THE TURNAGAIN-KNIK REGION.

By STEPHEN R. CAPPS.

INTRODUCTION.

LOCATION.

The Turnagain-Knik region, as here defined, includes the area bordered on the north and northwest by Knik River and Knik Arm and on the south by Turnagain Arm, Portage Creek, and Portage Glacier. As thus outlined the region is roughly triangular in shape and lies between latitude 60° 45′ and 61° 30′ and longitude 148° 30′ and 150° 5′. (See Pl. VI.) On its eastern edge the area studied is bordered by rugged unexplored mountains with glacier-filled valleys, in which travel is slow and difficult. The area of the present investigation was limited in that direction to the more accessible valleys, with the object of covering as much ground as possible within the field season.

PREVIOUS INVESTIGATIONS.

The first geologic investigation in this region was made in 1898, when W. C. Mendenhall,[1] who was attached to a War Department expedition in charge of Capt. E. F. Glenn, crossed from Portage Bay over Portage Glacier and descended Portage Creek for a few miles before returning by the same route. A few weeks later he traveled up Glacier Creek and its tributary Crow Creek to the divide and descended Raven Creek and Eagle River (Yukla Creek) to its mouth. In 1904 F. H. Moffit, while studying the gold placers of the Turnagain Arm region[2] visited the placer mines on Crow Creek and prepared a full description of the mining developments at that time. In 1911 B. L. Johnson and later A. H. Brooks, G. C. Martin, and B. L. Johnson made observations from Kern Creek to the head of Crow Creek and for a few miles into the head of Raven Creek valley. The information then obtained by them and procured from other sources was embodied in a description of the mining

[1] Mendenhall, W. C., A reconnaissance from Resurrection Bay to Tanana River, Alaska: 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, 1907.

operations in the Glacier Creek basin.[1] Topographically a large part of this district is still unmapped. In 1898 Mendenhall[2] sketched the topography along his route, and in later years R. A. Hamilton, R. H. Sargent, and T. G. Gerdine sketched the portions of the mountain front that were visible from tidewater. B. L. Johnson also elaborated Mendenhall's mapping of the Crow Creek basin.

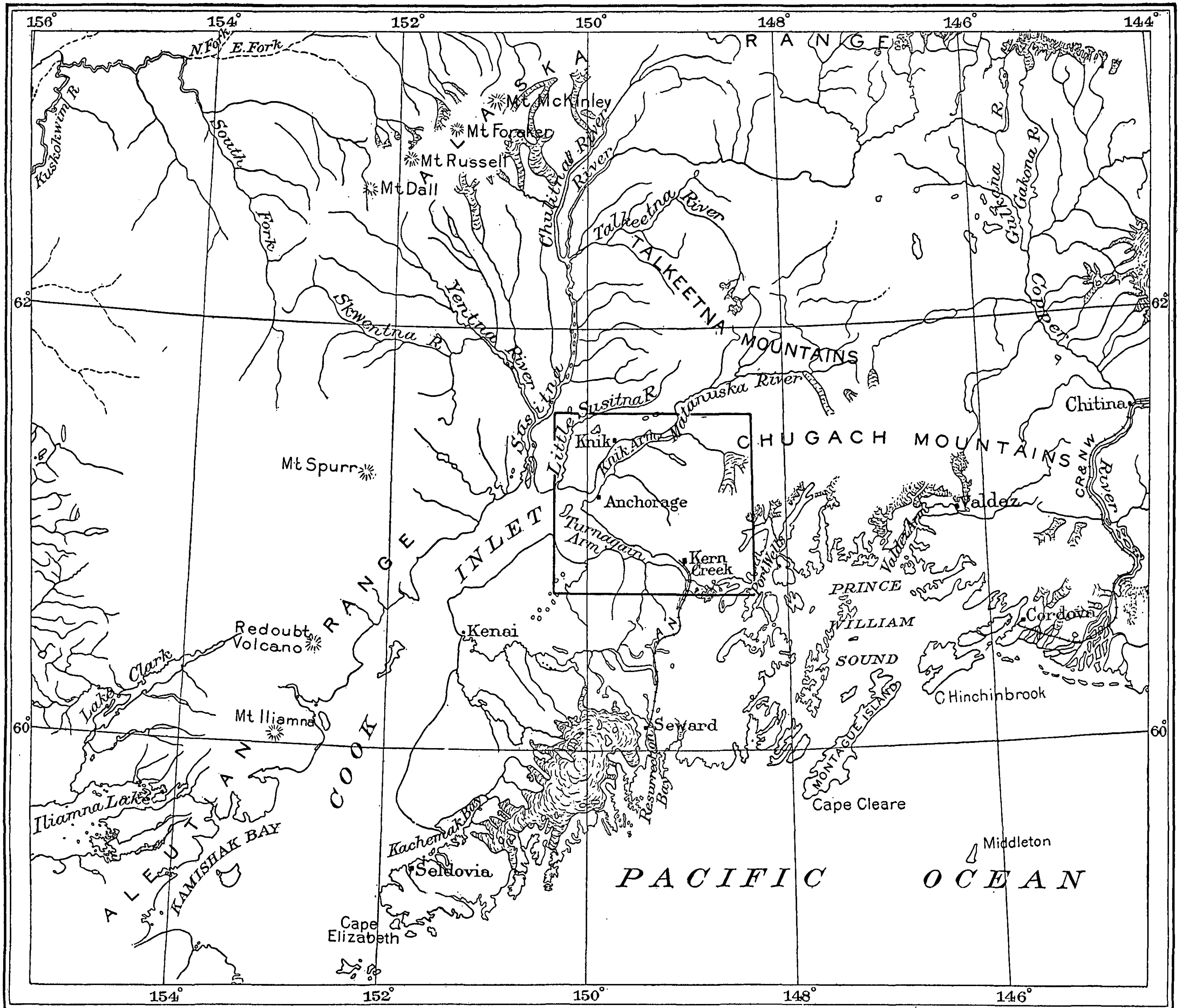
FIELD WORK.

With the announcement that the Seward-Fairbanks route had been chosen for the Government railroad, attention was immediately attracted to those portions of Alaska that would be directly served by this railroad. The route, following the north side of Turnagain Arm and the southeast side of Knik Arm, will bring railroad transportation within easy reach of the entire Turnagain-Knik region, and a large influx of people attracted both by the work incident to building the railroad and by the agricultural possibilities was readily foreseen. It was determined, therefore, to survey the entire region, both topographically and geologically. For this purpose two parties were organized, one in charge of J. W. Bagley to conduct the topographic surveys, and the other in charge of the writer to carry on the geologic work. Mr. Bagley landed at Ship Creek on June 3, 1915. At that time a tent town had already sprung into existence, and active construction on the railroad had begun. In burning the timber and vegetation on the right of way, however, a great amount of smoke was formed, and this was increased by numerous forest fires. The smoke was so serious a detriment to topographic work that on June 13 Mr. Bagley transferred his party to the Talkeetna Mountains. He returned to Anchorage in September and succeeded in extending the topographic mapping up Ship Creek, down Indian Creek to Turnagain Arm, eastward along the arm to Glacier Creek, up that stream and its tributary Crow Creek to the divide, and thence down Raven Creek and Eagle River to Knik Arm.

The writer, with a party consisting of a packer and a cook and five pack horses, arrived at Anchorage June 14, 1915, and remained in the district until September 1. Although the thick smoke caused considerable annoyance and delay, an area of about 1,400 square miles was mapped geologically. Unfortunately no topographic base map was available for a part of this area, and the mapping of the rock formations, as shown on Plate VIII, is the result of work on sketch maps made under unfavorable conditions. The outlines are therefore subject to modification when a more accurate base map

[1] 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.

[2] Op. cit., map 16.



INDEX MAP SHOWING THE LOCATION OF THE TURNAGAIN-KNIK REGION.

becomes available. The microscopic study of the rocks here described was made in the office by J. B. Mertie, jr.

GEOGRAPHIC FEATURES.

The Turnagain-Knik region may be divided into two provinces of distinctive and sharply contrasting topography. The smaller province consists of the lowland that borders Knik Arm throughout its length and Turnagain Arm for 12 miles southeast of Point Campbell. The lowland area has a maximum width of about 10 miles at its southwest border, near Point Campbell, but narrows gradually northwestward to the mouth of Knik River, where the river flows directly against the base of the mountains. This lowland is in fact an extension of the great lowland of the lower Susitna Valley, though separated from it by the shallow waters of Knik Arm. It consists of tidal flats near the water's edge and terraces and low rolling hills, commonly not exceeding 500 feet in elevation, farther inland. The tidal flats may be divided into two classes—those inundated at ordinary flood tides and those covered only at extreme tides but generally above tide level. The flats within the range of the average tides are expanses of blue-gray, sticky silt, bare of vegetation and cut by canyon-like gullies. In this area the extreme tidal range is great, being 33.6 feet at Fire Island and 38 feet at Anchorage, and as both Knik and Turnagain arms are shallow, wide areas along their shores are laid bare at low tide. Above the height reached by ordinary tides but below the level of the extreme tides there are, especially near the mouths of streams, flats that are inundated only at long intervals. These flats form grassy meadows or marshes but carry little or no timber. The remainder of the lowland area consists of flat-topped terraces and rolling hills, which gradually increase in elevation toward the mountains but show a sharp topographic break along the mountain face. They are generally timbered, though the forests are broken by marshes and meadows in the areas of poor drainage.

The other topographic province, which is much the larger of the two, consists of the mountainous part of the area. Turnagain Arm, on its south border, is a glacial fiord along which the mountains descend precipitously to sea level, there being practically no lowland except along the lower courses of the larger streams. However, a considerable area of bare tidal flats is exposed during low tide. The mountains are the westward extension of the Chugach Mountains, which reach from Cook Inlet to Mount St. Elias and which are continued to the east by the St. Elias Mountains and to the southeast by the Kenai Mountains. They are distinctly alpine in character, all the larger streams that flow from them heading in glaciers. The higher peaks in the center of the district reach elevations of 5,000 to 7,000 feet or more.

As the district is bordered on the south and northwest by tidewater, the streams in general have direct courses to the sea, are of steep grade, and have few tributaries. The valleys all show plainly the effects of severe glaciation. Knik River is much the largest stream, although only about 30 miles long. It heads in the great Knik Glacier and flows in a westerly direction to the head or Knik Arm. All its tributaries from the south, except one unnamed stream 7 miles below the glacier, are comparatively small. Eklutna Creek, Peters Creek, and Eagle River (Yukla Creek) all flow northwestward to Knik Arm. Each heads in ice fields, and the waters of Eklutna Creek and Eagle River are predominantly of glacial origin. A few smaller streams, the largest of which is Ship Creek, flow from this mountain mass into either lower Knik Arm or Turnagain Arm. Turnagain Arm has several large tributaries from the north and east. Portage Creek drains Portage Glacier and several smaller ice tongues and, although only 6 miles long, carries at times a large volume of water. Twentymile River emerges from two large ice tongues and joins Turnagain Arm at its head from the northeast. Glacier Creek, as its name implies, is fed by a number of small glaciers, and Bird and Indian creeks also carry portions of the drainage from the mountain mass to Turnagain Arm. In general the streams tributary to Turnagain Arm are much shorter than those flowing to the northwest.

ROUTES OF TRAVEL.

This part of Alaska is accessible only by ocean steamship, and two lines maintain regular schedules between Seattle and ports on the Gulf of Alaska. During the summer season steamships make regular calls at Anchorage, on Knik Arm, and although no docks had yet been constructed in 1915, passenger and freight were discharged at receiving barges and taken ashore by small boats. From Anchorage small launches connect with all upper Cook Inlet points and make trips up Susitna River as far as the mouth of Talkeetna River. Anchorage is the summer terminus of the new Government railroad from the coast to Fairbanks, by way of Susitna Valley. The rails on this line were laid from Anchorage to Eagle River in 1915. The ultimate coastal terminus of this railroad is Seward, and during the winter, when ice forms in upper Cook Inlet and navigation is closed, all travelers bound for the Knik-Turnagain district land at Seward. The old Alaska Northern Railroad, now incorporated into the Government railroad system, extends from Seward northward for 71 miles to Kern Creek, on the north side of Turnagain Arm, beyond which it had not been completed in 1915. When in operation this road could be used by travelers from Seward to Kern Creek, but for the last two or three years it has not been regularly operated. The route of the railroad line was used, however, by winter travelers journeying afoot or by dog sled from Seward to upper Cook Inlet and thence across the Alaska Range to Kuskokwim and lower Yukon rivers, and the mail was carried by dog sled over this route. From the terminus of the railroad at Kern Creek the winter trail follows the north shore of Turnagain Arm eastward to Indian Creek, ascends that stream to its head, crosses the divide to Ship Creek, follows that stream down to the base of the mountains, and thence goes around the shore of Knik Arm to the town of Knik. The old winter trail ascended Glacier and Crow creeks to Crow Creek Pass and thence followed Raven Creek down to Eagle River and that stream down to Knik Arm. This trail was well graded, at the cost of much labor, but the high winds prevailing at Crow Creek Pass in the winter led to its abandonment in favor of the Indian Creek and Ship Creek route. In the fall of 1915 the work of reopening the railroad from Seward to Kern Creek was begun, and as soon as the line is built between Kern Creek and Anchorage the district will have rail communication with Seward the year around. A telephone line from Seward to Anchorage is already in operation.

As throughout the winter foot travel to this district has been slow and difficult and the cost of transporting freight almost prohibitive, and as even water transportation during the summer has until recently been irregular and unreliable, the completion of a railroad with continuous service to the region will be of inestimable value in the development of its agriculture and mineral resources.

VEGETATION.

Within the area here described timber occurs throughout the lowlands, in the valleys of the larger streams, and on the lower slopes of the mountains. No general statement of the height of timber line can be made, for it varies greatly from place to place. The lowland between Point Campbell and the head of Knik Arm consists of timbered areas interspersed with treeless meadows and marshes. Timber in general extends up the mountain slopes to altitudes between 1,500 and 2,000 feet. The prevailing trees are spruce and birch 18 inches or less in diameter. Locally there are cottonwood groves, some of the trees in which attain a diameter of 4 or 5 feet. Timber is found along the lower slopes of Knik River valley almost to the glacier and also extends up the valleys of Eklutna, Peters, and Ship creeks and Eagle River for many miles above the mountain front. In general it may be said that the timber of the Knik Arm basin is too small to furnish lumber for other than local needs. In the Turnagain Arm basin the timbered area is small, but the trees are of much greater size. Along the lower slopes of the mountain and in the larger tributary valleys there is a good stand of spruce and hemlock, in which individual trees attain 4 feet in diameter. Plate VII shows the distribution of timber in this region.

A list of the trees and larger bushes seen includes spruce (two species), birch, hemlock, cottonwood, aspen, several varieties of willows, alder, and mountain ash, and the smaller bushes include devils club, currant, high-bush cranberry, raspberry, buck brush, blueberry, and roses.

Grass for forage is abundant on the highest tidal flats but is scarce in the timbered and marshy lowlands. On the timbered mountain sides sufficient grass of the variety known as red top can nearly everywhere be found and near timber line is usually present in great abundance. At still higher altitudes bunch grass is to be found locally, so that pasturage for stock is plentiful in all the larger mountain valleys.

GAME.

Some big game still exists in this district, although it is not particularly abundant. Moose range the Knik lowland and its tributary valleys, although it is to be expected that they will rapidly disappear from the vicinity of the railroad. Mountain sheep were seen in the rugged mountains at the heads of Peters and Eklutna creeks and of Eagle and Knik rivers, and goats occupy much the same range as the sheep. Black, brown, and grizzly bears are occasionally seen. Trout may be caught from nearly any clear stream, and grouse are fairly abundant in the spruce forests. Both willow and rock ptarmigan occur in great numbers above timber line; the willow ptarmigan haunt the areas of willow brush and high grass, and the rock ptarmigan prefer the high, nearly barren talus slopes and glacial moraines.

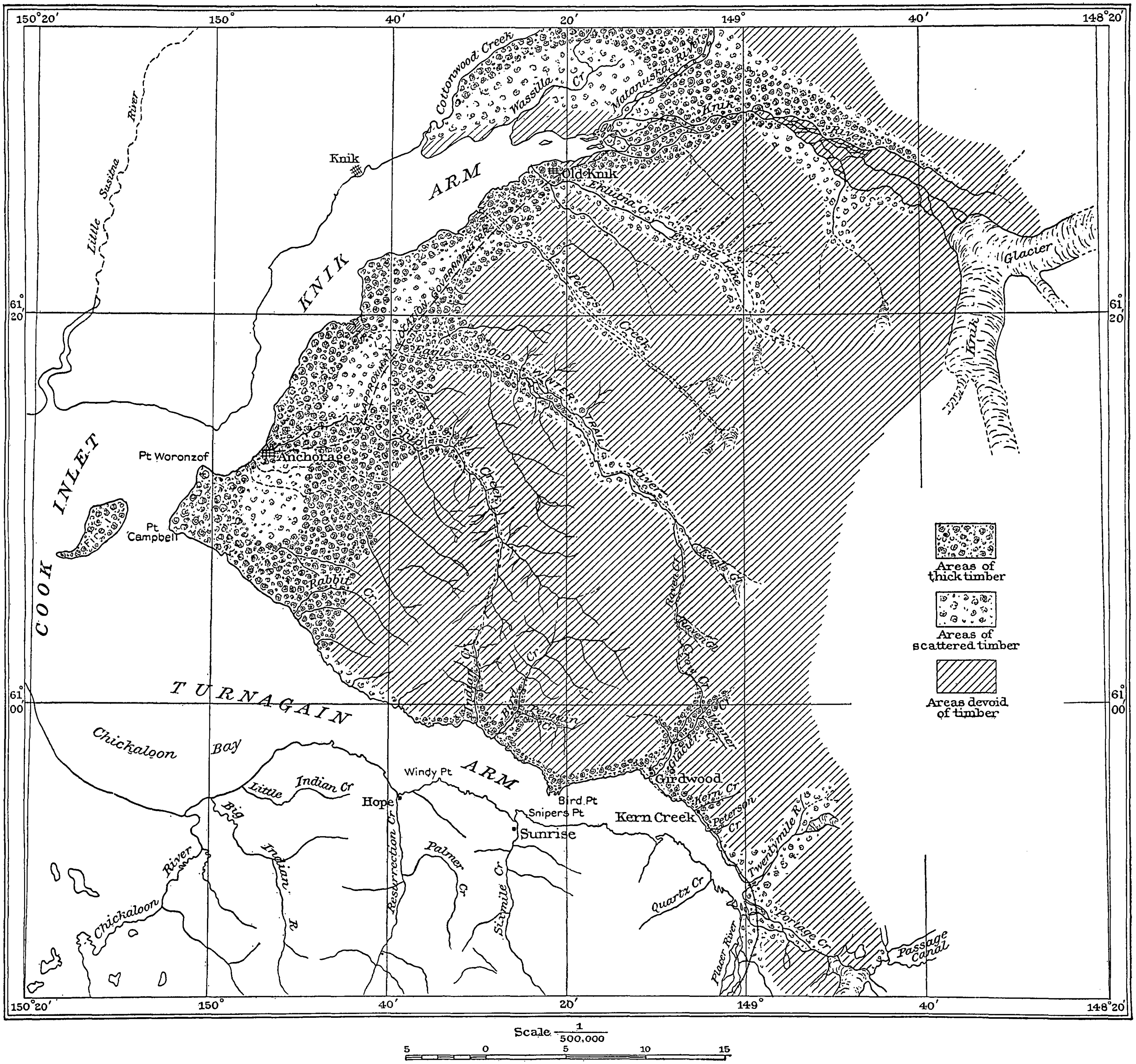
NATIVES.

Very few Indians were seen during the summer, as at that season they move to their favorite streams to catch and dry salmon for winter use. At Old Knik, near the head of Knik Arm, there is a village containing a few dozen houses and a church, all deserted at the time of the writer's visit. The natives are said to return to their homes in the fall and to spend the winter in trapping and hunting.

GEOLOGY.

PRINCIPAL FEATURES.

The rocks of the Turnagain-Knik region comprise a wide variety of materials and include sedimentary rocks in large volume and also abundant material of igneous origin, ranging from coarsely granular



SKETCH MAP SHOWING THE DISTRIBUTION OF TIMBER IN THE TURNAGAIN-KNIK REGION.

intrusive rocks to surface lava flows and beds of fragmental volcanic material. A study of the field relations of the rock formations has yielded some definite data in regard to their relative age, but actual age determinations have not yet been made. The accuracy with which any rock formation can be placed in its proper position in the geologic time scale must depend upon the fossils found in it or upon its relation to other fossil-bearing rocks. Unfortunately, the rocks of the region here discussed are peculiarly barren of fossils. Fossils have been found in only one formation and only a small area where specimens of a single species of doubtful diagnostic value were obtained. The age of the hard-rock formations is therefore still uncertain and must remain so until either satisfactory fossil collections are procured or the structural relations to some other associated formations, the age of which has been determined, are made out.

Plate VIII (p. 188) is a sketch map showing the geology of the region here discussed.

What are apparently the oldest rocks of the region occur along the west end of the mountains, in a belt that varies in width from north to south, being narrowest at its north end, near the mouth of Knik River, and widest toward Turnagain Arm. This belt probably continues southward on the south side of Turnagain Arm, but its extension in that direction is only surmised. The rocks in this belt can not be referred to any single rock type, for they comprise a wide variety of materials, all more or less metamorphosed. They include basic intrusive rocks, locally altered to serpentines, and altered intrusive rocks of a more acidic character, associated with much altered and crushed materials that are probably of sedimentary origin and some less altered slates. This whole assemblage has apparently been metamorphosed together, so that its structure is obscure. It comes into contact with both the slate and graywacke series and the greenstone tuffs described later and appears to be older than either.

Succeeding the metamorphic series is a great aggregation of argillites, slates, and graywackes, with minor amounts of conglomerate. These beds prevail along the north shore of Turnagain Arm from Indian Creek eastward to Portage Glacier and extend northward to the basins of Peters and Eklutna creeks and Knik River. They commonly strike in a northeast direction, have steep dips, and have locally been closely folded and faulted. They are known to contain beds of Mesozoic age, but their age limits have not been determined.

Next younger than the argillites and graywackes is an assemblage of greenstone and rhyolite tuffs, agglomerates, and flows, with some included clastic sediments. They occupy an area in the headward basins of Eagle River and Peters and Eklutna creeks and also occur on the south side of lower Knik River. These rocks are several thousand feet thick and lie with apparent unconformity upon both the argillite and graywacke series and the older undifferentiated rocks.

The youngest deposits of the region consist of unconsolidated materials, including morainal and outwash deposits laid down by the greater glaciers that formerly occupied the region and by the existing ice streams and also the gravels, sands, and silts of the present streams and the silts now accumulating in Knik and Turnagain arms. The unconsolidated deposits are most abundant in the lowlands of Knik River and Knik Arm, where they mantle the surface and attain a considerable thickness. It is not unlikely, however, that bedded materials of Tertiary age occur within this area, although for the most part covered by younger beds. Reports have been received that coal beds crop out along the shore of Knik Arm between Ship Creek and Point Woronzof, but these reports have not been confirmed.

UNDIFFERENTIATED METAMORPHIC ROCKS.

DISTRIBUTION AND CHARACTER.

The western part of the mountainous province of this region is occupied by an undifferentiated assemblage of rocks all of which show the effects of regional metamorphism. The area in which they occur is widest at the south and narrows gradually toward the north, ending in a point along the south side of lower Knik River. It includes all the mountainous portions of the basins of Rabbit, Campbell, and Chester creeks, most of the basin of Ship Creek, and parts of the lower basins of Eagle River and Peters and Eklutna creeks. The south shore of Turnagain Arm, west of Hope, has not been studied geologically, but such information as could be obtained indicates that this belt of undifferentiated rocks extends southwestward across Turnagain Arm. It is entirely possible that the area of these rocks shown on Plate VIII includes also some rocks that should properly be classified with the greenstones and greenstone tuffs described on pages 161–165, for time was not available in the investigation on which this report is based to follow out accurately the contracts of the several lithologic units.

The undifferentiated rocks of this assemblage comprise a wide variety of materials. They include altered igneous rocks of acidic composition that under the microscope prove to be altered andesites and andesite porphyries and basic rocks consisting of peridotite, dunite, serpentine, pyroxenite, altered gabbros, and tuffs and agglomerates of igneous origin. They also include altered argillites, graywackes, and cherts of sedimentary origin. This whole assemblage has been cut by both basic and acidic dikes and probably by the bosses of diorite that project through the unconsolidated deposits near the mouth of Knik River.

STRUCTURE AND THICKNESS.

As a whole this assemblage of rocks is difficult to study in the field, for even in the members of sedimentary origin the structure is obscure, and the igneous members have apparently no consistent relation to the sediments. Furthermore, all the rocks are generally so altered and weathered that determinable specimens are not easily obtained. As seen from a distance, however, the mountains composed of these rocks locally display a semblance of structure, due in part to jointing and possibly in part to the bedding of the included sediments, that seems to parallel in strike the line of contact with the younger bordering formations. On close inspection this structure is less evident. Along the shore of Turnagain Arm west of Indian Creek the contact between this assemblage of rocks and the argillites and graywackes 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.

No definite figures for the thickness of these materials were obtained. The belt which they occupy has a maximum width of 10 to 12 miles, and near Turnagain Arm mountains composed entirely of them reach altitudes of 5,000 feet. The rocks certainly have a thickness of several thousand feet, even though the present surface area is the result of reduplication by faulting and folding.

AGE AND CORRELATION.

The age of this assemblage of undifferentiated rocks is still undetermined. The most that can now be said concerning their age is that they lie with apparent unconformity below rocks of the Sunrise group, which are known to be in part of Mesozoic age. The Sunrise group may, however, contain also some Paleozoic sediments, though as yet no Paleozoic fossils have been certainly identified. As the Sunrise group is known to contain fossils of either Jurassic or Cretaceous age, the undifferentiated rocks here discussed may be said to be certainly older than the late Mesozoic, and so far as the evidence now available goes they may be Paleozoic or even older.

UNDIFFERENTIATED ARGILLITES, SLATES, AND GRAYWACKES.

GENERAL CHARACTER.

That part of the Turnagain-Knik region lying east of a line connecting the mouth of Indian Creek and the mouth of Knik River consists predominantly of metamorphosed sedimentary rocks, including argillites, slates, and graywackes, with minor amounts of conglomerate, quartzite, and limestone. (See Pl. VIII.) Within this area there are some smaller areas of younger igneous rocks, but the sediments form the base upon which the igneous rocks were poured out or the host into which they were intruded, and the sedimentary series is believed to be continuous throughout the area outlined, although it is locally covered by the younger deposits.

The materials of this great sedimentary series were laid down in comparatively shallow water, and with the exception of a very small amount of impure limestone, they represent the clastic materials derived from some old land mass, the position of which is not now definitely known. The sediments as deposited consisted of muds, feldspathic sands, and gravels, but these materials were later converted through the agencies of heat and pressure, by cementation and by regional metamorphism, into shales and slates, graywackes, and conglomerates, with here and there small areas of schist.

The commonest member of this series consists of thinly interbedded argillites and graywackes. The graywackes are of lighter color than the argillites and the two present a banded, ribbon-like appearance. Locally the alternating bands are thin, ranging from a fraction of an inch to a few inches in thickness, but every gradation from thinly bedded materials to massive beds of argillite or of graywacke 100 feet or more in thickness may be found. Within certain small areas either the argillite or the graywacke may predominate, but the series as a whole contains argillites and graywackes in approximately equal amounts.

The sediments of this series have been metamorphosed in varying degrees and are now all hard rocks. The metamorphism is mostly that resulting from cementation and from regional folding and tilting, and only locally has there been notable contact metamorphism along the margins of bodies of intrusive rocks. The rocks resulting from the metamorphism of the originally incoherent shallow-water sediments are quite different in appearance from the materials as they were first laid down. The feldspathic sands have been changed by cementation to hard graywackes, the muds to dense argillites, and the gravel beds to conglomerates. Deformation has produced in places a secondary slaty cleavage, and the group term "slates and graywackes" has been much used to describe this great series of rocks. Taken as a whole, however, rocks with a well-developed slaty cleavage form only a small proportion of the series, so that the term "slates" as applied to this series is not well chosen. The term "argillite," used to denote a hard siliceous mud stone, without well-developed slaty cleavage, is believed to be more appropriate, and the group term "argillites and graywackes" is therefore here used to describe this series of sediments. 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.

GRAYWACKES.

The graywackes of the Turnagain-Knik region are similar in all essential characteristics to those in the Prince William Sound and Kenai Peninsula regions, which have been so often described. They consist chiefly of angular grains of quartz and a variety of feldspars with fragments of other minerals and of bits of rock of various kinds, inclosed in a matrix of clayey material and containing more or less secondary silica as a cement. In texture they grade imperceptibly from the finer argillites through fine and medium grained sands to coarse gritty beds and conglomerates. The freshness of many of the particles of feldspar and ferromagnesian minerals and the relative abundance of particles of these rather easily decomposed materials indicate that the detritus from which these clastic deposits were derived came from a land mass in which erosion was more active than chemical decay. From particles of rock found in the graywackes and from pebbles in the interbedded conglomerates it is known that this land mass contained andesites, diorites, banded argillites, graywackes, and a good deal of quartz. The graywackes are generally of a grayish color.

In some places within this region the graywacke beds are so numerous and are individually so thick that the argillites form only an inconsiderable proportion of the beds exposed. In working out the structure of the rocks the attempt was made to use certain massive graywacke beds as horizon markers and by following their outcrops to decipher the structure of the whole series of sediments, but the result was disappointing, for each massive bed of graywacke was found not to be continuous along the strike for any great distance but to thin out laterally, giving place to other similar lenticular beds. Presumably the argillite beds also are lenticular. Along the edge of the stream flat south of Knik River, near Knik Glacier, graywacke beds are present in great abundance and form prominent bluffs. At this place, however, as well as along other stream valleys and on the north shore of Turnagain Arm, the graywacke beds are more conspicuous with relation to the argillites than their actual proportion in the series would justify, for they resist erosion more strongly than the softer argillites and stand out in prominent cliffs and bluffs, whereas the argillites have been eroded, and their areas are now represented by depressions.

The graywackes contain secondary calcite, both as a constituent of the rock mass and in the form of veinlets filling fractures. Quartz occurs also as a vein filling, and some veinlets consist of an intergrowth of quartz and calcite. At the locality near the head of Knik River already mentioned, the massive graywacke bluffs are cut by an intricate network of veinlets of quartz and calcite. In places the graywacke carries scattered grains of sulphides, chiefly pyrite and arsenopyrite.

ARGILLITES AND SLATES.

The argillites and slates of this group of sediments consist of the finer clastic materials driven from the same source as that which yielded the graywackes, and in composition they are not unlike the coarser associated sediments. In general the argillites and slates are darker than the graywackes, ranging in color from dark gray to black, and the contrast in color is especially conspicuous where rocks of the two types are interbedded in thin layers. The darker color is due to the fact that the typical argillites and slates contain more carbonaceous material than the graywackes. They also contain more clayey material, but they grade imperceptibly through increasingly coarser phases into fine graywackes, so that no sharp lines of distinction can be drawn.

The proportion of argillites and slates to graywackes necessarily varies from place to place. Locally the argillites are predominant and the graywackes almost or entirely absent. At other places the argillites and slates are present only in thin, widely spaced beds, the graywackes forming the greater part of the series. Considerable areas were seen in which the slates or argillites were almost unmixed with the coarser sandy materials, and in this respect the rocks of the Turnagain-Knik region are like those of adjoining areas in the Prince William Sound region, to the east.

The bedding of the argillites is usually distinct wherever they are well exposed. In the slaty phases, however, the secondary cleavage generally obscures the bedding, and the structure of the series at places where these phases occur must be determined from the more massive graywackes. The metamorphic processes that have caused the development of slaty cleavage in the fine, clayey sediments have generally left the more resistant graywackes little altered, and it is apparent that the rock flowage has taken place primarily along the less resistant fine-grained beds. The cleavage planes in the slates in many places run at angles across the bedding and terminate against an adjoining graywacke bed.

Both the slates and the graywackes are cut at many places by dikes and intruded by sills of acidic crystalline rocks. They also carry many veins and veinlets of quartz and calcite, which are especially abundant in the vicinity of the intrusive masses. A very few veins whose thickness can be measured in feet were seen, but most of the veins are small stringers varying from the thickness of a knife blade to an inch or more and reticulated through the whole mass of rock. At some places the argillites and graywackes are mineralized with small disseminated specks of sulphides, principally pyrite.

CONGLOMERATES.

The less prominent elements of the series, the conglomerates, quartzites, and limestones, constitute a very small proportion of the total volume. Of these the conglomerates are most abundant and occur in many parts of the district, but usually in beds of no great thickness. They are generally of a gray color, and most of their pebbles are argillite, but quartzite, quartz, and various igneous rocks are also represented. In most of the conglomerates seen the pebbles are less than 2 inches in diameter, although at a few places conglomerates with pebbles having a maximum diameter of 8 inches were seen. The matrix in general consists of a sandy argillite. The conglomerates apparently represent no important unconformities in the series, for wherever their relations to the adjacent beds could be made out they lie parallel to the underlying argillites and graywackes and show a gradation from the underlying bed, by a gradual increase in the abundance of pebbles, to a distinct conglomerate, and a similar gradation, by a decrease in the number of pebbles, to the overlying bed. As the whole series consists of distinctly shallow-water sediments, in which the coarseness of the beds depends largely on depth of water and nearness to the shore, the presence of a conglomerate bed at any locality does not necessarily mean an interruption in the deposition of the sediments and an unconformity, but it may mean only the deposition of unusually coarse materials near shore, without stratigraphic break.

Although conglomerates are by no means abundant in this district, they have been noted in place at a few localities and occur in the stream or glacial gravels in other valleys in which the actual outcrops were not observed. On the west side of Glacier Creek, about half a mile south of the mouth of Crow Creek, there are outcrops of a somewhat sheared conglomerate, composed of small, flat pebbles of shale and graywacke in a sandy matrix. On lower Crow Creek some conglomerate occurs in association with the argillites and graywackes. In the Eagle River basin half a mile above the mouth of Raven Creek there is a conglomerate composed of small fragments of slate in a coarse, gritty matrix. About 2 miles east of Kern Creek, along the railroad, there is an outcrop of massive conglomerate composed of argillaceous and cherty pebbles as much as 6 inches in diameter inclosed in a matrix of graywacke. The moraines of Raven Creek Glacier contain blocks of conglomerate composed of small pebbles of graywacke, argillite, quartz, and several types of igneous rocks inclosed in a matrix of argillite. Similar conglomerate bowlders were seen in the basin of Peters Creek, both in the valley of the main stream and on several tributaries.

STRUCTURE AND THICKNESS.

Structurally the beds of the argillite, slate, and graywacke series are tilted, folded, and faulted, and in general they have high dips. The best line of nearly continuous exposures across the beds is that offered by the wave-cut cliffs and steep mountain slope just north of Turnagain Arm. From a point 2 miles west of the mouth of Indian Creek to the head of the Arm and thence up Portage Creek, across Portage Glacier, and down to Passage Canal, a straight-line distance of 23 miles, the beds have a fairly uniform northeasterly strike and an average dip of about 70° either to the northwest or to the southeast. At many places small folds in the beds may be seen, but these are minor wrinkles on much larger folds that probably involve several thousand feet of beds. The prevailing high dips also show that the major folding was close, the two limbs of the fold approaching parallelism. Many small faults were observed, and larger faults of great displacement might well be present without being conspicuous. Great difficulty has been encountered by all geologists who have studied these rocks in attempting to work out the structure of the beds, for the series contains no beds sufficiently distinctive to serve as horizon markers, but appears to be monotonously alike in all parts; little assistance can be obtained from fossils, which are almost entirely lacking; and the normal attitude of the beds has been greatly altered by faulting, folding, and tilting. The mountains composed of these rocks have a relief of over 5,000 feet, and the beds along the 23-mile section above referred to have average dips of about 70°. As both faulting and folding have disturbed them, it is not possible now to estimate the total thickness of the beds involved other than to say that the original thickness must have been several thousand feet.

In the northern half of the Turnagain-Knik region the structure of the argillite and graywacke series is not so irregular as along the southern border. The average dip of the sediments is more moderate, folding has been less intense, and there is less uniformity in the general structural trend. In the Peters and Eklutna creek basins the dominant structure trends nearly east, but at the west edge of Knik Glacier the trend is north.

AGE AND CORRELATION.

The age of this group of sediments has not yet been determined. Mendenhall,[1] who in 1898 studied the rocks within the region here considered, named them the Sunrise series. Other geologists, working in the Prince William Sound region, have divided the rocks there into two groups, the Valdez and the Orca. It is now known that the rocks of these two groups extend westward into Kenai Peninsula and that in part, at least, they are the equivalent of the Sunrise "series." The Sunrise "series" can, therefore, be considered an undifferentiated group of rocks, probably containing parts of both the Valdez and Orca groups and possibly also materials not represented by either of these groups.

Neither the age of the Sunrise group nor that of any of its subdivisions has been definitely determined. The rocks are largely devoid of fossils, and although a few localities have furnished collections of invertebrate remains, these have been so imperfectly preserved or are so lacking in diagnostic value that no definite age determinations have been made by the paleontologists. Fossils procured by G. C. Martin and B. L. Johnson from the rocks at the heads of Crow and Raven creeks were identified by T. W. Stanton as follows:[2]

> 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 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.

It appears, therefore, that at least a part of the Sunrise group is of Mesozoic age, though it can not yet be stated positively whether this part is Jurassic or Cretaceous. On the other hand, on purely stratigraphic grounds it appears that the Sunrise includes some rocks of the Valdez group, believed to be probably of Paleozoic age. In the present investigation no further evidence was procured that throws light on the age of these sediments, and the problem of differentiating this great group of rocks of similar lithology but perhaps of a wide range in age is likely to be finally solved only when determinative fossils are discovered.

VOLCANIC TUFFS.

DISTRIBUTION AND CHARACTER.

An area including the central basin of Eagle River and the upper basins of Peters and Eklutna creeks and a smaller area along the

[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. 305–307, 1900.

[2] Johnson, B. L., The central and northern parts of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, p. 118, 1915.

south side of lower Knik River are occupied predominantly by fragmental volcanic materials, here referred to as tuffs. These areas are shown on the accompanying sketch map (Pl. VIII), but the tuffs doubtless extend eastward into the unmapped area. Bowlders of these characteristic rocks have been found along the shores of Port Wells, showing that they occur in the Prince William Sound basin, though the outcrops there have not been observed.

Although this series of rocks contains minor amounts of slate and graywacke and doubtless also some lava flows, it consists essentially of the products of violent volcanic eruption, the material having been ejected from the vents by explosions and the comminuted fragments having fallen into bodies of water in which they sank and were laid down as thick beds of tuff. In general the supply of volcanic material was so abundant that the ordinary forms of sediments, such as the sands and muds derived from stream erosion upon the land and brought down to be deposited in the waters to which the streams were tributary, constituted only a small percentage of the material being laid down, and these normal sediments form only an inconspicuous element in the series. In places thin shaly beds separate the tuff layers and so indicate the water-laid character of the tuffs. Here and there shale beds several feet thick were seen interbedded with the tuffs, but in most of the sections observed the tuffaceous materials are present almost to the exclusion of the ordinary sediments.

The tuffs vary in appearance from fine-grained rocks of green or gray color to coarser materials that might well be called agglomerates. Most of the exposures examined had a decided dark-green cast, although locally lighter shades prevail. At some places the rock is gray and its finer phases closely resemble graywackes. In fact, some of the tuffs resemble certain graywackes so closely in appearance, both in the hand specimen and under the microscope, that it is difficult or impossible to distinguish them. The most common phase of tuff, however, is so characteristic in appearance that it can be immediately identified. It consists of a fine to coarse grained matrix through which are scattered abundant angular fragments of black argillite or slate. In different beds or in different parts of the same bed the argillite fragments may vary greatly in size, but in any one block of rock the fragments show a general uniformity of dimensions. The uniformity in size of these fragments and in the way in which they are distributed throughout a great thickness of the tuffs and over large areas is not easily explained. The argillites and slates probably formed the vents through which the explosive material reached the surface, and no doubt quantities of such rocks were broken and thrown out with the materials of igneous origin, but it is interesting to speculate how the supply of these materials should have been maintained so steadily throughout what must have been a considerable period of time, and how they should have been broken to so nearly a uniform size and distributed so evenly through many cubic miles of tuffs.

As examined in thin section under the microscope the fragmental rocks prove to be dominantly greenstone tuffs and in minor degree rhyolite tuffs. The constituent particles consist of angular to subangular or rounded fragments of igneous rock in which are commonly inclosed fragments of argillite, slate, graywacke, and other materials. In the greenstone tuffs the rock minerals composing the particles are commonly altered, but in the groundmass original plagioclase feldspar, hornblende, pyroxene, and quartz have been identified, and secondary quartz, calcite, chlorite, serpentinous products and zeolites are generally present. The rhyolite tuffs show some quartz and orthoclase phenocrysts in a fine-grained, feebly polarizing groundmass.

Some rhyolite flows are associated with the rhyolite tuffs, and some basaltic flows occur with the greenstone tuffs, but the fragmental rocks preponderate greatly over the lavas.

STRUCTURE AND THICKNESS.

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, so that the structure is not easily determined. 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. This relation exists in Eagle River valley and in both Peters and Eklutna creek basins, where the dips near the border range from 20° to 30°. At some places the tuffs seem to lie conformably upon the slates and graywackes, but at other places there is a distinct angular unconformity, and the two series are believed to be generally unconformable. On account of the great variety of strikes and dips observed in the argillites and graywackes it is probable that in some places the bedding of the tuffs parallels that of the underlying argillites and graywackes, although the unconformity doubtless represents an erosion interval between the two formations. Furthermore, if the fragments of argillite and slate found so abundantly in the tuffs were derived from the underlying formation it is certain that they had been indurated and somewhat metamorphosed before the beginning of the period of volcanic activity that gave rise to the tuffs.

In the smaller area of tuff bordering lower Knik River on the south side the tuffs are either nearly flat or dip to the north. This area was apparently once continuous with the larger area to the south and has been separated by the erosion of the tuffs from the intervening district.

It is impossible now to estimate accurately the thickness of the tuffs. In the center of the main area of tuff, mountains having a relief between 4,000 and 5,000 feet are made up entirely of these rocks, and as no overlying materials are present, an unknown thickness of tuffs has been removed from these mountains by erosion. Even if allowance is made for possible reduplication by folding, the series can not well be less than a mile thick.

AGE AND CORRELATION.

Although no fossils were found in the rocks of the tuff series, certain conclusions respecting their age may be made. The tuffs overlie argillites and graywackes in the upper basin of Eagle River and are therefore younger than those beds. As already stated (p. 161) fossils have been collected from the argillites and graywackes at the heads of Crow and Raven creeks, and these fossils have been provisionally assigned to the Jurassic or Cretaceous. Apparently the sediments lying beneath the tuffs of upper Eagle River are continuous with and a part of the same group of rocks as those from which the fossils were obtained. If this is true, then the tuffs are at least of post-Jurassic and possibly of post-Cretaceous age.

In several places around Cook Inlet and the Susitna basin there are lignite-bearing beds of Eocene age, known as the Kenai formation. These beds consist largely of shales, sands, arkoses, and conglomerates, with lignite. In their induration, metamorphism, and general character they seem quite clearly to be younger than the tuffs here under consideration, although so far as known the two formations nowhere come into contact. If it is assumed that the tuffs are older than the Kenai and are younger than the argillites and graywackes of Crow Creek Pass, then they must be placed somewhere in the geologic column between the Jurassic and the part of the Eocene represented by the Kenai. It should be added, however, that the only formations found in this general province which resemble these volcanic rocks are some partly altered breccias, agglomerates, and tuffs described by Martin and Katz[1] as occurring in the Matanuska basin. These rocks carry Lower Jurassic fossils. The nearest

[1] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 17–19, 1912.

known outcrop of these beds is about 30 miles northeast of the Turnagain-Knik region, and the intervening area has not been mapped. A definite correlation between these two volcanic formations is therefore not justified, especially as the local evidence indicates that the volcanic rocks of the Turnagain-Knik region are of post-Jurassic age.

INTRUSIVE ROCKS.

Intrusive rocks occur within all the hard-rock formations of this region. The oldest group of rocks, which in this report is not differentiated into its constituent elements, contains a large proportion of intrusive materials, including diorites and quartz diorites, peridotites, pyroxenite, dunite, and their altered equivalents. These have already been briefly described. The series as a whole, as well as the overlying argillites and graywackes, have in places been intricately cut by younger dikes and sills of acidic character. These younger intrusive rocks have been found on microscopic study to include andesite porphyry, dacite, and diorite. Projecting through the unconsolidated deposits near the village of Old Knik are some small hills of coarsely crystalline quartz diorite. No other considerable bodies of granitic intrusive rocks were observed in this district, but in not far distant areas on Prince William Sound, in the Talkeetna Mountains, and at many other places in Alaska there are similar granitic intrusives that are generally believed to be of Mesozoic age. It was probably during this general period of granitic intrusion and in relation to larger masses of granitic rocks, some of which did not penetrate near enough to the surface to be yet revealed by erosion, that the numerous acidic dikes and sills of this region were injected.

QUATERNARY SYSTEM.

PREGLACIAL CONDITIONS.

The youngest hard rocks that have been recognized in this region are the greenstones and greenstone tuffs, and they are very old compared with the unconsolidated Quaternary materials, the next younger deposits. It may be that after the deposition of the greenstones and greenstone tuffs the region was submerged and covered with younger sediments, but in the absence of younger rocks it is unlikely that such a submergence took place. During early Tertiary time a great lowland is known to have existed along the present Cook Inlet and Susitna Valley depression, and from this lowland valleys reached back into the surrounding upland. In the lowland and its tributary valleys much sedimentary material, comprising muds, sands, gravels, and arkoses derived from the surrounding highlands, and considerable beds of peat were laid down as lowland or estuarine deposits. Locally, these materials accumulated to a thickness of several thousand feet. They were thickest in the lowest depressions and thinned out laterally as they overlapped the lower slopes of the bordering hills. Their accumulation was ended by the uplift of the surrounding mountains, and the beds were in many places tilted, folded, and faulted. Deposits representing this period of Tertiary deposition are present in Matanuska Valley; in the Willow Creek district, only 10 miles north of the region here considered; at many places on the east shore of Cook Inlet; and in the areas bordering the Susitna lowland. The major uplift and tilting of the Tertiary beds, which doubtless affected the mountains of the Turnagain-Knik region also, was followed by a long period during which the ordinary processes of land erosion were active. Great trunk valleys were formed or reexcavated, and the mountains were dissected to a mature topography. It is believed that at the end of this period of stream erosion all the main valleys now present were established. The streams in removing the rock waste from their basins had handled great quantities of material, and in some of this material there was a small quantity of native gold, contained in quartz veins and veinlets. The gold, being chemically inert and of high specific gravity, remained in the stream beds, and in those basins in which gold-bearing veins were especially abundant gold-placer deposits were formed.

GLACIAL EPOCH.

ADVANCE OF THE ICE.

The glacial epoch was ushered in by a change in climatic conditions that resulted in increased snowfall. The accumulation of snow and ice naturally took place first in the higher mountains, and small glaciers were formed. These grew and lengthened down the valleys, tributary glaciers joined the main drainage lines, and the larger ice streams pushed onward as they increased in thickness until all the mountain valleys contained vigorous glaciers. As the ice advance approached its climax the mountains were so deeply submerged by glacial ice that only the higher peaks and ridges projected above its surface. The ice streams from Turnagain Arm and from Knik and Matanuska river valleys pushed into upper Cook Inlet, there joined the southward-moving glacier from the Susitna basin, and advanced down Cook Inlet an unknown distance but at least as far as the forelands. Some idea of the magnitude of these great glaciers may be gained from the facts that at the mouth of Glacier Creek the Turnagain Arm depression was filled with ice to a height of at least 3,400 feet above sea level, and at the point where Peters Creek leaves the mountains the surface of the Knik Arm glacier stood nearly

3,000 feet above sea level. From these surfaces the slopes of the tributary valley glaciers upstream were steep, probably more than 100 feet to the mile, so that little of the mountain mass was visible above the ice surface.

The last great period of glaciation in Alaska is believed to have been contemporaneous with the Wisconsin stage of glaciation in the United States and Canada. In the main body of the continent there were several periods in Quaternary time during which the glaciers reached large size and moved southward into the Northern States. It is now known that in Alaska also there were at least two and possibly more distinct stages of glaciation, and the last great ice advance has been rather definitely correlated with the Wisconsin stage.[1]

In the Turnagain-Knik region evidences of only one great ice advance have been recognized. There may have been earlier glacial stages, but the last great glaciers became so large and their erosive effects were so profound that they went far toward obliterating the evidence of any former glaciers that may have been present.

The flooding of a mountain region, such as that here discussed, by glacial ice involves great changes in the shape of the land surface. The preglacial topography of this region was of the type resulting primarily from stream erosion. The valleys were broadly V-shaped in cross section; the streams flowed in somewhat devious courses around the ends of the mountain spurs that projected into the valleys from either side; chemical decomposition and physical disintegration had joined forces in breaking down the rocks and in causing the accumulation of extensive deposits of residual soils and of products of rock disintegration; and each stream flowed over a bed in which the gradient was adjusted to the size of the stream and to its load.

When the glacial epoch had begun the newborn mountain glaciers in advancing down the valleys found them adjusted to stream cutting and degradation but not at all adjusted to occupancy by glaciers. To these glaciers, therefore, fell the task of remodeling the valleys to shapes best suited to ice movement, and for this work they were well equipped. In their forward and downward progress they pushed before them or overrode such loose materials as they encountered and rapidly stripped away soil, talus, and stream gravels. Much of this detritus was incorporated into the body of the glaciers themselves, and each fragment, held firmly in the ice, served as a tool with which the moving glacier could attack its bed. By the removal of obstructing spurs and by undercutting the valley sides the glaciers tended

[1] 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; Two glacial stages in Alaska: Jour. Geology, vol. 23, pp. 748–756, 1915.

to develop straight, wide-floored, troughlike valleys. Cirques were formed at the valley heads, and as the cirques were cut headward the divides within the higher mountain masses were attacked and reduced to sharp-peaked ridges.

Although the topography was greatly modified by the glacial erosion, nevertheless it is believed that most of the glaciers, in spreading downward from the higher mountains, followed the preexisting valleys. Locally ice poured over divides and reduced them, so that new valleys having courses at variance with those of the preglacial streams were formed, but in the main the present drainage lines, although bearing unmistakable evidence of ice erosion, are believed to follow the valleys established by the streams before the glacial epoch.

Within the lowlands beyond the borders of the mountains the effects of the ice invasion were also notable, but of a very different character. No longer confined within restraining walls, the glaciers spread out laterally to form great, comparatively flat ice plains. With lower gradients and greater width the rate of movement was also decreased, and the ice, no longer able to erode vigorously, began to deposit its burden of detritus as a sheet of glacial till. Still farther down, at the ice front, the surface débris and that within the main ice mass was dropped as a terminal moraine or supplied to the streams to be deposited as glacial outwash.

RETREAT OF THE ICE.

After the glaciers had reached their greatest development there came about another change in climate, with increase in mean annual temperature and decrease in snowfall. As the supply of snow in the headward portions of the glaciers became less, they became progressively shorter and thinner. The lower ends shrank back and bared ground previously covered by ice. The upper valley walls, scored and smoothed by glacial erosion, began to emerge along the flanks of the ice tongues. As melting and shrinkage continued the valley glaciers became separated from the lowland glaciers and from one another, the lowlands gradually became free from ice, and glaciers were able to maintain themselves only in the high mountains and in basins somewhat protected from the sun's rays.

As the glaciers retreated, streams fed by the melting ice at once began to flow over the uncovered areas. The valleys were, however, no longer adjusted to stream drainage, and the streams immediately commenced to make this adjustment, which is still far from accomplished. Low, ice-eroded basins became lakes, many of which were later filled with stream gravels. Rock barriers were intrenched and now form canyons. The amount and character of this readjustment are discussed under the heading "Postglacial erosion" (p. 172).

The higher mountains of this region still support vigorous glaciers. The largest of these is Knik Glacier, at the head of Knik River. It is 3 miles wide at its terminus, and about 4 miles above that point it divides into two large tributaries, one heading eastward and the other southward. The upper portion of this glacier is unsurveyed and its area is unknown, but without doubt it includes the ice from part of the northern front of the high mountain range that supplies so many southward-moving glaciers to College Fiord. It is likely also that it receives ice from an extensive glacial field lying southeast of the heads of Peters and Eklutna creek basins and northeast of the head of the Eagle River basin. Natives and prospectors report a lake many miles long that occupies a valley along the east side of the southwest fork of Knik Glacier. This lake fills gradually and at intervals of six or seven years breaks out through Knik Glacier and sends great floods of water down Knik River and Knik Arm. Such a flood took place early in September, 1915, deeply inundating the flat valley floor of Knik River and causing considerable damage at the construction camps of the Government railroad, at the Knik River crossing.

No facts were observed that would indicate any great amount of recent retreat of Knik Glacier. In July, 1915, there were no large streams flowing along the western edge of the ice front, yet the dump moraine was very small, indicating that there may have been a recent readvance of the ice. The rock bluffs on the valley wall 200 feet from the ice edge and below the level of the frontal ice cliffs are covered with brush, and scraggy old dead spruce trees stand on the bluffs 50 feet above the gravel bars and 200 yards beyond the ice edge. The presence of these bushes and trees so near the ice front shows conclusively that the glacier is now almost as far advanced as it has been for many years.

Eklutna Creek above the lake forks into two branches, both of which are glacier fed. The south fork emerges from beneath a long, narrow ice tongue, and the volume of the stream indicates that the headward portion of the glacier is much larger than the lower portion, which can be viewed from the terminus. The southeast fork of Eklutna Creek is also large, and its turbid waters are certainly of glacial origin, though the glacier at its source was not seen.

The Peters Creek basin contains at least four glaciers, all small.

Eagle River heads in Eagle River glacier, an ice field 10 or 15 miles long and between a quarter and half a mile wide at its lower end. It shows white ice throughout its length, but has one prominent and another less conspicuous line of surface moraine on its lower portion. From half to three-quarters of a mile below the glacier there are two distinct crescentic lines of terminal moraine crossing the valley, and a strong lateral moraine appears along the northeast margin of the glacier. Within these moraines there is little vegetation, and the ice has apparently retreated, possibly as much as three-quarters of a mile, within recent years.

Raven Creek, the largest headward tributary of Eagle River, heads in a small but vigorous glacier. The bare slopes along its lower flanks and beyond its terminus indicate a moderate amount of recent retreat.

The southeast fork of Ship Creek and the main branch of Bird Creek originate in small glaciers, the westernmost within this district. Glacier Creek, as its name implies, has its source in several small glaciers, as has also its principal tributary, Crow Creek.

The Twentymile River basin contains two vigorous ice streams, and Portage River is fed by several small ice tongues and by Portage Glacier, which also sends some of its drainage eastward to Passage Canal.

The eastern, unsurveyed portion of the district includes the highest mountains and the largest glaciers, a number of which flow eastward into Harriman Fiord.

GLACIAL DEPOSITS.

Within the mountain valleys the ancient glaciers had comparatively steep gradients and were confined within abrupt valley walls, and their movement was consequently more rapid than in the lowlands. The characteristic effect of glaciation upon the mountains is therefore to be observed from the erosional results produced rather than from the constructional topographic forms built from the deposits of glacial débris. There are, however, certain distinctive glacial deposits left by the ice during its retreat or built by the glaciers after they had taken their stands near the positions in which they now remain. The most easily recognizable glacial deposits in the mountains are the lateral and terminal moraines. They form dumps of great blocks and bowlders mixed promiscuously with finer materials and having an irregular surface. They are not present in all the glaciated valleys, but are well developed at the edges of some of the existing glaciers and may be seen at some distance from the ice edge in a few valleys, notably in Crow Creek basin and near the head of Eagle River. The more prevalent but less conspicuous glacial material occurs as a sheet or veneer of glacial till coating the floors and sides of many valleys but presenting no easily recognizable topographic form. It can be best identified in the cut banks of streams and gulches; elsewhere it is likely to be obscured by a covering of vegetation.

The lowland areas received the greater part of the detritus removed from the mountains and transported downward by the moving ice, and practically all the surface deposits in the lowlands are composed of material supplied directly by the ice or by streams that issued from the glaciers and brought down the products of glacial erosion. Thus the flat valley of Knik River, from the glacier to the point at which the tides are effective, is floored with heavy deposits of gravel and sand. The material supplied to the river by the ice is so abundant that the stream is constantly loaded to its capacity, and it is slowly aggrading its valley floor. The finer materials, consisting of some sand and abundant silt, are carried down to tidewater in Knik Arm and deposited as mud flats. Like Knik River, all the other glacier-fed streams have more or less extensive flood-plain deposits of glacial outwash gravel. Similar gravel deposits occur throughout much of the Knik Arm lowland, though locally they attain altitudes of several hundred feet above sea level. This outwash gravel could not have been deposited in its present position under the existing drainage conditions, but was laid down in front of the retreating glacier that once filled Knik Arm, in much the same way as the present deposits in Knik River valley. The grading operations along the line of the new railroad through the lowland show that the gravels are present in great abundance. In the basin of Eklutna Creek, between Eklutna Lake and the rock canyon, 5 miles below, the stream is intrenched to a depth of several hundred feet in stratified gravels, probably deposited at a time when the mouth of this valley was blocked by the great glacier in the basin of Knik Arm and when Eklutna Glacier had retreated to about the present position of the lake. The next stream southwest of Eklutna Creek shows similar thick deposits of gravel. Glacial till, laid down directly by the ice, is also present in the lowland and probably occurs in extensive sheets beneath the covering of gravel outwash. Both the gravel-covered areas and those occupied by glacial till have fertile soils and give promise of productive farms along the railroad.

The results of the ice invasion, including erosion in the mountains and deposition in the lowlands of the material removed from the mountains, have had a very great influence on the economic development of this district. Within the mountains the ice, in overriding the preglacial stream gravels, removed them and the gold placer concentrations that they contained, and the gold was scattered far and wide in the morainal and outwash deposits of the lowlands. In a few especially protected localities some small areas of the preglacial stream gravels, with their included gold, may have been preserved and may some time add to the gold production of the district. In most of the stream basins, however, no preglacial placers were left, and such placer deposits as are now present are the result either of postglacial stream concentration of gold from the glacial deposits or of original concentration from bedrock.

In the lowland areas the results of glaciation, although of a different character, will exercise an even greater influence on the economic development of the district. The future development of the lowlands is largely concerned with their agricultural possibilities. From the mouth of Knik River to Turnagain Arm the lowland lying southeast of Knik Arm is covered with gravels, silts, and glacial clays deposited directly by the ice or in the rivers and embayments beyond the ice front. In general these materials are fertile, are well drained, and afford good soil for the production of crops. Climatic conditions also appear to be favorable, so that there is a strong probability that this lowland, now tapped by the new Government railroad, will support a considerable agricultural population.

POSTGLACIAL EROSION.

Upon the final retreat of the glacial ice from any part of the area which it had covered, the agencies of subaerial erosion immediately became operative, and these agencies have continued to be effective in greater or less degree ever since. Nevertheless, in terms of earth history, the period since the waning of the ice has been short, and in its larger features the land surface now to be seen is that developed and modified by the action of the glaciers. As the ice first retreated from the lowlands of upper Cook Inlet and gradually withdrew up each tributary valley, the lowlands and the lower parts of the valleys have been subject to postglacial erosion much longer than the upper parts. In fact, as the remnants of the old ice sheet still occupy considerable areas in the higher valleys, these areas may be considered to be still in the glacial epoch, and beneath the ice there has been no postglacial erosion.

Naturally erosion has been greatest along the lines of the major streams and along the margins of tidewater. The glacial widening and deepening of the floor of Knik Arm and Knik River valley left all the tributary streams from the south and southeast occupying hanging valleys, with very steep gradients at the mountain front. In these oversteepened portions the streams have cut canyons in the unconsolidated materials and in bedrocks, in their efforts to reestablish normal gradients. Higher up the valleys there are also places at which the streams, in crossing rock barriers, have cut canyons, and their minor tributaries likewise, occupying hanging valleys of the second order, have cut their beds deeply in readjusting their grades. Locally between the oversteepened and canyoned portions of the valleys there are basins that now contain lakes, as, for example, Eklutna Lake, or are filled with stream gravels.

The larger tributaries of Turnagain Arm from the north and east generally lie in valleys the lower portions of which were eroded by the ice to or below tide level, and the typical hanging valleys are not abundant. In fact, the lower valleys of Glacier, Twentymile, and

Portage creeks were fiords when first bared of ice, as Turnagain Arm is now, but were filled to sea level by detritus from the glacial streams that discharged into them.

Marine erosion has succeeded in postglacial time in cutting back the unconsolidated deposits between Point Possession and the mouth of Knik River, so that the shore line is generally bordered by steep gravel bluffs. At Point Woronzof the bluff stands 200 feet above mean tide. At the town of Anchorage the top of the bluff has an altitude of 110 feet. The distance horizontally that the bluffs have retreated before the cutting of the waves is not known. On Turnagain Arm similar gravel bluffs extend from Point Campbell southeastward for 12 miles, and thence to Twentymile River there are nearly continuous sea cliffs cut into the hard slates and graywackes. It is apparent, however, that wave cutting has done no more than to notch the base of the rocky walls that border this basin.

In addition to the work of streams and waves, the mechanical disintegration of the rugged mountains, especially in those places where they reach altitudes above the line to which vegetation grows freely, has been rapid, and considerable quantities of talus have accumulated at the bases of steep slopes. Chemical decay, however, has been relatively ineffective in postglacial time. No residual soils have been formed, and many glacially scoured rock surfaces still show the smoothness of contour given to them by the ice.

PRESENT STREAM AND MARINE DEPOSITS.

Most of the large streams within this region have their sources in glaciers, and their gravels are derived in part from material supplied by the ice, and in part from material supplied by the direct erosion of the streams upon their beds and banks. On such streams it is impossible to separate the present stream gravels from those of glacial origin, and no attempt has been made to discriminate between them on the accompanying map (Pl. VIII). Likewise the marine or estuarine silts and sands now accumulating so rapidly in Knik and Turnagain arms are in part of glacial origin and in part the product of stream erosion. The amount of fine material brought down to tidewater by the larger glacial streams is great, and the filling in of these arms of the sea must be proceeding at a rapid pace. The estuarine deposits now accumulating, if consolidated and somewhat metamorphosed, would yield a group of sedimentary rocks resembling in many ways the argillites and graywackes so abundantly represented in this general region.

The tidal variation in Knik Arm is great, and the waters are shallow, so that at low tide many square miles of tidal flats are laid bare. In addition to the areas within range of the daily tides there are mud flats, particularly at the mouth of Knik River, between the Indian village of Old Knik and Knik River, at the mouths of Peters Creek and Eagle River, and on Turnagain Arm along lower Glacier Creek, Twentymile River, and Portage Creek, that are covered by the sea during periods of extreme high tide but are dry most of the time. These flats support a luxuriant growth of grass and in summer would afford valuable pasturage for live stock.

MINERAL RESOURCES.

GENERAL FEATURES.

The mineral resources of the Turnagain-Knik region that have so far received the attention of miners and prospectors are the gold placers and the gold quartz lodes. From 1896 to 1898 a large number of placer claims were staked on the streams tributary to Turnagain Arm from the north, and on a few of these claims, notably those on lower Crow Creek, mining has been carried on each year since. The entire output of placer gold has been derived from the Turnagain Arm slope of the mountains. In 1915 some placer claims were staked on tributaries of lower Knik Arm, but none of these have yet been demonstrated to contain workable ground. Development work on gold quartz lodes has also been confined largely to the Turnagain Arm basin, although a few claims in the valley of Peters Creek and in the upper basin of Eagle River have received attention. In 1915 no gold had been produced from any of the gold quartz lodes.

The following description of the mines and prospects is based on observations made by the writer in 1915, with additional material already published in the reports of W. C. Mendenhall, F. H. Moffit, and B. L. Johnson, to which reference has already been made.

GOLD PLACERS.

GLACIER CREEK BASIN.

GENERAL FEATURES.

Glacier Creek is one of the larger tributaries of Turnagain Arm from the north and joins the Arm about 10 miles below its head, at a point 75 miles from Seward by way of the Alaska Northern Railroad survey. The main valley is a straight, broadly U-shaped trough and heads in a wide basin into which several small glaciers drain. A number of these glaciers are plainly visible from Turnagain Arm and have given the stream its name. Below the mouth of Crow Creek the stream flows through a gravel-floored valley, bordered in its lower reaches by a lowland in which marshes alternate with heavily timbered areas. Its larger tributaries are California and Crow creeks, from the northwest, and Winner Creek, from the southeast. Virgin Creek flows into the same broad valley but joins Turnagain Arm a short distance southeast of the mouth of Glacier Creek.

Crow Creek is economically the most important tributary of Glacier Creek. The mountains at its head are high and rugged and form the divide between the waters that flow to Turnagain Arm and those tributary to Knik Arm. They are broken at the head of Crow Creek by Crow Creek Pass at an altitude of about 3,400 feet, which affords a fairly good route from Crow Creek to Raven Creek, a tributary of Eagle River. From its source in the pass to its mouth Crow Creek is about 5 miles long. Near its head it is precipitous, descending in waterfalls and rapids for a vertical distance of over 1,000 feet within 1 mile of the pass. It is fed by several small glaciers, and during the summer its waters are turbid. Below the pass the stream emerges from its narrow stream-cut gorge into a gravel-filled basin. The basin is bordered at its lower end by a terminal moraine from a lateral valley, and the gravel fill is the result of the lessened gradient behind this morainal dam. Through its bowldery channel across the moraine the stream descends in rapids, to emerge into a narrow gravel-floored valley bordered by benchlike terraces of gravel and showing no rock outcrops. These conditions prevail to a point within half a mile of the mouth of the valley, where the stream enters a rock canyon, with nearly vertical walls, that extends to its mouth.

Throughout the basin of Crow Creek the bedrock consists predominantly of interbedded argillites or shales and graywackes, with some conglomerates, cut by numerous granitic dikes and sills. Locally the shale beds have been metamorphosed, with the development of slaty cleavage, and in places the metamorphism has been intense enough to produce a somewhat schistose structure. The prevailing strike of the beds in this basin is northeast, but locally the beds diverge considerably from this general trend. Near the mouth of Crow Creek they dip prevailingly at high angles to the southeast, but at the head of the valley folding has occurred, and the general trend of the structure swings around to an easterly direction.

PHYSIOGRAPHY.

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. As the distribution and concentration of placer gold are in large measure dependent on the erosional history of the areas in which they occur, and as the basin of Crow Creek contains the most productive mining camp of this region, it seems proper to discuss here in some detail the main physiographic events that have had an influence on the development of this stream basin and on the formation of its gold-bearing gravels.

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. Its history is discussed on page 179. 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.

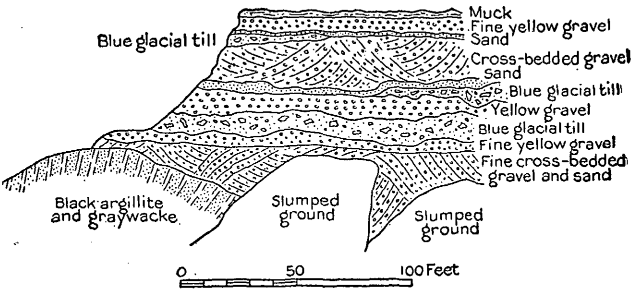


FIGURE 7.—Section exposed in placer workings of lower Crow Creek, showing interbedded stream gravels and glacial till overlying steeply tilted argillite and graywacke.

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.[1] Since that year 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 thickness 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. 7.) The excavations also show that this buried rock channel itself is joined by other old channels in bedrock. (See figs. 8 and 9.) Mining in one of these has exposed a section (fig. 10) which differs considerably from that shown in figure 7 but which also shows deposits of glacial origin interbedded

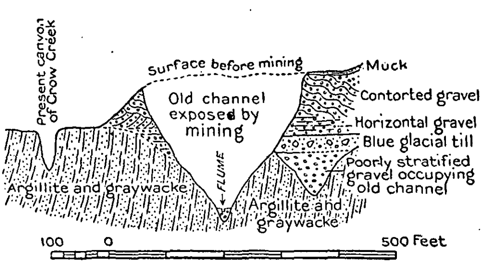


FIGURE 8.—Cross section of a part of lower Crow Creek valley, showing size and position of present canyon, the deepest buried canyon (now excavated), and another smaller buried canyon. This section is at right angles to that shown in figure 10.

[1] Moffit, F. H., Gold fields of the Turnagain Arm region: U. S. Geol. Survey Bull. 277, p. 41, 1906.

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, but data are not yet available for a complete interpretation of the succession of events. Apparently the old channel through the "big cut" is the deepest rock channel draining the Crow Creek valley, though this has not yet been definitely established. Moreover, 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.

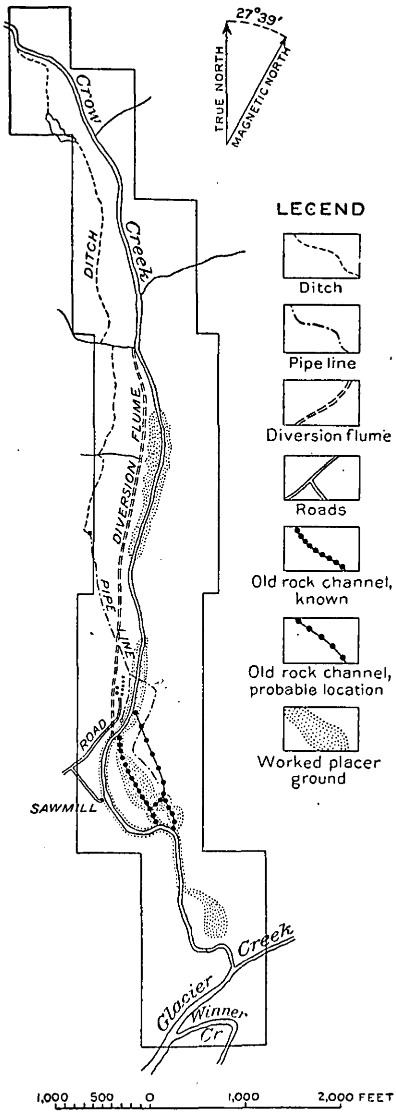


FIGURE 9.—Sketch map of claims of Alaska Crow Creek Mining Co. Adapted from sketch by Frank H. Lascy.

The history of the drainage changes in lower Crow Creek, as made out from the facts now available, is given below. In details the description of the succession of events here given may be open to some question, but it is believed that this description reasonably accounts for the conditions as they now appear. With further mining additional facts will be obtained that will throw more light on the complex drainage history of this place, and the necessary modifications in the interpretation can then be made.

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 V-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. In other parts of Alaska there have been at least two distinct ice ad-

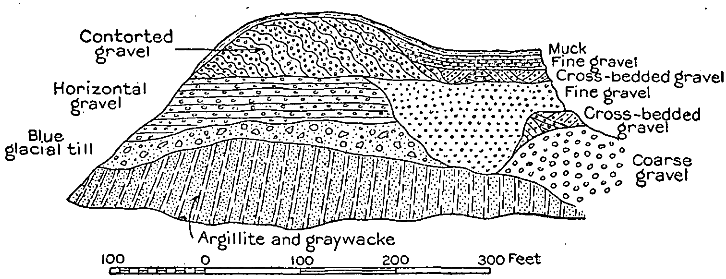


FIGURE 10.—Section on northeast side of the "big cut," lower Crow Creek, showing the relations of the glacial till and gravels to bedrock.

vances,[1] and there may have been more. It is probable that the upper Cook Inlet region also 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. It is therefore possible that the record of many early events of great importance in the erosional history of the region is now so obscure that their influence can not at present be properly estimated. The record of the more recent events is still distinct enough to be read with some confidence.

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

[1] Capps, S. R., Two glacial stages in Alaska: Jour. Geology, vol. 23, pp. 748, 756, 1915.

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 débris. 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.

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 alignment 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. 9.) 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.

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 depositing quantities of glacial débris 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. 7.) 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. Whether the till beds were laid down by the ice lobe from Glacier Creek or by that from Crow Creek, or whether they came in part from one of these sources and in part from the other, can not now be determined. The included bowlders and blocks of rock might have come from either basin, as rocks of all the observed types are present in both Crow Creek and Glacier Creek basins.

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. Except in that portion of its course which lies in the present rock canyon, Crow Creek had the same alignment as it had before the channel was deeply filled with glacial till and gravels. 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.

UNCONSOLIDATED DEPOSITS.

The unconsolidated deposits of Crow Creek basin may be roughly divided into three classes, which differ in age as well as in appearance. The oldest deposits are the lowest gravels found in the valley bottom above the canyon and in the bottoms of the old, buried rock canyons, and are observable only in the excavations made during the progress of placer mining. They consist primarily of rather coarse stream gravels and represent the material in process of transportation by the stream at the time when it occupied the deepest buried channel. They are thought to be older than the time of the last great ice advance, or at least to have been laid down during periods of temporary retreat during that glaciation. Next younger and lying immediately above the lowest gravels is a thick, irregular series of gravels, sands, and morainal materials. These materials form the bulk of the unconsolidated deposits, were laid down as glacial outwash or by the ice directly, and are to be correlated with the last stage of glaciation. Above the rock canyon they now appear at the surface as high benches on both sides of the stream channel which has been eroded into them and in one place as a distinct morainic ridge.

The third class of deposits comprises the gravels of the present stream. In general they are only a few feet thick and form the floor of the trench cut by the stream into the high bench gravels. They consist of a mixture of reworked bench gravels with whatever new material the stream has derived by erosion in its upper basin or from the glaciers in which it heads.

MINING.

A few claims have been staked in the main valley of Glacier Creek, but little or no actual mining has been done on them. The economic importance of this basin now lies in the tributaries of Glacier Creek, three of which—Crow, Winner, and California creeks—have produced gold in commercial quantities, and Crow Creek has been the scene of extensive mining.

Crow Creek.

The first claims to be located on Crow Creek are said to have been staked in 1897, near the mouth of the stream and on the site of the present placer workings. The early history of this ground is not clear, but it is known that eight partners, locally known as the "Crow Creek boys," were mining in 1904 in the vicinity of the rock canyon on the lower portion of the stream. Later the Crow Creek Consolidated Mining Co. was organized and operated until 1906. In 1907 the property was sold to the Nutter-Dawson Co., and in 1914 this concern was reorganized into the Alaska Crow Creek Mining Co. The sixteen claims now included in this property extend in a double tier from Glacier Creek, at the mouth of Winner Creek, up Crow Creek for the length of seven claims, with two additional overlapping claims above. (See fig. 9.)

In the years preceding 1903 most of the mining was done by pick and shovel on the most easily accessible gold-bearing gravels. The ground mined included the so-called Eagan bar, near the mouth of the stream, the present rock canyon, and some of the surface gravels above the canyon. In 1903 and 1904 hydraulic methods were used, but difficulty was experienced in reaching bedrock above the rock canyon. Late in 1904 an old, deeply filled rock channel lying northeast of the present canyon was discovered, and from 1905 to 1914 the efforts of the several companies operating at this place were in large part directed to removing the gravels above and in this old channel for the purpose of obtaining a bedrock drain to the gravel basin above the present canyon. This was a large undertaking, for the gravel filling contained little gold and the necessary excavation had a length of over 1,000 feet and a maximum depth of nearly 250 feet. During the work of clearing this old channel other buried rock channels branching from the main one were disclosed, and these have not yet been completely excavated.

The areas of gravels that had been mined by the fall of 1915 are shown in figure 9. At the time of visit mining was being done at but two localities—the lower at the junction of two subsidiary buried channels and the upper in the gravel-filled basin of Crow Creek, a few hundred feet above the camp. The underlying bedrock consists of black slates interbedded with graywacke and conglomerate, and these beds strike in a general northeasterly direction and dip at angles approaching the vertical. In the lower workings the unconsolidated materials above the bedrock form a complex series of interbedded gravels, sands, and glacial till. The upper workings in the present creek bed show 80 feet of gravels and sands.

Mining is now carried on by hydraulic methods. The water is obtained from Crow Creek near the upper end of this group of claims and conducted for about a mile to the penstock through an open ditch having a capacity of 4,500 miner's inches. From the penstock it is distributed by a 24-inch steel pipe to the workings. A head of about 300 feet is available at the upper cut and about 360 feet at the lower workings. In 1915 and for several preceding years the creek was carried around the edge of the valley floor by a diversion ditch that emptied into the upper end of the rock canyon. Mining in 1914 and 1915 lowered the cut so far below the level of this ditch that there was danger of its breaking over into the placer workings. Furthermore, it was found that the richest gravels extended over beneath the ditch. It was therefore decided to build a long diversion flume to remove the water permanently from the stream flat for a distance of about three claim lengths. To obtain the necessary lumber a sawmill was installed in the spring of 1915 at a point in the canyon southwest of the big cut. A dam 37½ feet high was built across the canyon, giving a head of 19 feet to a 24-inch turbine wheel. Over 250,000 feet of lumber was sawed in 1915, and the diversion flume was completed. It has a length of about 3,400 feet, is 8 feet wide and 3 feet deep, and has a 2.2 per cent grade. It is built on 4 by 6 inch sills and is 2 inches thick on the bottom and 1 inch on the sides. This flume is thought to be amply large to carry the stream even during floods. It discharges into the canyon about 500 feet above the sawmill. The sluice line and discharge flume for the mines extends from a point near the upper end of the workings down through the big cut and discharges into the canyon at its junction with the main old channel, covering a total distance of over 1,800 feet. The boxes are 5 feet wide and 4 feet deep. For the lower 400 feet the sluice line is set on a grade of 9½ inches to the 12-foot box length, and above this stretch a grade of 7 inches to the box length is maintained. The upper ten lengths of boxes are lined with 40-pound railroad rails as riffles, and the lower portion of the sluice line with hemlock block riffles cut to a height of 13 inches. The arrangements for the disposal of the tailings are ingenious and are said to work in a highly satisfactory manner. As often as the tailings accumulate below the end of the sluice line in sufficient quantity to threaten to impede the discharge the gate in the mill dam is opened and the waters from the mill pond rush down through the narrow canyon and quickly remove the accumulated tailings.

The gravels are moved almost altogether by hydraulic means, hand methods being used only for cleaning bedrock. Between 20 and 30 men were employed throughout the season of 1915, but the greater part of their labor was expended in getting logs to the mill, in sawing and transporting lumber, and in building the diversion flume. The working day is 10 hours, and the men receive from $105 to $120 a month and board.

At the upper workings two hydraulic giants were used. The larger, equipped with an 8-inch nozzle, was placed at the head of the cut and was used in caving down the gravels and driving them forward to the wings. A smaller giant, with a 5-inch nozzle, was placed on the high bank a short distance above the wings and was used for moving the gravels directly into the boxes. At this place the stream gravels have a maximum thickness of about 80 feet in alternating beds of varying coarseness. Bowlders over 2 feet in diameter are sent through the sluice boxes, but some coarser bowlders are broken with powder and then handled by the giants. Everything in the cut is disposed of through the boxes. Three distinct pay streaks are reported in this ground. The lowest, on bedrock, is only a few feet thick, but is said to be the richest. It consists of rather coarse materials and contains considerable sticky clay that breaks up with difficulty and is likely to resist disintegration in the sluice boxes, and so fail to give up some of the placer gold it contains. A second pay streak is 8 to 12 feet thick, and its bottom is 15 feet above bedrock. The third comprises the upper 10 feet of the stream gravels and is the result of concentration by the present stream. The excavation discloses the fact that at the time the stream flowed over its bedrock floor, during the erosion of the deepest buried channel, it occupied a steep-walled rock canyon, and its gravel deposits were small. Upon the obstruction of this canyon by the Glacier Creek ice tongue a deep gravel deposit filled the old excavation, and the stream has since been able to remove these gravels only to a depth controlled by the rock floor in the present canyon. The bedrock thus far uncovered consists of steeply tilted beds of slate, graywacke, and conglomerate. In general it affords a rough surface well adapted to retain the placer gold, but locally it has been cut into potholes and worn so smooth that little gold has remained upon it. The gold penetrates to a depth of 2 feet or more in the cracks of the slate, and the broken surface of the bedrock must be removed to a considerable depth in order to obtain this gold.

At the lower workings on this property, on a branch of the deepest old channel, one giant with an 8-inch nozzle was used in caving down a high bank of gravel, sand, and glacial till and in driving it into the main sluice line.

The gold is bright in color and assays about $15 an ounce. It would certainly be classed as coarse gold, although only a small proportion is in nuggets having a value of 50 cents or over. Although Mendenhall[1] reports a nugget worth $50 from this stream, the largest two nuggets that have been found by the present operators had values of $26 and $25. Pieces worth from $1 to $10 are common. The sluice-box concentrates show abundant black sand.

At the close of the mining season of 1915 a large amount of tedious and expensive dead work had been completed. The diversion flume was finished and ready to be opened, the sluice line had been reset and

[1] Mendenhall, W. C., op. cit., p. 320.

relined, and the pipe lines were in position. The owners stated that within a few hours after the stream opened in the spring active mining would be under way, and they confidently expected the most prosperous season in the history of these claims.

Plans have been drawn and bids called for by the owners of this ground on specially constructed high-carbon steel plates to be used instead of block riffles in the sluice boxes. With the large volume and bowldery character of the gravels mined at this place, block riffles, although comparatively inexpensive to install, have so short a life that maintenance charges are high. It is believed that plates 1 inch thick of very hard steel, although of much higher first cost, will ultimately effect a great saving. Furthermore, they are thought to offer a great advantage in that they will render it unnecessary to shut down the mine for some three weeks in midseason in order to reblock the sluice boxes, as has been done in past years.

A second group of claims on Crow Creek, known as the Girdwood property, begins at the upper end of the Alaska Crow Creek Mining Co.'s ground, about 2 miles above the mouth of the creek, and extends northward to the head of a moraine-dammed, gravel-filled basin. The most complete description of the workings at this place is that of Paige and Knopf,[1] written as the result of their examination in 1906, at a time when the mine was in operation. The claims at this place have been patented, and in recent years no mining has been done. The plant is provided with several buildings, still in good condition, and considerable equipment, including steel hydraulic pipe and derricks. Cables, sluice boxes, and other apparatus are scattered over the property in various stages of preservation. A brief summary of the mining done is given here. The data are for the most part taken from the published descriptions by Moffit and by Paige and Knopf, to which reference has already been made.

The ground to be mined was the gravel filling of a basin lying behind a well-defined glacial moraine that stretches across the valley, its convex side downstream. This moraine impounded the waters of the stream and caused them to deposit their load of gravels until the basin was filled to the level of the stream outlet across the moraine. According to Moffit, the filling consists of interbedded layers of fine sand, angular wash, and coarse bowlders. The angular material had been brought down and deposited during freshets. The beds abut against the upper side of the moraine, and in order to mine the gravels in this basin it was necessary to make a 60-foot cut through the moraine. This was a slow and expensive undertaking, as the rock piles on either side of the old cut still testify, for the

[1] Paige, Sidney, and Knopf, Adolph, Reconnaissance in the Matanuska and Talkeetna basins, with notes on the placers of the adjacent region: U. S. Geol. Survey Bull. 314, pp. 121–122, 1907.

moraine was composed of exceedingly abundant and large bowlders and blocks of rock, with a relatively small amount of fine material. Many of the bowlders were hoisted from the cut by a derrick and stacked at the sides, but those too large to be handled required blasting. Paige reports that about 50,000 cubic yards of gravel was washed in 1906, but in this operation bedrock was not uncovered. It is said that a number of holes to bedrock were made with a Keystone drill and that highly encouraging amounts of gold were found in the drill holes, but the expense of opening the cut to bedrock proved too great, and mining there was discontinued in 1906. In 1907 and 1908, it is reported, sluicing was done on the upper end of the property with fairly satisfactory results. Since 1908 little actual mining has been done.

Winner Creek.

Two claims on lower Winner Creek have been mined in a small way for several years by one man. The first gold was recovered from this creek in 1898, when two men took out 36 ounces. The present owner first located the ground in 1902, but soon relinquished it. It was later staked by another man and then abandoned, to be finally restaked by the present owner in 1908. A cut 150 feet long, 14 feet wide, and 8 feet deep was first worked out, and later an area 100 feet long, 34 feet wide, and 5 feet deep was mined on a high rim. Difficulty has been experienced in conducting water to the gold-bearing gravels under sufficient head for hydraulic mining. A ditch to acquire such a water supply is in process of construction.

Other prospects in Glacier Creek basin.

California Creek received a good deal of attention from prospectors in the years between 1898 and 1902 and yielded some gold. Since 1902 no mining has been done there, but tentative plans have been made to continue prospecting in 1916. Paystreak Creek, the first tributary of Glacier Creek above Crow Creek, has also been prospected, but no paying ground was found. The main valley of Glacier Creek below the mouth of Crow Creek has been staked for several years, though nothing more than assessment work has been done.

PROSPECTS IN TURNAGAIN ARM BASIN.

It is reported that some placer claims are held on the west side of Twentymile River, about 4 miles above its mouth, but no mining has been done on them. Peterson Creek, the first tributary of the Arm west of Twentymile River, is said to have yielded some placer gold many years ago, and one man is still doing the assessment work on some claims in the upper basin of that stream. Kern Creek was prospected both in 1898 and in 1903, and some gold was found on it, but not enough to warrant mining. The gravels on Bird Creek have been prospected by different persons at different times since 1898. One outfit is said to have found ground that would yield as high as $6 a day for each man employed, but the bowlders were so large and so abundant that mining was discontinued. Two men were engaged in 1915 in driving a tunnel on the east side of Bird Creek, about 8 miles above its mouth, in the hope of opening an old gravel-filled channel there. In August, 1915, the tunnel was reported to be 144 feet long, driven through slate, and the old channel had not yet been reached.

Considerable work was done a number of years ago on lower Indian Creek. A flood dam was built and a cut ground-sluiced out, but the operators were unable to reach bedrock, and the ground was abandoned.

At a point near the beach, 1 mile west of Indian Creek, one man has been engaged in prospecting for a number of years. An open cut, extending northward for about 270 feet from the beach and from 15 to 20 feet deep at the face, has been excavated by ground sluicing. The bedrock, a black slate striking S. 6° W. and standing nearly vertical, was encountered 170 feet back from the beach. At the face of the cut the section comprises 2 feet of mucky soil underlain by 2 feet of blue glacial till, between which and bedrock there is 12 to 15 feet of well-rounded, rather fine gravel, with a few bowlders. No sampling of the ground was done, but the owner reports abundant black sand, with some gold. A lack of water has retarded prospecting, but a ditch 1½ miles long, to take water from Indian Creek, has been laid out, and the lower mile has been completed.

PROSPECTS ON TRIBUTARIES OF KNIK ARM.

Prospecting for gold placers on the tributaries of Knik Arm was stimulated by the beginning of construction on the Government railroad. Gold strikes were reported on Ship, Chester, and Campbell creeks and on other streams near Anchorage, and a few persons stampeded to these streams, but the small amount of prospecting done by them failed to confirm the rumors. At only one place was any actual attempt to mine noted. At a point where one of the tributaries of Ship Creek from the southwest emerges from the mountains one man had built a small flood dam and had ground-sluiced a small open cut, but had not uncovered bedrock. He reports small amounts of gold, but at the time of visit, late in August, 1915, he had found no workable placer.

GOLD AND SILVER LODES.

TURNAGAIN ARM.

GLACIER CREEK BASIN.

As a result of the early discovery of workable gold placer deposits in the Glacier Creek basin, that locality was also chosen by prospectors in search of the lodes from which the stream gold was originally derived. The first discovery of a gold-bearing quartz lode was not made until 1909, more than 10 years after the first placer gold was mined. The only lode prospects in the basin on which any considerable amount of development work has been done lie in the upper valley of Crow Creek and in Crow Creek Pass, about 9 miles from Turnagain Arm. They include two separate groups of claims. At the time of the writer's visit, in August, 1915, no one was seen on these claims, though one man was said to be prospecting there. The principal workings were visited by B. L. Johnson in the fall of 1911, and at that time active work was underway. Developments were discontinued the following year, so that Johnson's description[1] is still essentially correct and is here quoted.

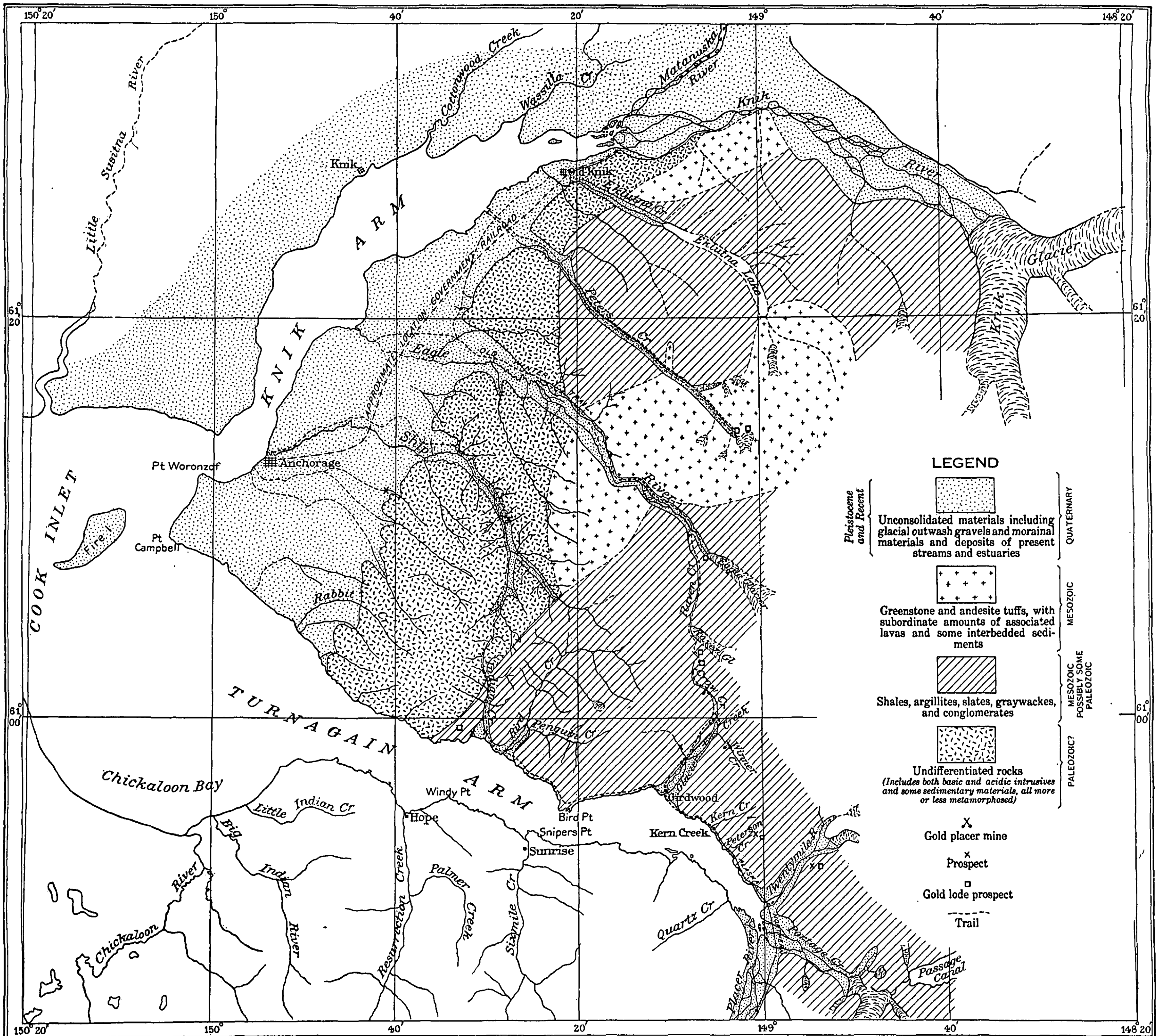
BARNES PROPERTY.

Location.—The property of the Alaska Gold Exploration & Development Co., known locally as the Barnes property, is at the head of Crow Creek, 9 miles from Girdwood, at the mouth of Glacier Creek. (See fig. 11.) * * *

History and development.—Although the first discovery of gold-bearing quartz on this property was made in September, 1909, by Conrad Hores, little work was done to open up the veins prior to August 1, 1910. Since that date, however, underground development has been actively carried on, all of it on the Stella claim. Three veins had already been found at the time this property was visited, and a fourth was discovered on the Ruth claim late in the fall of 1911. The developments on the Stella claim to January 1, 1912, consisted of 560 feet of adit levels, 56 feet of crosscut tunneling, 14 feet of drifts, and 52 feet of winzes, together with several open cuts on the different veins. These developments include three adit levels, two of which are on the south vein, one 100 feet vertically above the other. The upper of these two tunnels was 267 feet in length; two winzes, 42 and 10 feet in depth, have been sunk on the vein in this tunnel. The lower tunnel, started late in the fall, was only 50 feet long. On the northern vein, which is nearly parallel to this one, an adit level, 243 feet in length has been driven. A 56-foot tunnel intersects the third or crosscutting vein on the Stella claim. (See figs. 12 and 13.) Very little work has been done on the Ruth lode. Development work on this property ceased early in the spring of 1912.

Country rock.—The country rock of the ore deposit consists of dark slate, banded argillite, fine-grained graywacke, and conglomerate, folded and later intruded by several bosses of light-colored fine-grained granites and fine-grained to aphanitic acidic dikes, offshoots from the granitic masses. The strike and

[1] Johnson, B. L., The central and northern parts of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 173–176, 1915.



Scale $\frac{1}{500,000}$

5 0 5 10 15 Miles

1916

GEOLOGIC SKETCH MAP OF THE TURNAGAIN-KNIK REGION.

S. R. Capps.

dip of the sedimentary beds vary, but in general the strike is easterly and the dip northerly. Fossils are not abundant. Imprints of a small Inoceramus of Jurassic or Cretaceous age were found during 1911 on the bedding planes of the banded argillite in bowlders on the moraines of the Crow Creek and Raven Creek glaciers and in place on the west side of the Raven Creek glacier.

Inclusions of the banded argillite are found in some of the granite bosses, sharp contacts appearing between the igneous and sedimentary rocks. No development of contact minerals is noticeable. The angularity of the fragments of the talus, the appearance of the weathered surfaces, and the density of the rocks, as well as the reddish, rusty discoloration of the sedimentary rocks

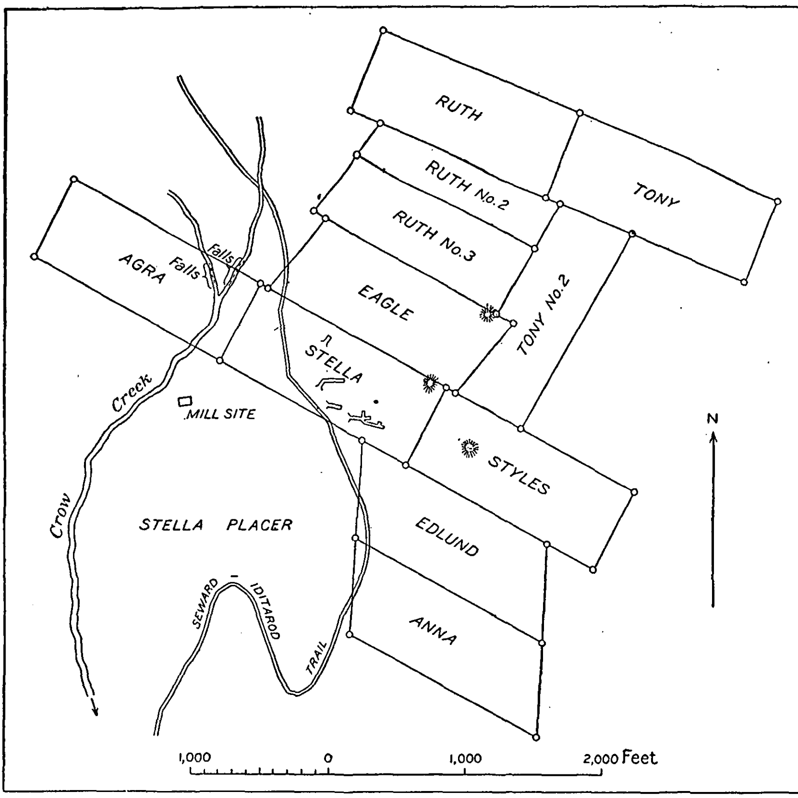


FIGURE 11.—Map showing location of mine workings on the Barnes property, Crow Creek. From map by C. H. Ballard (August, 1911).

of the area, suggests considerable heat action and mineralizing activity. Faults are numerous, the displacement, however, being usually only a few feet.

Ore deposit.—The ore body on the Stella claim consists of two parallel veins, a little over 100 feet apart, striking eastward, and a third vein crossing these with a strike of S. 18° E. The southernmost of the two parallel veins strikes S. 83° E., dips 55° N., and varies in width from 8 to 46 inches. The northern vein varies in width from 10 inches to 3 feet, strikes N. 87° E., and dips 68° N. The outcrops of these veins have been traced only a few hundred feet. The third or crosscutting vein ranges in width from 2 to 10 inches and dips 80° W. The vein on the Ruth claim is reported to strike eastward and to have a width of 6 to 8 inches.

Ore.—The gangue mineral of the gold veins is predominantly quartz, but it includes also some calcite. The vein quartz varies slightly in character. In some places it is coarsely crystalline and the vein contains numerous small vugs. Secondary banding parallel to the walls is noticeable in places, and sulphides have been deposited along some of the fractures. The quartz is jointed in some parts of the vein.

Arsenopyrite, pyrite, sphalerite, and galena are the principal sulphides. Chalcopyrite also occurs in small quantities. Pyrite and arsenopyrite occur as disseminated crystals in the metasomatically altered wall rock of the veins, as well as in association with the other sulphides in the vein quartz. In the open cuts the galena is often altered to cerusite. The crosscut tunnel on the Stella claim passed through a small vein containing molybdenite, pyrrhotite,

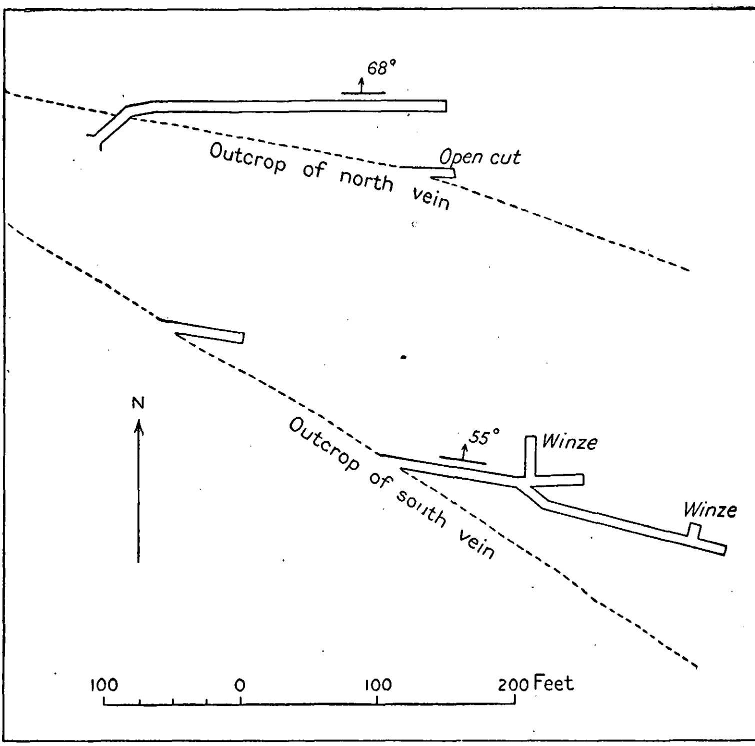


FIGURE 12.—Plan of workings on north and south veins, Stella claim, Barnes property, Crow Creek (1911).

and chalcopyrite in a gangue of vitreous-looking quartz. Pyrrhotite and chalcopyrite also occur in narrow seams in the banded argillite near the igneous rocks.

The ores are free milling. Tests on some of the more highly mineralized ore are reported to have saved 80 per cent of the gold by amalgamation and 16.4 per cent in the concentrate. The gold is found free in the quartz and occurs also in close association with the sulphides. It is also in places included in the grains of galena and arsenopyrite. Along some of the joint planes where the auriferous iron sulphides have been oxidized the gold is especially noticeable. Nuggets worth up to 63 cents have been found in the veins.

The ore from the larger veins on the Stella claim is reported by the owners to average $35 to $40 a ton for the southern vein and $12 a ton for the northern vein. Much higher assays have been obtained, however, in single samples. The limits of the ore shoots are not yet defined. About midway of the upper tunnel on the southern vein a stringer runs out into the hanging wall, and at this point sulphides are said to have been much more abundant and assays much higher than in other parts of the vein. Exceedingly high assays are reported from the crosscut vein on the Stella claim and from the vein on the Ruth claim. The wall rocks of none of the veins are said to carry gold.

TREASURE BOX CLAIM.

The Treasure Box quartz claim, in Crow Creek Pass, was located September 7, 1910, by James Patchell. The ore body consists of a quartz vein a foot wide, striking N. 11° E. and dipping 70° E. The vein is traceable for about 50 feet. No development work had been done at the time the lode was seen, and no data are available as to the gold content of the vein.

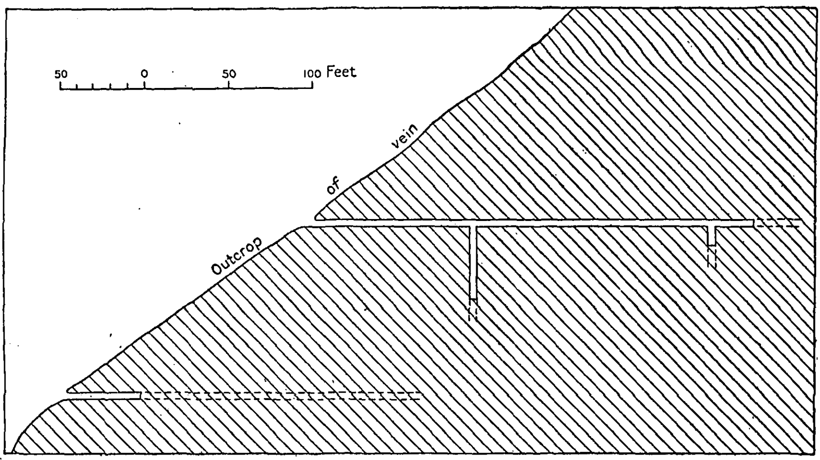


FIGURE 13.—Longitudinal section along plane of south vein, Stella claim, Barnes property, Crow Creek, looking north (August, 1911).

It is reported that in 1915 one man was engaged at Crow Creek Pass in driving a tunnel on a promising gold quartz vein, but the property was not visited.

BIRD POINT.

Two gold quartz claims were located along the Turnagain Arm beach just west of Bird Point in 1911. The vein outcrop was below extreme high-tide level, and in order to protect the mouth of the shaft from the tides a log cribbing, filled with clay, was erected around it. The shaft is reported to have been sunk to a depth of 22 feet, but after that depth had been reached an exceptionally high tide shifted the cribbing and flooded the workings, so they could not be examined at the time of the writer's visit. The quartz vein is said to range from 2 to 16 inches in thickness and to cut slate country rock. Both the vein and the slates strike about magnetic north. The quartz carries pyrite, chalcopyrite, galena, and copper carbonates in addition to the gold. A mill test of 4,200 pounds of ore, made in 1912, is said to have yielded gold at the rate of $52.75 a ton. Acidic dikes cut the slates and graywackes of the mountain north of Bird Point, and there may well be a genetic connection between the gold quartz veins and these intrusives. The dikes themselves and the neighboring portions of the quartz-veined sediments are said to carry gold in encouraging amounts.

OTHER PROSPECTS.

It is reported that assessment work has been done on some gold quartz claims about 4 miles above the mouth of Twentymile River, and also on claims in the upper part of the Peterson Creek basin, but only a small amount of development work has been accomplished, and the ground was not visited.

A number of claims have been staked and a small amount of development work is reported to have been done on a mineralized dike that cuts the slates, graywackes, and greenstones of the mountain west of lower Indian Creek. The claims were not visited, but at the point where the same dike crops out on the beach it appears as a fine-grained gray acidic rock, weathering to a rusty red. The containing slates and graywackes, as well as the dike itself, have been twisted and faulted, so that the dike rock now appears as disconnected bunches 12 to 18 inches thick and 1 foot to 6 feet long. Associated with the dike and locally cutting it are bunches and veinlets of calcite and quartz showing some pyrite and iron oxide, and the associated graywacke is mineralized with disseminated pyrite and is somewhat rusty.

KNIK ARM.

PETERS CREEK BASIN.

Active prospecting has been done for several years on a group of claims near the head of Peters Creek. The country rock in this vicinity consists of a massive series of greenstone and greenstone tuff, with small amounts of interbedded shale. A characteristic phase of the greenstone is a dense, fine-grained green rock inclosing abundant small angular fragments of slate. Two cabins have been built near these claims, which are several miles from the nearest available timber. One cabin is in the main valley of Peters Creek, near the point at which it emerges from beneath the glacier, and the other is high on the edge of the glacier some 2,000 feet above the lower cabin. On the mountain side northeast of the lower cabin and at an altitude about 1,100 feet above it a tunnel 37 feet long was driven on a fracture zone containing a quartz vein 2 inches or less in thickness. This vein strikes N. 60° W. and dips 75° SW. At a point 30 feet from the portal the tunnel cuts an intersecting quartz vein striking N. 77° W. and dipping 60° N., and showing a maximum of 2 inches of quartz. At the breast of the tunnel a second intersecting vein, parallel with the first, was encountered. It lies in a fracture zone that shows about 1 foot of gouge, broken greenstone, and quartz, in which the quartz reaches a greatest thickness of 8 inches. The quartz is sugary and somewhat banded and shows vugs lined with tiny, needle-like quartz prisms. It is cut in places by thin veinlets of calcite. Little mineralization other than some rusty stains was seen, but the ore is said to carry pyrite and lesser amounts of galena and chalcopyrite. The only assay made from this tunnel is said to have yielded $12.60 a ton in gold.

The other tunnels on this property lie on the steep mountain wall above the upper edge of the Peters Creek glacier, over 2,500 feet above the lower cabin. To reach them it is necessary to cross a portion of the glacier. At the time of visit—in June, 1915—there was no one resident on the property, and the snow banks on the mountain were so abundant that the tunnels could not be found and probably were covered with snow. It is reported that four tunnels have been started there, on two separate claims. On one claim is a 12-foot crosscut tunnel, not yet driven far enough to cut the main vein. Above the crosscut is a 45-foot tunnel on a quartz vein said to reach a thickness of 10 inches and to carry a small amount of pyrite. Assays from this vein are reported to show an average gold content of $38 to the ton. On the other claim one tunnel 8 feet long and another 18 feet long are said to have been driven on reticulated gold-bearing quartz veins.

EAGLE RIVER BASIN.

The only lode deposit so far discovered in this region whose chief value lies in some metal other than gold is at the head of Eagle River, near the foot of the glacier in which that stream has its source. This lode is known as the Mayflower lode. The claim was visited by B. L. Johnson,[1] in 1911, and, as no considerable amount of development work has been done on this property since that year, Johnson's description is here quoted in full:

> The Mayflower lode, on the south side of Eagle River, at the foot of the Eagle River glacier, was discovered June 1, 1911, by J. P. Frisbie, William Murray, and M. S. McMelan. The outcrop of the ore body is well exposed on the recently glaciated surface of the massive graywacke country. The ore body consists of mineralized sheeted zones in the massive graywacke. These zones have a north-south strike, dip vertically, and have been traced about 400 feet on the south side of the river. Their continuation on the north bank

[1] Johnson, B. L., The central and northern parts of Kenai Peninsula, Alaska: U. S. Geol. Survey Bull. 587, p. 178, 1915.

is reported. They have a rusty appearance, resulting from the decomposition of the iron sulphides. Two of the zones, 50 feet apart, carry a few mineralized quartz stringers of variable width. The easternmost and widest of these sheeted zones has a width of about 50 feet, only part of which is much fractured. The largest quartz stringer observed lies near the eastern edge of this zone. It has a width of 1 to 6 inches, but in places it widens to 10 or 12 inches. The gangue of the veins is quartz with a little calcite. Small calcite veins also occur along joint planes in the graywacke. The metallic minerals of the ore deposit are galena, pyrite, sphalerite, arsenopyrite, chalcopyrite, and a little malachite. The mineral association is similar to that of the gold quartz veins of Kenai Peninsula. Galena is more abundant than in most of the gold quartz prospects, and an assay from this ledge reporting 0.05 ounce gold and 24.80 ounces silver to the ton was probably made on a specimen consisting principally of galena. No free gold was seen in any of the specimens examined.