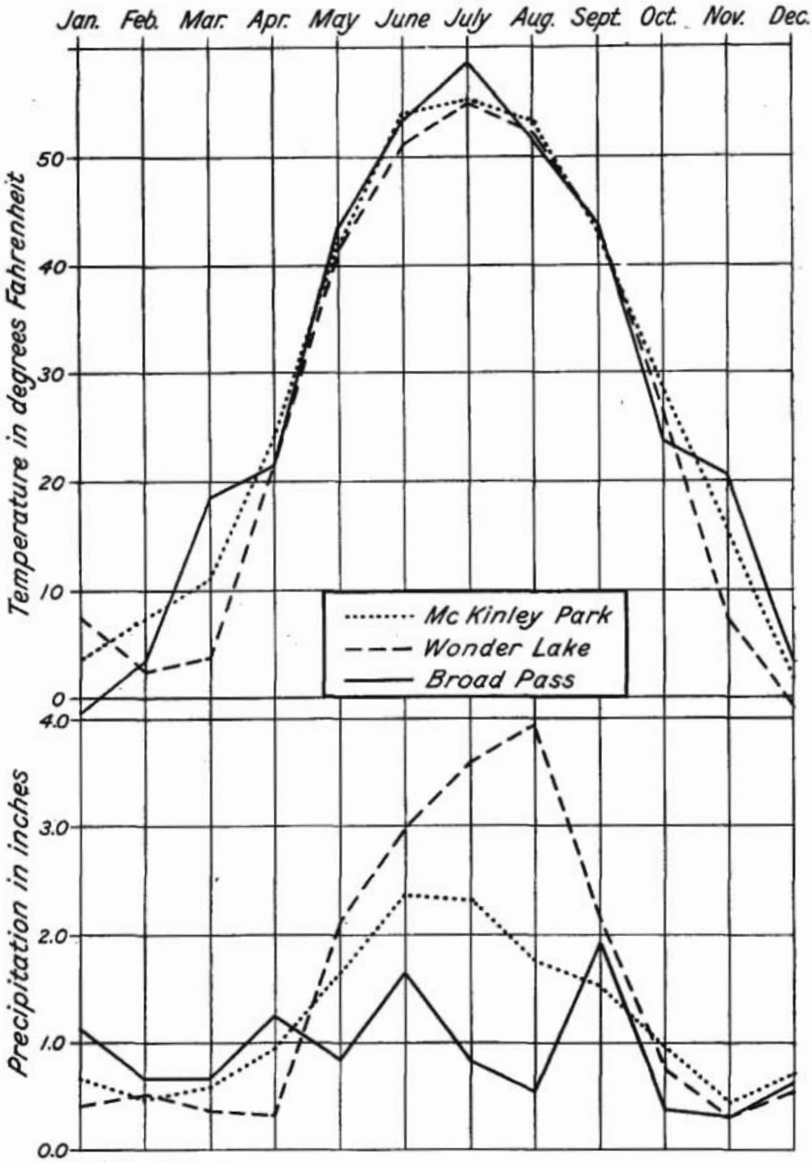

FIGURE 34.—Mean monthly temperature and precipitation at McKinley Park, Wonder Lake, and Broad Pass. (Means calculated from data given in accompanying tables.)

Monthly and annual mean temperatures at stations near the Mount Eielson district (°F.)

Broad Pass

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1923	0.2	8.1					62.4	56.7	[a] 43.8	33.5	18.2	3.1	
1924	2.2	−.5	20.0	19.3	46.8	53.2	54.9	46.5		14.4	22.8		
1925	−7.4	2.2	17.1	23.6	40.4								
Mean	−1.7	3.3	18.5	21.4	43.6	53.2	58.6	51.6	43.8	23.9	20.5	3.1	28.3

[a] 2 days omitted from record.

McKinley Park

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1922												[b] −4.6	
1923	−6.0	8.0	[b] 11.3	27.6	41.1	51.2	57.5	56.0	41.8	40.0	18.2	−10.6	28.0
1924	−6.1	−3.7	20.2	10.8	41.6	51.2	[b] 52.4		39.4	17.2	20.3	−7.6	
1925	−22.4	−7.7	13.0	26.0	42.3	[b] 51.2	[b] 52.6	51.2	[b] 44.8	39.5	16.0	[b] 10.6	26.4
1926	24.7	5.6	30.9	33.8	45.7	56.8	58.2	55.9	[b] 49.1	[b] 34.6	[b] 20.2	3.6	34.9
1927	4.0	15.1	6.4	[b] 19.4	41.6	[b] 55.4	60.0	55.2	[b] 40.3	[b] 20.7	−0.5	3.2	26.7
1928	15.2	21.0	−2.1	26.7	40.1	[b] 60.0	[b] 52.7	[b] 51.0	[b] 38.7	[b] 21.5	19.0	10.4	29.5
1929	14.2	13.2	−2.0	23.1	40.6	51.6	52.1	50.0	47.8	26.2		[b] 8.8	
Mean	3.4	7.3	11.1	23.9	41.9	53.9	55.1	53.2	43.1	28.5	15.5	1.7	28.2

[b] Data incomplete.

Wonder Lake

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1925		−5.5	12.7	25.0	42.0	48.8	52.4	51.9	43.2	33.0	5.5	−8.0	
1926	12.4	−4.0			41.6	55.2	56.6	53.4	47.0	30.0	15.9	−9.0	
1927	2.9	8.8	.6	17.8	40.0	52.4	58.1	52.8	36.2	18.2	−5.4	7.2	24.1
1928	7.2	10.0	−1.8			48.2	52.8					5.6	
1929					42.4	51.0	54.0	50.4	48.4	24.2	13.4	0	
Mean	7.5	2.3	3.8	21.4	41.5	51.1	54.8	52.1	43.7	26.3	7.3	−.8	25.9

Monthly and annual precipitation at stations near the Mount Eielson district (inches)

Broad Pass

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1923	1.44	0.70	1.20	0.12	1.56	1.65	1.11	0.12	3.05	0.71	0.32	0.70	12.68
1924	1.73	.69	.51	3.46			.53	.99	.82	.07	.31	.52	
1925	.20	.59	.31	.18	.13								
Mean	1.12	.66	.67	1.25	.84	1.65	.82	.55	1.93	.39	.31	.61	10.80

McKinley Park

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1923	0.69	0.75		0.17	3.40	3.93	1.21	1.21	0.82	0.04	0.24	0.01	
1924							.80		1.22	.96	.35	.42	
1925	.16	.43	0.44	1.16	.92	2.49	1.95	2.13	4.43				
1926	.34	.15	1.13	2.70	1.48	3.95	6.12	.46	2.78	2.75	.28	.52	22.66
1927	.14	.11	.88	.50	0	1.06	1.20	1.61	.53	.48	.11	.83	8.45
1928	.17	1.41	.48	.14	.77	1.63	.79	3.72	1.00	.36	1.29	1.38	13.14
1929	2.43	.04	.02	.95	3.21	1.16	4.11	1.55	0	1.05		1.05	
Mean	.65	.48	.59	.94	1.63	2.37	2.31	1.78	1.54	.94	.45	.70	14.38

Wonder Lake

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1925			0.32		1.72	3.34	2.78	3.80	3.61	1.01	0.32		
1926	0.02	0.13			2.12	2.51	4.88	6.17	3.39	.44	.25	0.60	
1927	.79	.58	.21	0.31	.83	2.32	1.05	3.07	.81	.71	.13	.77	11.58
1928	.38	.80	.56			5.24	1.80					.27	
1929					3.77	1.51	7.49	2.71	.92	.80	.51	.58	
Mean	.40	.50	.36	.31	2.11	2.98	3.60	3.94	2.18	.74	.30	.55	17.97

Miscellaneous climatic data for stations near the Mount Eielson district

Broad Pass

Year	Maximum temperature, °F.	Date	Minimum temperature	Date	Last date in spring with freezing temperature	First date in fall with freezing temperature	Number of days with maximum temperature 70° or more	Number of days with maximum temperature 32° or less	Number of days with maximum temperature 0° or less	Number of days with minimum temperature 32° or less	Number of days with minimum temperature 0° or less	Total snowfall, inches	Number of days with precipitation 0.01 inch or more
1922	79	July 25											
1923	92	July 24	−28	Jan. 28		Aug. 7	61	130	7				78
1924	88	June 24	−42	Dec. 19	June 9	Aug. 1			18	268	118		
1925			−41	Jan. 16									

McKinley Park station

Year	Maximum temperature, °F.	Date	Minimum temperature	Date	Last date in spring with freezing temperature	First date in fall with freezing temperature	Number of days with maximum temperature 70° or more	Number of days with maximum temperature 32° or less	Number of days with maximum temperature 0° or less	Number of days with minimum temperature 32° or less	Number of days with minimum temperature 0° or less	Total snowfall, inches	Number of days with precipitation 0.01 inch or more
1922													
1923	82	July 27	−40	Jan. 7	June 27	Sept. 19	42	134	40	219	95		
1924			−54	Dec. 1					52		106		
1925	79	July 24	−52	Jan. 19	(a)	(a)		128	42		101		
1926	89	June 18	−34	Dec. 21	May 26	Aug. 3	50		9	219	55	50.1	62
1927	85	July 9	−34	Nov. 29	May 30	Sept. 1			29			71.3	
1928	78	June 10	−31	Dec 12	May 28	July 21		138			64	57.1	55
1929	84	June 24	−38	Dec. 30	(a)	(a)	30		19				

Wonder Lake

Year	Maximum temperature, °F.	Date	Minimum temperature	Date	Last date in spring with freezing temperature	First date in fall with freezing temperature	Number of days with maximum temperature 70° or more	Number of days with maximum temperature 32° or less	Number of days with maximum temperature 0° or less	Number of days with minimum temperature 32° or less	Number of days with minimum temperature 0° or less	Total snowfall, inches	Number of days with precipitation 0.01 inch or more
1925	80	July 23			July 28	Aug. 10	27			269			
1926	92	Aug. 14	−44	Feb. 25	(a)	(a)	52	120	25	262	93		
1927	83	June 21	−56	Nov. 26	July 5	Aug. 30	55	144	30	282	155	66.1	78
1928	89	[b] July 5	−39	Nov. 20	(a)	(a)							
1929	88	[b] Aug. 4	−42	Dec. 30	(a)	(a)	49						

[a] Freezing temperature in each month.

[b] Data incomplete.

VEGETATION

The Mount Eielson district is entirely above the timber line, which lies at about 2,000 feet in this region. Shrublike forms of the willow and the cottonwood occur along the Thorofare River and on some of the lower slopes. During the summer, in a period usually extending from about the middle of June to about the 1st of September, camp stock can forage on the various grasses native to the region. Horses thrive on a vetch locally called pea vine, which is abundant in some of the valleys. Some of the mountain slopes are covered with thick growths of blueberries, and patches of small palatable cranberries grow locally on the "bars."

WILD ANIMALS

The north slope of the Alaska Range is famous for its wild game[19]—in fact, one of the reasons for the establishment of Mount McKinley National Park was to preserve the game in this great area when it should become easily accessible from the Alaska Railroad.

White mountain sheep (*Ovis dalli*) and caribou abound in the Mount Eielson district. It is doubtful if moose ever come as high as Copper Mountain Bar, as their range is usually confined to timbered country. A few grizzly bears are to be found in the district, and it is reported that the dark glacier grizzly inhabits Muldrow Glacier. In addition to these large animals, the region is inhabited by many smaller ones, including wolves, foxes, hoary marmots, ground squirrels, and wolverines. A few small grayling come as high as Copper Mountain Bar. All wild game is protected within the limits of the park.

POPULATION

There are no permanent residents in the Mount Eielson district. One prospector has a cabin on the north slope of Mount Eielson and occupies it nearly every summer. The National Park Service has built a cabin on Copper Mountain Bar. This cabin is occupied periodically by rangers on patrol work in the park and is also often used by travelers to or from the Kantishna region to the north. Near the ranger's cabin the Mount McKinley Tourist & Transportation Co. has a camp site with a cache and tent frames, which is sometimes used by tourists.

TRANSPORTATION

The various means of reaching the Mount Eielson district have already been mentioned, and in a later section the transportation

[19] Sheldon, Charles, The wilderness of Denali, Charles Scribner's Sons, 1930. Beach, W. N., In the shadow of Mount McKinley, Derrydale Press 1931.

problem as regards the possible future movement of ore and supplies will be outlined.

At present saddle and pack horses furnish practically the only means of transportation within the district. The gravel-floored valleys of the larger streams provide access to localities deep within the mountain fastnesses. The ubiquitous benches above the valley bottoms also may be easily traversed in the saddle. In many places it is possible to ride across the interstream divides by making use of game trails. Much of the higher, rougher country is practically inaccessible to horses and must be covered on foot.

Muldrow Glacier forms a fairly effective barrier to the country lying west of it. It has been crossed by pack train, but such travel is slow, laborious, and dangerous. It may be crossed without much difficulty on foot. Probably an easier though perhaps a slower means of reaching the country just west of Muldrow Glacier by pack train is to follow down the Kantishna trail to the point where it drops to McKinley Bar, below the end of the glacier, cross McKinley Fork there, cross a low divide, and proceed up the easternmost tributary of Clearwater Creek.

GEOLOGY

GENERAL OUTLINE

The areal distribution of the geologic formations that were recognized in the Mount Eielson district is shown on plate 22.

The relative ages of the various geologic units within the area are fairly well established; but because of the almost complete absence of fossils it is impossible to assign many of the formations to definite geologic ages. Such age assignments as have been made are for the most part dependent on long-range correlations, based on geologic association and lithology, with rocks of known age in other localities.

A thick series of limy sediments is distributed widely and constitutes the formation that is undoubtedly the oldest in the district. The formation is composed principally of light to dark bluish-gray thin to medium bedded limestone, interbedded here and there with graywacke and with black fissile shale. Locally the limestone has been replaced by epidote and to a lesser degree by various metallic sulphides. No recognizable fossils have been found in the formation in the vicinity of Mount Eielson. It is believed to be Paleozoic, probably Devonian, because of its position along the strike of a Paleozoic formation farther east in which occurs a band of massive limestone that carries Middle Devonian fossils. The portion of the formation displayed within the Mount Eielson district is at least a mile thick, and neither the top nor the bottom is exposed.

A greenstone formation several hundred feet thick and in part ellipsoidal, appears to be next younger than the Paleozoic limestone. The contact between greenstone and Paleozoic limestone is nowhere seen within the district, but Capps [20] believes that a profound erosional unconformity intervenes. This formation is probably Triassic.

The Paleozoic limestone and the Triassic (?) greenstone have been intruded by a group of plutonic and hypabyssal rocks which display a wide range of composition and texture. There is evidence that all members of the group are genetically related and collectively represent a differentiation series. The oldest member is gabbro, which has a small areal development. The bulk of the intrusive rock is porphyritic granodiorite, which occurs in large masses and also as dikes and sills in the greenstone and in the limestone. A third widespread member of the group is even-grained to slightly porphyritic granodiorite, which has not been found intruding the greenstone but only as stocklike masses in the limestone. Ore deposition appears to have been controlled by this member. The group was intruded during the Mesozoic era, and its intrusion period may cover a considerable span of Mesozoic time. It is probably older than the Cantwell, which, according to Capps, is Eocene or Upper Cretaceous,[21] and younger than the Mesozoic greenstone.

A great unconformity separates the rocks already described from those which remain. The latter are all Tertiary or younger, the one possible exception being a group of basalts, tuffs, and obsidians, which is quite definitely of the same age as the Cantwell formation and is therefore Eocene if the present classification of the Cantwell formation—which is based on fossil plants—as Eocene holds.

A lignite-bearing group of sandstone, shale, and gravel, which is younger than the rocks of Cantwell age, is found locally in the area. These rocks may be correlated with the Eocene lignite-bearing beds of the Nenana coal field. The lignite-bearing formation is succeeded by a deposit of yellow or buff gravel, the Nenana gravel, which is also Tertiary.

The Quaternary deposits mapped include accumulations of morainic material of Pleistocene glaciers and some morainic material of present glaciers, alluvial deposits of fluvial and glaciofluvial origin, and talus and fanglomerate deposits, which are forming at the present time.

The following table gives a brief outline of the stratigraphic sequence in the Mount Eielson district so far as it is known:

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[20] Capps, S. R., The Toklat-Tonzona River region Alaska: U.S. Geol. Survey Bull. 792, p. 90, 1927.

[21] Idem, pp. 94–95.

Cenozoic:

Quaternary:

Recent: Gravel, sand, and silt of the present streams; soils and rock disintegration products forming in place; talus accumulations and fanglomerate forming at the present time; deposits of existing glaciers.

Pleistocene: Deposits of older, more extensive glaciers.

Tertiary:

Eocene or later: Nenana gravel (loosely consolidated, yellow or buff, elevated and tilted sand and gravel).

Eocene: Lignite-bearing formation (sandstone, gravel, and clay, locally indurated and locally containing lignite).

Eocene: Rocks of Cantwell age (brown and black basalts, yellow, purple, and gray tuffs and breccias, and black and green obsidians). (Capps is of the opinion that the Cantwell formation may be Upper Cretaceous, but because of its fossil plants it is still classified as Eocene.)

Mesozoic:

Late Mesozoic (?): Intrusive differentiation suite consisting of granodiorite, porphyritic granodiorite, and gabbro together with other minor representatives. Stocks, dikes, and sills. Intrusive period may cover a considerable span of Mesozoic time.

Triassic (?): Greenstone formation (dark-brown, black, or reddish lavas, now greenstones intruded by the members of the differentiation suite).

Paleozoic:

Devonian (?) (Middle?): Thick series of gray or bluish thin to medium bedded limestones, limestone locally replaced by epidote and metallic sulphides.

SEDIMENTARY ROCKS

PALEOZOIC LIMESTONE

Character and composition.—The most widespread formation in the area consists of a thick series of strata whose members differ greatly in composition and texture. It is part of the group of rocks described by Capps [22] as post-Tonzona Paleozoic rocks, and, as Capps points out, the group will undoubtedly be subdivided when it can be studied in detail. The part of the formation in the Mount Eielson district must have originally consisted of shales, thin-bedded and medium-bedded limestones, conglomerates, graywackes, arkoses, and argillites. Locally the rocks have been changed by structural deformation and thermal metamorphism, related to igneous intrusion, to schists, slates, and various contact rocks. The formation has been intruded by stocks, dikes, and sills of granodiorite.

A large part of the formation is composed of gray medium-bedded impure limestone. This rock does not show evidence of much structural deformation except that it contains small flakes of white mica that exhibit a crude parallelism. Possibly the mica is part of

[22] Capps, S. R., The Toklat-Tonzona River region, Alaska: U.S. Geol. Survey Bull. 792, pp. 88–92, 1927.

the original sediment, but it seems more likely to have been developed later by directed pressure from material contained in the sediment. The material necessary for the mica formation probably was not contributed from outside the rock body, for this type is not closely associated with any large bodies of granodiorite and with only a few small bodies. Weathering produces a thin brown veneer, but as the rock is ordinarily more resistant to erosion than associated types it tends to crop out in jagged pinnacles and ridges which exhibit for the most part surfaces of the fresh gray rock. Locally long roll-like scallops, which somewhat resemble ripple marks, are present on bedding surfaces. Usually they have been formed in groups of two or three, each individual from 1 to 3 inches across and each group 6 inches to a foot from the next. The rolls are ordinarily more complete than ripple marks, and exceptional ones are entirely complete; and portions can be picked out that are shaped like short segments of garden hose. Perhaps this structure is due to deposition on a sloping surface, and the rolls were formed by the mud rolling under the influence of gravity. Possibly the phenomenon indicates that the material was deposited in very shallow tidal water.

A less common dark-gray limestone, which is found in beds about 3 inches thick, is in some places interbedded with quarter-inch to half-inch beds of fine-grained buff argillite. This type is ordinarily warped and contorted and in some places appears partly recrystallized. It is jointed in several directions, and most of the joints are filled with white coarsely crystalline calcite.

Very dark gray and black limy shales constitute a considerable proportion of the formation, and there is a minor amount of noncalcareous shale.

A thin bed of conglomerate occurs near the stratigraphic top of the portion of the formation that is exposed in the Mount Eielson district. Its areal extent is negligible, but as no conglomerate was seen below it, and as it probably occurs more widely in the higher country farther south, it may have some future importance as a horizon marker. It is composed of roughly rounded dark cherty pebbles and more perfectly rounded white quartz pebbles about a quarter of an inch in diameter. The cement is calcareous. In some places the pebbles have been stretched and flattened by structural forces.

Another prominent type is a rather fine-grained calcareous graywacke in which white mica is a prominent constituent. The fresh rock has a light-greenish cast, but the more common weathered rock is distinctly red or yellow. This rock crumbles readily, and in it erosion develops steep slopes of granular rusty-weathered material in which the mica plates are conspicuous.

Locally structural metamorphism has been severe enough to develop micaceous schists, which are more common in the southern than in the northern part of the district and are still more common farther south, outside the limits of the district.

Near the borders of the intrusive masses thermal metamorphism has produced by replacement large volumes of epidote and smaller volumes of sphalerite, galena, pyrite, and chalcopyrite. One of the ultimate products of this type of metamorphism is a yellowish-green massive epidote rock which is irregularly cut by a few stringers of late quartz. A thin-bedded type is more widespread, and examples show the original beds replaced in various degrees by dark cherty-appearing masses of epidote, zoisite, and clinozoisite. The degree of replacement, in general, seems to have been controlled by position relative to the granodiorite stocks, but in detail the replacement has been selective and apparently has been controlled by the composition of the individual layers of the thin-bedded rock. Thus siliceous layers from an eighth to half an inch thick alternate with thinner layers made up chiefly of epidote and clinozoisite. In some localities rocks made up of lamellae similar to those just described are composed of bands of limestone alternating with bands of epidote and clinozoisite. The completely unreplaced ancestral type of these rocks has not been definitely recognized but probably was thin-bedded limestone with alternating argillaceous or siliceous layers similar to the second type described in this paragraph. Some of the silica of these contact rocks is undoubtedly secondary, but it seems fairly certain that some of the original beds were siliceous.

Contact rocks rich in phlogopite are found locally, and in a few places very close to the contacts hornblende-epidote rocks have been developed.

The sulphides of lead, zinc, iron, and copper appear in different amounts in the replacement deposits and are discussed further in the section on economic geology.

Thickness.—The portion of the Paleozoic limestone formation that is exposed within the Mount Eielson district is at least a mile thick. Its actual thickness could not be determined within narrow limits because of faulting, of complex structure, and of large amounts of intrusive material. Neither the top nor the base of the formation was recognized within the district. The oldest rocks that crop out are cut off by one of the granodiorite stocks. The total thickness of the formation is much greater than the thickness exposed in this district, for it is the principal formation of the northern face of the range in this vicinity and is known to extend across the strike at least as far south as Anderson Pass, which is several miles south of Mount Eielson. The formation is completely separated into two parts by a fault whose strike makes a small angle with the general strike of the formation and whose displacement is not known.

Age and correlation.—No fossils have been found in this formation within many miles of Mount Eielson. About 10 miles east of Mount Eielson, in the Toklat Basin and approximately along the strike, Capps [23] found massive recrystallized limestone that lies along a belt extending eastward to the Nenána River, in which limestone with similar lithologic relations has yielded Middle Devonian fossils. This evidence appears only sufficient to date these rocks definitely as Paleozoic, for it is not even known whether they are older or younger than the Middle Devonian limestone.

TERTIARY COAL-BEARING FORMATION

Capps [24] says:

> Coal-bearing sediments of Eocene age occur at intervals along the north flank of the Alaska Range from the Kuskokwim Basin to the Alaska-Canada boundary, also on the south side of the range, in the basins of Susitna River and Cook Inlet. In the Cook Inlet region these beds have been called the Kenai formation, and there is little doubt that the coal-bearing Tertiary sediments on the north side of the range are, in part at least, the equivalent of the Kenai, though the exact identity of the two formations has not yet been established, and the sediments on the north slope have as yet received no formation name.
>
> North of the range this formation is best known and reaches its greatest development in the Nenana coal field, where the coals it contains have been mined for several years. Farther west, in the Toklat and Kantishna Basins and on the headwaters of the Kuskokwim, the Tertiary coal-bearing beds occur in small isolated areas on the flanks of the Alaska Range.

In the Mount Eielson district this formation has a very meager development, and only a few outcrops of it were found. Where seen, it consists chiefly of a light-colored gravel in which most of the well-rounded pebbles are about 3 inches in diameter. Locally the gravel is tightly cemented by reddish-brown hydrated oxides of iron. A few beds of cream-colored sand and gray clay are interbedded with the gravel. A few thin beds of brown or black woody lignite were also seen.

In this district not more than a 50-foot stratigraphic thickness of this formation was recognized. The upper contact with the next younger formation, the Nenana gravel, is somewhat arbitrary, however, and was nowhere placed very far above a horizon at which lignite was actually seen. No lignite bed more than 6 inches thick was noted, although it is possible that thicker ones are present; most of those observed are between a quarter of an inch and 3 inches thick.

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[23] Capps, S. R., The Toklat-Tonzona River region, Alaska: U.S. Geol. Survey Bull. 792, p. 83, 1927.

[24] Idem, p. 95.

The formation in its wider distribution has already been described by several authors.[25] It is known to be of Eocene age and is younger than the Cantwell formation and older than the Nenana gravel.

NENANA GRAVEL

The coal-bearing formation is overlain by a series of elevated gravel deposits which are widely distributed along the north flank of the Alaska Range. This formation, the Nenana gravel, is conspicuous near the Nenana River and has been described in detail by Capps.[26] He says in the report on the Toklat-Tonzona River region:

> The term "Nenana gravel" has been applied to a thick series of unconsolidated or only loosely cemented material, consisting for the most part of beds of well-rounded, rather coarse gravel, with subordinate beds and lenses of sand. Pebbles the size of cobblestones are common, though there is much finer gravel, and in some places boulders a foot or more in diameter were seen. The pebbles include a wide range of rock types, and the percentage of pebbles of various types differs greatly from place to place. * * * Harder materials such as quartz, quartzite, conglomerate, and various kinds of igneous rock predominate over the softer and more easily destroyed sedimentary rocks.
>
> A characteristic feature of the Nenana gravel is its yellow or buff color, which indicates that the gravel is old enough to have been rather thoroughly oxidized, whereas the deposits of the last glaciers and of the present streams that in many places overlie the Nenana gravel are gray and little oxidized.
>
> The Nenana gravel, being unconsolidated, yields readily to erosion by glaciers and streams, and the surface forms developed on it by erosion are generally of smooth outlines and gentle slopes, so that good exposures are not common.

The above description well fits the Nenana gravel as it was seen in the Mount Eielson district, although some good exposures of it were found there.

The maximum thickness of the Nenana gravel exposed within the district and east of Muldrow Glacier is probably between 200 and 300 feet. In the northwest corner of the district, west of the glacier, nearly 1,000 feet is exposed.

In the past this gravel was for a time considered Pleistocene and was grouped with the glacial deposits, but more recent evidence shows that it is older. Stratigraphic evidence shows it to be incontestably younger than the coal-bearing formation, and structural evidence, which will be discussed in a later paragraph, indicates that it is not much younger. For the present it is classified as Eocene or later Tertiary.

PLEISTOCENE GLACIAL MORAINE

The bench described on page 236 indicates the floors of old glacial valleys below which the present streams are entrenched. Large areas

[25] Brooks, A. H., The Mount McKinley region, Alaska: U.S. Geol. Survey Prof. Paper 70, pp. 94–103, 1911. Capps, S. R., The Kantishna region, Alaska: U.S. Geol. Survey Bull. 687, pp. 44–45, 1919. Martin, G. C., The Nenana coal field, Alaska: U.S. Geol. Survey Bull. 664, 1919.

[26] Capps, S. R., The Bonnifield region, Alaska: U.S. Geol. Survey Bull. 501, pp. 30–34, 1912; The Kantishna region, Alaska: U.S. Geol. Survey Bull. 687, pp. 51–57, 1919; The Toklat-Tonzona River region, Alaska: U.S. Geol. Survey Bull. 792. pp. 98–100, 1927.

of these old floors are covered by morainic deposits left by the waning glaciers that formerly occupied the valleys. The materials of the deposits differ in composition and texture in different localities but not surprisingly, for such variations are to be expected in a region whose terrane is made up of many rock types. In general the morainic material is unsorted, little rounded, and dark in color, especially as compared with the more thoroughly oxidized Nenana gravel. Some of it is of glaciofluvial origin. In most places this deposit is less than 20 feet thick, but locally it is over 100 feet thick. Its surface is of the rough hummocky sort typical of moraine areas, and small undrained depressions are common.

The last great glacial stage in Alaska was almost surely contemporaneous with the late Wisconsin stage of continental glaciation.[27] The high deposits in the Mount Eielson district are correlated with this stage, although there is evidence on the north side of the Alaska Range of an earlier and more extensive glaciation than the Wisconsin.[28] It is possible that some of the benches above the one extensively developed represent levels reached during more ancient glacial stages.

RECENT GLACIAL MORAINE

The surface of the portion of Muldrow Glacier that lies in the Mount Eielson district, with minor exceptions, is covered to various depths with morainic material, much of it brought down from high, remote parts of the range. Morainal deposits also occur along the sides of Muldrow Glacier, above the present surface of the glacier but much lower than the Wisconsin deposits, and bear witness to recent diminution of the glacier. Other recent moraine deposits in the area are related to small valley glaciers.

RECENT ALLUVIUM

Most of the streams of the district are glacier-fed, and therefore have widely varying flows, with consequent variation of erosive and carrying powers. The flood plains of the streams are ordinarily broad and are traversed by the streams in many anastomosing channels. Coarse boulders form the alluvium near the heads of the streams, but the material becomes progressively finer downstream.

The gradients of the small streams, many of them intermittent, which come from the steeper mountain slopes are greatly decreased where the streams cross the bench of the Wisconsin glacier floors; consequently much of their load is dropped and many alluvial fans have been built just above the bench. Many of these deposits of fanglomerate have coalesced into piedmont slopes.

[27] Capps, S. R., The Chisana-White River district, Alaska: U.S. Geol. Survey Bull. 630, pp. 69–75, 1916.

[28] Capps, S. R., The Bonnifield region, Alaska: U.S. Geol. Survey Bull. 501, pp. 33–34, 1912; The Kantishna region, Alaska: U.S. Geol. Survey Bull. 687, p. 60, 1919. Wells, F. G., oral communication.

IGNEOUS ROCKS

TRIASSIC(?) LAVAS

A series of altered basic lava flows, now greenstone, succeeds stratigraphically the Paleozoic limestone formation. The most widely distributed type is a very fine grained dark greenish-gray rock which is intricately jointed in several directions, so that weathering disintegrates it into small angular fragments. The joints are generally filled with thin seams of white crystalline calcite, but in places chlorite has been developed on the joint surfaces. The typical color of the weathered rock is a somber reddish brown. At a few localities masses resembling the pillows of pillow lavas were seen. The pillows are between 6 inches and 2 feet in diameter. Individual flows are ordinarily difficult to identify, and hence the structure is obscure, but from a distance structural planes are sometimes visible and are indicated chiefly by slight differences of color of the weathered rocks and by differences in reaction to erosion. A slight variant from the type described above is a lighter-colored rock, containing abundant black phenocrysts, which average about 1 millimeter in length. Microscopically the two types are nearly identical. The very fine grained groundmass is composed principally of calcite and chlorite, but contains a little feldspar and some quartz. Most of the phenocrysts are pseudomorphs of calcite and chlorite after pyroxene or olivine. Rarely parts of the original minerals remain.

The greenstone contains discontinuous pod-shaped bodies of sedimentary rock, that appear identical with some of the altered limestones and black shales of the Paleozoic formation. These may represent sedimentary material interbedded with the lavas, but from their composition, their lithologic similarity to the Paleozoic rocks, and their position near what is believed to be the base of the greenstone formation it seems at least possible that they are inclusions of the Paleozoic sediments in the igneous rock (xenoliths). The greenstone is cut by sills and dikes of porphyritic granodiorite and also by bodies of plutonic (deep-seated) and hypabyssal (intermediate depth) basic rocks. These intrusions are further discussed on pages 254–259.

The poor structural evidence does not permit a precise statement as to the aggregate thickness of the greenstone formation in the district. Its base is not definitely established and its top is not exposed, as the formation appears to be unconformably overlain by later rocks. Over 1,000 feet is, however, a conservative estimate of the exposed thickness. Capps,[29] in speaking of the greenstone in its wider distribution, says that it is apparently more than 2,000 feet thick.

[29] Capps, S. R., The Toklat-Tonzona River region, Alaska: U.S. Geol. Survey Bull. 792, p. 104, 1927.

Although the contact between the greenstone and Paleozoic limestone is not exposed in the Mount Eielson district because of intervening intrusive bodies and younger rocks, and although it is entirely possible that a fault, now concealed under more recent deposits, may also separate the two, nevertheless the regional relations indicate that the greenstone lies stratigraphically above the limestone. There is evidence for this interpretation elsewhere.[30] Capps[31] believes that the lavas lie unconformably upon the Paleozoic sediments. The greenstone is intruded by basic rocks and by dikes and sills of granodiorite and is therefore younger than the Paleozoic limestone and older than the period of igneous activity described on page 268. This is all that can be definitely stated. However, Moffit[32] tentatively assigned similar greenstones in the Broad Pass region to the Triassic, and Capps,[33] following this assignment and making an even broader correlation, came to the same conclusion for the greenstones here under consideration. As Capps points out, this assignment is to be considered tentative only. Possibly the greenstone represents an earlier surface facies of the gabbro which intrudes it, but this does not seem very likely because of the long time that appears to have elapsed between them.

GABBRO AND GRANODIORITE SERIES

The Paleozoic limestone and the Triassic (?) greenstone have been intruded by stocks, sills, and dikes, chiefly of granodiorite and gabbro but in minor part of types intermediate between these two or more extreme than either, such as aplite and peridotite. Field evidence, such as the age relations between widely different members of the series, the apparently complete gradation of one member into another both mineralogically and texturally and hence the complete inability to define contacts between closely related members, the areal distribution, and structure, indicates that these rocks are all differentiates of one parent magma—in other words, are members of a descent series.

The following table indicates the gradational differences as illustrated by 10 selected thin sections that appear to represent various stages in the differentiation process. The slides were selected from a total of 21 and were chosen without regard to texture, as textural differences appear to show essentially differences in physical environment only.

[30] Capps, S. R., The Toklat-Tonzona River region, Alaska: U.S. Geol. Survey Bull. 792, p. 89, 1927.

[31] Idem, pp. 104–105.

[32] Moffit, F. H., The Broad Pass region, Alaska: U.S. Geol. Survey Bull. 608, pp. 27–28, 1915.

[33] Capps, S. R., op. cit., p. 105.

Features of intrusive rocks shown by thin sections

Specimen no.	Name	Plagioclase		Dark mineral or minerals		Quartz (percent)	Orthoclase (percent)	Texture	Remarks
		Percentage	Approximate composition	Name	Approximate percentage				
92	Granite	40	$Ab_{67}An_{33}$	Chlorite	>2	50	4	Slightly porphyritic	
4	Quartz diorite	Predominant	$Ab_{70}An_{30}$	do		Considerable	Little	Porphyritic	Chlorite and calcite after hornblende.
44	Granodiorite	47	$Ab_{85}An_{15}$	Hornblende and chlorite.	Aggregate 8	31	11	do	About equal amounts of chlorite and hornblende.
32	do	50	$Ab_{60}An_{40}$	Chlorite	12	29	7	Slightly porphyritic	Chlorite after light-green amphibole.
39	do	58	$Ab_{55}An_{45}$	Chlorite and hornblende.	Aggregate 14	22	7.5	Very slightly porphyritic.	Chlorite: Hornblende as 6:1.
41	Diorite	Predominant	$Ab_{60}An_{40}$	Hornblende	Considerable	Considerable	None	Fine-grained groundmass, coarse phenocrysts.	Hornblende partly chloritized.
38	do	do	$Ab_{55}An_{45}$	Hornblende and chlorite.	Large proportion.	None	do	Porphyritic	
107	Gabbro	do	$Ab_{55}An_{45}$	Chlorite	Considerable	do	do	Fine-grained	Chlorite after olivine or pyroxene.
82	do	Large proportion.		Pyroxene and chlorite	Predominant	Considerable	do	Coarse-grained	Pyroxene predominant over chlorite.
12	Peridotite	Little		Olivine and pyroxene	do	None	do	Coarse-grained (poikilitic).	Olivine and pyroxene partly serpentinized.

The lack of more thin sections prevented including representatives of rocks more siliceous than granite in the table. It should be emphasized that the sections selected do not represent rocks at equal intervals along the descent line—for instance, the range between nos. 32 and 38 is no greater than that between nos. 92 and 4. There is a wide gap between nos. 38 and 107, and some representatives between these two would more firmly establish the hypothesis.

Gabbro.—Gabbro and related rocks are much less widely distributed than rocks of granodiorite affinities. The most typical rocks of this subgroup are dark colored and are coarse to medium grained. They are ordinarily massive but are cut here and there by joints, which are much more numerous in some localities than in others. Some of the joint surfaces show slickensides and are coated with serpentine or chlorite. Crystals of pyroxene and dark greenish-gray feldspar are visible to the unaided eye. Weathering develops dark-brown or black surfaces. The microscope shows the usual constituents to be principally pyroxene and feldspar. The pyroxene is euhedral to subhedral and in most specimens has partly altered to chlorite. The feldspar crystals are coated with a white fine-grained, claylike material, which makes their identification doubtful, although they are zoned. Some of the crystals are rimmed with a thin layer of albite-oligoclase. The usual accessories are magnetite, pyrite, long, slender prisms of apatite, and late quartz. A white opaque mineral resembling leucoxene is also present in some specimens.

A finer-grained facies of the gabbro is probably a quickly chilled border rock. Texturally it resembles a lava, as it exhibits traces of mineral parallelism and bands that differ in mineral constitution. This facies is composed principally of labradorite laths set in a fine-grained groundmass of chlorite and little indeterminable spherulites, which have a refractive index near those of the feldspar. Magnetite is conspicuous in both irregular and euhedral grains. The relatively large amount of calcite is interpreted as deuteric—that is, derived from alteration of the rock during the later stages of the consolidation of the magma and as a direct consequence of it. Some of the chlorite and calcite appear pseudomorphous after either olivine or pyroxene.

The most basic type identified is a very dark gray or black medium-grained rock, whose joints are coated with serpentine. It is an altered peridotite and is composed principally of olivine and pyroxene. The texture is poikilitic, the pyroxene enclosing the olivine. The olivine and to some extent the pyroxene are partly altered to serpentine and chlorite. The accessories are magnetite, apatite, leucoxene (?), sericite, feldspar, and biotite.

These basic rocks intrude the Paleozoic limestone formation, the Triassic (?) greenstone, and the granodiorite in the form of small stocks, dikes, and sills.

Granodiorite.—Granodiorite occupies a large part of the Mount Eielson district—in fact, areally, it is subordinate only to the Paleozoic limestone formation.

Most of the granodiorite is a greenish-gray porphyry in which the numerous white euhedral feldspar crystals and the rarer hornblende crystals average about a quarter of an inch across. In places the rock is mineralized with pyrite, rarely with pyrrhotite, and weathers to a dark rusty color, but normally the weathered surfaces are a little lighter gray than the fresh rock. Megascopic quartz occurs here and there. Locally the rock is impregnated with yellow epidote, and in some places the numerous intersecting joints are filled with epidote. Microscopic examination shows that the zoned feldspar phenocrysts are oligoclase or andesine. Most of the hornblende phenocrysts are partly or completely altered to chlorite. Orthoclase, in different amounts, seams and replaces the plagioclase crystals. The groundmass is made up of chlorite, feldspar, and quartz. Epidote, pyrite, magnetite, apatite, titanite (with titaniferous alteration products), calcite, and sericite are the usual accessories.

The texture of the porphyritic granodiorite is not everywhere the same. Differences in coarseness, in the number and identity of phenocrysts, and in the number and size of rounded segregated bodies of texturally different granodiorite, which in many places are found in the rock, are everywhere apparent. Some specimens have no phenocrysts; some have phenocrysts of feldspar only, and these in some places are very minute and in others have cross sections of at least half an inch; and some have phenocrysts of both feldspar and hornblende, the latter in places about 1½ inches long.

In places subrounded and rounded segregated bodies are very numerous, giving the rock the appearance of a breccia. Locally they are lacking or sparsely distributed in the mass. In all the exposures examined the segregated bodies were less porphyritic than the inclosing rock. They range in size from about half an inch to about 50 feet, and some of the larger ones contain smaller segregated bodies of still less porphyritic types. The microscope shows that as a rule the difference between the segregated bodies and the matrix is textural only. Dikes of slightly porphyritic granodiorite, apparently identical with some of the segregated bodies, cut more porphyritic rocks.

Another widespread type of granodiorite is a nonporphyritic, fairly coarse grained light-gray rock which on weathering becomes darker gray or yellowish. In some places the fresh rock has a pink or lavender tinge. It is composed principally of quartz, feldspar, biotite, and hornblende and is traversed by minute seams of epidote and in places by chlorite. A narrow bleached zone on each side of the epidote seams locally gives the rock a gneissic appearance. A few aplitic dikes between an inch and several feet thick were observed cutting granodiorite of this type. The dikes are fine grained and have very little dark mineral. Quartz is conspicuous in them.

The average feldspar of the granodiorite is andesine, and this mineral makes up about 50 percent of the rock. Typical feldspar crystals are zoned. The rock contains about 30 percent of quartz and from 5 to 10 percent of dark minerals, most of which is biotite. It also carries as much as 10 percent of orthoclase. Epidote is widely but sparsely distributed through the rock. The biotite is in places chloritized. Apatite, zircon, magnetite, and clinozoisite were observed as accessories.

Age.—Like most of the other rock units in the district, the gabbro and granodiorite series cannot be assigned within narrow limits of age. It is younger than the Mesozoic greenstone and is therefore probably post-Triassic. It is probably older than the Cantwell formation, which is at present classified as Eocene but which may be as old as Upper Cretaceous. This is all that is definitely known. On the basis of correlation with similar granitic rocks in the eastern Talkeetna Mountains, Capps[34] tentatively assigns these intrusives to the late Lower Jurassic or early Middle Jurassic, but he says that they may be as young as Upper Cretaceous.

Later work in portions of the Alaska Range south of McKinley Park indicates that many if not all of the granitic intrusive masses cut sediments that are as young as late Jurassic or Lower Cretaceous, and some even cut the Cantwell formation. The inference therefore seems justified that the granitic intrusives of the Mount Eielson district may be of late Mesozoic age.

There is, however, some evidence regarding the relative times of intrusion of the various members of the series, although just how much geologic time elapsed between the first and the last intrusion is not known. The more basic members of the group are the older, as is shown by dikes of porphyritic granodiorite cutting some of the basic bodies. It is true that in some places bodies of basic rock are found in the granodiorite, but they have a definite position in the granodiorite and are probably xenoliths. They are described in the section on structure (p. 267). In some places the even-grained facies of the granodiorite appears older than the porphyritic facies because it is cut by porphyritic dikes, but this should not be taken

[34] Capps, S. R., The Toklat-Tonzona River region, Alaska: U.S. Geol. Survey Bull. 792, pp. 105–106, 1927.

as a generality, for the segregated bodies of one type of porphyry in another and the presence of dikes of one type cutting another afford abundant evidence that the porphyritic types are not all of exactly the same age. The aplites appear to be the youngest members of the suite.

TERTIARY LAVAS AND ASSOCIATED ROCKS

In addition to the Triassic (?) greenstone, there is another series of volcanic rocks in the Mount Eielson district. One characteristic of this series is the great variety of colors displayed by its members. Red, green, violet, purple, yellow, white, and black rocks are all conspicuous, and, as might be expected, the rocks cover a wide lithologic range. In this district most of this series appears to be porphyritic andesite; but tuff, basalt, dacite, obsidian, and various breccias are also represented. None of these rocks are as indurated or as jointed as the Triassic (?) greenstone.

The andesite is gray, dark brown, or purple and in many places carries numerous phenocrysts of clear andesine as much as half an inch across. The darker-colored basalts are in many places very vesicular, and many of the vesicles are filled with calcite or zeolites. A widespread member of the series is a black obsidian which normally weathers to a gray rock but in some places weathers bright green. A little fine-grained conglomerate appears in the section, but light-yellow or white tuff is more common. At one locality a light-colored dacite, in which quartz, feldspar, and biotite were recognized, intrudes andesite and tuff. The dacite contains xenoliths of andesite as much as 6 feet in diameter. Many breccias occur in the series, and fragments of all the above-mentioned rocks appear in the breccias.

The granodiorite and the Paleozoic limestone are cut by a few dikes of basalt, which appear to follow joints in the older rocks. Although no definite connection between these dikes and the lavas could be demonstrated, it seems probable that the dikes were contributors to some of the flows. The dikes range in width from 1 to 50 feet, but most of them are about 6 feet wide.

This volcanic series is at least 500 feet thick within the Mount Eielson district, and its total thickness is probably much greater.

Its stratigraphic position, its textures, and the degree to which it has been metamorphosed show that it is much the youngest igneous preglacial formation in the district. To the east and to the west of the Mount Eielson district Capps[35] found these volcanic rocks interbedded with Cantwell beds, and the series is therefore of

[35] Capps, S. R., The Kantishna region, Alaska: U.S. Geol. Survey Bull. 687, p. 40, 1919; The Toklat-Tonzona River region, Alaska: U.S. Geol. Survey Bull. 792, pp. 92–95, 1927.

Cantwell age. Speaking of the region in the vicinity of Mount Eielson, Capps [36] says:

The volcanic materials associated with the Cantwell formation may be considered of the same general age as the Cantwell, for the surface lavas and tuffs are interbedded with the sediments. In the region here described the main accumulation of the sediments now remaining took place before the chief volcanic activity occurred. Farther east in the Toklat Basin, the bulk of the volcanic material occurs about in the middle of the Cantwell formation, and the major volcanism was preceded and followed by periods during which sediments were laid down with only a minor admixture of volcanic materials.

AREAL GEOLOGY

The areal distribution of the lithologic units which were recognized in the Mount Eielson district is shown on plate 2. More detailed work in adjacent areas would undoubtedly result in the subdivision of some of the units, particularly the Paleozoic limestone formation and the Tertiary volcanic rocks of Cantwell age.

The Paleozoic limestone is the most widely distributed formation in the district, and it also extends over very large areas on the north flank of the Alaska Range outside the district. Within the district the formation is divided into two distinct parts by a fault that can be traced from a point near the mouth of Intermittent Creek southeastward to the end of Sunrise Glacier. The limestone forms the bedrock of all the area lying south of the fault and east of Muldrow Glacier except for two masses of gabbro which lie just south of Mount Eielson itself, one mass of granodiorite which occupies an area along Muldrow Glacier south of the junction of Crystal and Glacier Creeks, and numerous dikes and sills of porphyritic granodiorite and a few of basic material which are widely distributed through the limestone but are conspicuously less abundant near the southeast corner of the district.

North and east of the granodiorite mass just mentioned, within a horizontal distance of three quarters of a mile, the limestone has locally been contact-metamorphosed, and beds have been selectively replaced by epidote and more rarely by sulphides. The rest of the limestone south of the fault shows little effect of igneous intrusion. Shale is conspicuous in places in the valley of Wolverine Creek, southwest of Wolverine Creek, on the south side of Crystal Creek, and northeast of Castle Rock. Graywacke is abundant in the higher country near the southern boundary of the district, particularly between Sunset and Sunrise Glaciers.

North of the fault the limestone areas are not as well defined, because of relatively much larger amounts of intrusive material and because more of the bedrock is concealed beneath a cover of later

[36] Capps, S. R., op. cit. (Bull. 792), p 95.

deposits. The largest area of the limestone north of the fault lies between the Thorofare River and the eastern border of the district and south of Gravel Mountain. The formation contains considerable dark shale in the valleys of the upper part of Gorge Creek and of the small stream that enters Sunrise Creek just above the Thorofare River. Much of the rest of the limestone of this area and also of the areas on the northern slopes of Mount Eielson is contact-metamorphosed.

There also are scattered patches of limestone north of Copper Mountain Bar and Thorofare Pass and still others west of Muldrow Glacier, notably near the southwest corner of the district.

The Triassic (?) greenstone occupies a large area north of Thorofare Pass and Copper Mountain Bar and incloses the limestone just mentioned in that vicinity.

In addition to the gabbro masses south of Mount Eielson there are several in the limestone areas north of Sunrise Creek and between that creek and the edge of the district. Gabbro also appears in the Triassic (?) lavas north of Thorofare Pass, but it has not been separately mapped.

The largest mass of granodiorite constitutes most of Mount Eielson itself. This mass is more porphyritic near its west end than elsewhere. A large area of porphyritic granodiorite lies south of Thorofare Pass; much of its westward extension south of Copper Mountain Bar is hidden beneath glacial moraine. The granodiorite near the confluence of Glacier and Crystal Creeks has already been mentioned. There remain considerable areas, composed principally of the porphyritic facies of the rock, on the west side of Muldrow Glacier.

The thousands of dikes and sills of granodiorite, which are apophyses of the larger masses mentioned or of similar buried masses, cut the older rocks so intricately, and many of them are so small, that they have had to be very greatly generalized to be shown on the geologic map.

The volcanic rocks of Cantwell age are found principally in three areas—north of the middle of the district west of Muldrow Glacier, in the vicinity of Green Point, and north of the west end of Copper Mountain Bar.

The Tertiary coal-bearing formation was recognized in four places only—in a small valley northwest of Gravel Mountain, at two localities near the west end of Thorofare Pass, and on the east bank of the Thorofare River just above the mouth of Gorge Creek. It probably has a wider distribution than is indicated, for it was differentiated only where coal was found in it.

The Nenana gravel occupies most of Thorofare Pass and forms the tips of the spurs that project into Copper Mountain Bar from the south. It is probably present locally beneath the alluvium of the bar.

A small but interesting area of gravel is situated just north of the peak of Gravel Mountain and gives the mountain its name. This gravel carries boulders as much as 6 inches in diameter and lithologically looks like Nenana gravel. Although it is only a few feet thick, no coal was seen in it, but at the foot of the mountain south of the east end of Thorofare Pass the lignite beds of the coal-bearing formation lie directly on the porphyry. It therefore seems probable that this gravel is Nenana gravel and not part of the coal-bearing formation.

Pleistocene glacial moraine material is widely distributed over the district, but it was mapped only where it formed a cover continuous enough or thick enough to prevent mapping the underlying rock with reasonable assurance. The largest area mapped lies on the northwest flank of Mount Eielson.

Talus and alluvial-fan material was mapped only on the northern slopes of Mount Eielson and just to the east across the Thorofare River, for in these localities it conceals areas within the sulphide-bearing zone. The largest alluvial area is that of Copper Mountain Bar, but the Thorofare River above the bar proper and Crystal Creek have broad alluvial flats.

STRUCTURE

The structural geology of the Mount Eielson district is not in general complex, but some of the structural details are complicated. On plate 23 a series of six parallel orthographic structure sections have been arranged clinographically [37] to represent the structure of the district. The lines of the sections are indicated on the geologic map (pl. 22). Although all the available data were used in the construction of the sections, they are generalized in part because of the limitations of the scale used.

The structural trends are essentially parallel or at small angles to the trend of the axis of the range (about N. 65° E. in this vicinity), except where they are distorted by igneous intrusions.

One of the dominant structural features of this district is the normal fault that extends from a point near the mouth of Intermittent Creek to the foot of Sunrise Glacier. The dip of the fault plane is steep, probably almost vertical, and its strike is about east-

[37] By an orthographic structure section is meant an ordinary structure section in which the geology is represented on a vertical plane along the line of the section. The scale is the same in all directions. If the sections were arranged in the same manner as drawn the front one would hide all the rest; therefore they have been arranged as in an isometric diagram, "clinographically," in which the eye is considered as being elevated a certain angular amount above the plane of the horizon and also moved laterally a certain distance to the right. The distance between the sections is correspondingly foreshortened.

west. At the head of Intermittent Creek the fault disappears beneath the alluvium, but the areal geologic pattern indicates that it extends at least as far as the edge of Muldrow Glacier. The fault was not traced beyond the limits of the district at Sunrise Glacier, but it undoubtedly continues farther east. The fact that the sediments on the south side of the fault near the eastern border of the district do not show as much steepening of dip due to drag along the fault plane as the sediments farther west, south of Mount Eielson, may indicate that the displacement is less near the eastern edge and that the fault may be dying out. No indication of a horizontal component of movement along the fault plane was observed, and it is therefore assumed that the movement was vertical or nearly so. No key horizon was recognized in the Paleozoic limestone formation on either side of the fault, and evidence of horizontal movement might not be observed even if such movement had occurred. Under the assumption that there has been little or no horizontal movement along the fault plane the areal distribution of the lithologic units, with the intrusive mass of Mount Eielson lying north of the fault, indicates that the downthrown side is the south side, as is diagrammatically shown in figure 35. The age of the fault is not known except that it is later than the intrusion of the gabbro and granodiorite and therefore later than the deposition of the ore. There is a little evidence to indicate that it is older than the Cantwell, for no volcanic remnants of Cantwell age were found south of the fault, whereas several were found north of it. If the fault were post-Cantwell, some remnants should be preserved in the area south of the fault, which is the downthrown side.

The southern boundary of the small granodiorite area between Glacier and Crystal Creeks is also a fault contact, as is witnessed by the straight contact, the absence of contact metamorphism in the limestone south of the contact, the disturbance of the structural trend of the limestone by the intrusion north of the contact and between it and the larger fault already described and the absence of such disturbance south of it, and the presence of fewer dikes and sills south of the contact projected. The fault trends about N. 50° E. and, if it is continuous as far as the other fault, may intersect that fault between the two gabbro masses south of Mount Eielson. However, it could not be traced that far in the field. It is possible that the small granodiorite mass is part of the Mount Eielson mass and has been faulted into position as shown in figure 36.

The average strike of the limestone south of the main fault is approximately N. 55° E. and thus makes an angle of about 35° with the major fault and is nearly parallel to the minor fault. The average dip is probably between 20° and 30° SE. Locally the attitude is much different. Steeper dips prevail near the main fault, probably owing to drag along the fault plane, but it has been pointed out that the steepening is less pronounced near the eastern border of the area. Regional metamorphism appears to have been more intense in the southern part of the district, and near the southern border schists

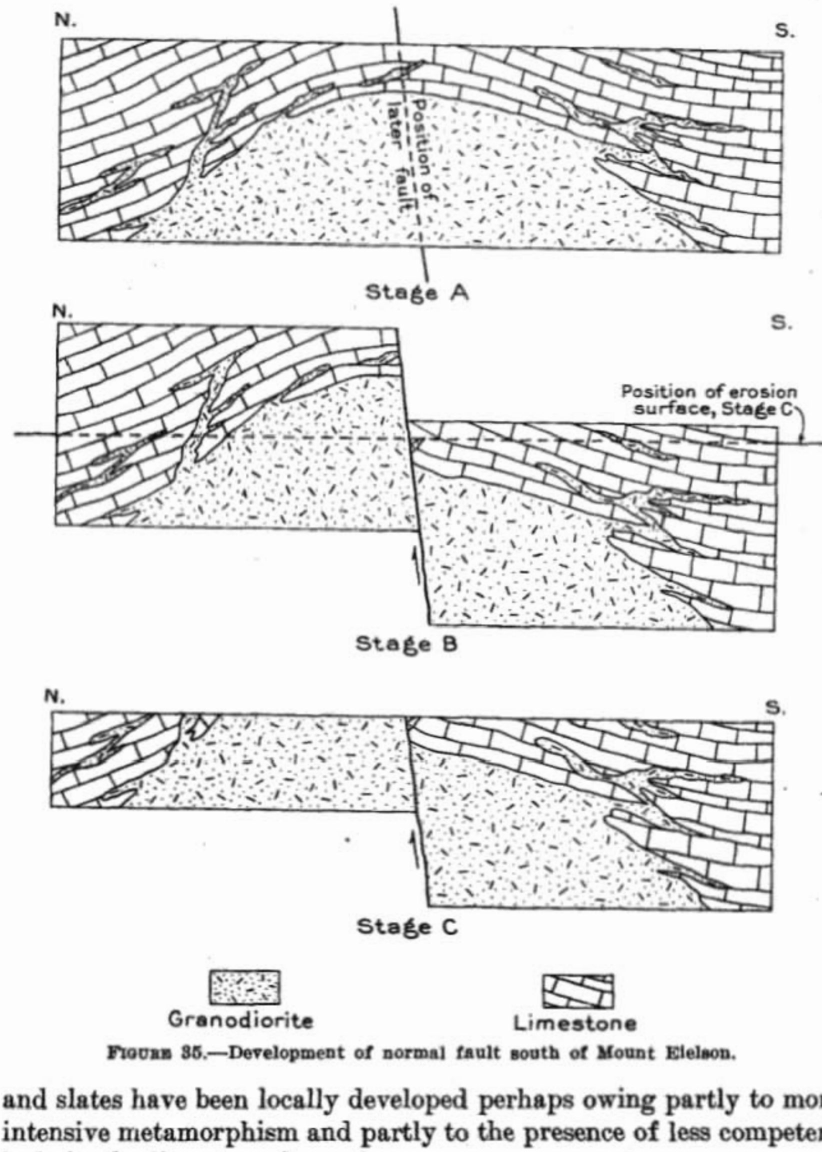

FIGURE 35.—Development of normal fault south of Mount Eielson.

and slates have been locally developed perhaps owing partly to more intensive metamorphism and partly to the presence of less competent beds in the limestone formation.

The rocks between the minor and the major faults are considerably disturbed, but the effect of warping over the nose of the small intru-

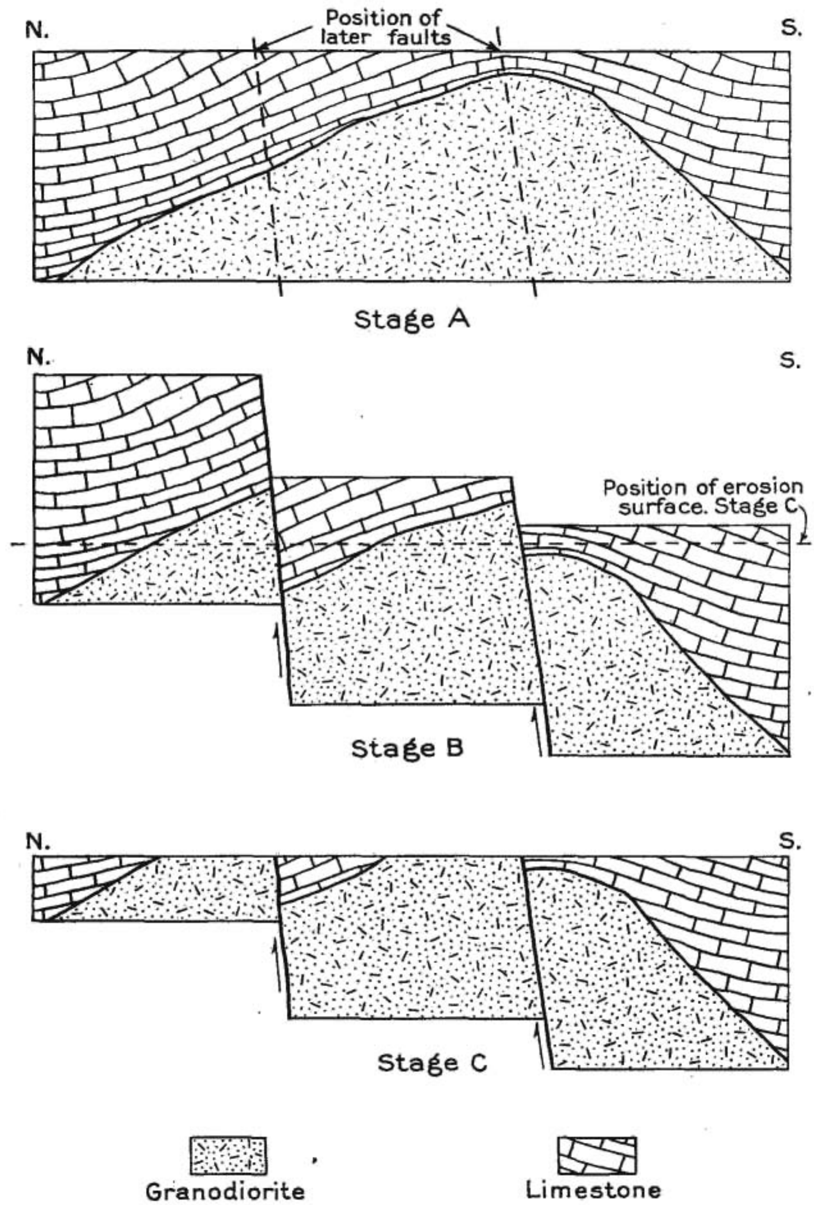

FIGURE 36.—Explanation of granodiorite mass in forks of Glacier and Crystal Creeks as part of the Mount Eielson mass cut off by faulting.

sive mass is apparent, as is shown by the structure symbols on plate 22.

The two gabbro masses south of Mount Eielson appear to be sills, although locally they cut some beds. It is possible that they are parts of the same sill. The general sill-like nature of the small granodiorite masses is also clear, although there are some dikes, many of which trend essentially parallel to the strike of the limestone.

North of the major fault the structure is more complex than south of it, owing in large part to the relatively much larger amounts of granodiorite which are there intruded into the limestone.

The strike of the sediments immediately north of the main mass of granodiorite of Mount Eielson is not uniform but is in general controlled by the intrusive and may average around N. 80° E. Farther east, on Bald Mountain and in the valley of Sunrise Creek, the average strike. following the shape of the intrusive, has swung around to about N. 65° W. With few exceptions the sediments everywhere dip to the north, and the dips are steeper close to the granodiorite. Thus, in general, the intrusive mass is seen to be of the conco-dant type, but study of the contact across the north face of Mount Eielson shows that there is a great deal of crosscutting. Many of the apophyses in the sediments in this vicinity are sills, but many are dikes, some of which, particularly some of the larger ones, are parallel to the strike of the sediments which they cut but dip to the north at lower angles than the sediments. The crude directional arrangement may be controlled by a joint system in the sediments. The contrast between the dark sediments and the light granodiorite dikes when viewed from a distance gives in some places an erroneous impression of the structure.

In the eastern part of the district between Sunrise Creek and upper Gorge Creek, there is a gentle anticline. This fold was not recognized west of the Thorofare River. The large mass of granodiorite that lies south of Thorofare Pass appears to rest practically conformably upon the underlying limestone. The isolated granodiorite area on the divide between upper Gorge Creek and Sunrise Creek is clearly part of the larger mass to the north and has been separated from it by erosion. The rock of these two areas is everywhere either porphyritic or fine grained and nowhere exhibits the plutonic textures common in the main mass of Mount Eielson. Indeed, much of the rock has some of the characteristics of lava flows. The mass appears to be the remnant of a large sill or laccolith genetically connected with the granodiorite of Mount Eielson and the sills and dikes in the sediments between the two are believed to be the feeders of the sill. The sill is made up of rocks of greatly different textures, and many dikes of one type cut masses of other types. This is believed to show that the material was intruded at different times and that cooling conditions differ from time to time during the pulsatory intrusions. However, the concentration of bodies of basic rock near the base of the sill suggests that they may be the result of fractional crystallization and crystal settling from a mass of considerable size which was probably injected in one of the earlier pulses of the intrusion, for the basic rocks have been cut by later porphyritic granodiorite and in places have been carried up as xenoliths into the sill, as at the upper bend of Gorge Creek northeast of Green Dome.

Plate 23 indicates that the thickness of sediments separating the intrusive mass of Mount Eielson and the sill is greater at the eastern edge of the district than at the cirque at the head of Grant Creek. The geologic map shows that the west end of the Mount Eielson mass is porphyritic. These observations suggest that perhaps the sill itself branches from the main intrusion near Muldrow Glacier, but this could not be proved because of the moraine cover in the critical area.

The top of the sill was observed only at the west foot of Stony Dome. Here the overlying rock is the Triassic (?) greenstone. No contact between the greenstone and the Paleozoic sediments was observed, but according to Capps [38] the two are unconformable. It does not seem unlikely that a plane of unconformity might control the intrusion of a mass such as the one just described. If this is the case the body cannot be considered a true sill.

The greenstone north of Thorofare Pass appears to strike about N. 60° E. and to dip about 30° NW. The Nenana gravel near the northeast corner of the district, on the east side of Thorofare Pass, strikes about N. 25° E. and dips about 15° NW. The coal-bearing formation near the mouth of Gorge Creek and on the south side of the pass strikes N. 30° E. and dips 17° NW. The small area of gravel near the top of Gravel Mountain rests on a weathered surface of porphyritic granodiorite. The base of the gravel has a northwesterly tilt, and projection of the plane of the base of the gravel by eye makes it appear to coincide with the base of the gravel at the foot of the mountain. It is possible that the gravel has been folded into the pass, but the steepness of the mountain north of the pass would necessitate a sharp fold in the gravel with a steep northern limb. Such a fold was not observed, although one may be present, but it seems equally possible that a fault of post-Nenana gravel age traverses the pass.

The Tertiary lavas and tuffs north of Copper Mountain Bar strike about N. 50° E. and have a low dip to the northwest. They appear to rest unconformably on the obviously much older greenstone. At

[38] Capps, S. R., The Toklat-Tonzona River region, Alaska: U.S. Geol. Survey Bull. 792, p. 105, 1927.

Green Point, at the west end of Mount Eielson, the obsidian and tuff strike N. 30° W. and dip about 60° toward the glacier.

The structural observations west of Muldrow Glacier are too few to permit detailed interpretation. The Nenana gravel at the northwest corner of the district has a northeasterly strike and dips at a low angle to the northwest. It lies unconformably on porphyritic granodiorite which includes masses of sediments that trend about east. The volcanic rocks of Cantwell age just across Muldrow Glacier from the mouth of Crystal Creek lie on the granodiorite which appears just north of it, and the several small outliers of volcanic rock south of the main mass and on the granodiorite indicate that the southern boundary is a depositional and not a fault contact.

Some evidence points to a north-south fault under Muldrow Glacier. Topographically the northern edge of the range proper lies farther southwest of the glacier. In general, the geologic patterns along the strike on opposite sides of the glacier do not match. They would match much better if the west side could be moved northward about 3 miles. On the other hand, the volcanic rocks at Green Point are similar to some directly west across the glacier. However, if a fault exists it might be pre-Cantwell. A fault is suspected under and parallel to the glacier, but its existence is not proved.

GEOLOGIC HISTORY

The geologic history of the Mount Eielson district begins in Paleozoic time, probably not much earlier nor much later than the Middle Devonian. A thick series of sediments, predominantly limy, was deposited in the Paleozoic sea, and many of the beds show evidence of being shallow-water deposits. Sedimentation continued for an unknown period, but by Mesozoic time (probably Triassic) sedimentation had ceased, the rocks had been disturbed by tectonic forces, and a certain amount of erosion had gone on, for the Triassic (?) lavas lie unconformably on the older Paleozoic rocks in the upper Toklat Basin just east of the Mount Eielson district. This is all that is known of the long span of time between the Middle (?) Devonian and the Triassic (?).

The historical record from Triassic (?) to Cantwell time (Eocene) is incomplete, but some of the principal events are known. After the pouring out of the great series of basic Triassic (?) lavas, and perhaps in part contemporaneous with them, a variety of granitic rocks were intruded into the Paleozoic sediments and the Triassic (?) lavas. The rocks of these intrusions range from peridotites to granites, but in general the basic members of the group appear to be the older. The region during this period was probably one of tectonic disturbance, which may have lasted for a considerable period of geologic time, for the granodiorite, the predominant intrusive, is of Mesozoic age and may be as young as Cretaceous. It was during this igneous cycle that the ore was formed in the district. Mountain building, normal faulting, and erosion all followed this period of intrusion but came before Cantwell time.

The events of Cantwell time are better recorded in the more widespread Cantwell formation than in the volcanic rocks that represent Cantwell time in the Mount Eielson district. Capps [39] says:

> An important geologic event that occurred during the closing stages of the Mesozoic era or at the beginning of the Tertiary period was the uplift of a part of the Alaska Range, probably along its present axis. This movement was the first of a series of uplifts that by their combined movements have given rise to the range that now contains the loftiest peak on the continent, Mount McKinley. To what height the range rose during the first upward movement we do not know, but certainly to an elevation high enough to rejuvenate the streams so that they flowed over steep gradients and handled coarse materials. The detritus thus removed by the streams at first consisted of coarse gravels, which were carried to the flanks of the mountains and there deposited as widespread gravel fans of low slope. As erosion in the mountains and deposition in the lowlands continued, the stream-laid deposits were increased until accumulations several thousand feet thick were formed. Gravel beds are present from top to bottom of this material, the Cantwell formation, but its upper part contains a much larger proportion of fine sandstones and shales and a smaller proportion of gravels than the basal part, indicating that erosion had already reduced the ruggedness of the mountins from which the material came. The accumulation of detritus in the lowlands also decreased the gradient of the streams and rendered them less able to handle coarse gravels.
>
> After the Cantwell formation had been laid down another uplift of the range occurred, which involved not only the area previously uplifted but also the basins in which the Cantwell sediments were deposited. The Cantwell beds, now consolidated into firm conglomerates, sandstones, and shales, were uplifted, folded, and faulted and rapidly eroded by the once more steepened streams. Great valleys were cut into them and into the associated older formations. The rugged topography of the mountain belt was again reduced to moderate slopes, and the streams discharged little coarse material.

Intrusion and extrusion of igneous materials interrupted Cantwell sedimentation from time to time.

During the part of Eocene time subsequent to the events just described fine mud, silt, and gravel were intermittently deposited in the broad valleys and basins, including parts of the Mount Eielson district north of the reduced range. Vegetation and organic debris accumulated in the region between the periods of deposition and became buried and compressed by overlying subsequent deposits, and the Tertiary coal-bearing formation resulted.

Then came renewed uplift of the range with correspondingly steeper stream gradients, and therefore more and coarser material,

[39] Capps, S. R., The Kantishna region, Alaska: U.S. Geol. Survey Bull. 687, pp. 71–72, 1919.

the Nenana gravel, was deposited over the coal-bearing formation. According to Capps,[40]

> At many places the Nenana gravel appears to lie conformably upon the coal-bearing formation, but at other places the coal-bearing beds were apparently uplifted and eroded before they were covered by the gravel or other material, indicating that the uplift of the foothills region proceeded unequally in different places, some areas remaining quiescent while others were being elevated and tilted. * * *
>
> After the Nenana gravel was deposited the main range and the foothills were still further elevated. The mountains grew both by bodily uplift and by folding and faulting, and all the Tertiary beds were more or less deformed. The folding, however, was less severe than that to which the Cantwell formation had been earlier subjected, and consisted of compression that tended to narrow the basins of coal-bearing materials into shallow synclines. Faults trending east and west, some of which have displaced the coal-bearing beds and the Nenana gravel for several hundred feet, have been observed, and the development of the foothill ranges is due to both folding and faulting. At the close of Tertiary time the Alaska Range and its subsidiary foothill ridges had probably been elevated to approximately their present position, and the agencies of erosion had actively attacked the young mountains and had cut great valleys in them. The gravels of the foothills and the associated coal-bearing beds had also been greatly eroded and had been reduced to rounded and well-drained topographic forms. Across the hard-rock ridges that lay athwart their valleys the streams had cut deep, narrow canyons, but in intervening areas that were floored with unconsolidated Tertiary materials great basins had been excavated.

There is evidence of at least two great glacial stages in the Pleistocene epoch which affected the north flank of the Alaska Range and consequently the Mount Eielson district. No apparent evidence now remains in the district of the earlier and more extensive stage. The later (Wisconsin) stage is abundantly represented by the broad glacier-carved valley floors and high-level morainal deposits which show a much greater advance of ice tongues from the mountains than that of the present glaciers. Climatic conditions caused the Wisconsin glaciers to retreat to about the position of the existing glaciers, and the streams have incised themselves below the old ice-scoured floors and have built up gravel bars of outwash material from the melting ice.

ORE DEPOSITS

HISTORY

Various accounts of the history of prospecting in the Mount Eielson district differ somewhat in detail, but the following outline was obtained from O. M. Grant, of Fairbanks, who has been familiar with the district almost since its discovery:

The first four claims at Mount Eielson were staked by J. B. and Fannie Quigley in 1920. Later in that year two more claims were

[40] Capps, S. R., op. cit. (Bull. 687), p. 73.

staked by Biglow and Perry. In August 1921 O. M. Grant and F. B. Jiles located 23 claims, 1 of which was recorded in the name of Mrs. Isabel Stanford, and in the same year several claims were staked by Harry Owen.

In March 1922 Grant & Jiles leased their claims to Thomas Aitken, and in June 1923 Aitken subleased to the Guggenheim interests, who worked the property during that summer. In the meantime John Anderson had located nine claims in 1922, and in 1923 W. J. Shannon relocated Harry Owen's claims, on which the assessment work had not been done.

In 1925 the property leased to Aitken by Grant & Jiles reverted to Grant, who has held most of it since, but many of the present claims have different boundaries and different names from the original ones. In 1929 John Anderson's claims reverted to the public domain, and in 1930 Grant transferred several of his own claims to Hugh Matheson. Early in 1931 Grant transferred a half interest in all his remaining claims to Joe Henderson, of Fairbanks, and in the summer of the same year Ben Cleary restaked two of John Anderson's old claims.

The present claim holders appear to be Grant & Henderson, Mrs. Stanford, Matheson, Cleary, and Shannon. The locations of the individual claims, except those of Shannon, whose claim corners were not all found, and one claim of Ben Cleary, which lies outside the area depicted on the diagram, are indicated as nearly as could be determined in figure 37.

Very little development work has been done in the district. In addition to three small adits on the Jiles claim, one of which was driven by Aitken and another by the Guggenheim interests in 1923, there are probably between 200 and 250 small prospect pits and open cuts. Many of these are now abandoned and are badly slumped.

There has been no production from the Mount Eielson district.

CHARACTER OF THE DEPOSITS

DISTRIBUTION AND GEOLOGIC FEATURES

As a whole the ore deposits may be considered as belonging to the replacement type and were formed by the replacement of originally limy beds by members of the epidote group and the sulphides of lead, zinc, and copper. Part of the materials came from a stocklike mass of granodiorite that was intruded into the limy beds, and they were deposited under chemical and physical conditions induced by the intrusion.

The deposits are found in a fairly well defined zone bordering the main intrusive mass of Mount Eielson on the north. The zone can be definitely traced for about 4 miles, from a point near the top of Bald Mountain westward to and beyond the headward cirque of Grant Creek. It may continue farther in that direction beneath the concealing moraine, but, as has been stated in the section on structure, there is some possibility that the bedrock beneath the moraine on the northwest flank of Mount Eielson may be largely granodiorite. The zone is cut off on the east by the fault south of Bald Mountain. The width of the zone at the surface is not uniform, although its thickness appears to be everywhere about 2,000 feet. The width of the outcrop of the zone, is therefore influenced both by topography and by structure. There is evidence of a little mineralization on the spur between Glacier and Crystal Creeks and also on the spur between Crystal and Intermittent Creeks, and it has been referred to the granodiorite body lying to the south. The localities at which this evidence was observed are indicated in figure 37.

Although in general the distribution of the ore was controlled by distance from the granodiorite, it was in detail affected by the relative ease with which various individual beds were replaced, and possibly also by other factors, such as joint systems. The evidence appears to indicate that the numerous porphyritic dikes and sills emanating from the main intrusive body did not affect the localization of the deposits.

No key beds were recognized in the rock of the ore zone, and no beds or subzones especially susceptible to replacement by ore minerals could be traced for more than a few hundred feet, partly because of lack of continuous exposures. The evidence indicates that the ore replacement even in the same bed varied greatly from place to place. Although the intrusive appears in general to be of the concordant type, still it is discordant in detail at many places (see pl. 23, particularly sections *D–D′* and *E–E′*), and therefore the bed in contact with the granodiorite is not everywhere at the same horizon, and the zone does not everywhere embrace the same stratigraphic span.

The areal geology of part of the ore zone is shown in more detail on plate 24 than on the geologic map of the whole district. The claim locations are also shown on the plate. Inasmuch as the dikes and sills that emanate from the granodiorite are to be numbered in thousands and range in thickness from a fraction of an inch up to at least 150 feet, it has been impossible to map them individually, even on the scale of plate 24, which must be considered generalized so far as they are concerned.

MINERALOGY

Gangue minerals.—The mineralogy of the ores from Mount Eielson is simple. The only abundant gangue minerals are members of the epidote group, and of these clinozoisite appears to be the most common, although in places either zoisite or epidote may predominate. The fine-grained dark greenish-gray clinozoisite aggregates appear cherty and were often mistaken for chert in the field. Quartz and white calcite are minor gangue minerals.

Ore minerals.—Sphalerite, galena, chalcopyrite, malachite, and azurite are the ore minerals that were definitely recognized. They are listed in the order of decreasing abundance. In addition Davis [41] mentions an occurrence of native copper, and Moffit [42] lists tetrahedrite. Pyrite is a common metallic mineral in the district but is of no value. Sphalerite appears to be the earliest of the ore minerals. Galena was deposited in part contemporaneously with the sphalerite and in part after the sphalerite deposition was complete. Chalcopyrite has been observed veining sphalerite and galena, and wherever associations of the three minerals were studied the chalcopyrite was the latest. Assays show the presence of some silver, and microscopic examination of polished sections reveals minute specks in galena of a mineral which has tentatively been referred to pyrargyrite. Some galena assays show very little silver, but some of the sphalerite appears to carry considerable.

The typical ore consists of alternating bands of fine-grained minerals of the epidote group and sulphides. In most places the sphalerite is fine grained, but the galena in some places is coarsely crystalline. The widths of the bands are with rare exceptions between one sixteenth inch and 1 inch. The bands are defined in barren contact rock by slight differences in color or texture of the epidote minerals or by thin, dark seams which may be carbonaceous material. Lean ore shows stringers, patches, and isolated crystals of sulphides in the epidote. Whole bands are replaced to form richer ore, and in some places the replacement has been complete and only sulphides remain, though even in these the original banding is ordinarily apparent.

Chalcopyrite cuts across the bands in little stringers more commonly than the other sulphides.

GENESIS OF THE ORES

The ore deposits of Mount Eielson are the result of one phase of a large-scale replacement process which affected a zone about 2,000 feet thick in Paleozoic sediments consisting of thin-bedded limestone, shale, graywacke, and sandstone, when the sediments were intruded in Mesozoic (probably late Mesozoic) time, by a stock of granodiorite. The main mass of the intrusion probably never reached within sev-

[41] Davis, J. A., Annual report of the mine inspector to the Governor of Alaska, p. 135, 1922.

[42] Moffit, F. H., The Kantishna district, Alaska: U.S. Geol. Survey Bull. 836, p. 315, 1933.

eral thousand feet of the surface, for it was capped by a considerable thickness of the limestone formation and also by a thick lava series. The mineral associations also point to a rather high temperature of formation. According to Lindgren [43] the temperature range for deposits of this type lies between 400° and 600° C. The replacement zone is cut by a myriad of dikes and sills of porphyritic granodiorite which have a wide range in size. Many of these may be feeders to a large sill-like mass of porphyritic granodiorite which lies stratigraphically above the replaced zone. The porphyritic granodiorite represents material given off from the main stock, but the replacement processes appear to be related to the main intrusive body only and not to the dikes and sills in the zone nor to the large overlying sill. The time relation between the apophyses of the stock and the formation of the ore is not certainly known.

As the intrusion came into place a vigorous exchange of material occurred because of the chemical and physical differences between the intruding and the intruded rocks. The replacement was selective, however, and practically unchanged limestone beds occur within the zone. One of the chief processes was the introduction of large quantities of silica. Quartz, however, is a very uncommon gangue mineral. General conditions, such as the absence of quartz veins and areal distribution, indicate that the silication preceded ore deposition. Therefore, either the silicated beds were not those into which the ore was later introduced, or some of the silicated beds were in turn completely replaced by other minerals into which the ore was introduced. There is some evidence that many of the beds which are at present siliceous were originally siliceous sediments.

The most widespread process of replacement was that of epidotization—that is, the formation of any member of the epidote group. Large volumes of the limestone have been replaced with the loss of CO_2 and the addition of SiO_2 and Al_2O_3, but the details of bedding and structure have been faithfully preserved. The epidotized rocks were later partly and in places completely replaced by sulphides. Incipient stages of ore replacement show sphalerite and in places also galena in sporadic bunches in the epidote rock or, more commonly, as thin discontinuous streaks parallel to the bedding. Locally the replacement of epidote by sulphides continued until an end product was formed which consists of an aggregate of sphalerite, galena, and chalcopyrite.

The deposit appears somewhat unusual because of the scarcity or complete absence of other common contact minerals such as garnet and amphibole.

[43] Lindgren, Waldemar, Mineral deposits, 3d ed., p. 783, 1928.

ECONOMIC FACTORS

The principal objects of the investigation of the Mount Eielson district were to determine the type and extent of the ore deposits and to find out as much as possible about the tenor and composition of the ores. Although no attempt is here made to discuss in detail the economic factors that will enter into mining and treatment of the ore of any possible future development, a few general statements appear to be warranted.

Transportation.—There is no custom smelter in Alaska, and any ore or concentrates would have to be shipped to some smelter outside the Territory. The new road described on page 234 will soon make the district readily accessible by automobile from McKinley Park station. Except in winter the road could be used by motor trucks or tractors to haul ore to the railroad at the station unless the National Park Service restricts its use. The haul could be shortened somewhat and some grades could be cut out by leaving the roadway at places and making greater use of the gravel bars. The road is being built primarily as a scenic highway and climbs some hills for the fine views to be had from the summits. Not much snow falls in the region, and ore and supplies could probably be moved at most times during the winter by tractors and sledges. Material can be moved to or from McKinley Park station by rail during all months.

Climate.—The long, cold winters are to be seriously considered, both as to their effect on actual mining and treatment of ore and as regards housing and living conditions, though experience elsewhere proves that mining can be conducted throughout the year under even more severe climatic conditions than prevail here.

Labor and wages.—Although there is no labor supply in the district, there is a sufficient supply of labor in Alaska which probably would be available at the usual Alaska rate of about $5 a day with board.

Timber and fuel.—There is no timber in the district. The rock in which any mining would be done is so massive, however, that probably little mine timber would be required. Timber or lumber needed for any purpose would either have to be shipped in from outside or brought in from the lower country to the north or west for a distance of at least 20 miles over roadless swampy country. Logs could be hauled much more easily from the country to the north in winter than in summer. Lignite for fuel can be obtained in sufficient amounts for mine and mill use from the coal-bearing beds in the valley of the upper part of Moose Creek, which lies a short distance north of the district.

Water.—Most of the local streams are so muddy and have such fluctuating flows that they could probably not be used for power development. The flow of Grant Creek is not great but may be sufficient to develop enough power for a small mill, at least in the summer.

METALLURGY

Sphalerite is by far the most common ore mineral, and any future mine will probably be operated primarily as a zinc mine, though as considerable galena is present lead would undoubtedly be one of the products. The assays given on pages 278–284 show that the silver content of the ores is extremely variable, but silver is usually present in recoverable quantity, and local bodies of ore rich in silver could probably be found.

McCarty [44] ran a series of tests on ore from the Mount Eielson district that according to O. M. Grant came from the Jiles claim and summarizes his results as follows:

> Owing to the highly disseminated nature of the lead and zinc in this ore it is impossible to make high recoveries without grinding the ore so that about 80 percent will pass a 200-mesh screen. When ground to this mesh good recoveries of both lead and zinc may be obtained by the proper flotative mixtures.
>
> The best results were obtained when potassium xanthate was used in an alkaline circuit with sodium cyanide, zinc sulphate, and steam-distilled pine oils. This flotative mixture yielded a 51.74 percent lead concentrate with a 65.4 percent extraction and containing 12.10 percent zinc; and a 49.10 percent zinc concentrate with a 77.8 percent extraction and containing 13.80 percent lead. Other tests showing slightly lower lead recoveries but containing only about 7.0 percent zinc might prove better for practical purposes. This depends on economic conditions such as the distance from smelter and smelter rates and penalties for different grades of concentrates. The grade of any of the concentrates, however, could be improved by treating in cleaner flotation cells. The silver extraction has been found to parallel quite closely the percent extraction of the lead. The best recovery made was 84.7 percent of the total silver content of the ore. The greater part of the chalcopyrite is recovered with the lead, the rest being floated with the zinc concentrate.
>
> Recoveries obtained in this laboratory investigation would warrant construction of a pilot mill, in which further metallurgical testing should be carried on to perfect a flow sheet. Such testing work would at the same time improve both recovery and grade of the lead and zinc concentrates.

THE PROPERTIES

In the following detailed descriptions of the individual prospects, the present claims, as shown in figure 37, will be used for convenience, although it is realized that the locations of many are temporary, as none are patented or even surveyed.

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[44] McCarty, W. J., Differential flotative treatment of a complex silver-lead-zinc ore (thesis submitted to the Alaska Agricultural College and School of Mines, 1927).

HUGH JOHN

The Hugh John claim of O. M. Grant and Joe Henderson forms the northwest corner of the group of claims shown in figure 37.

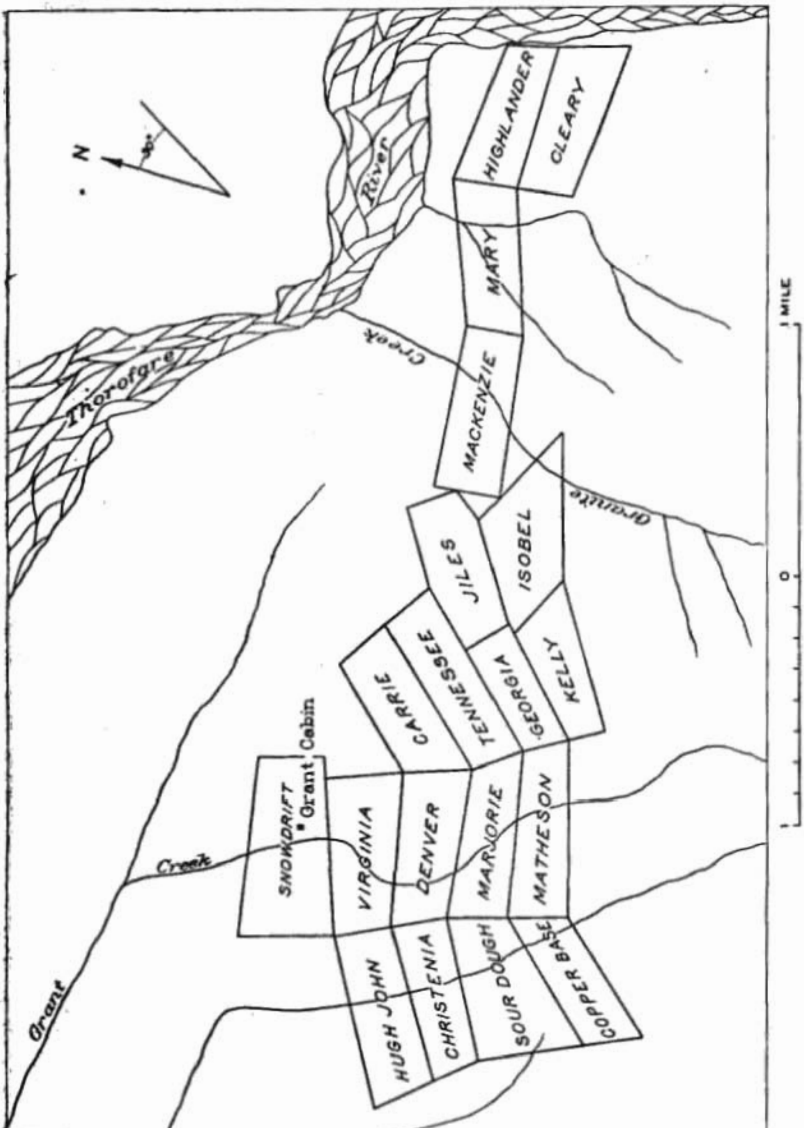

FIGURE 37.—Generalized sketch map showing the location of claims on the northern slope of Mount Eielson.

There has been no development. The claim is in a moraine area, and no bedrock is exposed except in the bed of a small brook where it crosses the northern boundary of the claim. A 10-foot thickness of epidote rock, carrying considerable sphalerite and galena, is exposed. No chalcopyrite was seen, and the sphalerite predominates over the galena.

CHRISTENIA

Grant & Henderson own the Christenia claim, which lies just south of the Hugh John. The claim is developed by two very small prospect pits, in the upper one of which about 5 feet of ore-bearing material is exposed. Most of the claim is buried beneath moraine. The strike of the ore-bearing beds is nearly east-west, and the dip is about vertical. There appears to be very little galena on the Christenia, and no chalcopyrite was noticed. Sphalerite is the principal metallic mineral, but a little pyrite was seen. An assay of a picked specimen of sphalerite to determine its silver content showed no copper, no lead, 41.37 percent of zinc, and 0.20 ounce of silver to the ton. The principal gangue minerals are epidote and calcite. A little pale-green andradite is also present.

SOUR DOUGH

There is one small prospect pit on the Sour Dough claim, which belongs to Hugh Matheson. A little low-grade zinc ore is exposed. The claim lies south of the Christenia, and is likewise mostly covered with glacial moraine.

COPPER BASE

The Copper Base claim, which forms the southwest corner of the group, also belongs to Hugh Matheson. There are two prospect pits on the claim, both of which are caved so that no rock was seen in place. Some good ore was seen on the dumps of the pits. It consists of a banded aggregate of epidote, sphalerite, galena, and pyrite. There appears to be relatively more pyrite and galena here than in most other places.

SNOWDRIFT

The Snowdrift claim extends across Grant Creek just below the mouth of the canyon, where the creek leaves the mountain proper and flows across the bench above Copper Mountain Bar. Grant Cabin is on this claim, most of which is covered with fan material from the mountain. There are showings of ore near the southern boundary of the claim in the creek bank and also near the southwest corner as revealed by small prospect pits. The claim is owned by Grant and Henderson. The pit in the creek bank exposes epidotized sediments with a little pyrite, chalcopyrite, and sphalerite.

VIRGINIA

The Virginia claim abuts the Hugh John on the east and lies just south of the Snowdrift. It includes the mouth of Grant Creek and a portion of the canyon. In addition to the excellent exposures in the canyon the claim is developed by 7 prospect pits and 2 small adits, 20 and 10 feet long. This is one of the claims of Grant & Henderson. The ore shows the usual epidote-sulphide association, and the original bedding is well preserved in most places. Vein quartz is rare at Mount Eielson, but a little was seen here.

The sediments lie nearly horizontal in the canyon on this claim and are cut by large numbers of the granodiorite dikes. Sills are not very common at this particular locality. Many of the beds do not appear to be much changed by replacement. The dikes carry xenoliths of the sediments at least 10 feet in diameter, most of which are altered to ore.

Mineralization has occurred especially at three places on the claim—(1) on the east side of the creek near the southern boundary of the claim, (2) on the east side of the creek near the middle of the claim, and (3) at the mouth of the canyon on the west side. At the first locality a stratigraphic thickness of 12 feet of ore is exposed for a horizontal distance of 30 feet. An assay of a chip sample shows 0.90 ounce of silver to the ton, and 0.14 percent of copper, 3.56 percent of lead, and 3.99 percent of zinc. Both the top and the bottom of this bed are concealed, but beginning about 40 feet above the top of the exposed part three other bands of ore crop out, each about 2 feet thick.

At the second locality an ore zone about 3 feet thick borders a granodiorite dike and cuts across the bedding. This is practically the only crosscutting ore body that was observed in the district. The exposures at the third locality indicate weak mineralization.

DENVER

The Denver claim also includes part of the Grant Creek Canyon. It lies south of the Virginia and east of the Christenia. It is developed by about half a dozen small prospect pits and open cuts, in addition to which there are many excellent exposures in the canyon walls. The Denver belongs to the Grant & Henderson group.

The strike of the sediments across Grant Creek on the Denver is N. 85° E. and the dip is 55° N. The dip flattens quickly downstream, so that on the Virginia the beds are nearly horizontal. The beds are locally crumpled in this vicinity.

An ore-bearing bed at least 10 feet thick and having the attitude given in the preceding paragraph is well exposed on the west side of the creek near the middle of the claim. What is apparently the same bed may be traced up the east bank to a point about 500 feet away horizontally. It is possible that this is the same bed that appears at locality 1 on the Virginia claim. Some good ore shows in the bed of Grant Creek near the Virginia line. The Denver ore is of the usual type but locally appears to carry more chalcopyrite than the ore from many other localities. Locally chalcopyrite has weathered to malachite and azurite. An assay of a chip sample from the open cuts on the west side of the creek shows 6.00 ounces of silver to the ton, 0.10 percent of copper, 10.45 percent of lead, and 16.28 percent of zinc for a 10-foot thickness at that place.

MARJORIE

Grant & Henderson's Marjorie claim lies south of the Denver and east of the Sour Dough. There is one small open cut to bedrock on the east side of Grant Creek about 100 feet above the stream level, in which are exposed epidotized sediments carrying sphalerite and porphyritic granodiorite. Townsend [45] mentions an outcrop on the west side of Grant Creek on what was then the Caribou claim and which now must lie on the Marjorie or on the Denver claim. One assay from a 6-foot cut showed 0.03 ounce of gold to the ton, 0.3 percent of copper, 1.5 percent of lead, and 2.56 percent of zinc; and another assay from a 10-foot width, 0.03 ounce of gold and 0.6 ounce of silver to the ton, 2.3 percent of copper, 3.5 percent of lead, and 7.0 percent of zinc.

MATHESON

Hugh Matheson owns the Matheson claim, which lies south of the Marjorie. A small prospect pit beside the creek exposes about 10 feet of epidotized rock which strikes N. 85° E. and dips 75° N. and which is impregnated with some sphalerite. Assay returns show 0.3 ounce of silver to the ton, no copper, no lead, and 2.21 percent of zinc.

CARRIE

The Carrie claim of Grant & Henderson abuts against the Denver on the east. The development consists of half a dozen small pits and open cuts along the crest of the bluff in the southern part of the claim. The sediments that form the country rock are crumpled in places but in general display a low dip to the south. There are many granodiorite dikes and sills. Exposures are too poor to determine the areal extent of the ore-bearing beds, but some high-grade ore may be seen in some of the prospect openings. Sphalerite seems to be more plentiful than galena. No chalcopyrite was observed on this claim.

TENNESSEE

Grant & Henderson own the Tennessee claim, which lies south of the Carrie and east of the Marjorie. It is developed by half a dozen

[45] Townsend, Harry, unpublished data in the files of the Alaskan branch of the U.S. Geol. Survey.

pits and open cuts, two of which are near the east end, close to the Jiles claim, and the rest are above the openings on the Carrie. The pits show considerable fair ore of the usual type. No structural observations could be made.

GEORGIA

The Georgia claim, which lies east of the Matheson and south of the Tennessee, is also owned by Grant & Henderson. It is developed by three open cuts and two prospect pits. There are some good exposures near the west end of the claim, but much of the rest of it is covered with talus. The sediments near the common corner of the Matheson, Marjorie, Tennessee, and Georgia claims strike N. 80° E. and dip 50° N. A few hundred feet east, near the discovery post of the Georgia, the strike is N. 70° W. and the dip is very steep to the north or vertical.

Considerable mineralization has occurred along the common boundary of the Matheson and the Georgia. Here there appears to be but little galena. One grab sample assayed 0.8 ounce of silver to the ton, 0.57 percent of copper, 0.11 percent of lead, and 21.0 percent of zinc. The open cuts near the discovery post expose ore-bearing beds for about 150 feet along the strike and 40 feet across it. A composite chip sample from these cuts, estimated to be average for the band exposed, shows 0.02 ounce of gold and 2 ounces of silver to the ton, 0.22 percent of copper, 2.33 percent of lead, and 5.46 percent of zinc. Another band of ore is exposed for about 150 feet near the southwest corner of the claim. This band is about 10 feet wide, and the ore is similar to that from the 40-foot band.

The talus slopes below the visible ore-bearing bands contain ore minerals in conspicuous amounts. There are undoubtedly other ore zones that are covered. A particularly rich part of the slope, with an area of at least 120,000 square feet, was roughly sampled by taking many grab samples, and the composite result showed 1.30 ounces of silver to the ton, 0.52 percent of copper, 6.66 percent of lead, and 12.28 percent of zinc.

KELLY

The Kelly claim of Grant & Henderson lies south of the Georgia. The only metallic mineral that was observed was a little chalcopyrite, partly weathered to malachite, from the one small prospect pit.

JILES

The Jiles claim lies east of the Georgia and south of the east end of the Tennessee. It has been developed by eight pits and open cuts and three small adits, two of which are about 100 feet long and the third about 70 feet long. About half of the claim, the east end, lies on the piedmont slope above the Thorofare River; the other half is on the lower slopes of the mountain. The development is confined to the western half. The three adits and some of the surface workings are in the small gulch south of the southeast corner of the Tennessee; the rest are in or near the gully near the northwest corner of the claim. The two lower adits were inaccessible, but in the upper one nothing was observed that could not be better seen on the surface, in the gulch just above.

The usual type of geology is represented, altered sediments and many dikes and sills of porphyritic granodiorite. A 16-foot thickness of sulphide-bearing material is exposed near the northwest corner of the claim. The strike here is about N. 16° E., and the dip is 45° W. An assay of a chip sample across the face reveals 0.6 ounce of silver to the ton, 0.16 percent of copper, 4.78 percent of lead, and 13.12 percent of zinc. Sulphide-bearing material can be traced continuously by float and by outcrop from this pit to the prospects in the gulch where the adits are driven. A 12-foot face above the upper tunnel was roughly sampled and showed 2.4 ounces of silver to the ton, 0.12 percent of copper, 8.33 percent of lead, and 14.49 percent of zinc. The band here exposed may be 40 feet wide. Other mineralized beds occur farther down the gulch. Some high-grade galena ore lies on the dump of the middle tunnel, and Grant reports that it came from an 8-foot bed. A grab sample assayed 8.70 ounces of silver to the ton, 62.11 percent of lead, and 7.35 percent of zinc. A composite sample of a rich talus slope on the Jiles assayed 0.01 ounce of gold and 3.80 ounces of silver to the ton, 8.89 percent of lead, and 10.82 percent of zinc. The area of the slope is at least 100,000 square feet.

ISOBEL

The Isobel claim is east of the Kelly and south of the Jiles. It is developed by several small prospect pits and belongs to Mrs. Isobel Stanford. The only evidence of mineralization observed was on the north side of Granite Creek. There is much intrusive material in this vicinity. The sediments strike N. 25° W. and dip 30° SW., but this attitude is not certain for any but a very small area. The mineralization was weak, and garnet and vein quartz are present in addition to the ordinary epidote and sulphide replacement deposits. Chalcopyrite is the most abundant sulphide at this outcrop.

MACKENZIE

No evidence of mineralization was observed on the Mackenzie claim of Hugh Matheson. The entire claim is on the slope that borders the north and northwest base of Mount Eielson. A little pyrite and chalcopyrite were observed in the creek bank in altered sediments in intimate association with fine-grained granodiorite and porphyritic granodiorite, in the area between the northeast line of the Isobel and the south line of the Mackenzie.

MARY

The Mary claim also belongs to Hugh Matheson. It lies east of the Mackenzie and is developed by two small prospect pits. The only showings are along the small tributary to the Thorofare River that enters the river east of Granite Creek. At one pit the strike is N. 75° E. and the dip is about 75° N. The epidotized sediments carry sphalerite, galena, and chalcopyrite. Chip samples of an 8-foot face showed 0.3 ounce of silver to the ton, 0.2 percent of copper, and 2.81 percent of zinc. In the other pit there is considerable copper stain.

HIGHLANDER

The Highlander is one of the claims of Hugh Matheson. It lies east of the Mary. There are few outcrops on the claim, but an excellent section is exposed along the east line of the claim in the cliff along the west side of the Thorofare River, and it is along this cliff that the development work, which consists of a small open cut, has been done.

The section reveals altered and in places unaltered sediments, which in general strike about N. 75° W. and dip 50° N., and many sills of porphyritic granodiorite. A few strike faults with displacements apparently too small to map were also observed here. A bed about 60 feet thick, carrying sulphides throughout, crops out near the middle of the east line. Half of this thickness is richer than the rest, and a chip sample of it assayed 0.01 ounce of gold and 1.50 ounces of silver to the ton, 0.83 percent of copper, 2.89 percent of lead, and 5.57 percent of zinc. The ore is of the usual type. Several more stringers of ore were seen between this locality and the north boundary of the claim, and boulders of high-grade ore appear in the slide rock along the river near the line between the Highlander and the Cleary claim.

CLEARY

The Cleary claim, which lies south of the Highlander, belongs to Ben Cleary. It is developed by one small prospect pit along the river near the center of the east line of the claim. The geology is typical of the district. The sediments strike about N. 70° E. and dip 40° N. The mineralized bed is about 5 feet thick, the richest 2 feet of which assayed 0.01 ounce of gold and 15.3 ounces of silver to the ton, 0.78 percent of copper, 4.22 percent of lead, and 20.16 percent of zinc. There appears to be some faulting at this locality.

HIGHWAY

The discovery post on the Highway claim of Ben Cleary is on the northwest ridge of Bald Mountain, at an elevation of about 4,600 feet. The claim is developed by two small prospect pits. Sphalerite is the only ore mineral that was recognized.

OTHER LOCALITIES

Sulphide minerals were observed at many places in the Mount Eielson district other than the localities just described. In all these places the geology and the mineralization conform to the type ordinarily found in the district. It seems to be generally true that chalcopyrite is more common near the main intrusive than it is a few hundred feet away, where lead and zinc predominate, and also that the chalcopyrite mineralization does not seem to have been so intimately controlled by original bedding as that of the other sulphide minerals.

Other localities where evidence of mineralization was particularly noticed are near the northwest base of Bald Mountain along and above the east side of the Thorofare River, in the roof pendants below the east peak of Mount Eielson and in the area of sediments between these pendants and the piedmont slope to the north, in the sedimentary area southwest of the southwest corner of the Copper Base claim, on the noses between Intermittent and Crystal Creeks and between Crystal and Glacier Creeks, on the west side of Muldrow Glacier along the south side of the valley lying north of the mountain composed principally of Tertiary volcanic rocks, in the sedimentary rocks along the west side of Muldrow Glacier just south of the most northerly small lake, and at several localities west of the mapped area.

SUMMARY AND RECOMMENDATIONS

The ore deposits of the Mount Eielson district have been formed by the selective replacement of thin-bedded limestone and calcareous shale by minerals of the epidote group, pyrite, chalcopyrite, sphalerite, galena, and other minerals. The main ore-bearing zone exhibits a definite relationship to the granodiorite mass of Mount Eielson. A large part of the zone has been described in detail by reference to the unpatented claims that cover most of the better showings.

Very little development work has been done in the district, and as much of the potentially valuable ground lies beneath a cover of postmineral deposits, the most urgent need is for much more systematic prospecting. The present natural exposures and prospect pits indicate a reserve of many hundreds of thousands of tons of zinc and lead bearing material, which, from the indications of the few assays, should carry at least 10 percent total sulphides. Silver would no doubt be recovered from any ore mined at Mount Eielson, but the assays show that the silver content of the ores is in general low and spotted. The silver content does not seem to bear any very definite relation to the lead content, and, although some of the silver undoubtedly occurs in the galena, either in solid solution or as inclusions of definite mineral species, some of it is probably in association wth sphalerite. It is possible that copper would also be recovered, but it would be a very subordinate product.

The mining conditions at Mount Eielson are generally good, especially for a large-scale operation. Most of the ore zone could be developed to a depth of several hundred feet by a tunnel. The rock and ore are massive and would require little timbering. The individual ore bodies are large enough to lend themselves to some caving method of mining. Some of the conditions, however, are not favorable. There is no timber in the district. Sufficient coal could probably be mined a few miles to the north, but it would have to be transported to Mount Eielson in winter over frozen ground unless a road was built. It is possible that Grant Creek could be developed on a small scale for power. The winter season is long and cold, but operations could no doubt be carried on all the year round.

The ore would probably be concentrated in a mill at Mount Eielson. Its mineralogy is simple, and galena, sphalerite, and chalcopyrite could be separated.

Transportation of concentrates would be one of the greatest problems in any mining venture in the district. The concentrates could be trucked during the summer over the park highway to McKinley Park station. Perhaps a cheaper way would be to haul them by tractor in winter, either through the same passes that the road follows but by a shorter route making greater use of stream bars, or by a longer but not so hilly route down Stony Creek to the low country and thence east to Kobe. The cost of this part of the journey would be nearly negligible as compared with the cost of shipment to Seward by the Alaska Railroad according to the present quoted rate of $1.63 per 100 pounds of lead concentrates for a 50,000-pound minimum shipment from McKinley Park station to Seward and $1.22 for corresponding zinc concentrates. From Seward lead concentrates would probably go to Selby, copper to Tacoma, and zinc to Trail, British Columbia, or some more distant smelter equipped to handle such concentrates.

It seems doubtful that a successful mining enterprise could be carried on at Mount Eielson under the existing prices of metals and the adverse transportation conditions. However, the cost factors are many and variable, and as a large ore reserve exists at Mount Eielson it is entirely possible that with changed conditions profitable operations could be instituted there.

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