

## GEOLOGY OF THE KNIK-MATANUSKA DISTRICT

By KENNETH K. LANDES

### INTRODUCTION

*Location and area.*—The area described in this report lies between Knik and Matanuska Rivers in south-central Alaska. These rivers flow westward and converge as they enter Knik Arm, a branch of Cook Inlet. Owing to this convergence the region studied has a triangular outline. It is bounded on the east by a line drawn from Kings Mountain, on the south bank of Matanuska River, to the Knik Glacier. Each leg of the triangle is approximately 25 miles in length, and the area included within it is about 335 square miles. (See pl. 1.)

Most of the region is mountainous, and only the edges are readily accessible. The Alaska Railroad crosses the extreme western apex, and a branch line runs from Matanuska station eastward along the north bank of Matanuska River to Chickaloon. Both rivers are difficult to ford. Cables span the Matanuska at Palmer and at the mouth of Chickaloon River. It is quite possible to line a boat up Knik River from the railroad bridge. A trail leads across the flat from the Palmer cable crossing to the north bank of the Knik and up that river to Metal Creek. Save for a few ranchers close by the Palmer cable crossing and a placer miner here and there on Metal Creek the region is uninhabited.

*Earlier surveys and present investigation.*—The area covered by the present investigation had not been geologically explored. Some earlier surveys in regions to the south, north, and northeast crossed the border of the area for short distances. In 1906 Paige and Knopf<sup>1</sup> mapped the geology of portions of the Knik and Matanuska Valleys on a reconnaissance scale. Topographers in the same party mapped as much of the drainage into the two rivers as was visible from the valley floor.

In 1910 Martin and Katz<sup>2</sup> mapped in detail the geology of the lower Matanuska Valley. Their investigation was almost entirely

<sup>1</sup> Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, 1907.

<sup>2</sup> Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, 1912.

confined to the north side of the river. The preceding year R. H. Sargent, topographer, prepared a base map which covered that area and also part of the area south of the river.

Capps<sup>3</sup> in 1915 mapped the geology of the region south of Knik River.

In connection with a geologic survey of the upper Matanuska Valley in 1924, Capps,<sup>4</sup> assisted by the writer, mapped on a reconnaissance scale the geology of the south flank of the Matanuska Valley from Gravel Creek as far west as Kings Mountain.

The present investigation was carried on during the summer of 1925 by the writer, accompanied by Alex Liska, of Anchorage. Knik River was ascended by boat, and the Matanuska Valley was reached by the Chickaloon branch of the Alaska Railroad. Matanuska River was crossed by boat and at Palmer by cable. Camps were made on the banks of the two rivers at the mouths of the larger tributaries. The extreme ruggedness of the region necessitated back packing up the tributaries, where side camps were established.

The base map used for plotting the areal geology is a portion of the topographic map of the region traversed by the Alaska Railroad. This particular part was a compilation derived largely from the topographic surveys previously mentioned. It was incomplete, as the work was done near tide level, and much of the topography toward the interior of the area was hidden from view, so that the center of the area was entirely unmapped. A few topographic corrections and additions were made in the field. Owing to the character of the base map and the difficulties of travel in the region, the field work was necessarily of a reconnaissance nature.

At the end of the season a hasty trip was made along the railroad from Knik River to Eklutna and south of Anchorage between Potter and Indian in order to make a further study of the greenstone series. The results of this investigation are included in the present report.

## PHYSIOGRAPHY

### CHIEF FEATURES

The two chief physiographic features of this district are the mountains and the flats. Between them on the south flank of the Matanuska Valley lies a high terrace.

The mountains form a spur of the Chugach Range. They are strongly dissected, and the peaks along the divide range in elevation from 6,000 feet toward the west to more than 8,000 feet at the east-

<sup>3</sup> Capps, S. R., The Turnagain-Knik region, Alaska: U. S. Geol. Survey Bull. 642, pp. 147-194, 1916.

<sup>4</sup> Capps, S. R., Geology of the upper Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 791, 1927.

ern boundary. They continue to increase in elevation east of the area studied and probably reach more than 14,000 feet along the divide between Cook Inlet and Prince William Sound. The higher peaks are snow-covered and where tapped by the headwaters of the larger streams contain small glaciers.

Both Matanuska and Knik Rivers follow braided courses over extensive sand and gravel flood plains. In times of high water these flats are inundated. The flats range in width from  $2\frac{1}{2}$  miles on the Knik down to half a mile and less on the Matanuska. In several places Matanuska River passes through canyons where the velocity of the water has prevented the deposition of any flood-plain material whatever.

Alongside and about 10 feet above these present-day flood plains there is a flat extending from the western extremity of the mountain range to the point of junction of the two rivers. This is a level surface save for a row of sand dunes bordering Knik River and a few isolated hills of bedrock rising above the plain. This low terrace, like the modern flood plains, is composed of river-deposited sand and gravel. At one time Matanuska and Knik Rivers flowed at a higher elevation. Serious overloading, undoubtedly caused by the vast amount of material supplied to the streams by the many valley glaciers then existent, necessitated much deposition. At the confluence of the two rivers an extensive flood plain resulted. The present buttes rising above the flat were islands of resistant bedrock. With a further recession of the glaciers less material was supplied to the rivers, and they started to erode again. Each stream deepened its channel, leaving a part of the old flood plain as a low terrace. This valley deepening continued until the gradient was so reduced that the rivers could no longer cope with the load supplied by tributaries and glaciers and were forced once again to build up a flood plain.

The terrace on the south flank of the Matanuska Valley is best shown in the vicinity of the Wolverine Lakes, where it stands about 200 feet above the river. This height decreases upstream, and the terrace finally blends with the valley floor at the foot of the Matanuska Glacier. It is discontinuous, being interrupted at some places by tributary stream valleys and at others pinching out altogether where the main valley narrows. Its surface is rough in comparison with that of the lower terrace, small ridges, hills, and depressions being common features. Bedrock is exposed in the hills and along the stream valleys. It is covered in most places, however, by a veneer of unconsolidated soil, sand, and gravel. These deposits are thick enough in places to conceal the bedrock completely.

The surface of this terrace represents the valley floor left by the receding glacier. In its earlier advance the glacier carved out a

U-shaped valley. The floor of this valley was somewhat irregular, owing to the difference in hardness of the several kinds of bedrock encountered by the glacier. During its recession the glacier and the streams running off from it deposited drift irregularly over the valley floor. The resulting comparatively flat surface, created by the glacier through a combination of erosion and deposition, was made into a terrace by the postglacial activity of Matanuska River. Since the glacier receded this powerful stream has deepened its channel 200 feet below the bottom of the U-shaped valley at its western extremity. The amount of postglacial deepening decreases upstream, and at the foot of the glacier there is none.

Except where swampy the two terraces are densely forested. The trees decrease in number toward the mountains and disappear altogether at the timber line, about 2,000 feet above sea level. Game, consisting of mountain sheep, brown and black bear, ptarmigan, and grouse, is plentiful in the mountains. Ducks are common on the lakes and swamps of the flats. Trout are rare, owing to the fact that most of the streams head in glaciers and are therefore muddy.

#### DRAINAGE

All the surface run-off in the Knik-Matanuska region finds its way into one or the other of the two rivers. The major tributaries of the Matanuska are Carpenter and Wolverine Creeks; those of the Knik are Metal, Friday, and Jim Creeks. Owing to their large size and great velocity none of these streams can be forded on foot except where they distribute themselves on their fans or near their headwaters.

The major tributary valleys likewise contained glaciers in the past and with the exception of Jim Creek still contain small remnants of these glaciers at their heads. The tributary glaciers, however, were much smaller than the main valley glaciers and were therefore unable to erode their valleys to anywhere near the depth reached by the Knik and Matanuska Glaciers. When these glaciers receded the tributary valleys were left hanging several hundred feet up on the side of the main valley. Postglacial erosion by the tributary streams has resulted in the formation of terraces and canyons. Many of the canyons are very deep adjacent to the main valley, and most of them are impassable.

Drainage from the southwest flank of the mountain spur is conducted across the low terrace flats by a number of sloughs that empty into Knik River. The flats here are thickly covered with swamps and shallow lakes. The hanging valley of Jim Creek or the mountains near by may be reached only by boat up lower Jim Creek and tributary sloughs. The poor drainage on the flats in this vicinity

is due to a belt of sand dunes parallel and adjacent to the north bank of the Knik, which has dammed up the normal drainage. Many of these dunes are over 60 feet in height. They are caused by strong down-valley winds, which pick up sand from the river flood plain and pile it up in dunes along the river bends. This wind results from the atmospheric movements caused by the presence of cool air overlying the glacier and hot air in the lower valley, a condition which exists on almost every midsummer afternoon. Sandstorms prevail while this difference in temperature is in effect.

The Jim Creek slough has been able to keep its channel open through the dune belt and into Knik River. This slough and those tributary to it meander greatly and have in times past flooded their banks, building up natural levees as they did so. The presence of these dikelike banks several feet high separating the sloughs from the swamps prevents direct drainage from one into the other and thus furnishes an added reason for the swampy condition between Knik River and the mountain front.

## DESCRIPTIVE GEOLOGY

### PRINCIPAL FEATURES

Rocks in great variety crop out in the region between Knik and Matanuska Rivers. (See pl. 1.) Metamorphic rocks predominate over unmetamorphosed sediments, and igneous rocks are intermediate in abundance. The general trend of the formations is southwest, parallel to Matanuska River and to the axis of the Chugach Range. The formations decrease in age from south to north.

The metamorphic slate and graywacke in the upper Knik Valley are assumed to be the oldest rocks in the region. Immediately to the northeast of them lies the greenstone formation, consisting of an enormous series of chloritized and epidotized lavas and associated rocks. Into this formation is intruded a small batholith of diorite, the long axis of which likewise runs southwest. The greenstone and diorite form the backbone of the mountain range in the area under discussion. On the south flank of the Matanuska Valley next above the greenstone lies the Cretaceous sedimentary series. Tertiary sediments crop out in a band in the terrace east of Wolverine Creek and in the neighborhood of Kings Mountain.

Kings Mountain is an intrusive plug of rhyolite. Acidic dikes radiate from this mountain into the sedimentary series. Other acidic dikes, probably offshoots from the diorite, penetrate the greenstone. Basic dikes cut the Cretaceous and Tertiary rocks between Carpenter and Wolverine Creeks.

Glacial gravel is prominent on the high terrace and in several of the tributary valleys where the smaller glaciers deposited lateral and

recessional moraines. More recent alluvium makes up the low terrace west of the mountain range, and considerable sand and gravel has been deposited by Matanuska and Knik Rivers on their present-day flood plains.

As no fossils were found in the metamorphic rocks their exact age is a matter of considerable doubt. The unmetamorphosed sedimentary rocks are continuations of the same series from the north side of Matanuska River, where Martin and Katz<sup>5</sup> worked out the age relations in detail.

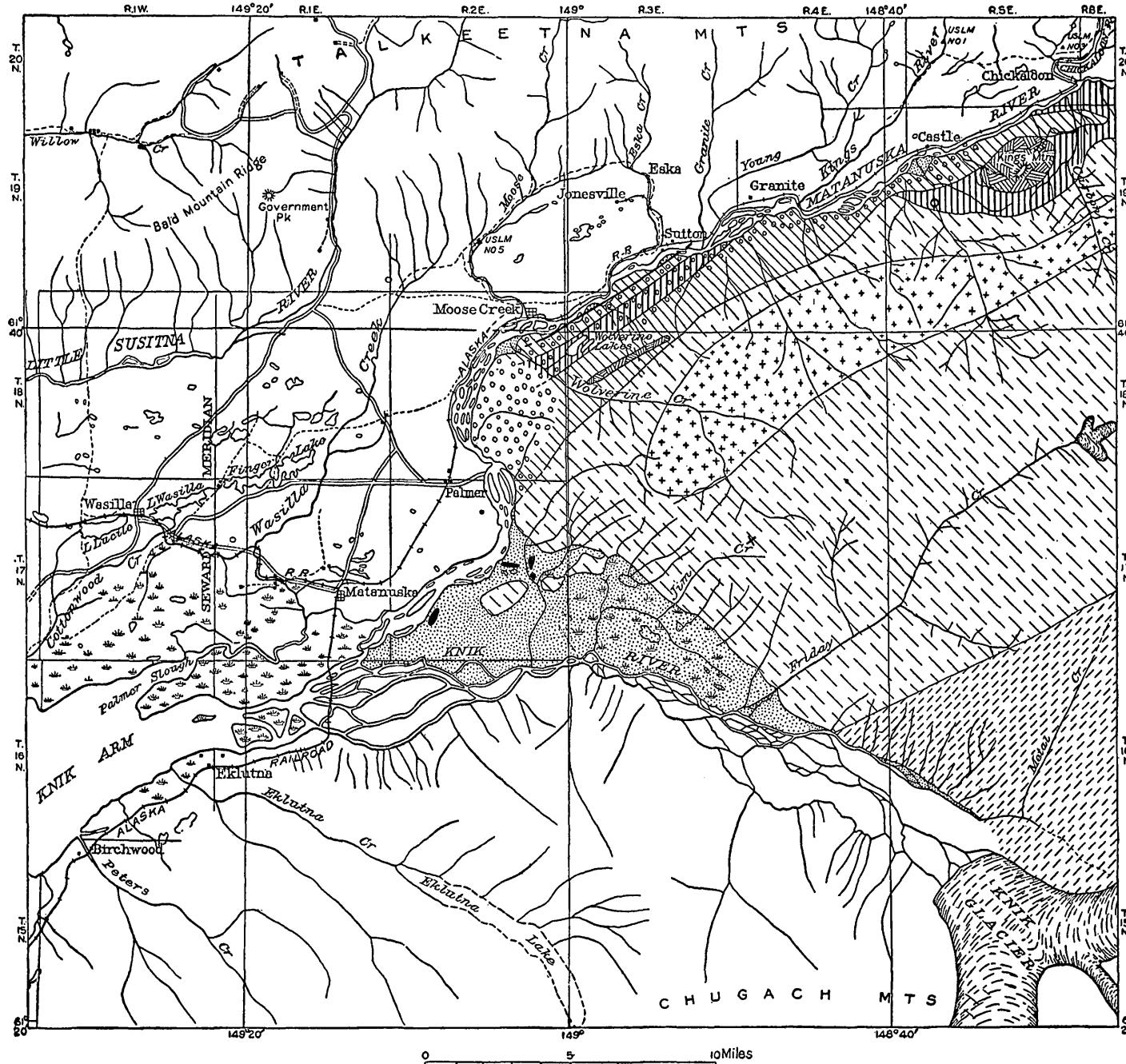
#### SLATE AND GRAYWACKE

*Distribution.*—Interbedded slate and graywacke crop out on the north flank of the valley of Knik River east of Wolf Point, a prominent rock cliff rising from the water's edge about 3 miles above the mouth of Friday Creek. The contact with the greenstone at this point bears N. 60° E., a trend which carries it diagonally across the mountains forming the north wall of the valley. Thus the area of exposure of the metamorphic series increases greatly toward the east. Just how far east of the area studied it extends is not known. The morainal débris about the foot of the Knik Glacier and on the ice itself is composed exclusively of the same material. It would appear that the slate and graywacke extended at least as far as the divide separating the Knik River drainage from that flowing into Prince William Sound. The presence of this same series was also noted south of Anchorage, in the vicinity of Indian.

*Character.*—The commoner of the two varieties of rock is the graywacke. It ranges in color from gray to black and usually cleaves parallel to the bedding. A tendency toward schistosity was noted in some specimens. The grain is fine enough to give the rock a dense compact appearance but without that excessive fineness necessary to the production of a slaty cleavage. At P. R. Strong's camp, at Indian, the graywacke is cut by minute quartz veins. Here it has suffered considerable faulting, and the gouge along the fault planes contains disseminated specks of chalcopyrite.

In the thin section this rock is seen to consist of minerals and rock fragments of a size too large for it to be called a slate or argillite. Because of the size and the diversity of material contained the rock is known as graywacke. The mineral grains seen under the microscope are largely quartz and feldspar, present in widely varying proportions. Mica is another common constituent. The rock fragments were derived from the breaking up of a fine-grained rock, perhaps a lava. Organic material is usually present. Great irregularity of size and shape of the grains is a characteristic feature.

<sup>5</sup> Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, 1912.



**EXPLANATION**

**SEDIMENTARY ROCKS**

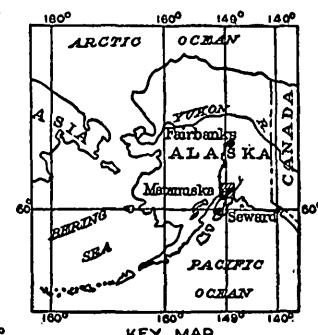
- Recent alluvium
- Glacial drift
- Chickloon formation (sandstone, shale, conglomerate)
- Sandstone, shale, conglomerate
- Greenstone
- Slate, greywacke

**IGNEOUS ROCKS**

- Diorite, rhyolite, gabbro
- Diorite

**Other symbols**

- Fault
- × Copper prospect
- Coal prospect



GEOLOGIC MAP OF THE KNIK-MATANUSKA DISTRICT

60570°—27. (Face p. 56.)

The graywacke belonging to this series shows definite metamorphism, which distinguishes it from similar rocks of later age. In many specimens the larger mineral and rock grains form augen about which the mica plates bend. Where the grain is more uniform metamorphism has produced a less noticeable parallelism of minerals. The quartz grains invariably show strain effects. Later alteration has kaolinized the feldspars. Some of the biotite has been converted to chlorite. A mass or vein of calcite here and there completes the list of secondary products.

The slates are dark greenish-gray. They are rarely conformable to the overlying and underlying beds of graywacke. The stresses and strains which the rocks of the region have had to withstand in times past found many of the slate layers incompetent. These layers are consequently crumpled, although no such results were noted in the graywacke. Some slipping took place between the layers, producing smooth and shiny surfaces. The green color is undoubtedly due to secondary chlorite formed during the crumpling.

Many thin quartz veins are found in the slate. Most of them are interbedded, although a few cut across the bedding at a low angle. Where the slate is crumpled the quartz veins follow its twists and turns. A great many such thin white veins, all parallel to one another and highly contorted, give the rock a gneissic appearance when worn smooth.

*Structure.*—No rock older than the slate and graywacke has been found in this area. The source of supply of the clastic material that makes up the series remains in doubt, along with its thickness and its structural relations to the underlying rock. At the contact with the greenstone at Wolf Point the slate and graywacke strike N. 60° E. and dip 30° N. Only minor fluctuations from this structure reading were noted above Wolf Point and in the canyon of Metal Creek.

*Age and correlation.*—Owing to the dearth of fossils a definite age can not be assigned to this series. It continues south of Knik River into the region studied by Capps,<sup>6</sup> who indicates it on the map as "Mesozoic, possibly some Paleozoic." Mendenhall<sup>7</sup> in 1898 named the slate and graywacke the Sunrise "series" (now called Sunrise group). Similar rocks appearing in the Prince William Sound region have been divided into the Valdez and Orca groups. Positive age identification of this extensive group of rocks must await the discovery of diagnostic fossils.

<sup>6</sup> Capps, S. R., The Turnagain-Knik region, Alaska: U. S. Geol. Survey Bull. 642, pp. 147-194, 1916.

<sup>7</sup> Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 305-307, 1900.

### GREENSTONE

*Distribution.*—The rocks in the greenstone formation are mainly of volcanic origin, although interbedded sediments appear in a few localities. The igneous rocks occur both in flows and sills and as tuffs, breccias, and agglomerates. They are mainly intermediate in chemical composition, although in places rhyolites predominate. The entire volcanic series has been subjected to regional metamorphism. The ferromagnesian minerals have been altered to chlorite and, with feldspar, to epidote. These two secondary minerals are green, and their presence in abundance in the rocks gives the formation its name. The rhyolites present here and there in the volcanic series are lean in ferromagnesian minerals and so remained unaffected by this alteration and have kept their original white or gray color.

In the region between Knik and Matanuska Rivers the greenstone is by far the most prominent formation. It crops out in a belt about 14 miles wide, which trends southwest throughout the area. Within this belt lies the long, narrow outcrop of the diorite batholith. The two formations together make up most of the mountainous part of the region. To the west a few greenstone buttes rise abruptly above the gravel flats. The same formation crops out along the railroad track south of Knik River between the bridge and Eklutna and between Potter and Indian.

*Character.*—The intermediate volcanic rocks that constitute the major part of the greenstone formation exhibit wide variations in texture. On the south flank of the Matanuska Valley, between the Cretaceous sediments and the diorite, the rock is a tuff, consisting of small green angular fragments. South of the diorite batholith and in the valley of the Knik the rocks are severely altered, having a green or yellowish-green color and a much more homogeneous texture. Some of these rocks are greasy in luster; others are dull. Thin ramifying calcite veins are practically everywhere present, but secondary quartz is uncommon, except in the vicinity of sulphide mineral veins. Adjacent to deposits of chalcopyrite near the headwaters of Jim Creek and of sphalerite and galena on the scarp between Eklutna and Peters Creeks the greenstone country rock is extensively silicified.

South of Anchorage, between Potter and Indian, slate inclusions in a green matrix are exceedingly common. They range from a very small size to 6 inches or more in length and are so abundant in places as to constitute 75 per cent of the rock. Quartz veins under an inch in thickness traverse these agglomerates irregularly.

Microscopic examination shows that both the fragmental and the massive rocks have a similar mineral composition, and they are therefore grouped together in one formation. When the volcanism was

explosive in character the clastic rocks were produced. Less violent eruption resulted in the extrusion of lavas. The minerals vary widely in size of grain, owing to differences in rates of cooling. At two widely separated localities the rock is large grained, like a granite. Here the cooling must have been slow, as in a large feeder dike or other intrusive body, where the magma was well insulated from the surface. The fragments in the tuff on the south flank of the Matanuska Valley and many of those in the agglomerate exposed between Potter and Indian were derived from a fine-grained lava rock containing a few small phenocrysts in a cryptocrystalline groundmass. Most of the greenstones represent an intermediate phase between the large-grained deep-seated rocks and the fine-grained lavas. Here the texture is porphyritic, but the phenocrysts are numerous and large, and the minerals in the matrix itself are by no means minute. These rocks crystallized either in thick flows or in sills between the flows, where cooling was slower than at the surface.

The primary mineral composition is fairly constant despite the textural variations. Feldspar is by far the commonest mineral. It is usually albite, but microcline and orthoclase appear locally in minor amounts. Primary quartz is less common, rarely appearing in the porphyritic rocks as phenocrysts and usually forming but a small part of the groundmass. The ferromagnesian minerals have almost everywhere been completely altered. A few remnants of biotite and hornblende attest to the presence of these minerals, but in amounts subordinate to the feldspar. Magnetite was the only other primary mineral recognized.

In composition and texture these rocks are soda trachyte porphyries. They verge with increased quartz on dacite porphyry and with increased size of grain on syenite porphyry.

From 30 to 90 per cent of the original volcanic rock has undergone alteration. The commonest secondary minerals are epidote and chlorite; hence the green color of the altered rock. Both of these minerals were derived from ferromagnesian minerals. Considerable epidote was also derived from feldspar through a reaction between that mineral and biotite or hornblende.<sup>8</sup>

Other secondary products, present in varying abundance, are calcite, quartz, and kaolin. Calcite veins were seen in almost every thin section studied, and many of them are thick enough to be visible in the hand specimen. Much of the albite has been partly replaced by calcite. The lime for both the veins and the replacement deposits was probably obtained locally from feldspar and ferromagnesian

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<sup>8</sup> Clarke, F. W., The data of geochemistry, 5th ed.: U. S. Geol. Survey Bull. 770, p. 609, 1924.

minerals. Secondary quartz appears with the vein calcite and has also replaced a large part of the country rock adjacent to the sulphide veins previously mentioned. Ground-water activity has caused a partial alteration of feldspar into kaolin.

The origin of the greenstone involves several stages. In the first place the lava was blown and poured out over the surface of the land, eventually accumulating to considerable depth. Later this mass of igneous material was subjected to regional metamorphism. Hot waters circulated through the lava and tuff, changing biotite to chlorite, feldspar to epidote, etc. These changes took place without the importation of new material from outside the greenstone. Metamorphism was not accompanied by severe pressure, otherwise the shale and limestone within the greenstone series would have been altered. Here and there ascending metal-bearing solutions introduced silica and calcite into the surrounding rock. Calcite, with some quartz, was also deposited in veins and replacement bodies by carbonated waters that were present during the metamorphism and by ground waters that have been active since that time.

Interbedded with the trachytic rocks are a few layers of rhyolite. They are usually unimportant quantitatively, but on the scarp facing Knik Arm between Eklutna and Peters Creeks they reach considerable thickness. The rhyolite is white or light gray and contains quartz and orthoclase phenocrysts. The thin section shows that these minerals constitute most of the groundmass also. The only other mineral of importance present is muscovite. Ferromagnesian minerals are lacking. In texture the rhyolite ranges between a fine and a coarse porphyritic phase. Alteration has been largely confined to kaolinization of the feldspar. Small amounts of vein calcite may also be present. Silicification is dominant near the lead-zinc veins on the scarp above Knik Arm. The rhyolite was undoubtedly extruded at the same time as the trachyte and has undergone the same subsequent history, but owing to the absence of ferromagnesian minerals no chloritization or epidotization took place. The acidic rocks have therefore retained their light color.

The igneous activity that produced the trachyte and rhyolite was interrupted at times by periods of quiescence and submergence, as shown by the presence of sedimentary rocks here and there within the greenstone formation. Among these sediments shale predominates. It covers a considerable area between the canyon mouth and the forks of Friday Creek. It is dark gray and in places verges upon slate but is nowhere truly slaty. Near the mouth of Friday Creek knots of greenstone as much as 4 inches across occur within the slaty shale. Perhaps these were volcanic bombs that were thrown into the sea, joining on the sea floor the much finer material deposited by inflowing rivers.

In a terrace at the mouth of Friday Creek and between Potter and Rainbow graywacke beds were found. In the Friday Creek locality the rock consists of subangular and generally small grains of feldspar, quartz, and rock fragments. The feldspar grains were severely kaolinized, and the rock itself was chloritized to some degree. The graywacke occurring west of Rainbow is interbedded with greenstone agglomerate and was derived from that rock. It is greenish gray to black and contains partly rounded grains of greenstone material.

Conglomerates are rare in the greenstone formation. Toward the headwaters of Carpenter Creek a massive conglomerate containing very jagged and irregular fragments as much as 3 feet across is exposed. A 1-foot bed was noted on Friday Creek interbedded with shale.

In the vicinity of Potter there is a limestone bed which likewise lies within the greenstone formation. This limestone is a gray, finely crystalline rock, irregularly crossed by narrow white veins. Under the microscope the veins are seen to consist of large calcite crystals, and the gray groundmass contains very fine crystals of the same mineral. The limestone grades on one wall into a massive rock of great hardness, composed of fine-grained white quartz crystals stained yellow on the surface by limonite. In thin section this rock is seen to consist of very fine interlocking quartz crystals. Veins containing much larger quartz crystals cross the section, and still later veins of calcite cut both matrix and quartz veins.

The calcite and quartz are probably travertine deposits. Solutions containing at one stage calcium carbonate and at another silica emerged through hot springs to the surface of the ground and there evaporated, depositing these minerals as they did so. Hot springs are common in regions of volcanic activity. Later ground-water activity produced the veins noted in the two deposits.

*Structure.*—The greenstone formation overlies the slate and graywacke metamorphic series. At Wolf Point the slate and graywacke dip under the greenstone at an angle of 30°. The strike is N. 60° E. Reliable structure readings on the greenstone itself are impossible, and the shales found here and there within the formation must be utilized for that purpose. The nearest shale to the slate and graywacke contact lies in the valley of Friday Creek. Close by the forks of this creek the sediments strike N. 70° E. and dip 40° N., but along the west side of the valley below the forks they dip at low angles. Evidently the greenstone formation is folded here into an asymmetrical syncline. The eastern limb is steep and is roughly conformable to the underlying metamorphic series. The western limb is gentle. The presence of the shale along the axis of the syncline accounts for the large area of its outcrop.

On the north side of the range, between the diorite batholith and the Cretaceous sediments, the greenstone dips northwest and strikes northeast. Variable dips given by shales found between that locality and Friday Creek indicate the presence of several fluctuations of structure. Evidently the greenstone formation repeats itself, in part at least, between its contacts, and therefore no measurement of its thickness can be made.

Because of the generally massive structure of the rock, faults are difficult to recognize. The only faults of importance noted are on Carpenter Creek. A short distance south of the contact between greenstone and Tertiary rocks a 100-foot bed of conglomerate followed by several hundred feet of shale crosses the creek. These sediments dip fairly steeply to the south, whereas the adjoining greenstone supposedly dips to the north. Probably a pair of strike faults allows the repetition of Tertiary sediments at this point.

*Age and correlation.*—No fossils were found by the writer within the greenstone formation. From its position it is evidently later than the metamorphic rocks and pre-Cretaceous. Martin and Katz<sup>9</sup> mapped this series east of King's Mountain and called it Lower Jurassic. Their evidence was based on fossils collected from similar rocks exposed elsewhere in the Matanuska Valley. The greenstone formation also crosses Knik River to the south, extending into the territory mapped by Capps,<sup>10</sup> who refers to Jurassic or possibly Cretaceous fossils found in the underlying slate and graywacke and concludes that the greenstone is Mesozoic. Heretofore the greenstone of Knik River and the volcanic rocks of the upper Matanuska Valley have been considered separate series, but the field work of the summer of 1925, coupled with microscopic examination of the rocks involved, leads to the conclusion that they belong in the same formation. In that case the age is probably early Jurassic. The fossils of questionable age occurring in the underlying slate and graywacke in the Turnagain-Knik district must belong to even earlier Jurassic time.

#### CRETACEOUS ROCKS

*Distribution.*—The Cretaceous sedimentary rocks appearing in the Knik-Matanuska region consist of sandstone, shale, and conglomerate. They crop out in a belt south of and parallel to Matanuska River, underlying most of the high terrace. In the vicinity of the Wolverine Lakes Cretaceous rock laps up on the mountain range itself, owing to the presence there of a hard basal conglomerate. Farther east, where this conglomerate is lacking, the line of

<sup>9</sup> Martin, G. C., and Katz, F. J., op. cit., pp. 29-32.

<sup>10</sup> Capps, S. R., The Turnagain-Knik region, Alaska: U. S. Geol. Survey Bull. 642, p. 164, 1916.

demarkation between plateau and scarp likewise marks the contact between sediments and volcanic rocks.

*Character.*—The Cretaceous sandstones vary considerably in appearance but not in composition. In color they may be either gray or green, but the green is more common. Some are fine grained and very dense; others are medium grained. They may be so massive as to conceal the bedding. In places the sandstone is sufficiently hard to form scarps that rise above the terrace surface. Microscopic examination shows that not over 15 per cent of the grains are quartz. The rest are mainly feldspar and rock fragments. They are exceedingly angular and evidently traveled but a short distance. Chlorite is common, both in the cement and replacing the grains. Calcite and kaolin are other abundant secondary minerals. The rock fragments are very suggestive of the greenstone in appearance. In all likelihood when these sediments were being deposited greenstone near by was being eroded, and most of the clastic material was derived from that source.

The shale members are thicker and more abundant than the sandstones but are less prominent topographically owing to their inferior hardness. They are black and on exposure break into small, jagged fragments.

Conglomerate is rare save on the scarp south of Wolverine Lakes, where it reaches considerable thickness. The pebbles in this conglomerate are subangular to almost spherical. They range in size from 2 millimeters to 2 centimeters and were derived from a fine-grained greenish metamorphic rock, probably the greenstone. Limonite forms the cement and gives the entire rock a brownish-yellow color.

*Structure.*—The sedimentary rocks form an asymmetrical syncline whose axis approximately parallels the mountain range. The conglomerate adjacent to the greenstone contact dips steeply to the north, but the sandstone and shale on the south bank of the Matanuska dip gently to the south. No exposure of the actual contact between greenstone and sediments was found, but it would appear from the position of the Cretaceous rocks near the contact that the two formations are roughly conformable.

One large fault wholly within the Cretaceous was noted. The canyon of Matanuska River east of Moose Creek marks the course of this fault for a little over 2 miles. On the north bank of the river the sediments dip steeply to the north; on the south bank they have a mild southerly dip. At the upper end of the canyon the river bends sharply to the north, but the fault, still marked by a conspicuous depression, continues eastward and is rejoined by the river a short distance below Sutton. From that point eastward and

from the lower end of the canyon westward the fault disappears under a mantle of drift and alluvium.

*Age and correlation.*—The Cretaceous rocks in the region south of the Matanuska are continuations of much more extensive exposures of the same sediments on the north side of the river. Martin and Katz<sup>11</sup> have worked out the geology of this region in detail and from definite fossil evidence have concluded that these rocks are of Upper Cretaceous age.

#### TERTIARY ROCKS

*Distribution.*—The Tertiary sedimentary rocks in the region between Knik and Matanuska Rivers lie in two small patches on the south flank of the Matanuska Valley. One of these is the westward extension of the Tertiary rocks of Coal Creek. These rocks cross from Carbon Creek to Carpenter Creek in a belt between Kings Mountain and the main range. Their lesser resistance has resulted in the presence of a low divide between the two creeks which isolates Kings Mountain from the mountains to the south. But this patch of Tertiary rocks pinches out between greenstone and Cretaceous rocks within a short distance beyond Carpenter Creek.

The other Tertiary sedimentary outcrop is long and narrow. It projects across from the north side of Matanuska River near Granite Creek, extends southwestward, and disappears under a thick veneer of glacial gravel west of Wolverine Creek.

*Character.*—The Tertiary sedimentary rocks that crop out in this area belong to the Chickaloon formation and include sandstone, shale, and a small amount of conglomerate. Coal is present at several horizons within the series. The distinction between the Chickaloon formation and the underlying Cretaceous rocks in places may be very difficult to make out. Where the Chickaloon occurs in an alternating series of sandstone and shale beds 1 to 2 feet thick there is no difficulty, for the Cretaceous strata, so far as known, do not possess exactly that habit. Where more massive strata occur and fossil evidence is lacking it is necessary to fall back on a less definite set of criteria.<sup>12</sup> The presence of coal is considered to be proof of Tertiary age.

The usual sandstone of the Chickaloon is a loosely cemented "salt and pepper" aggregate of partly decomposed and angular grains. It may be green and fine grained, however, and no megascopic difference can be noted between such rock and the Cretaceous sandstones. Under the microscope the Tertiary sandstone, like the Cretaceous, is seen to be deficient in quartz and high in rock fragments. But the presence of many fairly fresh feldspar grains, besides the usual

<sup>11</sup> Martin, G. C., and Katz, F. J., op. cit., pp. 34-39.

<sup>12</sup> *Idem*, p. 36.

greenstone fragments, leads to the belief that a granitic body was likewise being eroded when the Tertiary sediments were deposited. This body, probably one of the several diorite batholiths known to exist in the Matanuska region, had not yet been uncovered in Cretaceous time.

The shales of the Chickaloon formation are generally soft and gray, but where much organic material is present they are black. Very thin coaly streaks are common, and thicker coal beds appear in places. These are described in the section on economic geology.

Conglomerate is exposed in several places along lower Wolverine Creek. One bed is 15 feet thick. It forms a low ridge and a constriction in the stream channel, owing to its superior hardness. Other smaller beds were noted. The pebbles are generally small and subangular.

*Structure.*—The Tertiary tract in the vicinity of lower Carpenter Creek was probably faulted into its present position. The dips in that area are northward and would carry the rocks under the Cretaceous unless an abrupt reversal took place. Cretaceous rocks are entirely missing between the Tertiary and the greenstone to the south, but their absence may be due to erosion.

The second Tertiary tract owes its presence to the local rock structure. The sedimentary rocks are here folded into a syncline along the axis of which the Tertiary beds crop out. These beds dip rather steeply and may even be overturned for a short distance on the south flank of the syncline.

*Age and correlation.*—The Tertiary sedimentary rocks south of Matanuska River continue across to the north side of the river, where they crop out much more extensively. They belong to the Chickaloon formation, within which are found the Matanuska Valley coals. Martin and Katz<sup>18</sup> describe the flora and fauna of this formation and conclude that it is probably Eocene.

## IGNEOUS ROCKS

### DIORITE

A belt of diorite from  $1\frac{1}{4}$  to  $3\frac{1}{2}$  miles wide appears wholly within the greenstone, on the south flank of the Matanuska Valley. It trends southwest and forms many of the mountains on the north side of the range. Its contact with the greenstone usually passes through a notch where it crosses a divide between creeks.

The diorite body is batholithic in form, as is shown by the irregularity and nonconformity of its contact with the greenstone, by the downward divergence of its walls, and by the presence of dikes in

<sup>18</sup> Martin, G. C., and Katz, F. J., op. cit., pp. 49-52.

the greenstone that are believed to be offsprings of the diorite mass. A few xenoliths of greenstone in diorite were also found.

In the hand specimen the diorite of Matanuska Valley is characterized by a granitic texture, with half the grains white plagioclase and the other half greenish-black hornblende. Adjacent to the greenstone contact on upper Carpenter Creek the diorite is gneissoid, probably as a result of slight movement while the magma was crystallizing.

In thin section the diorite is seen to consist almost exclusively of soda feldspar and hornblende, in about equal proportions. Quartz is present in maximum proportions of 5 per cent, except in the gneissic phase, where it is more abundant. Biotite, apatite, and pyrite are very minor accessories. The feldspar grains are only slightly kaolinized, a condition which accounts for the fresh appearance of the rock as a whole. Chlorite ranges from a trace in the majority of sections to several per cent in the gneiss, but it nowhere approaches the proportion present in the greenstone, although the diorite has a much greater ferromagnesian content than the original volcanic rocks of that series. Obviously chloritization and epidotization preceded batholithic intrusion, or the diorite would also have succumbed to this alteration.

In age the diorite is later than the greenstone and therefore probably post-Jurassic. Diorite porphyry sills intruded into Cretaceous and Tertiary sediments in the Matanuska Valley are described by Martin and Katz.<sup>14</sup> If these are offshoots of the batholith, the diorite must be likewise post-Chickaloon.

#### RHYOLITE OF KINGS MOUNTAIN

Kings Mountain is a prominent peak lying just south of Matanuska River between Carpenter and Carbon Creeks. It is offset from the main range and owes its isolation to its girdle of less resistant Cretaceous and Tertiary sedimentary rocks. The rock forming the core of the mountain is rhyolite. It filled the neck of an old volcano whose outlines have been completely destroyed by erosion. But the igneous plug remains and assumes a mountainous form owing to its superior hardness.

Several periods of activity marked the life of this volcano, as is attested by the presence of more than one type of rhyolite about the flanks of Kings Mountain. The mountain itself, although prevailingly light colored, exhibits various tints of yellow and red where an abundance of iron is present.

The rhyolite most typical of Kings Mountain is slightly porphyritic, with phenocrysts of quartz and orthoclase. The groundmass

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<sup>14</sup> Martin, G. C., and Katz, F. J., op. cit., pp. 56-61.

is dark gray and very dense, but microscopic examination proves it to be entirely holocrystalline. Accessory minerals, visible only in thin section, are biotite, muscovite, and apatite. They are all very subordinate to the quartz and orthoclase. Later calcite is fairly common. A small amount of black chalcedony was present in one specimen. Limonite may or may not be present.

A very much darker rock with quartz and calcitized orthoclase phenocrysts was found well up on the side of Kings Mountain, in contact with the rhyolite just described. It proved to be also a rhyolite with the same mineral composition except for the presence of small black opaque grains. These are nonmagnetic and have a hexagonal outline suggestive of ilmenite. They constitute about 20 per cent of the rock and undoubtedly are the cause of its dark color.

A large number of rhyolite dikes radiate from Kings Mountain into the sedimentary rocks on the west. Owing to their superior hardness they form narrow ridges rising above the general level of the region. They represent offshoots of the main igneous body into the country rock.

The rhyolite in the dikes differs considerably in appearance from the rhyolites of Kings Mountain. It is white and dense and covered with little specks of red iron oxide. Study of thin sections shows the rock to be fine-grained but holocrystalline, with quartz and orthoclase the principal minerals and muscovite and hematite secondary. The presence of hematite in rhyolites is unusual.

As the rhyolite plug and associated dikes are intruded into Cretaceous and Chickaloon (probably Eocene) sediments they must be subsequent to these sediments in age. They probably belong to a late Tertiary epoch.

#### ACIDIC DIKES

Innumerable dikes of alaskite cut the greenstone in the neighborhood of the diorite batholith, with which they are undoubtedly genetically related. In the hand specimen this rock is white and dense, but the thin section shows its granitic texture. Quartz and feldspar in almost equal proportions are the sole primary minerals. The secondary minerals, calcite and kaolin, are present in small amounts—the calcite in thin veins, the kaolin partly replacing feldspar.

A dike of similar origin but of slightly different composition was observed just north of the diorite contact on Carpenter Creek. This rock is likewise granitic and contains no black minerals, but it carries from 10 to 15 per cent of muscovite. The dominant minerals are microcline and quartz.

Numerous rhyolite dikes, probably continuations of those about Kings Mountain, cut through the sedimentary rocks that crop out on

lower Carpenter Creek. All are porphyritic, with quartz and feldspar phenocrysts. The groundmass is gray or green and in most of the dikes is composed of fine crystals, but in one dike the crystals attain fair size. Minerals accessory to the quartz and feldspar are magnetite and biotite. The biotite is usually chloritized. Later veins of quartz are locally present. Calcite appears in veins and replacing feldspar. These dikes are of post-Chickaloon age. One of them completely truncates a coal seam exposed in the canyon of Carpenter Creek.

#### INTERMEDIATE AND BASIC DIKES

A few intermediate dikes traverse the sediments and the greenstone on the south flank of the Matanuska Valley. Where intruded into the stratified rocks, as in the vicinity of the Wolverine Lakes and on lower Carpenter Creek, these dikes rise above the general topographic surface as long, narrow ridges. The intermediate rocks are dark gray or green and contain scattered phenocrysts of plagioclase feldspar. Microscopic examination shows chloritized biotite to be the only other primary mineral present in any considerable quantity. Magnetite and the secondary minerals calcite and chlorite may or may not be present.

The only dike of sufficient size to warrant representation on the geologic map is a dike of gabbro which crops out on the mountain side south of the Wolverine Lakes. The rock is dark green and consists largely of fair-sized plagioclase crystals with lesser amounts of fayalite. Some chlorite is likewise present.

Half a dozen basic sills are intruded into the coal-bearing Tertiary rocks on lower Carpenter Creek. They range in thickness from 4 to 20 feet and dip with the strata, to the northeast. The rock in the sills is dark colored and usually very finely crystalline. Plagioclase is the most abundant mineral constituent; magnetite is subordinate. Varying amounts of chlorite and kaolin are also present. In one slide the feldspar was seen to be strongly calcitized.

Most of the intermediate and basic igneous rock bodies are intrusive into the Chickaloon formation and therefore must be of post-Chickaloon age. The few that cut the Cretaceous and greenstone formations may very well be post-Chickaloon also, but their age can not be proved. It appears that there was during middle or late Tertiary time an epoch of igneous activity which produced the Kings Mountain plug and the many dikes and sills on the south flank of the Matanuska Valley.

### GLACIAL DEPOSITS

Glacial deposits may occur in any part of the area that was covered by glacial ice. On the geologic map accompanying this report such deposits are shown only where they reach sufficient thickness to seriously obscure the bedrock geology; likewise in the following paragraphs only those localities are described where glacial materials are abundant.

Sand and gravel deposited by the Matanuska Glacier cover most of the high terrace north of the mountain range. The thickness of the mantle ranges from a knife-edge where a hogback of stratified rock or a dike projects through it to over 100 feet where drift has filled in a low place in the preglacial surface. The glacial deposits are rudely or not at all stratified. The gravel, which predominates, consists of fairly coarse subangular boulders.

At the western extremity of the mountain range drift deposits lap up on the mountain side to an elevation of 800 feet. They were deposited by the Matanuska and Knik Glaciers where these two bodies of ice expanded and met on reaching the confluence of their separate valleys.

Small morainal deposits, both lateral and recessional, are common in all the tributary valleys. In the valley of Wolverine Creek lateral moraines were found along the sides of the valley at an elevation of 2,900 feet. At the foot of each glacier still existent in the region there is considerable coarse drift.

### RECENT ALLUVIAL DEPOSITS

The low terrace lying between Matanuska and Knik Rivers west of the main range is composed of river-deposited sand and gravel. The north side of the terrace is well drained, and the land is suitable for agriculture.

The two main rivers are running over extensive flood plains of sand and gravel which they themselves have formed in recent time.

### ECONOMIC GEOLOGY

#### COPPER

A copper deposit of promise, lying wholly within the greenstone formation, is exposed in a tributary draw near the headwaters of Jim Creek. The vein crops out on the north side of the valley several hundred feet above the creek bed and 4,150 feet above the sea. It was discovered and located by Joe Conroy and P. Marion in 1906.

The strike of the vein is N. 80° W., and the dip practically vertical. The course of the ore deposit may be traced by its gossan for a few hundred feet to the east, where it crosses the divide to

upper Wolverine Creek. To the west talus slides obscure the outcrop, but the locators report picking it up again in the next two draws.

The vein is badly sheeted. Evidently the ascending solutions depositing the ore minerals followed the path of least resistance through a shear zone in the greenstone. Deep-seated portions of the slowly crystallizing diorite batholith which undoubtedly underlies this rock may have been the source of the ascending waters.

The vein itself averages about a foot in width. It consists of an intermixture of massive chalcopyrite and pyrrhotite. In the hand specimen the chalcopyrite appears to predominate, and gangue minerals, if present at all, are subordinate. A shallow gossan 4 to 8 feet wide marks the outcrop of the vein.

Microscopic examination of a polished section of the ore shows the presence in a fine intergrowth of approximately equal amounts of chalcopyrite and pyrrhotite. These two minerals constitute about 80 per cent of the section. Sphalerite is the only other ore mineral present, composing about 15 per cent of the total. It occurs in scattered aggregates of small irregular masses. The only gangue mineral appearing in this section is calcite, which occurs in short veins and constitutes the remaining 5 per cent of the mineral content.

Samples taken from the 1-foot vein of massive sulphides assayed as follows: Copper, 15.08 per cent; zinc, 2.95 per cent; silver, 1.75 ounces to the ton; gold, trace.

The south wall of the sulphide vein for a distance of 12 or 15 inches consists of light-colored dense rock cut by minute veins of arsenopyrite. Study of thin sections shows this to be greenstone country rock largely replaced by quartz and calcite introduced by the ore-bringing solutions. It assayed 0.41 ounce of silver to the ton and 0.04 per cent of copper.

About 50 feet lower down the side of the valley lies the top of a 200-foot series of slates. Even these are cut and partly replaced by fine quartz veins, probably of the same generation as the ore minerals. At 500 feet above the sulphide vein a dike of alaskite, another offshoot from the diorite batholith, crops out.

The chief difficulty with developing this ore deposit would lie in its inaccessibility. The flats between Knik River and the mountains can be crossed at present only by boat. From the mouth of the Jim Creek Canyon to the prospect there is a climb of 4,000 feet. Until the floor of the hanging valley above the canyon is reached it is necessary to climb steep rock slopes—an impossible feat for a pack train. Tramming seems to be the only feasible method for transporting the ore down out of the mountains. However, in spite of these handicaps to development, it appears that this deposit is well worth further prospecting.

The presence of copper float has been reported from upper Wolverine and Carpenter Creeks, but the ore has not yet been found in place.

#### LEAD AND ZINC

The claims of W. S. Myers, near Eklutna, were examined toward the end of the season. This property lies at an elevation of 1,500 feet in a slight draw in the face of the cliff between Eklutna and Peters Creeks. The country rock is greenstone with a considerable amount of associated rhyolite. It has undergone extensive silicification in the neighborhood of the mineral deposits.

At one point the country rock is impregnated through a vertical zone about 3 feet wide with scattered crystals and small masses of arsenopyrite, pyrite, sphalerite, and galena. At a slightly lower elevation the country rock is cut by a distinct vein less than 2 inches in width containing calcite with scattered bits of sphalerite, galena, and chalcopyrite. About 6 inches of slightly mineralized rusty gouge lies on each side of the vein.

At neither of these points are there sufficient base-metal minerals exposed to encourage development work.

#### GOLD PLACERS

Desultory gold-placer operations have been carried on along Metal Creek for the last 20 years. The stream bed has been staked for the first 10 miles, but many of the claims have been allowed to lapse. No figures are available for the total production from this creek, but it probably does not exceed a few thousand dollars.

Metal Creek is a turbulent stream occupying a steep-walled hanging valley to a point near its mouth, where it drops down through a canyon into Knik River. Above the canyon it runs over a narrow flood plain, consisting in part of huge boulders. It is too large and too swift to ford during the summer. There are several small streams tributary to lower Metal Creek that are available for sluicing or developing power.

The gold lies on the bedrock well below high-water mark. It is difficult of access except during periods of low water in the fall, when prospectors have had some success "sniping." Sluicing has been done on a group of claims about 8 miles above the mouth of the creek.

Colors can be panned anywhere along lower Metal Creek. The gold is reported to become increasingly coarse upstream. The country rock is slate and graywacke near the mouth of the creek and greenstone farther up. Granite (diorite?) is reported to be the country rock toward the headwaters. The gold found in the bed of Metal Creek probably came from lode deposits in or near the granite.

## COAL

A 3-foot bed of coal crops out on the west side of Carpenter Creek in the tract of Chickaloon rocks about half a mile south of Matanuska River. A prospect tunnel 20 feet long has been driven into the seam about 30 feet above the creek bed.

The coal bed strikes N.  $75^{\circ}$  W. and dips  $17^{\circ}$  N. It is interbedded with carbonaceous shale. At 20 feet below the portal of the tunnel lies a 4-foot basic sill, one of several that are intruded into the Chickaloon sediments in this vicinity. A rhyolite porphyry dike about 20 feet thick completely truncates the bed of coal between the portal and the top of the hill.

The coal itself is clean and shiny, but movements suffered since its formation have slickensided it and made it somewhat friable. This particular coal bed gives little promise of future value owing to its character and its relation to the igneous intrusive, but there may be in the vicinity other seams of better quality and more favorable location.

A well dug on the fur farm of Bailes & Keily, between the Wolverine Lakes, encountered a few fragments of coal on the bedrock surface. This coal is dirty and broken and is traversed by narrow stringers of calcite.

A coal outcrop has been reported on the south bank of Matanuska River across from Granite Creek, but it was not found by the writer. It is quite possible that coal exists in the narrow belt of Chickaloon rocks that extends westward from the mouth of Granite Creek, but at almost all points these sediments underlie high terrace gravel and thus are difficult to prospect.