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THE GIRDWOOD DISTRICT, ALASKA

BY

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Investigations in Alaska Railroad belt, 1931

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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

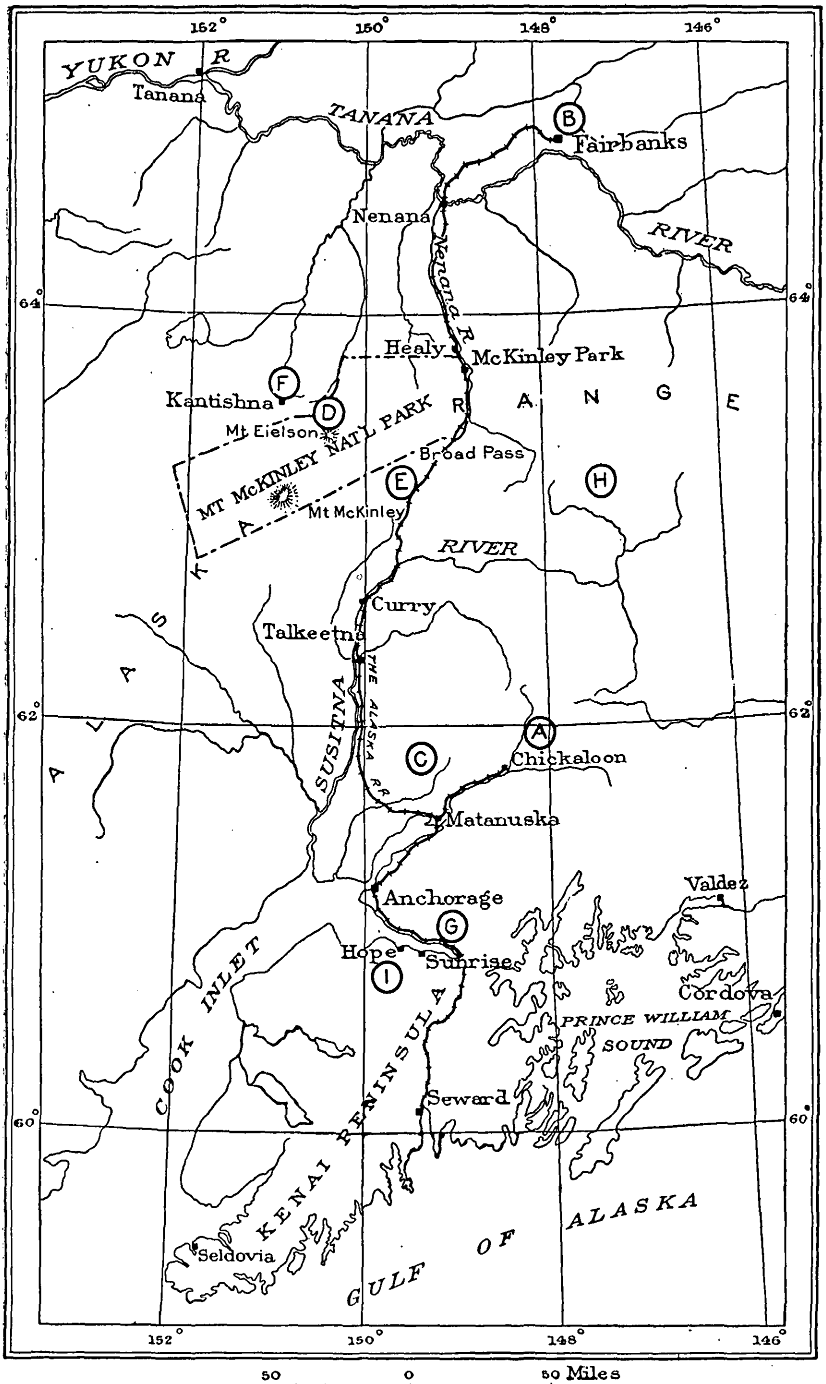

FIGURE 1.—Index map showing areas investigated in Alaska Railroad belt, 1931. A, Anthracite Ridge B, Fairbanks; C, Willow Creek; D, Mount Eielson; E, West Fork of Chulitna River; F, Eureka and vicinity; G, Girdwood; H, Valdez Creek; I, Moose Pass and Hope.

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 GIRDWOOD DISTRICT, ALASKA

By C. F. Park, Jr.

ABSTRACT

The Girdwood district has been known for about 35 years to contain placer gold, but the source of the gold in veins was not discovered until about 1909. When the Alaska Railroad was completed through Girdwood it was hoped that the improved transportation facilities would enable the lode mines to operate at a profit and also to furnish tonnage to the railroad. Production from the quartz veins, however, has been negligible, although one placer mine has been operating steadily for several years.

The predominant sedimentary rock of the region is a series of thinly banded argillite and graywacke, containing some conglomerate, impure limestone, and partly indurated sandstone. On the basis of fossils, obtained at six different localities within the district, the rocks are considered of Upper Cretaceous age. The thickness of the argillite and graywacke is unknown but must be 4 or 5 miles. These Upper Cretaceous rocks apparently were deposited unconformably above an undifferentiated metamorphosed series of lava, tuff, agglomerate, intrusive rocks, and sedimentary rocks of undetermined age. The metamorphic rocks, whose thickness is unkown, are found in the western part of the district.

Greenstone tuff several thousand feet thick, probably of Upper Cretaceous age, unconformably overlies the argillite-graywacke series.

The rocks intruded into the argillite-graywacke series are classified as quartz diorite, dacite, and dacitic aplite. The igneous rocks are in the form of dikes, sills, and exceedingly erratic pipes that are composed essentially of a network of thin medium-grained dikes. Some of the individual dikes are only an inch or even less in thickness, but they are granitoid in texture, and several have been traced on the surface for 100 feet or more. The district is peculiar in that the details of the intrusions are apparently independent of any observed structural control.

The region has been the site of considerable widespread structural deformation, and the beds are highly tilted, folded, and faulted. The main axes of deformation follow the general trend of the Chugach Mountains, 10° to 20° east of north. Both normal and reverse faults occur, and their strikes also tend to aline themselves with the main axes of folding. A minor system of tear faulting is developed in a general east-west direction. Much but not all of the faulting was earlier than the intrusions, and in places dikes tend to follow the fault planes for short distances.

The rocks of the region are not greatly altered, although some recrystallization due to processes of rock deformation has begun. Fine brown tourmaline needles and small reddish-brown garnets have been observed in argillite bordering an irregular intrusive pipe. Near the dike contacts silicification has taken place, but the introduction of silica is much more intense within an inch

or two of the intrusive mass than farther away. Silicification is intense in the vicinity of the pipelike intrusions and extends 20 feet or more from the contact; chlorite, muscovite, sericite, and some epidote are also usually developed.

The ore deposits are small arsenopyrite-gold-quartz veins and the placer deposits derived from these veins. The most prominent vein deposits are grouped in a small area near the headwaters of Crow Creek. The veins are thin and irregular but in places contain small pockets of rich gold ore with minor quantities of sulphides—chalcopyrite, galena, sphalerite, pyrrhotite, and molybdenite. Most of the deposits lie approximately parallel to the bedding planes or cross them at low angles. There has been considerable postmineral movement along many of the veins, and the quartz and sulphides in places form a breccia in gouge and sheared wall rock. It is thought that the veins will continue in depth with essentially the same mineral composition.

The veins are all grouped around the irregular pipelike intrusive rocks, and owing to the hydrothermally altered condition of these rocks and the noticeable contact action, as well as the constant association of these intrusive rocks with the veins, it is thought that the two have a closely related history. The fine-grained dikes and sills are apparently not closely associated with the ores.

INTRODUCTION

LOCATION AND EXTENT OF THE AREA

The Girdwood district is situated near the head of Cook Inlet, on the north shore of Turnagain Arm. (See fig. 1.) The area mapped includes the drainage basins of Crow and Raven Creeks, parts of the basins of Glacier Creek, Winner Creek, California Creek, North Fork of Ship Creek, and the headwaters of the Eagle River. Its approximate limits are latitude 60°55′–61°10′ and longitude 149°–149°20′, and its area is slightly more than 125 square miles.

PREVIOUS SURVEYS

The first geologic information concerning this region published by the Geological Survey was gathered by Mendenhall[1] in 1898. Moffit[2] visited the district in 1904 while making a study of the gold deposits of the Turnagain Arm region. Johnson, in a report on the geology of Kenai Peninsula,[3] presents a study of the general features of the district with detailed descriptions of the individual prospects. Capps[4] in 1916 gave comprehensive information concerning the area in a general report on the Turnagain-Knik region. Capps' work has been freely drawn upon, and many of his statements, with which the writer concurs, have been embodied in this report. Other reports of the United States Geological Survey that contain notes and infor-

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[1] 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. 265–340, 1900.

[2] Moffit, F. H., Gold fields of the Turnagain Arm region: U.S. Geol. Survey Bull. 277, pp. 7–52, 1906.

[3] Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: U.S. Geol. Survey Bull. 587, pp. 173–176, 188–193, 1915.

[4] Capps, S. R., The Turnagain-Knik region, Alaska: U.S. Geol. Survey Bull. 642, pp. 147–194, pls. 6–8, 1916.

mation about the Girdwood district and adjacent areas are listed below:

Paige, Sidney, and Knopf, Adolph, Reconnaissance in the Matanuska and Talkeetna Basins, Alaska, with notes on the placers of the adjacent regions: U.S. Geol. Survey Bull. 314, p. 107, 1907.

Grant, U. S., and Higgins, D. F., Jr., Notes on geology and mineral prospects in the vicinity of Seward, Kenai Peninsula: U.S. Geol. Survey Bull. 379, pp. 98–103, 1908.

Atwood, W. W., Mineral resources of southwestern Alaska: U.S. Geol. Survey Bull. 379, pp. 110–111, 1908.

Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U.S. Geol. Survey Bull. 500, pp. 16–17, 1912.

Martin G. C., The Mesozoic stratigraphy of Alaska: U.S. Geol. Survey Bull. 776, pp. 308–310, 482–483, 1926.

Capps, S. R., Geology and mineral resources of the region traversed by the Alaska Railroad: U.S. Geol. Survey Bull. 775, pp. 89–91, 116–117, 118, 1924.

Mineral resources of Alaska, report on progress of investigations. Bulletins, published annually, containing notes concerning current devlopments in the various Alaskan mining districts.

PRESENT INVESTIGATION AND ACKNOWLEDGMENTS

The detailed study of the Girdwood district was undertaken during the field season June 7 to September 18, 1931, as part of an investigation of the mineral resources in the area tributary to the Alaska Railroad. S. R. Capps was in general charge of the investigation, and many of the writer's conclusions have been discussed with him. D. F. Hewett spent several days in the field and offered valuable suggestions and criticism. P. S. Smith offered constructive criticism in the preparation of the report. The writer wishes also to express his gratitude to the property owners in the district for their whole-hearted support.

The field mapping was done in cooperation with a topographic party in charge of W. G. Carson, and members of this party helped to facilitate the investigation in many ways. Beginning at Girdwood, the survey was carried up Glacier and Crow Creeks, across the divide to Raven Creek, down Raven Creek to the Eagle River, from the Eagle River up Magpie Creek to the divide into the North Fork of Ship Creek, thence down Ship Creek to the head of Bird Creek. The field work has been confined as nearly as possible to the parts thought to be most favorable for the development of mineral resources.

GEOGRAPHY

DRAINAGE

The streams in the Girdwood district flow either southward into Turnagain Arm or northwestward into Knik Arm. These two drainage slopes are separated by high, rugged mountains, which contain many small glaciers and cirques.

Nearly all the streams encountered head in or receive part of their waters from melting ice. Stream flow is variable; on warm days even the small creeks may become difficultly passable torrents, but on cool days and at night the flow is greatly diminished. The water in many of the creeks is turbid, and during times of flood large quantities of rock flour and silt, with some coarser rock fragments, are dumped into Turnagain and Knik Arms. Some of the streams, notably Winner Creek, California Creek, and Magpie Creek, contain water that is clear or only slightly milky. They probably owe their lack of turbidity to the fact that they head in well-protected areas of snow, where the melting and run-off take place gradually.

The Eagle River, with its tributaries Raven and Magpie Creeks, is the largest stream in the area. This drainage is emptied into Knik Arm, into which Ship Creek also flows. The Eagle River heads in Eagle Glacier, the largest body of ice and snow in the region. The country near the head of the glacier is so inaccessible that almost nothing is known of it. The gathering ground for the snow that forms Eagle Glacier appears to be separated from the main ice field of the little-known Chugach Range by barren ridges. This upland is in striking contrast with the lowland along the Eagle River. The broad flat valley of the Eagle River contains many shifting channels along the braided stream course. The numerous islands and the main stream banks are covered with a tangled mass of intergrown trees and brush.

The valleys of the northern branch of Ship Creek and of Raven Creek are somewhat alike: each has a broad, gently rounded form, due to former ice erosion. The valleys are swampy in places and in their lower courses contain matted growths of brush and trees. The upper parts of the basins are covered during the summer with thick grass, in many places waist-high.

The streams of the district that flow into Turnagain Arm include Glacier Creek and its tributaries California Creek, Crow Creek, and Winner Creek, also Virgin Creek and Bird Creek.

Glacier Creek is a good example of a glacier-fed stream. Its headwaters are steep and abrupt, but the valley floor itself is wide and flat, in places swampy, and mostly covered with luxuriant vegetation.

Little is known about Winner Creek, and its headwaters have not been mapped. The divide between its basin and that of the Twentymile River is said to be low. The stream is about 10 miles long. In its upper 6 or 7 miles it trends about S. 60° W., then makes a sharp bend and flows approximately N. 45° W. into Glacier Creek. The valley has a low, even gradient for about 7 miles from Glacier Creek, but farther upstream the ascent becomes steeper.

The other stream valleys of the region all show many signs of former glaciation. The valleys are broadly U-shaped and commonly contain wide longitudinal grooves high on the valley sides. The grooves and valley floors are in many places swampy, but in general the higher lands are well drained.

Stream piracy and unadjusted drainage are common in recently glaciated regions. One interesting and peculiar example may be seen in the extreme western part of the Girdwood district, near the head of Bird Creek. (See pl. 33.) The small stream that forms the head of Bird Creek makes a sharp U-shaped bend. An old open stream channel connects the base of this U with Ship Creek, and the slope of the channel shows that what is now the headwater stream of Ship Creek formerly flowed into Bird Creek.

During glacial time the main ice stream moved down Ship Creek Valley. This ice stream, high on the south side, had a branch outlet down Bird Creek. The ice gradually retreated, and Ship Creek Valley was filled with gravel and debris to a thickness that is unknown but surely several hundred feet. The level of this gravel floor must have been nearly even with the Bird Creek outlet. Most of the drainage from the ice went down Bird Creek. The upper part of Bird Creek flows across hard layers of graywacke and argillite, materials that effectively resist stream wear, but the valley of Ship Creek, on the contrary, was filled with unconsolidated gravel. Glacial streams may carry very large quantities of water and transport considerable loads during times of flood. If, during one of these floods, the Bird Creek channel was unable to carry all the water, the excess may have broken away down Ship Creek, and once established in the gravel channel, the stream continued to flow down Ship Creek after the flood had subsided.

The capture by Ship Creek of the stream formerly tributary to Bird Creek is considered to be postglacial, as the abandoned stream channel is still open. The capture may have been aided by the formation of aufeis or some similar obstruction. Other abandoned stream channels parallel to Ship Creek may be interpreted as evidence of this process of freezing, overflow, and channel cutting.

RELIEF

The country mapped is exceedingly rugged, and the relief is considerable; the topography is typical of that developed in mountainous regions by strong alpine glaciation. The main ridges are bare and ragged, many with slopes descending precipitously as much as several thousand feet to small cirques or sheltered névé fields. Near the bases of these ridges countless rock slides have formed prominent talus cones.

Northeast of the district mapped is the main range of the Chugach Mountains—an area almost inaccessible and unexplored. This area is a great gathering ground for snow and ice. For miles, as far as the eye can see, irregularly spaced bare, jagged peaks and ridges project upward through an otherwise smooth, wind-swept expanse of white.

The mountains near the shore of Turnagain Arm rise to elevations between 4,000 and 5,000 feet. These coastal mountains have been glaciated up to about 3,400 feet[5] and their valleys are broadly rounded. Most of the valley sides contain wide longitudinal grooves and prominent rock-cut benches and otherwise show the effects of glaciation.

The maximum relief is along the Eagle River just south of the junction with Raven Creek. The river here flows at an elevation of about 700 feet, and the peaks on each side rise abruptly to crags over 7,000 feet high. Few of the mountains have slopes of less than 30°, and in many places the average inclination of the surface for several thousand feet is 50° to 60°. Many of these mountains are entirely inaccessible, but some can be ascended from one side, usually the north.

CLIMATE

Girdwood lies just within the coastal rain belt. The annual precipitation, shown by scanty and incomplete records kept by the Alaska Railroad at Girdwood, is probably about 50 inches. Heavy fogs and light persistent rains are very common during the summer. The surface is so high that snow may be expected on the peaks at any time. Considerable snow falls during the winter, and much of it remains throughout the summer in sheltered or protected spots. The peaks and high ridges usually conceal small névé fields and pockets of ice.

In the higher parts strong winds are common. These winds are persistent during much of the winter and at times assume the proportions of blizzards. It is reported that the old mail-route trail through the Crow Creek-Raven Creek divide was abandoned on account of these winds. During the summer the winds mostly subside, and the climate in these higher parts is cool and pleasant.

VEGETATION

The lowlands along Glacier Creek are thickly wooded and furnish some of the finest timber in this section of the Territory. Spruce and hemlock trees attain a diameter of 4 feet, and groves of cottonwood and small birch trees are plentiful in many of the valleys.

[5] Capps, S. R., The Turnagain-Knik region, Alaska: U.S. Geol. Survey Bull. 642, p. 166, 1916.

Timber line ranges from 1,000 to 2,500 feet but averages about 1,500 feet. Alder and willow thickets extend to an elevation of 2,000 feet, or in some places above 2,500 feet. Most of the larger valleys are filled with a tangled mass of fallen trees and underbrush, which includes buck brush, mountain cedar, devilsclub, blueberries, cranberries, currants, raspberries, and many other small plants. Multitudes of wild flowers last throughout the summer. The otherwise bare slopes and ridges are spotted with many different kinds of mosses and grasses. Redtop and bunch grass are abundant and in many places waist-high. They furnish ample food for stock during the summer.

GAME

Mountain goats and sheep and black bear are found in the remote regions. A few moose, brown bear, and fur-bearing animals are present, and wolves and coyotes are occasionally seen. Ptarmigan and grouse, the only game birds seen, were nowhere abundant. Most of the streams are glacier-fed and, owing to the turbid condition of the waters, contain no fish. Trout are found in a few clear streams.

POPULATION

The only people in the district are those near Girdwood and Crow Creek and a few prospectors who roam the hills during the summer. California Creek, near its junction with Glacier Creek, furnishes power for a sawmill, and some timber cutters and prospectors live in the Glacier Creek Valley. Girdwood contains a store-hotel, a forest ranger's cabin, a post office, and a dozen or so other buildings. The permanent population of the entire district probably averages between 25 and 50 people. No signs were seen that would indicate that any native tribes frequent this district.

ROUTES OF TRAVEL

The Girdwood district is served by the Alaska Railroad from the station of Girdwood, on Turnagain Arm. From the railroad a surfaced road extends for about 5 miles along the west side of Glacier Creek to Crow Creek and about 2½ miles up Crow Creek Valley. This road was built and is maintained by the United States Bureau of Public Roads. A tractor road connects the end of the surfaced road with the summit of the divide between Crow and Raven Creeks, from which a trail follows down Raven Creek to the Eagle River. The old trail into the interior of Alaska by way of Old Knik extended down the Eagle River to Knik Arm. This trail has been washed out and overgrown, so that it is inaccessible to summer traffic.

A footbridge crosses Glacier Creek just below the junction with Crow Creek and connects the gravel road with a trail up Winner Creek and also with the Virgin Creek trail down the east bank of Glacier Creek. The well-built trail up Winner Creek was constructed by Axel Linblad. Late in the summer of 1931 the Forest Service undertook to extend this trail across the low divide to the Twentymile River.

GENERAL GEOLOGY

PRINCIPAL FEATURES

The oldest rocks in the Girdwood district (see pl. 33) are a hydrothermally metamorphosed series of clastic sediments, lava flows, and intrusive rocks. This series forms a belt 10 to 12 miles wide along the western border of the mountains.

Unconformably overlying the metamorphosed rocks is the most widespread series of the region, a monotonous succession of argillite and graywacke. These rocks extend along Turnagain Arm from Indian Creek to Portage Glacier and northward to Knik Arm.[6]

In the extreme northwestern part of the area is a series of greenstone tuffs, younger than the argillite-graywacke series. The greenstone tuff has been studied only along the high, almost inaccessible crags south of the Eagle River.

The youngest sedimentary materials are unconsolidated or partly indurated Quaternary deposits of glacial and stream origin and recent unconsolidated deposits of similar types. No Tertiary beds have been recognized in this district, though sedimentary rocks of Tertiary age occur in a wide belt along the coast near Anchorage, and beds of recognized Eocene age are found in the Chickaloon region and south of Turnagain Arm near Point Possession.

UNDIFFERENTIATED METAMORPHIC ROCKS

Character and distribution.—The hydrothermally metamorphosed rocks comprise a wide variety of materials. They include altered igneous rocks of acidic composition, altered andesite, and, especially, water-laid tuff and agglomerate. They also include altered argillite, graywacke, and chert of sedimentary origin. This whole series has been cut by both basic and acidic dikes.

The study of these rocks has been limited to a section along the Alaska Railroad from Potter to Girdwood and one small area near the head of the North Fork of Ship Creek. The study has yielded little in addition to that already published by Capps.[7]

Structure and thickness.—Owing to the deformed and metamorphosed character of this series of rocks only a vague idea of their

[6] Capps, S. R., op. cit., p. 153.
[7] Idem, pp. 154–155.

structure has been obtained. They are difficult to study in the field because they are generally so greatly altered and weathered that determinable specimens are not easily obtained.

Along the shore of Turnagain Arm west of Indian Creek the contact between this group of rocks and the argillite and graywacke to the east has been the site of intense deformation, with shearing and brecciation. Bunches of argillite and graywacke are apparently squeezed and infolded into the metamorphic rocks, and the linear arrangement of these included materials is roughly parallel to the line of contact. The axes of the main folds aline themselves approximately with the axial trend of the mountains and also roughly parallel to the line of contact with the argillite-graywacke series. This direction is N. 10°–20° E. The folds plunge north at relatively flat angles. Numerous faults of both normal and reverse types and with great differences in amount of offset are present. Most of these faults are parallel to the axes of folding, although a transverse east-west fault system is developed.

No information concerning the thickness of these rocks was obtained. Capps considers them to be at least several thousand feet thick, and this estimate appears to be as close as can at present be made.

Age and correlation.—The age of this group of rocks is probably pre-Cretaceous, although where the contact with the argillite-graywacke series has been seen deformation, infolding, and alteration have been so severe that definite relations are difficult to establish. It is impossible from the information obtained to state that either rock series definitely overlies the other, but the metamorphic rocks are much more intensely deformed and intruded than the argillite-graywacke group and are therefore considered older. This is in accord with Capps' conclusion.[8]

ARGILLITE-GRAYWACKE SERIES

Character and distribution.—Nearly the whole of the area is underlain by argillite and graywacke. The argillite and graywacke are locally covered by Pleistocene or Recent deposits or, in places, intruded by igneous masses of small areal extent. Minor quantities of conglomerate, limestone, and partly indurated sandstone are interbedded with the argillite and graywacke, forming many small but distinct lenticular beds.[9]

Thin-banded argillite and graywacke are by far the most common rock types. The bands range in thickness from a fraction of an inch to more than 100 feet, although the average is between 2 and 3 inches.

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[8] Capps, S. R., op. cit., p. 155.
[9] Idem, p. 156.

Gradational bedding, cross-bedding, and in few places ripple marks testify to the shallow-water origin of the deposits. It has not been feasible to attempt to differentiate between argillite and graywacke on the map.

Graywacke.—The graywacke grades on the one side into argillite and on the other into sandstone and conglomerate. It consists mainly of sharply angular bits of rock and fragments of quartz, feldspar, and other minerals. Coarse muscovite and some biotite are common constituents, and some hornblende is present. Fragments of coarse epidote, clinozoisite, and a few broken tourmaline grains have been seen. Small crystals of apatite are common. Most of the feldspar present is either basic oligoclase or acidic andesine, although orthoclase and other members of the plagioclase series may be present.

The groundmass is a fine-grained aggregate of chlorite, sericite, graphite, and, in places, much calcium carbonate, both in grains and in stringers. A little epidote and limonite are widespread, a mineral of the kaolinite group is common, and leucoxene may be present. Many specimens of the somewhat schistose rock are partly recrystallized and have a groundmass composed chiefly of very fine grained feldspar needles, probably near oligoclase in composition. The rock fragments are usually bits of fine-grained graywacke or argillite. In some areas the fragments measure more than an inch across, although usually much less. Macroscopic argillite fragments may be evenly and closely distributed through beds as much as 100 feet thick or even more. Some phases of the rock strongly suggest a tuff, and such rock is with difficulty distinguished from the later greenstone tuff series.

The graywacke in many places is mineralized, and the oxidized rock has a dull reddish-brown color.

Argillite.—The argillite locally grades into schist and slate, but usually the rock cleavage is undulating and irregular. The color of the fresh rock is dark gray, and under the microscope much graphitic material is seen.

The rock consists of very fine particles of quartz, with some feldspar. The particles are subangular, probably somewhat water worn. The groundmass is exceedingly fine and consists of chlorite, sericite, a member of the kaolinite group, and graphite. The argillite shows almost no recrystallization, but in the more schistose phases of the rock recrystallized minerals are slightly developed.

Many specimens of the argillite resemble fine water-laid tuff, and it is entirely possible that considerable volcanic material is included in the series.

Conglomerate, sandstone, and limestone.—Conglomerate, sandstone, and limestone form scattered lenticular beds in the much more abundant argillite and graywacke.

The conglomerate grades from indurated grit to rock containing boulders as much as 10 feet in diameter, although the average diameter is probably less than 1 inch. The pebbles vary greatly in composition; fragments of argillite and graywacke are the most common, but igneous and other sedimentary rocks are present. The pebbles of igneous rock are usually granitoid in texture and have the composition of a diorite. The matrix of the conglomerates is usually argillite or, more commonly, fine-grained graywacke. This matrix is in places slightly mineralized, and one spot of free gold was seen in a conglomerate lens found in the most recent gorge of lower Crow Creek. As mentioned by Capps [10] and also by Martin, Johnson, and Grant,[11] the conglomerate does not form sharp, distinct beds but grades in all directions into the finer sedimentary rocks. Most of the conglomerates are intraformational and do not mark any significant break in deposition. Many are sheared and deformed; the pebbles tend to flatten parallel to the cleavage.

Sandstone is nowhere very common, and it grades locally into quartzite, although the mineral grains are rarely well cemented. The fresh sandstone is usually feldspathic and grayish. It merges gradually into graywacke.

Several small lenses of impure limestone have been observed. These are especially common near the summit of the pass between Crow and Raven Creeks. The limestone has a fine granular texture and a dark bluish-gray color.

Structure and thickness.—The argillite and graywacke have been considerably deformed and tilted. The strike of the beds corresponds approximately with the general trend of the mountains. The dip is usually steep and in the district studied is mostly to the west, although it may be in any direction.

The difficulty in interpreting structure in this region is due primarily to the lack of any persistent or characteristic bed that would serve as a key or reference bed. The beds have been considerably disturbed; they are lenticular in character and present a monotonous sameness in appearance throughout the series. On the east side of Raven Creek there are several massive coarse graywacke layers scattered stratigraphically through about 1,000 feet of the formation. These beds are individually 100 feet or even more in thickness and are separated by beds of argillite. This massive graywacke zone has

[10] Capps, S. R., op. cit., p. 159.
[11] Martin, G. C., Johnson, B. L., and Grant, U. S., op. cit., p. 117.

furnished by far the best marker bed in the district, but an attempt to follow it gives a good idea of the variable character of the beds. The character of the rock changes along the strike until within 2 miles the identity is completely lost. In most places it is not possible to follow an individual bed more than 100 to 200 feet with any degree of assurance that it is the same bed.

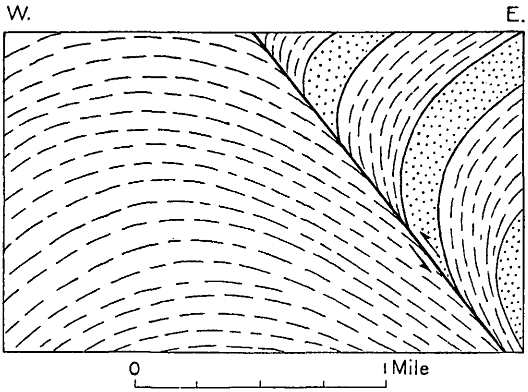

FIGURE 46.—Goat Mountain thrust fault.

Folding and faulting are both common but difficult to trace for any distance. No attempt has been made on the map to show the many minor crenulations and small faults. The same symbol is used on the map for both faults and prominent shear zones.

There are two main systems of faulting, one striking a few degrees east of north, parallel to the axial trend of the mountains, and the other, a secondary system, at nearly right angles to this. The faults of the east-west system have the appearance of minor tear faults or flaws between major north-south lines of deformation.

The north-south system of faults is prominent in places, but the individual breaks are very difficult to follow. (See fig. 46.) Compression faults of the normal and reverse types are present (see fig. 47) and at many places change along the strike into obscure folds. It has been found impossible, except in a very few places, even to estimate the amount of offset along the faults. Small breaks with a throw from a few inches to a few feet are common.

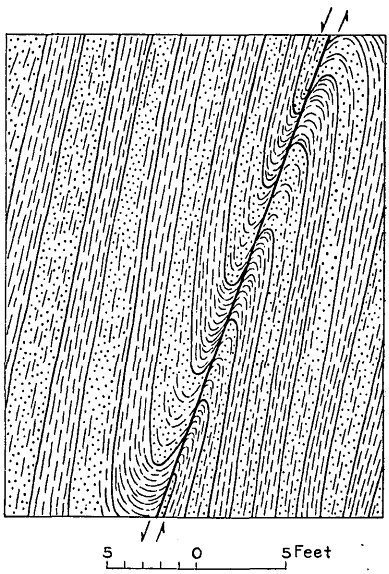

FIGURE 47.—Normal fault caused by compressive stresses.

The difference in competency of the beds is well shown in places: argillite yields primarily by rock flowage, but graywacke, under the same or similar conditions, will more readily fracture. Where the crustal disturbance has been great this difference in competency is especially noticeable. Huge blocks of graywacke have been broken and infolded or dragged into the argillite until they are completely isolated in the more plastic materials.

Capps[12] states, in discussing the rock cleavage:

The local development of slaty cleavage in rocks within this region can in most places be attributed to the position of the slaty bed in relation to folds. In general, the fine-grained mudstones have received a secondary cleavage more readily than the coarser graywackes, and a well-developed bed of slate may be bordered, both above and below, by massive graywacke beds that show no such cleavage. Within small areas, however, all the rocks have become somewhat schistose, and a secondary cleavage is present in the slates, graywackes, and conglomerates.

The pitch of this cleavage is, in general, 10°–30° N. 5°–10° E. A few observations taken give the direction of pitch west of north. The major joints strike in general from N. 65° W. to west and usually dip more than 65° N. The angle between the bedding and the rock cleavage is commonly small, not more than 10°, and the bedding, as a result, may be much obscured or even totally destroyed. The two fault systems in general correspond with the direction of pitch of the cleavage and the strike of the joint planes.

The thickness of this series of argillite and graywacke is not known. Capps[13] says that the original thickness must have been several thousand feet. The cross sections in plate 33 indicate that, although considerable repetition by folding and faulting has probably occurred, the thickness of this series of rocks in the Girdwood area may be between 4 and 5 miles.

Age and correlation.—The recent study has yielded fragments and imprints of *Inoceramus* sp. from six different localities scattered throughout the region. In reporting on these fossils, J. B. Reeside, Jr., says:

In their state of preservation it is not possible to tell whether more than one species is present or to refer them with assurance to a named species. Nevertheless, it seems wholly improbable that one would find in any rocks older than Cretaceous as many specimens of *Inoceramus* as are contained in these collections and no other fossils. It is my opinion that these fossils are Cretaceous, and more likely Upper than Lower.

This determination agrees in general with the earlier report of T. W. Stanton,[14] who examined some *Inoceramus* of undetermined species found by G. C. Martin and B. L. Johnson at the head of Crow Creek. Stanton says:

These consist entirely of imprints of a small *Inoceramus*, which is possibly identical with the Yakutat fossil described by Ulrich as *Inoceramya concentrica*. There is also a closely related form in Martin's [Upper] Cretaceous collections

[12] Capps, S. R., op. cit., pp. 156–157.
[13] Idem, p. 160.
[14] Martin, G. C., Johnson, B. L., and Grant, U. S., op. cit., p. 118.

from the Matanuska region. * * * There is no essential difference in general type between the Jurassic species of *Inoceramus* and some of those in the Cretaceous, hence it is impossible to make positive discriminations on the evidence of *Inoceramus* alone unless species of known stratigraphic range can be positively identified.

From the paleontologic evidence these beds are considered to be of Upper Cretaceous age. There must, however, have been a considerable time interval between the deposition of this Upper Cretaceous series and the Eocene coal-bearing beds of the Chickaloon region. Northwest of the area mapped the argillite-graywacke series is covered by several thousand feet of greenstone tuff. These two formations are separated by a distinct angular unconformity. In the Chickaloon region the lower Tertiary (Eocene) coal beds are described [15] as unconformably overlying the argillite-graywacke series. No direct evidence has been obtained concerning the relationship between the postargillite greenstone and the Eocene coal beds. From the lithologic dissimilarity of these rocks, especially the indurated condition of the greenstone tuff, it may be logically reasoned that the tuff is pre-Tertiary and was consolidated and partly eroded before the deposition of the lowest Tertiary beds.

If the above reasoning is correct, the conclusion may be drawn that the argillite-graywacke series cannot be the youngest Upper Cretaceous formation, because it is separated from the basal Tertiary beds by several thousand feet of clastic rocks and by two definite, widespread unconformities.

As the area described in this report is so small, it is entirely possible that other parts of the argillite-graywacke series are older than Upper Cretaceous.

VOLCANIC TUFF

Character and distribution.—The volcanic (greenstone) tuff is found northwest of the argillite-graywacke series mapped and covers an extensive area as far north as Eklutna Lake. Owing to the inaccessibility of the region where the tuff was seen its study has been necessarily limited.

Thin layers of argillite are commonly interbedded with the tuff. Capps reports rhyolite tuff in small amounts and probably also some flow rocks. These were not observed in the region studied by the writer.

Small fragments of black argillite are scattered through most of the rock. In small specimens, these black fragments are of approximately the same size and are distributed homogeneously, but in thick

[15] Capps, S. R., Geology of the upper Matanuska Valley, Alaska; U.S. Geol. Survey Bull. 791, pp. 41–42, 1927.

beds they vary more both in size and in distribution. The uniformity in size and the homogeneous distribution of these fragments throughout a great thickness of the tuff and over large areas are difficult to explain.

The tuff is usually greenish, owing to the presence of quantities of a dark-green chlorite. Many of the small fragments are quartz and plagioclase feldspar. Capps reports in addition some microscopic hornblende and pyroxene. The secondary minerals include quartz, carbonate, chlorite, and zeolites. Veins and stringers more than a foot in width are common. These veins contain only calcite and some prehnite.

The matrix of the tuff is commonly composed of carbonates and serpentinous material, although in places it may be glassy.

Structure and thickness.—Concerning the structure of these beds Capps [16] says:

> The rocks of the tuff series have been somewhat folded and faulted, but as a whole they are less deformed than the underlying formations. The beds are generally massive; interbedded clastic sediments are present only in small amounts; and in most places the jointing is more conspicuous than the bedding. From a study of the contact relations with the underlying rocks and of such sediments as are present in the series, however, it appears that the large area of tuffs that occupies the central part of this region is in the form of a rather simple synclinal basin, in which the prevailing strike is parallel to the outer border of the tuff area and the beds dip from the margins toward the center of the basin.

These statements are in agreement with the evidence obtained in the present investigation. The greenstone tuff is separated from the older argillite-graywacke series by a distinct angular unconformity, well shown north of upper Ship Creek. From its extent this unconformity is thought to represent a considerable time interval.

The most that can be said concerning the thickness of this series of tuffs is that it is composed of probably several thousand feet of volcanic material.

Age and correlation.—No fossils have been found in the volcanic tuffs. These tuffs are younger than the argillite-graywacke series, which is considered of Upper Cretaceous age. The volcanic materials are more indurated and are different in character from any of the known Tertiary beds. Eocene beds occur in several nearby localities but are usually coal-bearing and contain many fossils. On lithologic grounds alone, the greenstone tuffs are tentatively considered Upper Cretaceous. They have not been definitely correlated with any other formations.

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[16] Capps, S. R., The Turnagain-Knik region, Alaska: U.S. Geol. Survey Bull. 642, pp. 165–174, 1916.

INTRUSIVE ROCKS

Character and distribution.—The intrusive rocks do not offer a wide variety of types. Under the microscope the mineral constituents are seen to be well-zoned feldspars, medium andesine to basic oligoclase in composition, quartz, both as an original and as an introduced constituent; and some accessory apatite, magnetite, titanite, and a few zircons. Hornblende was observed in only one specimen; biotite is somewhat more common but not plentiful.

Alteration has been common and in places intense. Areas of chlorite contain scattered spots of leucoxene and are thought to represent former biotite grains. In the coarser rocks well-formed books of muscovite are present; sericite is found in all intrusive rocks. Epidote, chlorite, and carbonates are common constituents, and tourmaline has been observed. Small amounts of rutile-bearing quartz are present, and the long rutile crystals in some places continue through several grains of quartz. In a few places albite has been introduced, but albitization is not extensive. Small amounts of sulphides, especially pyrite and pyrrhotite, are present in most of these intrusive rocks.

Microscopically most of the intrusive rocks are highly altered quartz diorite and the fine-grained equivalent, dacite. There are a few fine-grained white dikes that contain almost no ferromagnesian minerals except a few spots of epidote and magnetite. The rock is a fine-grained aggregate of quartz and andesine feldspar, highly sericitized and with some carbonates developed. This white rock is termed a dacitic aplite.

The zoning of the feldspar is somewhat peculiar, in that twinning bands are not very prominent. The feldspars gradually fade from medium andesine at the center to a basic oligoclase at the outside of the grains.

All the sedimentary and metamorphic formations studied have been intruded in many places by dikes, sills, and irregular pipes or plugs. No time was available to study the basic intrusives in the metamorphic rocks, and most of the work has been confined to the intrusive rocks in the neighborhood of the ore deposits. As the area was mapped early in the season, when part of it was covered with snow, it is certain that many dikes and sills were overlooked, especially in the high country south and east of Ragged Top Mountain.

Effects of contact metamorphism.—The effects of contact metamorphism around most of the intrusive rocks are negligible. A few very irregular shaped crosscutting bodies of quartz diorite that contain crystals of muscovite as much as half an inch across have had some influence on the adjacent argillite-graywacke rocks, as shown by the development of sericite, small grains of tourmaline, and a few reddish-brown garnets. Silicification is intense near the contacts, but the effects are in few places noticeable more than 15 to 20 feet from the intrusive plugs.

The fine-grained dikes and sills show almost no pyrometasomatic action; the contacts are in many places of knife-edge sharpness and are well defined. Some silicification has usually taken place within a few inches of the contact.

Structure.—The most striking things to the casual observer in this district are the prominence and erratic distribution of the dikes and sills. Owing to the scale of the map it has not been possible to show the many irregularities of the intrusive materials, and the small areas shown as intrusive rocks may contain as much as 50 percent of argillite or graywacke. The argillite and graywacke may be badly shattered and cut in all directions by coarse-grained intrusive rocks from a fraction of an inch to over 100 feet in thickness. There is no definite pattern nor determined structural control for the small offshoots of any intrusive body. From the map there appears to be a general alinement of the dikes in a north-south direction.

The impression obtained in the field is that these rocks were intruded fairly close to the surface, although there is no direct evidence in proof of this. It is difficult to conceive of the factors controlling such fantastically distributed intrusions. At depth and under great pressure molten materials would possibly tend to follow the well-defined breaks and structure, although near the surface, where fracturing was more common and the rocks more easily broken, the ascending magma might traverse a more erratic path. The imperviousness of the rock intruded may have been an important factor affecting intrusion.

Many of the dikes follow preexisting faults for part of their strike and dip. In a few places faulting has offset the dikes, as shown in some of the small intrusive bodies at the head of California Creek and also on Crow Creek. But most of the dikes and sills are undistorted and most of the folding is considered earlier than the intrusion. Many of the dikes conform with the bedding for a short distance and in those parts of their courses may be considered sills. The veins are usually later than the dikes.

Age.—Most of the intrusive rocks in this region are younger than the argillite and graywacke, and the writer therefore considers that they are probably younger than Upper Cretaceous. Martin, Johnson, and Grant[17] consider them probably pre-Tertiary, although diorite porphyry intrusives are known to cut the Tertiary coal formations in the Matanuska region.[18]

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[17] Martin, G. C., Johnson, B. L., and Grant, U. S., op. cit., p. 120.

[18] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley: U.S. Geol. Survey Bull. 500, pp. 58–61, 1912.

The metamorphic series of rocks in the mountains west of the area mapped appear from a cursory examination to contain many more intrusive bodies than the argillite-graywacke group. Some of these intrusive rocks collected as float on lower Ship Creek are basic types—gabbros and associated differentiates. None of these basic intrusions have been found in the argillite-graywacke rocks and it seems probable that the basic rocks are older than the argillite-graywacke series. The fact that many of the intrusions seen appear deformed helps to strengthen this conclusion.

QUATERNARY DEPOSITS

GLACIATION AND GLACIAL DEPOSITS

The preglacial and glacial conditions of this region have been thoroughly discussed in the papers already cited, especially that by Capps.[19] The last great period of glaciation (Wisconsin stage)[20] in the Turnagain-Knik region destroyed practically all the preexisting topographic features.

Part of this region may be considered as still in the glacial stage, and most of the area mapped as occupied by unconsolidated materials is covered by deposits formed directly by ice or by glacial streams. In the mapping no attempt has been made to differentiate these materials.

The section of Capps' report that deals with the geologic history of Crow Creek will be quoted here in part, as it illustrates the complexity of processes active during the glacial epoch. An understanding of this history is especially necessary in any study of the placer deposits of the region.

> The physiographic history of Crow Creek is highly complex, but fortunately the deep excavations made during the progress of mining have yielded much valuable information concerning it. * * *
>
> For about half a mile above its mouth Crow Creek flows through a very narrow, steep-walled canyon cut into bedrock. The cutting of this canyon is, however, a very recent event in the erosional history of the valley, for the canyon is conspicuously younger than the valley above it. The rock canyon is bordered on the northeast by high benches of unconsolidated material, and for over a mile above the head of the canyon the stream flows over gravel bars and between high gravel benches. Prospecting above the canyon has shown that the stream bed throughout this distance lies 50 feet or more above the rock floor of the valley.
>
> During the season of 1904 mining developments near the middle of the rock canyon showed the lower end of a distinct gravel-filled channel east of the present channel and joining it from above. This old channel has been sluiced out to obtain a water grade to the bedrock valley floor above the canyon. This cut required the removal of materials having a maximum thick-

[19] Capps, S. R., op. cit. (Bull. 642), pp. 165–181.

[20] Capps, S. R., An estimate of the age of the last great glaciation in Alaska: Washington Acad. Sci. Jour., vol. 5, pp. 108–115, 1915.

ness of over 230 feet and forming a complicated section composed of assorted beds of coarse and fine gravels and glacial till. Some of the gravel beds are horizontally bedded, some are cross-bedded, and others are contorted. (See fig. 48.) The excavations also show that this buried rock channel itself is joined by other old channels in bedrock. (See figs. 49 and 50.) Mining in one of these has exposed a section (fig. 51) which differs considerably from that shown in figure 48 but which also shows deposits of glacial origin interbedded

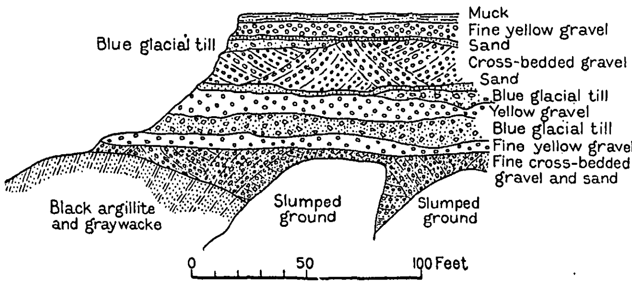

FIGURE 48.—Section exposed in placer workings of lower Crow Creek, showing interbedded stream gravel and glacial till overlying steeply tilted argillite and graywacke.

with water-laid sands and gravels. The erosional history at this place is important, as it has been largely influential in determining the location and richness of gold placer deposits. * * *

Apparently the old channel through the "big cut" is the deepest rock channel draining the Crow Creek Valley. * * * It has not yet been determined whether this old channel was the preglacial course of the stream or whether it was carved in the interval between two glacial advances. Its steep sides and high gradient, however, indicate that it was formed after the Glacier Creek Valley had been deepened by glacial scour and that it was cut by Crow Creek in its endeavor to reduce its valley to grade with Glacier Creek. This suggests at least the possibility that there may have been two distinct periods of glaciation, separated by an interglacial period long enough for the cutting of the deepest old channel. * * *

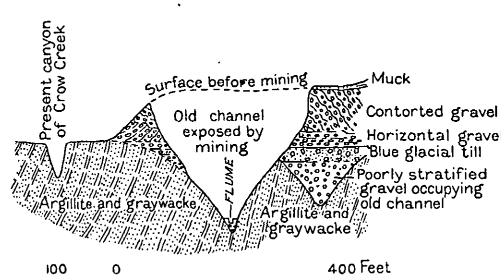

FIGURE 49.—Cross section of a part of lower Crow Creek Valley, showing size and position of present canyon, the deepest buried canyon (now excavated), and another smaller buried canyon. This section is at right angles to that shown in figure 51.

Before the earliest of the Pleistocene glacial advances had taken place the ordinary processes of stream erosion had carved deep valleys into the mountains. These valleys lay in much the same positions as those now occupied by Glacier and Crow Creeks and their tributaries, but instead of being wide, straight U-shaped troughs, such as we now see, each was a narrower V-shaped valley with a normal stream gradient and followed a somewhat sinuous course between the spurs that projected into it from either side. It seems certain that during this long period of preglacial stream erosion stream placer deposits were formed containing the gold that had been present in the rocks which the stream had removed.

In Pleistocene time glaciers formed in the valley heads and gradually extended downstream, uniting to form an ice tongue that filled the Glacier Creek Valley and reached Turnagain Arm, there to join the great ice stream moving westward to Cook Inlet. * * * It is probable that the upper Cook Inlet region has been glaciated two or more times, but this has not been conclusively proved, for the last glaciers by their severe erosion removed the conspicuous evidences of the work of any glaciers that may have preceded them. * * *

The first glaciers by their erosion profoundly altered the shape of the basins through which they moved. They widened and straightened the valley floors and steepened the side slopes, giving the valleys a broadly U-shaped cross section. They also had a tendency to erode more rapidly at the basin heads than below, thus developing cirques, and left the gradient flattened below the cirques. During the glacial erosion and reshaping of the valleys the unconsolidated stream gravels were readily removed by the ice, and with them the contained placer gold, which was scattered among all the glacier-borne debris. It is presumed that such alterations were made in the Glacier and Crow Creek Valleys before the present rock canyon of lower Crow Creek was cut and also before the cutting of the old bedrock channels now exposed by the placer workings.

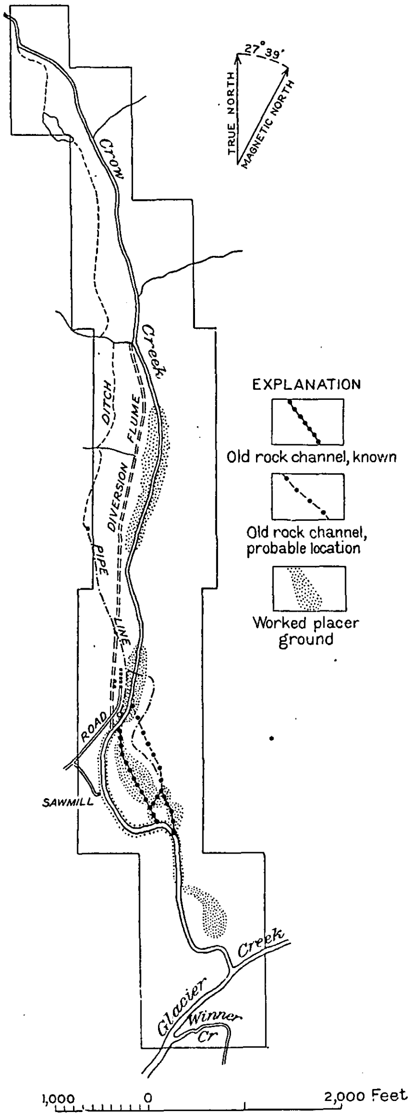

FIGURE 50.—Sketch map of claims of Holmgren-Erickson mine. Adapted from sketch by Frank H. Lascy.

With the retreat of these earlier glaciers the valley floors were again exposed to stream erosion. Apparently the floor of the Glacier Creek Basin had been deepened by glacial scour at the mouth of the Crow Creek Valley, and Crow Creek thus had an oversteepened gradient in its lower course and began to intrench itself in that portion of its valley and cut a deep canyon into bedrock. That canyon now appears as the deepest old channel uncovered by the placer-mining operations. It appears to be too steep-walled and to have too narrow a floor to be the bottom of the preglacial outlet from the Crow Creek Basin. The suggestion is therefore made that it was eroded in the interglacial stage between the last great ice advance and another that preceded it. Evidently, however, the cutting of the old canyon was not accomplished without interruption, for associated with it are other buried channels, similar to the deepest one, but not so well developed or so continuous. They represent episodes in the development of the main old channel but indicate that during its erosion it was at times dammed somewhere below, probably by the oscillating edge of the Glacier Creek glacier. When obstructed the bedrock canyon was filled by stream gravels. When the obstruction was removed the stream again intrenched itself along the same general course, first cutting through the gravel fill and then into the bedrock. Throughout most of its course each successive canyon coincided in alinement with the original one, and when bedrock was reached the deepening of the old canyon continued. Locally, however, loops of the later canyons departed somewhat from the course of the main channel, and in this way a network of buried canyons was developed. (See fig. 50.) Within these rock canyons and along the stream bed above and below them the placer gold from the eroded glacial till and the outwash gravel was again concentrated, though probably in deposits much less rich than those of preglacial time.

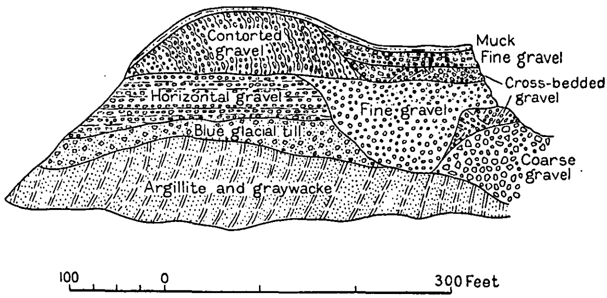

FIGURE 51.—Section on northeast side of the "big cut", lower Crow Creek, showing the relations of the glacial till and gravels to bedrock.

After the deepest old channel was eroded to its present dimensions this region was again subjected to intense glaciation, in which the ice further modified the land forms, in some places widening and deepening the valleys and in others disposing quantities of glacial debris either as morainal material or as stream-borne outwash gravel. Under the influence of the advancing Crow Creek glacier and impeded by a dam formed by the ice tongue in Glacier Creek Valley, the rock canyons on lower Crow Creek were filled with stream gravels and later completely overridden by the great glaciers that filled this whole basin.

The final retreat of the glaciers to their present positions was not a single continuous process but consisted of a long series of oscillations backward and forward, the sum total of the recessions being greater than that of the advances. The critical stage during this retreat, so far as the unconsolidated deposits of lower Crow Creek are concerned, was the time during which the Glacier Creek and Crow Creek glaciers had separated but were still not far apart. At this time an advance of only moderate extent by the ice in Glacier Creek was sufficient to impede the drainage from Crow Creek, and similarly a moderate recession of that ice tongue allowed the free escape of the Crow Creek waters. That such oscillations actually occurred is plainly shown by the section exposed on lower Crow Creek. (See fig. 48.) There the deposits of glacial till can mean only that the ice advanced over this area at least three times and that in the intervals between the advances stream gravels were laid down. Furthermore, it is believed that the unconsolidated materials there represent only the deposits made during the last great glaciation, and most of them were doubtless laid down during the final stages of retreat of the glaciers, the successive till deposits representing minor oscillations of the ice tongues. * * *

Upon the final withdrawal of the glaciers Crow Creek flowed over a broad valley floor of gravels and glacial materials that completely filled the bedrock channel of that stream and buried the rock canyons near its mouth. These unconsolidated materials locally had a thickness of over 250 feet. As the former obstruction to Crow Creek caused by the ice in Glacier Creek had been permanently removed, lower Crow Creek had a very steep gradient to its junction with Glacier Creek and descended in a series of rapids and falls. Erosion by the swift stream was rapid, the channel was soon cut to bedrock, and the excavation of the present bedrock canyon began. * * * In reducing its valley again, under the stimulus of a lowered and unimpeded outlet, it quickly cleared away the surficial deposits near its mouth, but in the hard rock of its canyon it made slower progress, and that canyon at its upper end still lacks about 80 feet of being cut down to the level of the adjoining buried rock channel. Above the canyon the stream gravels could be removed only as fast as the canyon bed was lowered, and the presence of a heavy fill of gravel in the valley bottom, extending from the head of the canyon up to the mouth of Crow Gulch, is the result of the protection from erosion given to it by the resistant rocks of the canyon.

POSTGLACIAL DEPOSITS

After the last retreat of the main ice stream high jagged peaks and ridges were left between the former ice lobes. Below these peaks and ridges high talus cones have collected. This talus in many places merges gradually into the glacier and stream deposits.

Hot-spring deposit.—A small area of travertine that appears to have been deposited by thermal springs has been found on the hillside southwest from the junction of Raven Creek and the Eagle River. This travertine is massive and almost unaltered. Although no water is flowing from these former springs at the present time, the deposits are probably not very old.

Volcanic ash.—The lowlands near the junction of Raven Creek and the Eagle River are covered on the surface with a thin layer of highly altered siliceous volcanic ash. The thickness of this ash averages about a quarter of an inch. The source of the ash is undetermined, as there are no known volcanic centers in the vicinity.

ECONOMIC GEOLOGY

HISTORY OF MINING

The history of mining in this region has been discussed in considerable detail by Moffit, Johnson, Capps, and Smith, in the reports already cited. Placer gold was discovered on California Creek in 1895 and on Crow Creek in 1896, although there was no production until 1898. There are few new developments in placer mining, and no new discoveries have been made since 1915. Work on lower Crow Creek has been the most active in the district, and hydraulic mining was being done during the summer of 1931.

The vein deposits on upper Crow Creek were located in 1909 by Conrad Hores, and development was begun in 1910. Work has been very sporadic since that time, and in 1931 only about 9 men were employed doing underground development.

PRODUCTION

The only mineral of economic value taken from this district is gold, and almost the entire amount produced has come from the placer mines. The total production of ore from the veins in the 5 years preceding 1931 is about 10 tons. No figures relative to the value of the minerals recovered are available, and the tonnage mined in the early days is unknown but not large.

Crow Creek is the only stream of economic importance in the district, as its drainage basin contains most of the placer ground as well as the most promising lode prospects. Minor amounts of gold have been taken from placer workings on lower Winner Creek and lower California Creek.

PLACER DEPOSITS

GENERAL FEATURES

The Girdwood district, in spite of the fact that the region has been severely glaciated at least three times, contains commercially workable placer deposits formed during preglacial or interglacial stages. The preservation of such deposits depends upon whether their location was such that they were not exposed to direct glacial scour. The known economically valuable deposits are in abandoned and filled stream channels. The time elapsed since the last glacial stage has apparently not been sufficient to allow large placer deposits to form.

Crow Creek has been practically the only productive stream in the district. This creek is fed by seven small glaciers, and the divides and peaks of its upper basin are exceedingly rugged. The creek is precipitous throughout its upper course, and the several falls and rapids are not favorable for the formation of large commercial placer deposits. At an elevation of about 1,500 feet the creek enters a gravel-floored valley, bordered by benches of alluvium. The stream has been diverted from its channel about a mile above its mouth and now flows through an old gorge that was cut during interglacial time and was later filled with gravel and covered with glacial debris and till. Most of the gold has been obtained from this and similar old buried stream channels. The history of Crow Creek has been given in some detail on pages 398–402, and sections through the placer deposits along its lower course are given in figures 48–51.

MINING PROPERTIES

CROW CREEK

The hydraulic workings of the Holmgren-Erickson property, on Crow Creek above the junction of Crow and Glacier Creeks, were the only ones in operation during the season of 1931. One 6-inch nozzle was used here, and 6 men were employed on two shifts of 12 hours each. The deepest old buried channel mentioned by Capps[21] has been cleaned out, and Crow Creek now drains through this channel. Mining efforts at the present time are being profitably concentrated on one of the shallower branch channels.

The gold is medium to coarse, although Capps[22] states that only a small proportion of nuggets have a value over 50 cents. The gold is bright and assays about $15 an ounce, or approximately the same as the gold obtained from the lode deposits of upper Crow Creek.

A. S. Erickson, one of the present operators, reports that the average run of till and gravel, exclusive of pay streaks, carries about an eighth of a cent of gold to the cubic yard. This sparse concentration of gold in the glacial debris is thought to preclude the possibility that the gold of the commercial deposit had its origin in this debris. The pay streaks are associated with rock of many types, but in all those seen the gravel and boulders are quartz diorite, intrusive rock of the same type as that found near the lodes at the head of the creek. Seams of yellow or blue clay commonly accompany the gold.

No quartz diorite has been found in the basin of Glacier Creek above Crow Creek, either in place or as float. The quartz diorite in the placers resembles that on upper Crow Creek, and the constant association of this quartz diorite with the pay gravel, as well as the physical similarity of the gold from the two areas, leaves little doubt that the source of the placer gold was in the lodes of upper Crow Creek. The economic deposits are formed in stream channels which were filled with debris during several later oscillations of the ice front.

The valley of Crow Creek for more than a mile above the Crow Creek Gold Mining Co.'s holdings is known as the Girdwood property. This property is patented, but no work has been done on it for several years. The ground is reported to have been adequately sampled and to be rich enough to mine. Mining was stopped as the result of a lawsuit brought by a company downstream from the Girdwood property in order to prevent dumping of tailings. Work has never been resumed, although at the present time it appears that mining could be carried on with little damage to the lower properties.

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[21] Capps, S. R., op. cit. (Bull. 642), p. 177.
[22] Idem, p. 184.

Some prospecting and work have been done on upper Crow Creek as far as the summit of the divide into the Raven Creek Basin. Colors may be obtained in many places, but no stratified gravel deposits of any size have been found, and no work is now being done. Colors may be panned on the hillsides below most of the prospects.

WINNER CREEK AND GLACIER CREEK

A small amount of gold was taken from lower Winner Creek some years ago. This gold is reported to be not so coarse as that on Crow Creek but of approximately the same composition. Quartz diorite is also present in the gravel, but its relation to the gold is not known. Similar quartz diorite occurs in several places on upper Crow Creek and on Winner Creek east of the area mapped.

Glacier Creek has undoubtedly had a complex history—an idea of how complex may be obtained from a study of the placer cuts in lower Crow Creek. The rock exposures on Glacier Creek above Winner Creek are very poor except in the gorge of the present stream. A thick mat of underbrush further conceals the rock outcrops. Traverses have been made on both banks of the stream, and in the past this valley has been subjected to considerable prospecting. At one time a trail was cut through the brush, and systematic prospecting was continued during one summer. It is reported that a single small color was found. Glacier Creek does not appear to contain the source of the gold on lower Winner Creek, because Glacier Creek appears to be gold-poor and because quartz diorite, which has not been found on upper Glacier Creek, is present in the gravel along lower Winner Creek. The similarity in fineness of the gold on Winner Creek to that on Crow Creek suggests that the two deposits may have the same source, but no evidence was seen that Crow Creek ever extended east of the present Glacier Creek Canyon. Some claims have been held for years on Glacier Creek below Crow Creek, but practically no mining nor prospecting has been done on any of them.

Winner Creek, like the other streams, has a complex history. The present creek flows for a long distance over a gravel-floored valley similar to the lowlands of Crow Creek. The stream has not always followed the same course, and even now rock slides force the channel from one side of the valley to the other. Winner Creek has a low, uniform gradient for at least 6 miles above the rock canyon in its lower valley. It is a clear-water stream, fed by small glaciers and sheltered snow fields. Small rock knobs or rounded knolls project through the gravel in places, and the impression gained is that these knobs have been at least in part carved by the stream, although the water now may flow entirely on one side of them. Similar conditions exist as far as the stream was traversed, a distance of about 7

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miles from its mouth. In prospecting Winner Creek it should be borne in mind that the present channel is of relatively recent origin and has had hardly enough time to form placers of economic value, even if gold is present. It is thought that if prospecting is concentrated on old stream channels or gravel bars the results are likely to be more fruitful. One man has been systematically prospecting Winner Creek from its mouth toward its source, on the assumption that the gold came from some point near its source. The prospecting should be greatly facilitated by the extension of the trail up Winner Creek, as under present conditions, owing to the matted growths of alders and other brush, the creek is very difficult to traverse.

CALIFORNIA CREEK

For several years a crew of men has been employed drilling and sinking test pits near the mouth of California Creek. Small quantities of gold have been found along the stream, but the occurrences are so erratic as to increase mining costs above feasible economical limits. Late in the summer of 1931 the operators decided to abandon the project, and the drill rig was removed to a locality near Hope, on the south shore of Turnagain Arm.

RAVEN CREEK

A few prospect pits have been sunk on Raven Creek, and some colors were reported to have been obtained. Eight claims were staked in 1929, but the owner was killed in an accident, and no work has been done since then.

VEIN DEPOSITS

STRUCTURAL FEATURES

The country rock of most of the vein prospects visited consists of finely banded argillite and graywacke. At the Eagle River prospect and also at the Brenner property the banded argillite and graywacke give way to a coarse, massive graywacke. The strike and dip of the rocks are extremely variable, although in general the strike parallels the axial direction of the mountains, about N. 15° E. The dips are steep east or west.

The nature of the country rock is a very important factor in the consideration of the formation of ore deposits. Shale, especially the tough, pliable types, yields by bending in preference to fracturing. Any fractures that are developed in it are usually of small dimensions and slight extent. Under pressure the rock tends to fill in all open spaces, much as putty would do under similar conditions. The result is obstruction to the flow of mineral-bearing solutions. Nevertheless, where these solutions have penetrated the country rock and have found conditions favorable for the deposition of their loads, exceptionally rich pockets may be formed.

In the Girdwood district some of the dikes are slightly mineralized, but in 1931 no work was being done on any of them. The mineralization was usually weak and erratic. It is questionable whether, under present economic conditions, any of the dikes seen will have a commercial value.

The veins are all small and irregular, along both the strike and the dip. Offshoots and branching veinlets are common. In some places the veins follow the dip and strike of the enclosing formation, but more commonly they cut the bedding, many of them at low angles.

As mentioned by Johnson,[23] there are in general two systems of veins, one trending slightly east of north and the other a few degrees north of west. The northward-trending system follows the general axial trend of folding and also the direction of pitch of the schistosity. The westward-trending system follows in general the direction of strike of the major joint planes, and in some places the veins and joints may coincide. The westerly set of veins also corresponds with the direction of flaw or minor tear faulting. Both sets of veins are mineralized, although most of the prospecting and development has been done on the east-west set.

Fracturing later than the mineralization is evident on both sets of veins. Mineralized quartz and country rock are shattered and recemented by a second generation of quartz, usually barren. Fragments of country rock are largely replaced, but recognizable remnants are commonly present. The latest movement has been along the east-west veins, and in places where the lodes cross, the north-south veins may be offset. As there has been considerable post-mineral movement, the relative ages of the two systems of veins is undetermined: they may have formed at nearly the same time, or the east-west set may have formed slightly later, as indicated at several crossings. These conditions are best illustrated on the surface above the Bruno Agostino mine.

Vugs are commonly developed in the veins but are usually small. Irregular comb structure is present, and the interstices among the quartz grains are filled with carbonates or the metallic minerals. Molybdenite and chalcopyrite are especially well developed in partly filled vugs.

The sulphides and quartz in many places form a crude banding which is broken and crossed by veinlets containing later barren quartz.

MINERALOGY

Gangue minerals.—Quartz is by far the most common gangue mineral in the ores. At least two and possibly more generations of this mineral are present.

[23] Martin, G. C., Johnson, B. L., and Grant, U. S., op. cit., p. 138.

Calcite in small quantities is a widespread constituent. This calcite in places is light yellowish brown and contains several percent of iron and magnesium; it grades toward ankerite. Aragonite containing small quantities of barium and strontium is present in a small vein on Ship Creek. Prehnite is a common constituent of the small veins in the greenstone.

Sericite is developed in both the veins and the nearby wall rocks. Although sericite is commonly widespread it is abundant only in a few localities. Coarse muscovite is found in many places but is especially common in the granitoid igneous rocks.

The wall rock of the veins is usually chloritized, and in many places chlorite imparts a greenish tint to the vein quartz. Small fragments of the wall rock included in quartz and almost entirely replaced by quartz can be identified by concentrations of chlorite. Small quantities of epidote are widespread, especially in the wall rocks.

Ore minerals and paragenesis.—The ore minerals identified include arsenopyrite, pyrite, marcasite, sphalerite, galena, chalcopyrite, molybdenite, and free gold containing 25 percent by weight of silver. Small grains of magnetite accompany the gold and may best be seen in the concentrates obtained by panning some of the ore. Native silver has not been seen by the writer, but Johnson[24] reports a nugget of this mineral found on Crow Creek.

Arsenopyrite is quantitatively the most abundant metallic mineral in the ore. It is also one of the earliest vein minerals formed and has been shattered and veined by most of the other constituents. Small corroded remnants of arsenopyrite are found entirely surrounded by later sulphides.

Pyrrhotite, although plentiful in the district, is seldom found with other sulphides. Some specimens of massive pyrrhotite have been obtained from the 50-foot level of the Brenner prospect, where it occurs in veinlets through arsenopyrite and is considered to have been deposited slightly later than the arsenopyrite. Some well-formed rhombic crystals of arsenopyrite are isolated in the pyrrhotite, and galena occurs along a few minute fractures through both of the other minerals.

The pyrite usually occurs in association with arsenopyrite, in veinlets and around grains of arsenopyrite, and in vugs. The relative age of pyrrhotite and pyrite are undetermined, but both are early minerals. Pyrite is shattered and cut by veinlets filled with quartz and later sulphides.

Sphalerite is the next youngest mineral after pyrite. The zinc sulphide occurs in veinlets through arsenopyrite and pyrite and is exceptionally rich in blebs of both galena and chalcopyrite. As both galena and chalcopyrite indicate in several ways that they are later than sphalerite and replace it, these blebs are thought to be due to a replacement of the sphalerite by the later minerals instead of to an unmixing of the constituents. Small, irregular-shaped fragments of arsenopyrite were also observed in the sphalerite.

The galena is thought to be younger than the sphalerite in most places, although the periods of deposition of these two minerals may overlap. Galena is found in fractures through arsenopyrite, pyrite, and sphalerite. It also occurs in blebs in sphalerite and around the peripheries of older mineral grains. When galena is polished and the surface slightly etched with nitric acid, small spots and needles of a silver mineral, probably hypogene argentite, may be seen along the cleavages. The presence of these small grains of argentite shows why galena commonly has a high silver content. Although the silver mineral is associated with galena, it does not follow that all of the galena assays high in silver; the silver distribution is sporadic.

[24] Martin, G. C., Johnson, B. L., and Grant, U. S., op. cit., p. 134.

The chalcopyrite is considered to be slightly younger than any of the sulphides so far considered, although here again the periods of deposition, especially of galena and sphalerite, may overlap. Chalcopyrite occurs with both galena and sphalerite in small veinlets through shattered arsenopyrite. Chalcopyrite is also found in veinlets through sphalerite and galena, although its relations with galena are not entirely clear. Some chalcopyrite in association with marcasite may represent a later generation, the deposition of which is possibly related to the present ground-water level.

Molybdenite is a common constituent in several veins but has not been identified in any polished sections, hence the time of its deposition in relation to the other minerals is unknown. Molybdenite occurs in partly filled vugs in quartz, but although common it is too sparse to be of immediate economic value.

Gold is the valuable mineral sought in this district. The metal in both the veins and the placer deposits contains about 25 percent by weight of silver and is of a very light yellow color. The gold is thought to be the latest metallic mineral to be deposited by ascending solutions. It occurs sporadically through the veins, in some places associated with galena, in some places with chalcopyrite, and in other places in veinlets through arsenopyrite. In some specimens the gold is found in stringers through quartz and is independent of the sulphides. There is no evidence that the gold is in any way related to the surface, and its intimate mixture with the sulphide minerals of undoubted hypogene origin indicates that it was deposited by ascending solutions. The mineral should continue in depth, but there is no reason to believe that the deposits will be richer in depth.

Marcasite has been identified in well-defined veinlets through some of the massive pyrrhotite from the Brenner prospect. The marcasite occupies only the sides of these veinlets, with quartz and chalcopyrite in the center. Owing to the fact that marcasite has been identified just below the water table and not above, it is thought that the marcasite is probably formed by near-surface processes. As the chalcopyrite is in veinlets with marcasite and in a few places cuts across the marcasite, this chalcopyrite is also considered supergene.

Covellite forms near the surface and has been observed veining and surrounding grains of chalcopyrite, galena, and sphalerite.

Cerusite, malachite, and scorodite are found in the iron-stained outcrops of the veins. Native copper has been reported from the Brenner prospect.[25]

OXIDIZED ZONE

None of the mines are very deep, but three of the tunnels on the Bruno Agostino property are between 100 and 200 feet below the surface. The Jewel tunnel at its face is about 100 feet vertically below the vein outcrop. The vein materials are partly oxidized in all these places, and limonite is abundant, especially along the vein walls and in the breccias. Thin films of scorodite are associated at many places with the arsenopyrite, and some cerusite and malachite may be found near the surface.

Owing to the recently glaciated condition of the region, it is somewhat unexpected to find the veins oxidized to a depth of more than 200 feet. Most of the veins studied are on steep hillsides,

[25] Smith, P. S., personal communication.

which in this region are almost entirely bare of vegetation and are well drained. The oxidation may be due in part to the steady rains and the melting snows, which cause a continuous and vigorous downward circulation of water during the summer. As the argillites are not readily permeable, the fractures and open joints receive an exceptionally large quantity of water, and the circulation is correspondingly greater.

The Brenner property, in the bottom of Crow Creek Valley, furnishes the only information available concerning the character of the veins below the water table. The amount of work done on this prospect is so little that generalizations for the district cannot be drawn from it with safety. The ground is oxidized more in the first few feet below the surface than farther down. The deepest oxidation seen is about 30 feet vertically below the collar of the shaft; below this are found quartz and a few fresh sulphides, with some supergene marcasite and chalcopyrite.

The oxidation everywhere is exceedingly erratic, and it is not at all uncommon to find entirely fresh sphalerite, pyrrhotite, or other sulphides cropping out at the surface. Unaltered pyrrhotite was observed in the outcrop of one of the irregular masses of quartz diorite. It is thought that the time interval from the last period of glaciation to the present is ample to account for the amount of oxidation. If the oxidation on the Brenner property is a safe criterion, it is indicative that the weathering is largely above the present water table.

The veins are commonly less resistant to erosion than the country rock, and as a result their position is marked by slight depressions. These depressions tend to retain mechanically part of the gold that was originally in the rock removed from the present surface. The exceptionally high assays obtained from many surface samples may be due partly to this mechanical and negative enrichment. The enriched zone probably averages less than 15 or 20 feet below the surface. Below this level the gold is in approximately its original position and the enrichment is negligible. Several available sets of assays serve to illustrate the effectiveness of mechanical enrichment.

There is no evidence pointing toward chemical enrichment of gold in this district.

GENESIS OF THE ORES

The argillite-graywacke series, especially in the vicinity of the mineralized veins, has been intruded by numerous dikes, sills, and irregular-shaped pipes or chimneys of quartz diorite.

Definite age relations between the sills and dikes and the veins are difficult to establish, as there were probably several periods of intrusion and possibly more than one period of vein formation. In some places veins cut dikes and sills; in other places definite offset of the veins along dikes is seen. Many dikes and sills, especially the finer-grained ones, are free of mineralization, although in some places they show later mineralized quartz stringers. The contacts of these dikes and sills and the wall rocks show very few effects of contact metamorphism; the country rock right at the contact may be entirely unaltered or at most slightly silicified.

Petrographically similar dikes and sills are common on Raven Creek and Ship Creek in areas that contain only very poorly mineralized vein prospects. Field conditions there appear at least as favorable as on Crow Creek, yet mineralized quartz is nearly absent. From this evidence it is thought that although many if not most of the dikes and sills probably originated from the same magma as the mineralized veins, nevertheless their genetic relationships are somewhat different.

The irregular, coarse-grained quartz diorite plugs and a few of their associated dikes illustrate somewhat different conditions. The country rock around these pipes is usually mineralized and shows pyrite, with later limonite, and some evidence of silicification and tourmalinization. The igneous rock is hydrothermally altered, and muscovite and sericite are developed. Some of the mineralized veins cut these intrusive masses, although rarely, if anywhere, are the veins confined entirely to the igneous rocks. The prospects being worked at present are all in close proximity to the quartz diorite pipes.

The impression obtained is that although all the dikes, the irregular plugs, and the veins may have a common origin, the relation between the plugs and the veins is much closer than that between the dikes and the veins. If these deductions are correct, the ground in the vicinity of the medium-grained quartz diorite plugs is more favorable for prospecting than that containing only the finer dikes and sills. There is no known reason why the quartz diorite plugs should be found only in the Crow Creek Valley. Adjoining areas should also be prospected, especially along the general axial trend of the mountains, north to N. 20° E.

FACTORS AFFECTING DEVELOPMENT

Transportation.—Most of the prospects are in the Crow Creek drainage basin, 9 to 11 miles from the railroad station. The road for 7¾ miles is graded and surfaced, but the remainder is narrow-gage or tractor road. The surfaced road is open to traffic for about 5 or 6 months of the year. The tractor road to the summit is under snow in its higher parts for about 10 months, but this time could be reduced by about 2 months, as much of the snow that remains in hollows and pockets could be almost entirely avoided by rerouting the road up the valley floor, with a few switchbacks below Crow Pass.

The ground is wet during the summer, and rock creep becomes considerable. Slides are of common occurrence. A slide in shale has given much trouble, as at intervals it covers and destroys a section of the tractor road. This particular slide is at present held back by a poorly adapted retaining wall. Some well-placed charges of powder should bring down enough rock to remove the hazard for a long time.

Most of the freight is brought to Girdwood from Anchorage, 38 miles by rail, unless shipped directly from Seattle. The distance from Seward to Girdwood is 75 miles. The approximate freight rates in 1931 are given below. Rates from Girdwood to the prospects vary with the location of the prospects, but average $8 to $12 a ton. Trucks and tractors may be hired in Girdwood.

Freight rates from Anchorage to Girdwood

	Rate for 100 pounds
Class 1. Automobiles, carts (passenger vehicles), wagons	$0.98
Class 2. Eggs	.83
Class 3. Gasoline	.69
Class 4. Mining machinery,[26] lime, coal	.59
Class 5. Groceries, canned goods [27]	.49

Explosives, two times class 1 (lots over 12,000 pounds one and a half times class 1, lots over 20,000 pounds same as class 1).

Through steamer and rail rates from Seattle to Girdwood range from an average of about $2.82 per 100 pounds of class 1 to $1.44 per 100 pounds of class 5. Cheaper rates may be obtained on larger shipments.

Favorable rates on ore shipments are given by the Alaska Railroad and the coastwise steamship companies. The rates from Girdwood to the smelter in Tacoma are $9 a ton for less than 10-ton lots, $7.50 a ton for 10 to 20 ton lots, and $6 a ton for lots of more than 20 tons. A $10 sample fee is charged at the smelter on small tonnages in addition to the regular smelter charges. It is possible to keep the entire shipping and smelting charges below $25 a ton on shipments of less than 10 tons.

Labor and wages.—All work at the vein prospects during 1931 was done by owners or men who have a share in the ownership. A small supply of labor may be obtained from the towns along the railroad, especially from Anchorage, at $4 a day and up, plus board and lodging. If a large number of skilled laborers is needed, they must be brought in from the States.

[26] More than 30,000 pounds rated as class B.

[27] For some kinds a higher rate is charged.

Timber.—The part of the Girdwood district near the mines is included in the Chugach National Forest, and permission to cut timber must be obtained from the Forest Service. The cost of hauling to the mines is the most expensive item in the cost of timber. Spruce and hemlock poles suitable for lagging are abundant in the nearby valleys and may be had for the cutting or a small additional cost. Culled railroad ties are often obtainable at the railroad, and these furnish good mine timbers at small cost. If longer or heavier timbers are needed, spruce and hemlock can be obtained from the sawmill on California Creek. The trees have a maximum diameter of about 4 feet and a maximum height of 75 to 100 feet, so that lumber large enough for most purposes is obtainable.

Water.—There are many small streams, and water is abundant. The glacier streams, the melting snow, and the frequent rains furnish plenty of water for ordinary mining and milling needs during the summer. A few springs do not freeze over entirely during the winter except for 2 or 3 months, and water for domestic use may be obtained from them. There is abundant snowfall, and if other sources fail snow water may be used. In one of the prospects a bulkheaded crosscut is used as an auxiliary reservoir.

Power.—Most of the streams, especially the larger ones, head in glaciers or small ice pockets. These streams are usually precipitous near their sources and during the summer furnish water power, which is used at the vein prospects. Storage sites for the development of water power are scarce, and at most of them the storage capacity would be small. During part of the winter most of the streams freeze entirely or their flows are so greatly diminished that they are useless for power development. It is necessary to use gas or oil engines while the streams are thus frozen. Gasoline, in drums, costs about 40 cents a gallon purchased in Anchorage and delivered at the mines.

METALLURGY

Very little study has been made of the metallurgy of these ores. The Bruno Agostino Mining Co. has had a mill test made of its ore, and a satisfactory milling process is thought to have been developed.

Much of the gold is free and should amalgamate with little difficulty. The high percentage of silver present in the gold may be somewhat detrimental, as alloys high in silver do not respond to amalgamation as readily as pure gold.

Part of the gold is intimately mixed with sulphides, mainly arsenopyrite, galena, and sphalerite, with small amounts of chalcopyrite. In order to free this gold fine grinding with the formation of a minimum of slimes is desirable. The sulphides, with most of the gold they contain, might be concentrated on tables and the concentrates then cyanided or shipped directly to the smelter. Owing to the complex nature of the ore selective flotation, which would be necessary if flotation were installed, probably cannot be used unless unexpectedly large tonnages of ore are developed.

The solution to the milling problems of the district appears to lie in the erection of a small mill, available to all the prospects. This would have a number of advantages. The prospects are small, and although the veins may locally be rich, it appears from the evidence obtained that the mines will remain small. Many of the veins cannot support an adequate mill alone, whereas for a group a mill might be economically profitable. Under the present practice the operator mines a small tonnage, then constructs some sort of plant and attempts to mill the ore. The result of this usually is that much time and labor are spent, often with little or no return. With a mill serving all, this unnecessary expenditure would be avoided and the operators could devote their entire time to mining. The cost of a mill, probably of 5 or 10 ton capacity, equipped with crusher, amalgamation plates, and tables, need not be very great, and with the cooperation of the prospect owners it might be profitable.

Approximately 5,000 tons of milling ore is available in the several prospects. This tonnage could probably be substantially increased if more development work was done. Fifteen samples taken at random from the veins gave assay values from a few cents to over $50 a ton, and samples collected from the region by other engineers and by owners are reported to assay as much as several hundred dollars. The gold is so sporadic through the veins that it is questionable if a fair estimate of the value of the quartz in general can be reached by ordinary hand sampling. A minimum mill grade of ore could possibly be maintained by hand picking of waste, if necessary.

MINING PROPERTIES

BRUNO AGOSTINO MINING CO.

The property of the Bruno Agostino Mining Co., controlled and operated by four men in partnership, is situated near the head of Crow Creek. Four mining claims, which have been surveyed for patent, are being held. A mill site adjoins the mining claims, and the company is also holding land for water-power development.

This group of claims was originally known as the Barnes property and has changed owners several times since. Control was obtained several years ago by the Monarch Mining Co. This company was taken over by the Crow Creek Mining Co., Inc., which has given a lease and option to the Bruno Agostino Mining Co. The last group pushed development vigorously during 1931.

The development of the property is planned to open two parallel veins, called by the owners the North and South veins. There is one adit 260 feet long on the North vein and one 267 feet long on the

South vein. In addition to this there are two crosscutting adits, one containing 295 feet of workings and the other 60 feet. (See fig. 52.) A lower adit, planned to crosscut the workings in depth, has been driven 190 feet. A winze on the South vein is open for 40 feet and is reported to be 10 feet deeper but filled with debris. There is also a 10-foot winze on the South vein. The total length of underground workings is 1,072 feet and the winze length more than 50 feet.

Most of the summer of 1931 was spent by the owners on the surface building and installing equipment so that mining could be started during the winter. Water power will be used as far as possible, and a pipe line for that purpose was being installed. A

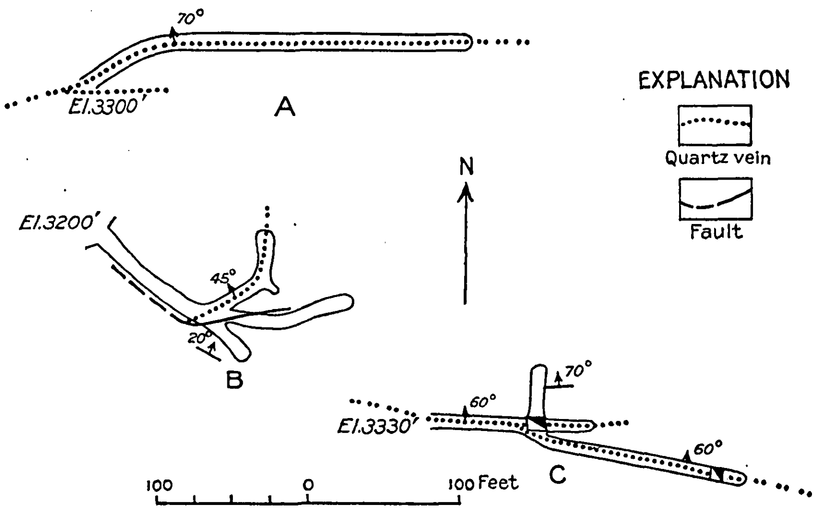

FIGURE 52.—Sketch map of the upper workings, Bruno Agostino mine.

building for a small mill and a compressor, a blacksmith shop, and comfortable living quarters have been constructed. It is planned to install a small tramway from the mine to the mill, a distance of about 1,200 feet.

The country rock is the thin-bedded argillite-graywacke series striking nearly west and dipping 40° N. near the mine. Many dikes and small, very irregular shaped intrusive bodies of medium-grained holocrystalline quartz diorite occur near the prospect. The country rock has been badly shattered in the vicinity of the veins, and part of the deformation is postmineral, resulting in brecciated vein materials, which in some places have been recemented and again fractured. The impression obtained is that there has been some continuous movement, possibly up to the present time. Both the North and the South veins are traceable several hundred feet along the strike.

The South vein ranges in width from 6 inches to about 4 feet, with an average of 9 inches in the tunnel. The strike is from east to S. 80°

E., and the dip is 55°–70° N. The gangue is either massive or sugary quartz. In some places the vein splits into several nearly parallel stringers, separated by gangue or by sheared and partly oxidized wall rock. The quartz is commonly stained with limonite, and in places scattered spots of sulphides are visible. Many fragments of country rock are isolated in the quartz.

The North vein strikes about N. 80° E. and dips about 70° N. Where exposed in the tunnel and in several surface cuts it is from 10 inches to 3 feet wide, with an average of 1 foot. The North vein appears to be somewhat better defined than the South vein and may be traced farther on the surface.

There are several small crosscutting veins 6 inches wide that strike a few degrees west of north and dip either east or west. These crosscutting veins appear to be faulted, and in the lower adit of the old workings the strike swings from due north to N. 45° E. The small veins striking north appear to be slightly older than the main North vein, as they are offset along unbroken quartz in the North vein. The junctions of the crosscutting veins with the South vein have not been seen, as they are obscured by a rock slide. The crosscutting veins of the north-south system are very persistent for this district, and one mineralized veinlet 6 to 8 inches wide was followed for more than 500 feet.

The strike of the cleavage in the argillite near the mine is in general slightly east of north; the strike of the bedding is about west, and the dip 40° N. From this it is seen that the North and South veins both cross the strike of the bedding at very low angles, about 10°. There is apparently no enlargement or change in the veins where they cross the somewhat obscured bedding planes. The veins are possibly formed along tear fractures developed between two main lines of stress and at an angle of about 90° to these stress lines.

The minerals include at least two generations of quartz, small amounts of calcite, galena, arsenopyrite, sphalerite, chalcopyrite, pyrrhotite, molybdenite, pyrite, and gold and silver. As noted on page 408, the silver, where not with the gold, seems to follow the galena. Considerable magnetite is found in the concentrates obtained by panning.

Late in the summer it was planned by the owners to abandon temporarily the tunnel that was being driven to cut below all the upper workings. The longest crosscut tunnel was to be continued to intersect both the North and South veins. A raise was planned to connect with the winze on the South vein. If this development is completed it should furnish a very good measure of the potential ore.

There is an old 1-stamp mill on the property. This mill was operated before the present owners obtained control and was used to extract gold from small lots of high-grade ore. Some exceptionally good returns were reported. This high-grade ore came from the surface of a small shoot on the south vein, and some very high assays have been obtained from the crushed quartz in this shoot.

Not enough work has been done in the district to obtain much evidence concerning the structural control of the ore shoots. The small but rich shoot on the South vein appears to be localized where there is a roll and flattening of the vein. With increasing depth the angle of dip changes from 55° to 70°. The vein in the lowest part of the workings, near the shoot, is complicated by the junction of one or possibly more smaller veins. These branch veinlets may be at least a contributing factor in the localization of the ore.

Several veins contain molybdenite, especially one vein in the bottom of Crow Creek and one of the so-called "crosscutting veins." A random sample on this crosscutting vein gave 0.26 percent molybdenum.

BAHRENBERG

The Bahrenberg prospect, at the head of Crow Creek, comprises the Hottentot, which was originally staked in 1910 by James Patchell as the Treasure Box claim,[26] and one other claim. The old location was allowed to lapse, and the claims remained vacant until restaked in 1926 by Henry Bahrenberg. The property is now owned by two men in partnership, and one of them spends his entire time at the prospect.

The country rock is mainly argillite (strike N. 25° W. and dip 45° E.), but along part of the vein one wall is quartz diorite. The occurrence of this quartz diorite is peculiar, as it is found in apparently detached blocks or lenses of different sizes from 6 feet in diameter up. There is evidence of some movement, but many of the walls are tight, and the impression gained is that the igneous rocks were, in general, intruded in their present positions.

The main vein strikes N. 80° W. and dips 80° N. The average width is about 8 inches, but the vein has not been prospected to a depth of more than a few feet. There is a shallow adit about 65 feet long and one small surface cut. It is possible to trace this vein only about 75 feet along the outcrop, as a branch of Raven Glacier covers the east end, and the country to the west is so precipitous that it is entirely inaccessible.

The property contains several other small veins, which have been superficially prospected. These veins strike nearly west and dip 70° N.

The gangue minerals of all the veins are quartz and calcite. The ore minerals include arsenopyrite, pyrite, galena, and sphalerite,

[26] Martin, G. C., Johnson, B. L., and Grant, U. S., op. cit., pp. 176–177.

with a few spots of visible gold. The gold appears to be in the quartz; the calcite is barren. In one of the veins the gold is associated with arsenopyrite and the galena is poor; in another vein the reverse is true—the galena is rich and the arsenopyrite valueless. Sphalerite is commonly associated with the galena.

From this property 7 tons of ore has been shipped to the smelter at Tacoma, and at the time of visit there was 8 tons sacked and at the base of the mountain. According to the operator one 3-ton lot brought a total of $125 and one lot of 1,500 pounds brought $145 above smelter and shipping costs.

An arrastre was constructed and put into operation during the later part of the summer of 1931. It was planned to save the concentrates and ship them to the smelter at Tacoma or store them for later extraction of the gold. Considerable difficulty was experienced in saving the gold in the finely divided sulphides, as the sulphides formed a scum and floated off with the waste water. According to the latest report this problem has been satisfactorily solved.

Owing to the location of the prospect transportation is a problem. The mine is about 1,000 feet above the tractor road and is separated from the road by two steep cliffs. Freight is taken over the lower of these two cliffs by means of a windlass, but over the upper 500 feet it is back packed or carried by a dog. The lowering of the ore is simple and cheap; the rock is tied in burlap ore bags, which are turned loose on the snow, then collected at the base of the hill.

The plans of the present owners call for an adit driven from the base of the upper cliff. This would probably require several hundred feet of underground working.

JEWEL

The Jewel prospect of four unpatented claims is owned by John Holmgren, of Girdwood. The prospect was originally located by a Mr. Whitney but has since changed owners several times. The property has gone through a period of overinflation and stock promotion with the usual results. The present owner bought the property at auction. The prospect is located near the head of Crow Creek and at one time had a complete mill outfit, water wheels and power equipment, compressor, assay office, bunkhouse, and a tramway from the tunnel to the mill. Snowslides have removed much of this equipment, but the bunkhouse and tramway are usable, as well as parts of the compressor and mill machinery.

The country rock is banded argillite and graywacke with strike and dip the same as the vein, strike S. 30° E. and dip 60° E. There are numerous intrusions of both medium and fine grained quartz diorite in the vicinity of this prospect, especially on the ridge east of it. The vein developed ranges in width from 2 inches to 1 foot and consists of quartz containing massive sulphides. One tunnel is driven about 145 feet along the vein. Late in the summer of 1931 a contract was given for 50 feet of drifting. Installation of a compressor and considerable development were planned for the next summer. The owner reports that the vein widens in the face to about 1 foot. The strike of this vein is S. 30° E. and the dip is 60° E. Several other small veins are present on the property, but no work has been done on any of them.

The minerals seen are quartz, arsenopyrite, chalcopyrite, pyrite, pyrrhotite, molybdenite, galena, and free gold. Limonite, cerusite, and scorodite form the oxidation products.

So far as known very little ore has been produced from this prospect—at the most only a few tons.

BRENNER

The Brenner prospect, owned and operated by Clyde Brenner, is situated in the bottom of Crow Creek and exposes a small vein which strikes N. 45° E. and dips 65° N. Two unpatented claims have been relocated along the strike of this vein.

The country rock near the vein is massive graywacke. On the west side of Crow Creek the vein is opened by a drift 175 feet long. At the start of the drift the vein averages 6 inches in width, but it gradually pinches down to a thin slip in the face. A 54-foot inclined shaft is sunk on the vein on the east side of Crow Creek, and two levels from this shaft extend along the strike of the vein. The upper level is about 30 feet in length and the lower level about 50 feet. A second vein, which strikes S. 35° E. and averages about 6 inches in width shows up in the shaft. The second vein is separated from the main vein by about 10 feet of graywacke. At the time the property was visited the lower level from the shaft was being driven to try to cut the intersection of these two veins. The main vein at places is as much as 1 foot wide in the two levels.

The gangue is quartz with a small amount of calcite. A few sulphides—galena, sphalerite, pyrite, pyrrhotite, arsenopyrite, molybdenite (?), and marcasite—are present. There are some green stains of copper carbonate in the tunnel.

EAGLE RIVER

The Eagle River property, originally known as the "Mayflower lode", is located on the south bank of the Eagle River just below the terminus of the glacier. The prospect has recently been restaked, but apparently little work has been done since Johnson[27] visited it in 1911.

The country rock is fine-grained massive graywacke with several large interbedded conglomerate lenses and minor quantities of argillite. The mineralization occurred along a sheeted zone that strikes north to N. 5° W. and stands nearly vertical or dips about 65° W. There are, in the vicinity, several parallel sheeted zones, separated by thin beds of graywacke. Two of these zones near the prospect are especially conspicuous, owing to the prominent iron-stained and silicified outcrops, from which all vegetation and debris have been removed by scouring of the ice. The most conspicuous zone is about 50 feet wide and may be traced for about 400 feet on the south bank of the river. The probable continuation of the same zone has been located on the hill north of the river.

Mineralized quartz stringers occur through the sheeted zones. North of the river the country rock is of the same type and is best seen in one of the numerous small gullies. The stringers vary greatly in width but all seen are less than 1 foot, and the usual width is 1 to 3 inches.

The mineralization produced sulphides in quartz with a few veinlets and spots of barren calcite. The metallic minerals, commonly almost entirely unaltered at the surface, are galena, pyrite, sphalerite, arsenopyrite (?), and chalcopyrite. Johnson reports a little malachite, but this was not seen during the present study. Malachite would be expected, as copper sulphide is present.

The silver content of the stringers, especially in association with the galena, may in places be considerable. Johnson gives an assay of gold 0.05 ounce and silver 24.80 ounces to the ton. More recent assays of samples collected by prospectors are reported to give returns of similar proportions, with silver content ranging from 10 to 25 ounces to the ton. Little work has been done in the prospect, as the gold content is discouraging, and in this region gold has been the metal most sought.

OTHER PROSPECTS

Throughout the district but especially near the headwaters of Crow Creek there are many small veins, in places mineralized. Many of them have been or are staked and have been worked a little. The veins are of the same type as those already described and are without exception irregular along both the strike and dip.

It is reported that one small vein was worked late in the summer of 1931. This vein is on the east side of Summit Mountain, west of the Bahrenberg prospect. Some rich float was reported to have

[27] Martin, G. C., Johnson, B. L., and Grant, U. S., op. cit., p. 178.

been found just below the outcrop, and some digging had been done on the surface in previous years. The country rock is banded argillite and graywacke, badly distorted and intruded near the vein by an irregular mass of medium-grained quartz diorite. The strike of the vein is N. 30° W. and the dip is 60° W.

Some work has been done on a vein in Crow Creek just southwest from the end of the surfaced road. The country rock is banded argillite and graywacke. The vein, where exposed in an open cut, averages about 7 inches in width but ranges from 1 inch to about 2 feet. Galena, pyrite, and limonite are present in a quartz gangue. The vein strikes S. 50° E. and dips 40° W. The quartz is badly shattered, apparently by postmineral movement. A sample taken from a 2-foot cut assayed gold 0.01 ounce to the ton, silver 1.4 ounces to the ton, lead 1.12 percent. Numerous small mineralized stringers were seen on the steep mountain side south of this property.

A little prospecting has been done on the northeast slope of Ragged Top Mountain, near an irregular-shaped intrusive plug. Several small but well-mineralized quartz veins are exposed. These veins cut both the intrusive rock and the banded argillite and graywacke.

SUMMARY AND RECOMMENDATIONS

The Girdwood mining district contains many small quartz veins in argillite and graywacke and the placer deposits resulting from the breaking down of these veins. The economically valuable mineral is free gold, but sulphides are commonly present. The gold usually occurs in small bunches or pockets. The veins are irregular, along both the strike and the dip. They appear to be genetically related to irregular plugs or pipes of quartz diorite.

In estimating the possibilities of the veins of this district several factors must be considered. The prospects are located in a region of severe winters, but the difficulties due to climate are by no means insurmountable, and it is entirely feasible to work throughout the winter. The favorable and unfavorable features concerning development of the district are summarized below.

Favorable features:

- High grade of the ore pockets.
- Probable continuation of the gold in depth.
- Abundance of granitoid siliceous igneous rocks, especially small pipes.
- Cheap timber; vein walls require but little support.
- Few pumping problems.
- Abundant water supply furnishing cheap power for small operations.

Unfavorable features:

- High cost of development and mining owing to the type of deposit and the spotty character of the gold in the veins.

Unfavorable features—Continued.

- Unfavorable geologic character of the country rock for the development of large, persistent veins or breaks.
- Weak mineralization, as shown by the small extent of contact metamorphism.
- Absence of any wide-spread intensive alteration of the country rock (sericitization, chloritization, silicification, etc.).
- Tightness of the wall rocks.
- Lenticular character of the veins and tendency to finger out into many small, widely scattered stringers.
- Exceptionally strong, persistent winds and frequent snow and rock slides, which may cause additional expense.

There seems to be very little if any hope for the development of a mine of large tonnage. There are, however, several small properties which, if carefully managed, should be developed at a profit. The best method of handling these small veins appears to be to stay close to the ore.

Numerous other veins in the district are well mineralized, but they are small and irregular and in some places nearly inaccessible. There is a chance that some of them may be developed in the future.

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