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THE KAIYUH HILLS, ALASKA

BY

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THE KAIYUH HILLS

By J. B. MERTIE, JR.

ABSTRACT

The Kaiyuh Hills constitute an isolated geographic province which lies southeast of the Yukon River in west-central Alaska. These hills are uninhabited, and little information has hitherto been available regarding them. The present report states the result of a reconnaissance geologic survey of this province made during the summer of 1934.

The geologic section of the Kaiyuh Hills includes ancient metamorphic rocks, bedded lavas and associated sedimentary rocks of Carboniferous (?) age, nonmetamorphic sedimentary rocks of Paleozoic and Mesozoic age, and unconsolidated sediments of Quaternary age. The hard rocks have been intruded by granitic rocks of Mesozoic (?) age, which are believed to be of much significance as a possible source of mineralization. The known sites of such granitic rocks are mapped, and suggestions are given regarding their discovery in unmapped areas.

No mineral deposits of great value have so far been discovered in the Kaiyuh Hills, but small bodies of silver-lead ore have been found, both in these hills and in the adjoining Ruby mining district. Traces of alluvial gold were also observed by the party of 1934 at the southwest end of the Kaiyuh Hills, in the vicinity of a body of granitic rocks. It is concluded by the writer that further prospecting would be justified in this region.

INTRODUCTION

The Kaiyuh Hills are a part of the general upland province that extends south and southwest from Ruby into the lower valleys of the Yukon and Kuskokwim Rivers. They are defined geographically as that portion of this upland region which begins about 25 miles west-southwest of Ruby and extends in the same direction for about 75 miles, terminating at the Yukon River about 15 miles downstream from Kaltag. The geographic limits are approximately 156°15′ to 158°30′ west longitude and 64° to 64°40′ north latitude. (See fig. 6.)

The present report states the results of an exploratory survey of the Kaiyuh Hills during the summer of 1934. Preparations for this work were begun at the usual time in the spring, and a Geological Survey party had been organized and was ready to sail from Seattle on May 26, but meanwhile a longshoremen's strike had developed, so that the party was obliged to remain in Seattle until June 12. Moreover, when shipping was resumed, an acute shortage of cargo

space made it necessary to ship the packhorses and equipment on a slow freighter. As a result of these conditions, the party and its working equipment were not assembled at Ruby until July 15, or 4 weeks later than had originally been planned.

The field party consisted of six men, including the writer, and 14 horses. The temporary personnel consisted of R. D. Ohrenschall and Martin Webories, camp assistants; R. L. Phillips and John

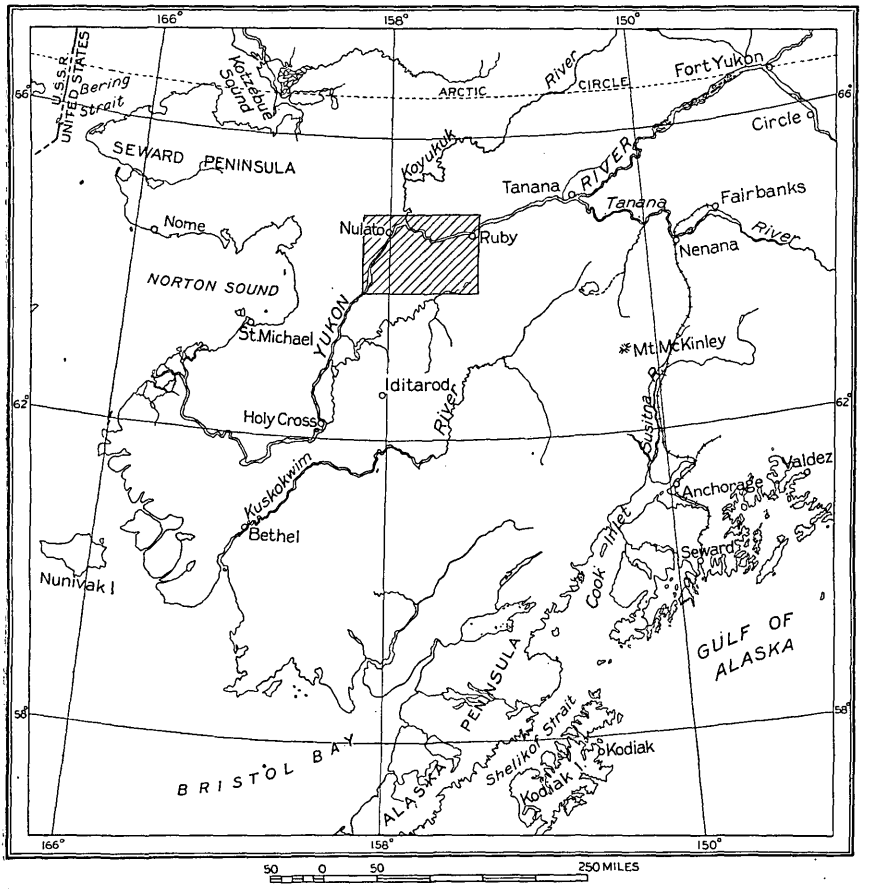


FIGURE 6.—Index map showing location of the Kaiyuh Hills.

Van Zanten, respectively packer and assistant packer; and Edwin Aanensen, cook. All these men gave efficient and faithful service, but the writer wishes particularly to acknowledge the able field assistance rendered by Mr. Ohrenschall.

During the summer of 1935 an expedition led by Frederica de Laguna was engaged in archeologic work along the Yukon River between Tanana and Holy Cross. A. J. Eardley, a member of this expedition, made a time and compass traverse of Kaiyuh Slough and Khotol River. The writer wishes to thank both Miss de Laguna

and Mr. Eardley for making available this geographic information, which has been included in the map accompanying this report.

The Kaiyuh Hills constitute an uninhabited country in which no earlier mapping had been done. The present work was essentially a plane-table survey of the regional drainage and a study of the geologic formations, with special reference to their importance as the source of mineral deposits. The field mapping was done on a scale of 1:180,000 but has been compiled on a scale of 1:400,000, for publication on a scale of 1:500,000, or about 8 miles to the inch. This small scale is justified by the exploratory character of the work and by the lack of detailed information, due in large measure to the shortness of the field season. To render more intelligible the geographic and geologic relations of the Kaiyuh Hills to adjoining areas, the accompanying map has been made to include an area extending eastward to and somewhat beyond the longitude of Ruby and Poorman, the nearest settlements to the east, and an area extending northward to the Yukon River between Ruby and Kaltag, including the settlement of Nulato, near the mouth of the Koyukuk River.

GEOGRAPHY

DRAINAGE AND RELIEF

The Kaiyuh Hills have a length of about 75 miles and an average width of about 15 miles. These hills form an isolated geographic unit, because they are sharply delimited on all sides by alluvial flats. On their northwest side they are separated from the Yukon River and the hills to the north by a great swampy lowland, which opposite Nulato has a width from the hills to the river of about 30 miles. On the east and southeast the wide valley of the Yuko River intervenes between the Kaiyuh Hills and the Ruby district; and to the south lie the low timbered ridges and wide alluviated valleys that characterize the northern tributaries of the Innoko River. At their southwestern extremity the higher part of the Kaiyuh Hills is terminated rather abruptly by a wide marshy valley occupied by a fork of the Kluklaklatna River, locally called "Mud River", a tributary of the Innoko, but west of this valley is a group of low hills, which may be considered the southwestern continuation of the Kaiyuh Hills. The western slopes of these low hills approach within 4 or 5 miles of the Yukon River, but along their western base flows an outlying channel of the Yukon River, the Khotol River. Between the Khotol River and the main Yukon River there are more alluvial flats, which form part of the floor of the Yukon Valley.

The Yuko and Innoko Rivers and their tributaries therefore drain the east, south, and southwest slopes of the Kaiyuh Hills. The northwest slopes are drained by small streams tributary to the

Yukon, of which the two largest are Bishop and Kalakaket Creeks. The east slopes of the low hills that constitute the southwestern continuation of the Kaiyuh Hills are drained by the Kluklaklatna River, but the west slopes are drained by short gulches that flow directly into the Khotol River.

The Yuko River flows into the Yukon River about 20 miles downstream from Ruby. This stream has two large branches, which unite about 25 miles from the Yukon and both of which have intricate drainage patterns. For 15 miles below the forks the Yuko meanders tortuously over a valley floor, which ranges in width from 2 or 3 miles to less than a mile. The narrowest place in the valley floor is at a point about 4 or 5 miles below the forks, where a long ridge that extends southwest from Yuko Mountain approaches very close to the river, and it was at this point that the expedition of 1934 rafted the river. There the Yuko is about 100 feet wide and at a moderate stage of water has a current of about 2 miles an hour. The depth in the deeper part of the channel, along the east bank, is more than 12 feet. From the forks downstream to this narrow part and for some distance downstream the Yuko River has numerous low gravel bars, particularly on the inside of the meanders, but cut banks are more prevalent. As the river flows out of its own valley and cuts across the valley floor of the Yukon, the gravel bars disappear, and the Yuko flows in a meandering course with a lower gradient and slower current through cut banks to join the Yukon.

The west branch of the Yuko is the larger of the two branches. The lower end of its valley is asymmetric, with long spurs on the northwest side, some of which extend for 1 or 2 miles from the main ridge southeastward to the stream. This west branch has three main headwater tributaries, which together drain two-thirds of the southeastern slopes of the Kaiyuh Hills. The farthest downstream of these tributaries flows southwestward and is thus a back-hand drainage channel with respect to the main stream. It also has an asymmetric valley, and the spurs on the northwest side are rather long. The next tributary flows east-northeastward, and the headwater tributary has a devious though in general a southeasterly course that is probably controlled in considerable measure by the rock structure. Only the headwaters of these three tributaries were closely inspected, as the course of the expedition was in general along the main ridge line of the Kaiyuh Hills; but viewed from this upland country the lower valleys of these three tributaries appear to be wide and swampy, and the streams appear to flow between cut banks, without gravel bars.

The east branch of the Yuko heads against the Innoko drainage system, but details regarding its headwater tributaries are lacking. For 15 miles above its confluence with the west branch, however, it

flows nearly parallel to that branch, the two being separated by a narrow but well-defined ridge of hard rock. For about 3 miles to the southwest, above the forks, this interstream ridge is a long, gently sloping spur, the lower mile of which is nearly flat and may in reality be an old river terrace. Still farther southwest, however, this ridge increases progressively in height for several miles and then decreases in height and finally disappears. About 5 miles above its confluence with the west branch the east branch receives a large tributary, which drains the southwest slopes of Yuko Mountain. This tributary has a southwesterly course and therefore constitutes another example of back-hand drainage in the Yuko system.

The southwest end of the Kaiyuh Hills is drained by two streams, which probably flow together some miles to the south to form the Kluklaklatna River, one of the northern tributaries of the Innoko. The eastern of these two streams does not differ materially in character from the headwater tributaries of the Yuko, but the western stream heads in the wide, flat marshy depression that delimits the west end of the higher part of the Kaiyuh Hills. This depression is 6 to 8 miles wide and is so flat and featureless that the divide that separates the Innoko drainage system from that of the Yukon cannot be recognized with assurance, even from the tops of the high hills to the east. The main stream and its tributaries within this wide depression are deep, sluggish streams, with cut banks of silt, and can be crossed with pack horses only by means of bridges. The expedition of 1934 built three such bridges in crossing this depression.

The Khotol River drains the west side of the low hills west of this depression and also the northwest slopes of the Kaiyuh Hills. It is said to have two inlets from the Yukon River, one of which is about 20 miles above Kaltag. The latter, which is known as the Kaiyuh Slough, has a general southeasterly course and joins the Khotol River about 15 miles in an air line from the Yukon. From the junction of Kaiyuh Slough with the Khotol River, the course of this overflow channel is generally southwestward and more or less parallel to the Yukon River, which it rejoins about 20 miles below Kaltag.

The Khotol River, in its lower course, is essentially a wide sluggish slough in which little or no current can be detected at ordinary stages of the Yukon, though the banks give ample evidence of the effects of erosion and deposition at stages of high water. Several timbered spurs extend westward from the low hills west of the headwaters of the Kluklaklatna River down to the Khotol River, and at the foot of one of these spurs, where the expedition of 1934

rafted this slough, it was found to be a deep stream, from 150 to 200 yards in width, with no appreciable current. People who have traversed it in boats, however, say that there are shallow stretches, or perhaps bars, in its course, that even small boats have difficulty in crossing. The sides of the slough are mainly steep-cut banks, lined with logs and much driftwood, and only here and there do good bars occur, mainly at the mouths of tributary gulches.

From the northwest slopes of the Kaiyuh Hills several small streams flow northward toward the Yukon and the Khotol Rivers, but their lower courses are not well known. Bishop and Kalakaket Creeks, the largest of these streams, have a general northeasterly course out of the hills, but Bishop Creek veers northwestward in crossing the flats to the Yukon. According to a note by G. C. Martin,[1] Bishop Creek follows a meandering course across the flats and enters the Yukon River near Bishop Mountain; and Kalakaket Creek enters the upper end of Louden Slough. Southwest of Bishop Creek are several streams that flow northwestward from the Kaiyuh Hills to join the Khotol River. The principal ones of these, named in order from northeast to southwest, are Bonanza, Canoe Portage, Eddy, and Yukon Creeks. Bishop and Kalakaket Creeks, as well as the other small streams that drain the northwest slopes of the Kaiyuh Hills, are characterized by sharply incised headwater valleys, as opposed to the relatively open headwater valleys of the tributaries of the Yuko that head against them and drain the southeast slopes.

The Kaiyuh Hills form essentially a well-dissected ridge country. The main divide between northwestward-flowing and southeastward-flowing streams is well defined for a distance of about 60 miles. This main ridge consists of a succession of gently rounded or nearly flat domes, separated by broad but deeply incised saddles. The general course of this ridge is S. 65° W., but the crest line is more or less sinuous—markedly so at the southwest end of the hills. The complex drainage pattern of the Yuko River, however, gives rise along the southwest slopes to subsidiary ridges that have the general characteristics of the main ridge except that their elevation is less.

The domes or summits along the main ridge range from 2,000 to 3,000 feet above sea level. The average elevation of these tops, as gaged by a mean of the elevations of 20 triangulation stations, is about 2,200 feet, though the average for the main ridge as a whole is probably closer to 1,500 feet. The highest peak is one with a conical top that marks the southwest end of the Kaiyuh Hills proper. This peak, which is 27½ miles S. 70° E. from Kaltag, is visible from Kaltag and from many other points along the Yukon River above and below Kaltag. Ruby, on the Yukon River, is approximately 275

[1] Brooks, A. H., Mineral resources of Alaska, 1921: U. S. Geol. Survey Bull. 739, pp. 38–39, 1923.

feet above sea level, and Kaltag less than 200 feet. The average difference in elevation, therefore, between the main ridge and the Yukon is about 1,200 feet, but the maximum relief is about 2,700 feet.

CLIMATIC CONDITIONS

No climatic records have been kept at any station within the Kaiyuh Hills, but partial records of the precipitation, snowfall, and temperature were kept by the United States Weather Bureau at Nulato for about 10 years in the interval between 1894 and 1924. Partial records were also kept at Ruby for the 4 years 1917 to 1920, but these are too incomplete to have much value. Fairly complete records have been kept at Tanana for 50 years and at Holy Cross for 40 years, and these, together with the observations at Nulato, which is about halfway between Tanana and Holy Cross, give a general idea of climatic conditions in this part of the Yukon Valley.

As Nulato is the nearest point to the Kaiyuh Hills where weather records have been kept, the means of these observations are presented herewith:[2]

Mean precipitation, snowfall, and temperature at Nulato, Alaska

	Precipitation (inches)	Snowfall (inches)	Temperature (° F.)		Precipitation (inches)	Snowfall (inches)	Temperature (° F.)
January	1.23	19.3	−9.1	August	2.32	0	52.9
February	1.33	14.3	−1.6	September	2.09	1.3	40.0
March	1.48	14.6	6.0	October	1.98	12.9	24.4
April	.47	4.0	16.8	November	1.16	10.6	.1
May	.54	.6	39.1	December	.93	12.5	−8.0
June	1.17	0	52.1				
July	1.98	0	55.8	Annual	16.68	90.1	22.4

From the records now available it appears that the mean annual precipitation is about 13 inches at Tanana and increases down the Yukon River to about 17 inches at Nulato and about 20 inches at Holy Cross. In the Kaiyuh Hills, however, at an elevation of 1,300 feet or more, the precipitation is believed to be more than at Nulato and possibly closer to that recorded at Holy Cross. At all three of these stations, as in other parts of interior Alaska, the greatest precipitation occurs in July, August, and September. At Tanana the maximum precipitation is in July; at Nulato and Holy Cross the wettest month is August.

The mean annual temperature, however, does not change progressively in going down the Yukon, as the records show 23.2° at Tanana, 22.4° at Nulato, and 26.3° at Holy Cross. The temperatures

[2] Summary of the climatological records of Alaska, by sections: U. S. Weather Bureau Bull. W, 2d ed., vol. 3, 1926; also Climatological data, Alaska section, vols. 8–10, 1922–24.

at Nulato therefore appear to be more nearly comparable with those at Tanana. The temperatures within the Kaiyuh Hills are not definitely known and cannot be reliably inferred from the temperature records in the main Yukon Valley, except to state that the annual temperature is probably neither appreciably greater nor appreciably less than that at Nulato.

The climate in general is similar to that which prevails elsewhere in interior Alaska and is typically subarctic, with long, cold winters and short, fairly warm summers. It is characteristic of interior Alaska as a whole, however, that climatic conditions year by year differ materially from mean climatic conditions, so that there are few summers or winters that do not appear to be abnormal in some respects. The Kaiyuh Hills and the adjoining Ruby district are no exception to this generalization. Thus the summer of 1933 was abnormally warm, with very little rainfall. The summer of 1934, on the other hand, was decidedly cool, and freezing temperatures with snow squalls occurred in the middle of July. The precipitation was also abnormally heavy throughout the summer of 1934, and even when it did not rain the sky was overcast by heavy clouds during much of the summer.

TIMBER, FORAGE, AND GAME

Spruce is the most common type of timber in and around the Kaiyuh Hills, but considerable poplar also grows, particularly on the lower slopes and along the streams of the larger valleys. Birch and tamarack are indigenous to this country, but few of these trees were seen in the Kaiyuh Hills. Along the banks of streams, in upland gulches, and in damp places near timber line willows and alders grow in great profusion, and above timber line some dwarf birch brush is also found, though most of the area just above timber line is covered with moss and niggerhead grass. Timber line ranges from 1,600 to 1,800 feet above sea level.

The stand of timber in the Kaiyuh Hills is nowhere heavy, and in the upland country the spruce is scrubby, though in places rather thickly grown. Over most of the spruce-covered hills, however, pack horses can be led with little cutting, but in the timbered saddles, where brush and undergrowth are mingled with the spruce, considerable trail cutting is necessary. In the larger valleys, as on the lower part of the Yuko, spruce grows to a diameter of 2 feet, and both at the Yuko and at the Khotol River ample timber was available to build 30-foot rafts.

The great forest fires that have destroyed so much timber in the Ruby-Poorman district have not in general spread into the Kaiyuh Hills. Most of these fires have stopped at the Yuko River, although

one burned area of considerable size was seen along the main ridge at the heads of the easternmost tributaries of Bishop Creek, mainly along the south or Yuko slopes. Close to the Yukon some good-sized burned areas were also observed, particularly along the western slopes of the wide depression that cuts across the southwest end of the Kaiyuh Hills. The fact that these hills are uninhabited and their isolation from the neighboring inhabited areas undoubtedly account for the preservation of the timber. Owing in part to the impervious character of the bedrock in these hills, but also in some measure to the freedom from burning, water occurs high in the headwater gulches and even on the spurs at timber line during summers of average rainfall, thus facilitating summer travel and camping on the ridges. Forage for stock is fairly plentiful along the valley floors of the larger streams, such as the Yuko, but good horse feed is also found among the alders near timber line.

The Kaiyuh Hills are peculiarly destitute of animal life, particularly in view of their isolated and uninhabited character. No caribou or recent signs of caribou were seen, nor do moose appear to be plentiful in the lower valleys. Relatively few signs of black bear were noted. A few ptarmigan were observed, but few rabbits, ground squirrels, or other small game animals appear to live in these hills. Grayling were seen in the headwaters of Bishop Creek, however, and the streams are believed generally to be well stocked with these and other fish.

SETTLEMENTS AND COMMUNICATION

Ruby, Nulato, and Kaltag, the three principal settlements nearest to the Kaiyuh Hills, have populations, according to the census of 1930, of 132, 204, and 137, respectively, of whom, however, a considerable part are natives. Nulato has a wireless radio station, maintained by the United States Signal Corps, and Ruby has a privately operated wireless and radiophone station. The telegraph line that was formerly used for communication along this part of the Yukon River is now abandoned, but the wire between Nulato and Kaltag is still in fairly good condition and is used for telephone communication. These towns and others along this part of the Yukon are served by a fortnightly steamboat schedule, operated by the Alaska Railroad, between Nenana and Marshall.

The Kaiyuh Hills are entirely uninhabited at the present time except for occasional prospectors, of whom, however, few signs were observed. About 12 years ago a silver-lead lode near the head of Bishop Creek was worked for a short time, and in that vicinity cuttings and other signs of habitation were seen. Likewise at the southwest end of the Kaiyuh Hills signs of old habitation were noted, but in general these hills appear to have been little visited by white men.

The Yuko River affords the best approach to the northeastern part of the Kaiyuh Hills, as it is navigable for small boats at least as far upstream as the forks. The southwest side of the hills is not readily accessible by river, although the Khotol River flows along the base of the western group of outlying hills. In winter, however, the Kaiyuh Hills should be reasonably accessible from the Yukon River by the use of dog-team transportation. An old trail that was formerly used for carrying winter mail from Lewis, opposite the mouth of the Yuko, to Dishkakat, was crossed by the expedition of 1934 and was found to be still fairly well marked and possible to travel with a little cutting. Another old winter trail, from a point on the Yukon about 15 miles below Kaltag, leads southeastward to Dishkakat by way of the Kluklaklatna River.

GEOLOGY

OUTLINE

Bedrock is not well exposed in the Kaiyuh Hills. The individual domes that occur along the main ridge rise only a few hundred feet above timber line and for the most part are covered with moss and vegetation of the tundra type. Where this vegetal cover is lacking the bedrock shows mainly as rubble, so that only at a few localities is it possible to make any structural observations. Between the domes the main ridge for miles is mantled by vegetation of various kinds, ranging from timber in the saddles to brush and tundra on the slopes, so that most of the bedrock is effectually concealed. The geologic map that accompanies this report (pl. 9) is therefore a generalized delineation of the distribution of various types of bedrock, based upon scattered exposures on the higher parts of the main ridge. Laterally the map has been extrapolated to the limits of the hills by means of long-distance field observations and according to the best judgment of the writer.

All the geologic formations that crop out in the Kaiyuh Hills are likewise found in the Ruby district, east of these hills, and in order to show the geographic and geologic relations between the two areas the accompanying map has been made to include an area extending eastward to and slightly beyond Ruby, Long, and Poorman. This extension adds several small areas of geologic formations other than those that occur in the Kaiyuh Hills, but these formations will not be described in detail, as they are only outlying parts of geologic units that are extensively and more typically developed farther south and have already been adequately described in an earlier publication.[3]

The oldest rocks of the Kaiyuh Hills are a group of undifferentiated metamorphic rocks, of pre-Paleozoic or early Paleozoic age,

[3] Mertie, J. B., Jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska; U. S. Geol. Survey Bull. 754, 1924.

which include various types of sedimentary and igneous schists, phyllite, and slate, together with a minor proportion of chert and limestone. So far as practicable the areas of limestone have been separately mapped. These metamorphic rocks constitute more than half of the exposed bedrock, both in the Kaiyuh Hills and in the Ruby district.

The next younger geologic unit is a group composed mainly of basic igneous rocks of greenstone habit, which are in part surficial and in part intrusive. With these igneous rocks, however, are included some sedimentary rocks that it has not been practicable to separate. This group of rocks, which are considered to be probably of Carboniferous age, form the bedrock in nearly half of the Kaiyuh Hills and in about a third of the Ruby district.

Both the undifferentiated metamorphic rocks and the later greenstones have been intruded by granitic rocks, which are mainly of Mesozoic (?) age. Three small areas of such granitic intrusives are shown on the geologic map, together with two smaller areas that may be younger. A small area of Tertiary basaltic lavas is mapped in the vicinity of Poorman.

The youngest sedimentary rocks of this region are sandstone, shale, and conglomerate, most of which are considered to be of Cretaceous age. The low hills that form the extreme southwestern continuation of the Kaiyuh Hills are composed of such rocks, and a similar area is present southeast of Poorman. The latter area is the northern limit of a much larger body of such rocks which occupies much of the area between Poorman and the Kuskokwim River.

Alluvial deposits of various types, of both Pleistocene and Recent age, occupy large areas in this region, covering the bedrock deeply in the larger valleys and extending upstream into the uppermost headwater tributaries. In addition to those deposits, most of which are of fluviatile or lacustrine origin, much of the bedrock in the hills is overlain by a mantle of residual and semiresidual deposits.

UNDIFFERENTIATED METAMORPHIC ROCKS

DISTRIBUTION

The undifferentiated metamorphic rocks form the bedrock of the southwest half of the Kaiyuh Hills, extending from the wide depression at the head of one of the forks of the Kluklaklatna River northeastward into the headwaters of the west branch of the Yuko River and around the northwest slopes of the Kaiyuh Hills into the valleys of Bishop and Kalakaket Creeks. At the head of the most westerly tributary of the Yuko several small bands of limestone occur in the schist. These are too small to be shown on a scale of 1:500,000, but their position is indicated on the map as a single unit. Similar bands

of limestone are known to exist on the spur between Bishop and Kalakaket Creeks, but their position is not sufficiently well known to be mapped. It therefore seems probable that the northeastern limit of the undifferentiated metamorphic rocks, where they approach the Carboniferous greenstones, is characterized by the presence of these bands of limestone.

In the Ruby district the metamorphic rocks are irregularly distributed on the headwaters of the Sulatna River but in general occupy a belt that extends from the headwaters of the North Fork of the Innoko River northeastward in the direction of Ruby. Such rocks constitute most of the bedrock in the valley of Long Creek but also extend as far east as the valley of Poorman Creek. Several bodies of crystalline limestone also occur in the Ruby district. Two bands of such limestone crop out about 4½ miles upstream from Ruby, and another conspicuous band of limestone forms the river bluff just downstream from Ruby. The largest body of crystalline limestone in the Ruby district lies along the north side of the Sulatna River about 7 miles northeast of Poorman. This mass measures 3 by 7 miles, with the longer axis trending northeast. The smaller bodies of limestone along the Yukon and the large mass at the bend of the Sulatna River are believed to be integral parts of the metamorphic complex. The two small bands of limestone at the head of Beaver Creek and the somewhat larger body at the head of Main Creek are younger than the metamorphic complex and infolded into it.

LITHOLOGY AND STRUCTURE

As the metamorphic rocks are not well exposed in the Kaiyuh Hills, relatively few samples of these rocks were obtained, and thus it was possible to have thin sections cut of practically all the rocks collected. The following lithologic and petrographic data are based essentially on microscopic examination of 40 such slides.

The most common types of metamorphic rocks found in these hills are quartz-mica schist, quartzite schist, and mica schist. True quartzite, almost free of micaceous minerals, was found at only a very few localities. Interspersed with these schists are albite-chlorite schist, albite-mica schist, ottrelite-mica schist, and glaucophane-mica schist. Some phyllite and slate and also sheared chert and other sheared or semischistose sedimentary rocks were also found, but such rocks appear to be less common than in the Ruby district. The argillaceous varieties, however, such as phyllite and slate, may be more prevalent in the valleys and may therefore constitute a larger proportion of the regional bedrock than they appear to do as judged from ridge exposures.

The quartz-mica schist and the mica schist are essentially the same rocks, except that the former contains considerable quartz and the latter has relatively little. The essential minerals of the quartz-mica schist are quartz and muscovite, biotite being relatively rare. The quartz is commonly intergrown as interlocking grains, and many of these show highly developed strain shadows. The muscovite occurs in sheaths and bundles, intergrown with the quartz. Chlorite is also an abundant constituent of some of these rocks but more commonly is an accessory mineral. The other common accessory minerals are calcite, apatite, zircon, and iron ores. The iron ores occur in some specimens as splotches, irregular areas, and stringers. Garnet and a few grains of green hornblende were seen in one of these schists, and a little tourmaline was found in another. These rocks resemble lithologically the late pre-Cambrian schists rather than the early pre-Cambrian quartz-biotite schists of the Yukon-Tanana region, farther upstream in the Yukon Basin.

The quartzite schist consists essentially of quartz, with sufficient mica to produce foliation. As in the quartz-mica schist, the quartz has been recrystallized and occurs in interlocking grains. Muscovite is the usual mica of these rocks, though biotite, together with muscovite, was observed in two specimens. Only one or two rocks were observed that were sufficiently free of mica to be classified as quartzite.

Ottrelite-mica schists were found at several localities, and glaucophane-mica schist at two localities. The ottrelite-mica schists consist essentially of quartz, muscovite, chlorite, and ottrelite but also contain apatite and iron oxides as accessory constituents. One specimen also contained considerable biotite. The glaucophane-mica schists are similar, except that glaucophane takes the place of ottrelite, as the two minerals ottrelite and glaucophane were not found together in any one rock. The term "glaucophane" is here used in a generic sense, as the optical characters of the blue amphiboles as a group have not yet been carefully studied, and much confusion is apparent in the existing nomenclature.

Albitic schists were identified at several localities in the Kaiyuh Hills. Most of these were found to be albite-chlorite schist, containing, in addition to albite and chlorite, epidote and iron oxides. Both green hornblende and glaucophane were also observed in one of these albitic schists, and calcite in another. Only one specimen of albite-mica schist was collected, and this was found to consist of quartz, albite, muscovite, biotite, zoisite, and garnet. It seems probable that these albitic rocks are the metamorphosed representatives of ancient igneous rocks, of intermediate or basic composition.

Several beds of crystalline limestone occur at the head of the most westerly tributary of the Yuko River. The most conspicuous of

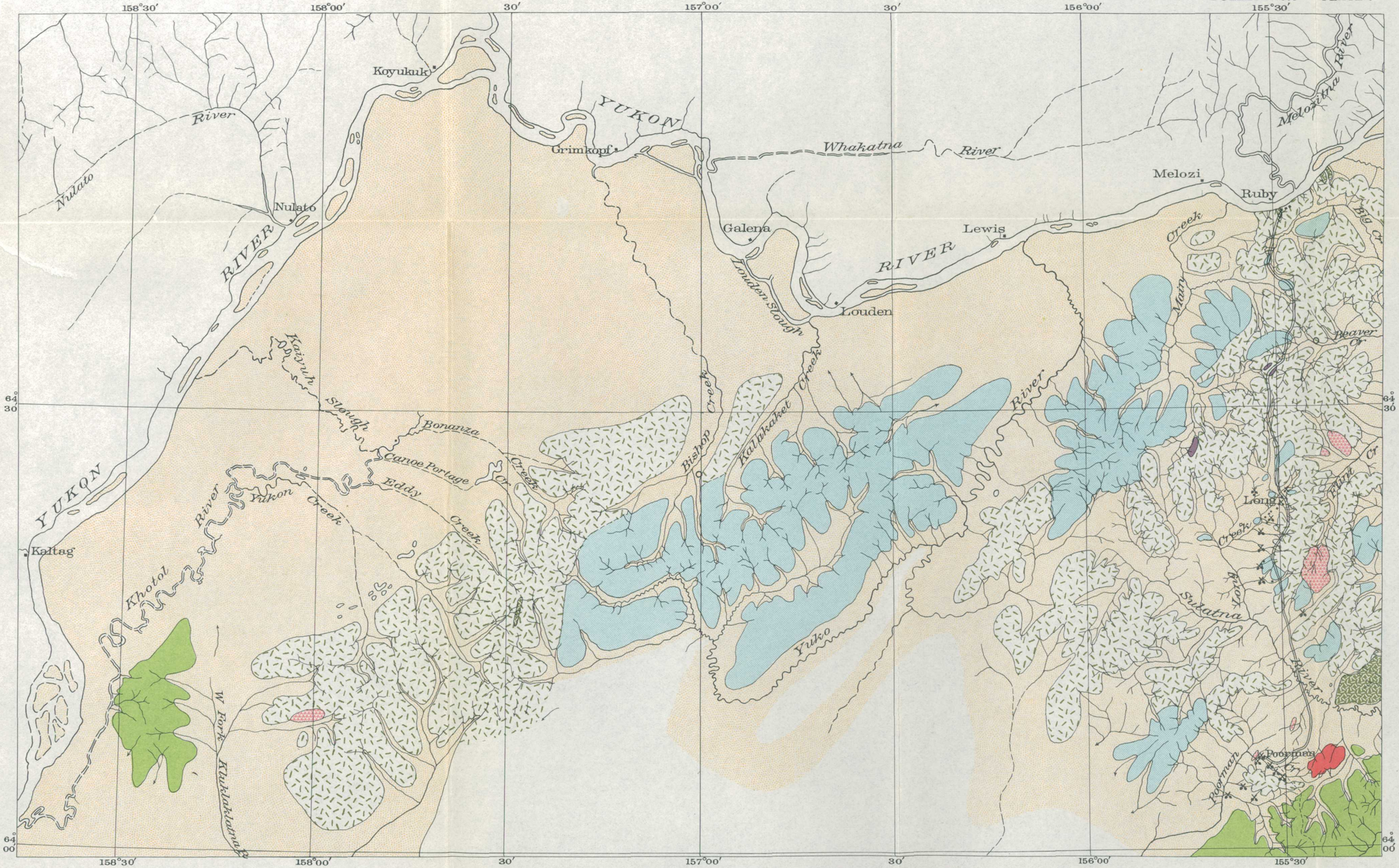
these beds crops out along the main ridge west of the extreme headwaters of this stream and has a thickness of at least 75 feet. The other beds of limestone occur farther to the northeast and appear to be thinner. Although these limestones constitute a relatively small part of the sequence, they are, nevertheless, worthy of special mention, because they afford the only evidence that was observed in the Kaiyuh Hills of the probable stratigraphic trend of the crystalline rocks.

In addition to the completely recrystallized rocks above enumerated, small bodies of partly recrystallized rocks were also observed. These include phyllitic rocks, slate, sheared chert, and impure quartzitic sandstones. One of the impure sandstones was found to contain some orthoclase and epidote, although 80 percent of the rock consists of quartz, with a sericitic matrix. This small group of less metamorphosed rocks probably represents fragments of younger Paleozoic formations that have been infolded into the metamorphic complex of older schistose rocks.

All the truly schistose rocks are entirely recrystallized, and the more micaceous varieties have a well-developed flow cleavage, as a result of which all traces of original bedding have been obliterated. The more massive quartzitic rocks also show cleavage, though it is less well marked. The strike and dip of these foliated rocks are inconstant. The more common plane of foliation strikes about east and was observed at different localities to dip either north or south; but in other places the strike is N. 10°–45° E., and the dip 10°–45° E. The limestone beds at the head of the most westerly tributary of the Yuko River have the latter strike and dip, and the limestones along the Yukon above and below Ruby also have the same strike, though they appear to dip westward. Some distance southwest of the limestones of the Kaiyuh Hills both east and northeast strikes were observed in the schists, though the east strike was the more pronounced. It is possible that the northeast strike represents an early stratification foliation or cleavage foliation, or both, that has been deformed during the development of the east-west cleavage. The variation in the regional dip of the east-west cleavage, however, suggests still later deformation of these rocks.

AGE AND CORRELATION

The crystalline schists of this region contain no recognizable remains of animal or plant life and therefore yield no paleontologic data regarding their geologic age. Moreover, so far as the Kaiyuh Hills are concerned, these rocks do not lie in contact with other sedimentary formations, but there can be little doubt that they are older than the Carboniferous (?) lavas that adjoin them on the east. In the



Drainage from earlier surveys by Alaskan Branch and by R. D. Ohrenschall, 1934

GEOLOGIC SKETCH MAP OF THE KAIYUH HILLS AND PART OF THE RUBY DISTRICT, ALASKA

Geology from earlier surveys by Alaskan Branch and by J. B. Mertie, Jr., 1934

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

10 0 20 Miles

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Ruby district, however, three small bodies of partly recrystallized limestone have been found, one of which has yielded fossils of Devonian age. These limestones are in contact with the metamorphic rocks, into which they are obviously infolded. Moreover, the difference in the degree of metamorphism between these contiguous formations indicates that the limestones are not only younger but probably considerably younger than the schists. It therefore follows that these undifferentiated metamorphic rocks are of pre-Devonian age.

The few structural data that are available in the Kaiyuh Hills suggest that the metamorphic rocks have undergone prolonged and repeated cycles of dynamic metamorphism. The thin beds of crystalline limestone at the head of the most westerly tributary of the Yuko River dip eastward, suggesting at least that the schists to the southwest of these limestones lie stratigraphically below them. Also, as the schists southwest of these limestones represent a large part of the metamorphic rocks exposed in the Kaiyuh Hills, it is probable that the limestones do not occur at these lower horizons, though, on the other hand, it is not demonstrable that they occupy the highest horizons in the metamorphic complex.

In the Yukon-Tanana region [4] two groups of metamorphic rocks exist, of which the older is known as the "Birch Creek schist." Small lenticular bodies of crystalline limestone, however, are known to occur both in the upper part of the Birch Creek schist and in the less metamorphosed rocks that overlie it. On the other hand, the assemblage of minerals found in these rocks is not characteristic of the lower horizons of the Birch Creek schist. All these data, therefore, lead to the conclusion that the metamorphic rocks of the Kaiyuh Hills may be of either late pre-Cambrian or early Paleozoic age.

DEVONIAN ROCKS

DISTRIBUTION

The younger limestones that are infolded into the metamorphic rocks of the Ruby district have been found in two general areas. At one locality, about 2 miles north of the head of Long Creek, two thin beds of such limestone crop out along the crest of the ridge; and about 8 miles N. 60° W. of Long a somewhat larger body of limestone occurs. Similar limestones have not been observed in the Kaiyuh Hills.

[4] Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872 (in press).

LITHOLOGY AND AGE

These limestones are generally dark gray but are partly recrystallized and grade into whiter varieties. They have been greatly brecciated and sheared, yet still contain recognizable remnants of organic life. In places crushed crinoid columns that are replaced by calcite show conspicuously against the darker limestone matrix.

Eakin [5] obtained a small collection of fossils from the larger body of limestone northwest of Long, which included an unidentifiable species of *Cladopora* and some crinoid columns that were possibly referable to the genus *Melocrinus*. Edwin Kirk, of the Geological Survey, who identified these fossils, believed that they indicated a Devonian age for the limestone.

CARBONIFEROUS (?) ROCKS

DISTRIBUTION

Igneous rocks and some sedimentary rocks, all of which are probably of Carboniferous age, form the northeast half of the Kaiyuh Hills and continue northeastward for 25 miles into the Ruby district. Numerous smaller areas of similar rocks at various localities in the Ruby district are shown on the geologic map, but it is possible that some of these may be older rocks of similar character.

One of the characteristics of these rocks is that they form flat, mesalike buttes at many places along the main ridge of the Kaiyuh Hills. Similar topographic forms are less common in the schistose rocks, farther southwest, except in the more massive types, such as quartzite schist and some of the feldspathic quartz-mica schists. These mesalike tops are not believed to be an expression of any original structure, as the bedding of the lavas and associated rocks is probably horizontal in few places. Such topographic forms appear to be the result of certain processes of weathering, involving repeated thawing and freezing, that are peculiar to subarctic climates.

LITHOLOGY AND STRUCTURE

The rocks observable along the main ridge of the Kaiyuh Hills within the area mapped as Carboniferous (?) are largely basic igneous rocks of greenstone habit, but here and there, particularly between and along the sides of the individual domes, sedimentary rocks were identified. Although igneous rocks thus appear to be the more abundant, the impression gained from these observations is that sedimentary rocks also constitute a considerable part of the sequence. The scarcity and poorness of exposures, however, along

[5] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, p. 22, 1914.

much of the main ridge, as well as the valley walls, render it impracticable to give any authoritative estimate of the ratio of igneous to sedimentary rocks. In the Yukon-Tanana region, where rocks that may be the equivalent of these have been studied, the writer has estimated that from a third to a half of the stratigraphic sequence is of sedimentary origin.[6] The observable facts in the Kaiyuh Hills do not warrant a statement as definite as this, but in view of the probable equivalence of these rocks to those in the Yukon-Tanana region, the ratio above cited may have some significance.

The igneous rocks of this sequence are mainly basalt and diabase of greenstone habit, most of which are considered to have originated as lava flows. There is also an undetermined proportion of basic intrusive rocks, which include diabase, gabbro, basic diorite, and pyroxenite. All these rocks, whether extrusive or intrusive in origin, have a characteristic greenstone habit.

Most of the basic rocks of surficial origin are entirely crystalline, though some partly glassy basalts were also formed. Amygdaloidal basalt, or lava rock with gas cavities filled by secondary minerals, was observed only at a few localities and cannot be regarded as typical of this sequence. The textures of the crystalline basalts and diabases are variable. Many of the basalts show a characteristic intersertal fabric, in which grains of pyroxene are set between bladed crystals of plagioclase feldspar; but one specimen shows exactly the reverse of this fabric, the feldspar occurring as grains occupying the interstices between bladed crystals of pyroxene. Other basalts do not have a characteristic intersertal fabric but instead veer toward a poikilitic texture. The diabasic rocks are in general wholly crystalline and coarser-grained. A few of them have the true poikilitic or ophitic fabric, in which laths of feldspar are almost completely embedded in larger crystals of pyroxene, but for the most part the feldspar and pyroxene crystals are of about the same size, and the blades of feldspar merely penetrate the pyroxene. Diabasic rocks of this type, by a decrease in the size of the mineral grains, grade imperceptibly into the true basaltic rocks.

The basalt and diabase contain the usual mineral assemblage of plagioclase feldspar, pyroxene, iron ores, and apatite but also, on account of their greenstone habit, include a number of secondary products, principally chloritic minerals, epidote, kaolinic and sericitic products, and quartz. Few of the feldspars can be identified in thin section, as they are largely altered to chloritic and kaolinic products, but originally they were probably close to labradorite in composition. The pyroxene, on the other hand, is com-

[6] Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872 (in press).

monly little altered and appears to be mainly diopsidic augite. The general alteration of the feldspar and the small degree of alteration of the pyroxene are comparable with the similar conditions observed in the volcanic rocks of the Rampart group, farther up the Yukon Valley;[7] but they stand in sharp contrast to the general chloritization of the pyroxene and the relatively little alteration of the feldspar in the volcanic rocks of the Strelna formation, of southern Alaska.[8] The iron ores include magnetite and ilmenite, both of which are more or less altered to iron hydroxides, and some secondary titanite or leucoxene. Apatite, which is rather common in the other Carboniferous volcanic rocks of interior Alaska, appears to be relatively scarce. Among the secondary minerals the absence or rarity of calcite is also noteworthy.

Coarse-grained intrusive rocks were observed to constitute a part of the volcanic sequence at several localities. Most of these rocks are gabbroic greenstone, but one that contained some graphic intergrowths of quartz and an altered feldspar may be of dioritic character. One ultrabasic rock, a pyroxenite, was also found, which consisted essentially of augite, olivine, and iron oxides.

Sedimentary rocks also constitute a part of this group. Along the top of the ridge that extends west-southwestward from the main part of Yuko Mountain chert was observed for a distance of 2 miles, and at one locality in this ridge a bed of dark-gray limestone about 20 feet thick was seen. The chert is smoky gray to dark gray, with a red mottling at some localities, and occurs in beds from half an inch to 3 inches thick. West-southwest of the chert more basalt and diabase occur, followed in turn in the same direction by more cherty rocks, but the last hill on this ridge, overlooking the Yuko River, is an altered basic rock. Chert was also observed along the east flanks of Yuko Mountain.

After crossing the Yuko River, at latitude 64°30′, and continuing west-southwestward up the long spur to the west, the first cropping found at the upper limit of timber line is a greatly decomposed basic tuff, consisting mainly of angular to subangular fragments of glassy basaltic rock, together with some coarser-grained basaltic material and numbers of pyroxene crystals, many of which are still fixed in fragments of lava. Up the hill from this tuff occurs lava, which in turn is followed by a massive reddish-brown rock in well-defined beds from 3 inches to 3 feet thick. Under the microscope these red beds are found to consist of angular to subangular fragments of fine-grained igneous rocks, quartz, feldspar, and iron oxides

[7] Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872 (in press).

[8] Moffit, F. H., and Mertie, J. B., Jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, pp. 54–67, 1923.

and hydroxides, together with chloritic material and many fine grains of red hematite. In places they alternate with green beds of the same general character but containing much more chloritic material. These beds continue west-southwestward for about half a mile, but they may continue farther, as the ridge top beyond them shows no rock croppings for a distance of about 6 miles. These beds strike about N. 5° E. and dip 50° E. The exposures of these rocks along the spurs east and west of the Yuko River are the best exposures of the sedimentary members of this sequence of rocks seen in the Kaiyuh Hills and are probably more or less typical.

No ellipsoidal lavas were observed in this sequence of rocks, and it is therefore improbable that these lavas were poured out into any considerable body of deep water. The sediments most closely associated with the lavas are tuffs and graywacke that have every appearance of terrigenous origin. The exact relation of the lavas to the cherty rocks and interbedded limestone is indeterminate; they may have either alternated with the sedimentary rocks or flowed out upon them. Certain conditions along the east flanks of Yuko Mountain suggest the latter relation, as the intrusive greenstones there appear to invade the chert.

AGE AND CORRELATION

No very definite stratigraphic data have been discovered to show the relations between these greenstones and the adjacent sedimentary rocks, and no paleontologic data whatever are available. Hence the geologic age is indeterminate. The character of the lavas and associated intrusive rocks, however, together with their observed association with adjacent sedimentary rocks, agrees strikingly with the conditions that prevail among the corresponding rocks of the Rampart group, farther up the Yukon Valley. The Rampart group has been determined, on both stratigraphic and paleontologic evidence, to be of Mississippian age and overlies a chert formation that forms the base of the Carboniferous sequence. It is probable, therefore, that the greenstones and associated sedimentary rocks of the Kaiyuh Hills likewise are a phase of this same general period of Carboniferous volcanism, but the evidence is not sufficiently cogent to assign them definitely to the Carboniferous period.

CRETACEOUS ROCKS

DISTRIBUTION

The only rocks of Cretaceous age that were observed in the Kaiyuh Hills occur in the group of low hills that lie between the west fork of the Kluklaklatna River and the Yukon River. Similar rocks, however, begin a short distance southwest of Poorman and continue for many miles to the south.

LITHOLOGY AND STRUCTURE

In the low hills above mentioned the Cretaceous rocks consist of conglomerate, grit, sandstone, and shale. No continuous exposures are visible, but instead the rocks crop out at irregular intervals along the main ridge top, so that the proportions of the various types of rocks and their stratigraphic relations to one another are indeterminate.

Conglomerate crops out at one locality about midway the length of these hills from north to south, and rubble of this rock was seen at other places. It consists of fairly well rounded pebbles as much as 3 inches in diameter, which are derived principally from greenstone and quartzite but also include considerable vein quartz, some granitic or dioritic rocks, and a little chert. The structure of the beds is not discernible. Similar but finer-grained gritty rocks are also present along this ridge and grade into sandstones of the same general composition. Only the more sandy shales were observed along the ridge tops, and these are dark gray, more or less massive, and moderately fine-grained, approaching arenaceous argillite in character. Fragments of more fissile and more truly argillaceous shale were also seen, but these rocks apparently do not crop out prominently and are doubtless more prevalent in the depressions along the main ridge and in the valleys. No structural data regarding these rocks were obtained in these low hills.

AGE AND CORRELATION

Fragmental plant remains were seen in these rocks, but no determinable fossils were collected. Nevertheless, their lithologic character is so essentially similar to that of some of the Upper Cretaceous sedimentary rocks that crop out along the Yukon from Ruby downstream that little doubt of their equivalence can exist.

The nearest Cretaceous rocks to the Kaiyuh Hills are in the country west of the Yukon River, between Nulato and Kaltag, where such rocks have been mapped by Smith and Eakin.[9] These rocks were shown to be of Upper Cretaceous age, and the series was divided into two major units, of which the lower was designated the "Ungalik conglomerate" and the upper the "Shaktolik group." The Ungalik conglomerate was described as an assemblage of conglomeratic rocks but included some sandstone. The Shaktolik group was separated into two divisions, the lower consisting of sandstone and shale, and the upper predominantly of black shale, with subordinate beds of calcareous sandstone. The rocks that crop

[9] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 54–60, 1911.

out along the Yukon River near Nulato, originally called by Dall,[10] in 1866, the "Nulato sandstones", were included by Smith and Eakin as a part of the Shaktolik group. Subsequently Martin[11] subdivided the Upper Cretaceous rocks along the Yukon River between Ruby and Andreafski into four formations, which, named in order from the base to the top of the sequence, are the Ungalik conglomerate, the Melozi formation, the Nulato formation, and the Kaltag formation. Of these, only the Ungalik conglomerate is said to contain any considerable proportion of conglomerate. These two methods of subdividing the Upper Cretaceous series are in agreement so far as the existence of a basal conglomeratic formation, the Ungalik conglomerate, is concerned. The Ungalik conglomerate also occurs in the lower Melozi Valley and along the Yukon River for 10 miles below the mouth of the Melozi, lying adjacent to the old crystalline rocks of the Ruby district. The rocks exposed in the low hills west of the west fork of the Kluklaklatna River are likewise adjacent to the crystalline rocks and contain considerable conglomerate. It is therefore inferred that they should be correlated with the Ungalik conglomerate and that they represent the basal part of the Upper Cretaceous sequence.

QUATERNARY DEPOSITS

A large part of the area shown on the accompanying geologic map is covered by unconsolidated deposits of alluvial origin. Between the Kaiyuh Hills and the Yukon River is an area almost twice as great as that of the Kaiyuh Hills, which is occupied by unconsolidated deposits, largely of fluviatile origin, that have been laid down by the Yukon River in the process of carving and widening its present valley. The valleys of the Yuko and Kluklaklatna Rivers and their tributaries are likewise the sites of thick deposits of the same general character.

In addition to these thicker alluvial deposits, a large part of the Kaiyuh Hills is covered by residual and semiresidual material, which effectively conceals much of the country rock. Such deposits are particularly prevalent on the lower spurs and along the valley walls, where they have in places a considerable thickness; but they also extend as a thinner veneer up the higher parts of the spurs and even to a considerable extent onto the main ridges. Indeed, if this thin surficial veneer were mapped with the thicker alluvial deposits, the resulting geologic map would show a very small area of hard rocks in the Kaiyuh Hills. Instead, the writer has preferred to

[10] Dall, W. H., and Harris, G. D., Correlation papers—Neocene: U. S. Geol. Survey Bull. 84, pp. 247–248, 1892.

[11] Hollick, Arthur, The Upper Cretaceous floras of Alaska, with a description of the plant-bearing beds by G. C. Martin: U. S. Geol. Survey Prof. Paper 159, pp. 23–24, 1930.

indicate only the thicker deposits and to show as hard rock those areas where intermittent croppings or even surficial hard-rock rubble indicates with some assurance the general nature of the bedrock below the surficial veneer.

The unconsolidated deposits of this region are of Pleistocene and Recent age, but they are for the most part so effectively covered by vegetation that it is not possible to separate them into distinct units on the basis of relative age. Their origin and character and the geomorphic history of the region during their erosion and deposition present problems of great magnitude and surpassing interest, but methods of study other than surficial observation will have to be developed and employed before any satisfactory solutions of such problems can be expected. At the present time the methods that are being utilized in geophysical prospecting, particularly the electrical and seismic methods, hold most promise for the subsurficial study and interpretation of such alluvial deposits.

A traverse of the main ridge of the Kaiyuh Hills affords little opportunity for observation of the fluviatile deposits, but the placer-mining operations that have been carried on for many years in adjacent mining districts, together with the natural exposures along the cut banks of the larger streams, have yielded considerable information regarding the character and origin of many of these deposits. In general, it has been found that the deeper stream channels have basal deposits of gravel and sand, not unlike those that are being eroded and deposited by the present streams of this region. Many of these basal deposits, however, show from the petrographic character of their component gravel that they were derived in considerable part from a preexisting mantle of residual deposits, in which a large part of the pebbles formed from the softer country rocks had been greatly disintegrated prior to their erosion, sorting, and deposition by stream action. The evidence for the presence of such ancient residual deposits is particularly convincing in the Poorman and Ruby districts, east of the Kaiyuh Hills. Many of these basal stream deposits, because they underlie other alluvial deposits of Pleistocene age, could be considered to be of either early Pleistocene or late Pliocene age; but no positive data have been found to suggest definitely that they are Pliocene.

The terms "ice age" and "Pleistocene" are not necessarily synonymous in Alaska. Large mountainous areas in southern Alaska are still covered with ice fields and may therefore be said not yet to have emerged from the ice age. Because these ice fields still persist it is possible that they did not begin to accumulate on a large scale in Alaska at the same time that they did farther south in North America. Moreover, the several alternating stages of frigid and temperate climate of the Pleistocene epoch, which are so well sub-

stantiated in the northern part of the United States, have not been differentiated in Alaska. Hence the precise correlation of glacial deposits in Alaska with Pleistocene deposits in Canada and the northern United States is not possible at the present time.

Interior Alaska was not in general glaciated during the ice age, though it was begirt by ice fields on the north, east, and south. The largest reservoir of glacial ice was located in the Alaska and Coast Ranges in southern Alaska, from which a vast sheet of ice, thousands of feet thick, moved southward to the Gulf of Alaska, while smaller glaciers debouched northward and northwestward for relatively short distances into central Alaska. The Brooks Range, to the north, was also the site of ice fields, which moved northward and southward from the range, but this glaciation was of a smaller order of magnitude than that which occurred in southern Alaska. In the upper Yukon Valley, Canada, these northern and southern ice fields coalesced, but there the country was lower and was in general an area of dissipation of ice rather than an area of accumulation. The ice fields of the upper Yukon Valley were undoubtedly the first to melt, and if alternating periods of cold and temperate climate existed in Alaska during Pleistocene time, it is even possible that a part of this region was not occupied continuously by ice.

In central Alaska only the higher groups of mountains, in particular those whose present elevation is 4,000 feet or more, supported ice fields, but the area occupied by mountains of such heights is negligibly small, in comparison to the vast area of unglaciated country between the Alaska and Brooks Ranges. These higher mountains were the sites of small ice fields, from which alpine glaciers moved outward a few miles into the surrounding lowlands. The Kaiyuh Hills do not rise to elevations of over 3,000 feet and have not been glaciated. The nearest glaciated area is in the Cripple Creek Mountains, about 50 miles to the southeast. The streams that drain the Kaiyuh Hills, such as the Yuko and Kluklaklatna Rivers, as well as the headwaters of the Sulatna River, in the Ruby district, are not now and have not in the past been fed by melting glaciers, and none of the Pleistocene or Recent alluvial deposits in these valleys can be considered to be of glacial origin.

After the ancient stream gravel was deposited in this region there occurred a long period during which the coarser fluviatile deposits ceased to be the usual result of alluviation in the Yuko, Kluklaklatna, and Sulatna Valleys. Instead, there were formed thick deposits of carbonaceous silt, under which the ancient stream gravel was deeply buried. This silt has certain peculiar characteristics, which render its origin and mode of deposition difficult of interpretation. It is a fine-grained sediment, composed of subangular to rounded grains of quartz and other rock-forming minerals. It is

carbonaceous and also contains the fossilized remains of extinct vertebrates and fresh-water invertebrates. The silt contains little interbedded gravel or other coarse sediments and evidently has not been deposited in running water. Most of these deposits of silt are solidly frozen, from top to bottom, and also contain wedges and lenses of ground ice, which, however, have probably been formed subsequent to the original deposition of the silt. The distribution of the silt is also significant, in that the thicker deposits in this district are restricted to relatively low valleys, particularly those that lie below elevations of about 600 feet. This generalization is not applicable everywhere in central Alaska, as in some of the mining camps on streams tributary to the Tanana similar thick deposits of silt occur up to elevations of 1,200 feet or higher. Thin veneers of this silt, or "muck", as it is more commonly called, also occur at all elevations in the valleys of interior Alaska, but particularly in the wider and more open valleys, where processes of soil flowage appear to be specially effective along the valley walls. This muck, however, is more likely to contain also coarse detritus and even boulders; but this general process of rock comminution and transportation is undoubtedly a major source of such silty sediments.

These thicker deposits of silt, though laid down during the Pleistocene epoch, are obviously not of glacial origin. By some geologists they have been considered to be lacustrine deposits, and some of them doubtless originated in that way. But all of the silt deposits are not of lacustrine origin—at least, they are not deposits that were laid down in large interior lakes, because such lakes would have left traces in the form of terraces and beach deposits, and such features are not evident on any major scale. Some of the silts, or at least the upper strata of some of the silt deposits, have been shown to be wind-blown, but this does not prove the eolian origin of all of them. Another possible explanation is that many of the silt deposits are of deltaic origin and were laid down from the lower valleys progressively upstream, under conditions of a slowly rising baselevel of erosion. This explanation, however, does not account satisfactorily for the essential absence of coarser material in these sediments, and it renders necessary certain assumptions regarding climatic conditions in central Alaska during the Pleistocene epoch that have not yet been substantiated by fundamental research. The origin and mode of transportation and deposition of these Pleistocene silt deposits therefore remain unsolved problems at the present time.

The history of the region since the deposition of the silt is also obscure. Evidence of the strongest sort is available in many parts of interior Alaska to show that stream channels were subsequently established on the surface of these silt plains that had no close relationship to underlying erosional channels in which the preglacial

gravel had been deposited. This has resulted in the superposition of streams on old valley walls, and even on preexisting bedrock divides; and many of the anomalous drainage features of this region are due to this process. It is therefore evident that the stage or stages of silt accumulation were followed by a general lowering of the base-level, vigorous erosion, and the dissipation of many of the silt deposits. Where the streams have moved laterally from their original preglacial courses, deposits of ancient gravel, overlain by thick deposits of silt, have at many places been preserved in the valleys. At some localities the bedrock channels of the present streams are either higher or lower than those of the ancient preglacial channels, but the difference in elevation between the old and new channels is not in general very great. The old placer deposits that occur in the preglacial channels, as in the Ruby and Poorman districts, are really buried placers, rather than bench placers, as they are so commonly called.

Recent time in this region has therefore been characterized by a general lowering of the baselevel of erosion, accompanied by rejuvenation of the Pleistocene streams and the establishment of conditions of transportation and deposition of detritus by streams more nearly comparable with the conditions that existed before the maximum advance of the ice in Alaska. Certain erosional processes, which are characteristic of subarctic climates and were doubtless very effective during the Pleistocene epoch, still continue, though possibly on a modified scale. Such processes depend for their effectiveness upon alternate thawing and freezing and upon a type of soil movement related to solifluction, whereby great volumes of unsorted detritus move down the hill slopes into the lower parts of the valleys. Partly, therefore, as a result of the rejuvenation of the streams and partly also as a result of changing climatic conditions, the hillside detritus, though initially moving streamward by processes more characteristic of the Pleistocene, is now being transported by processes more characteristic of postglacial time. The net result is that deposits of sand and gravel, mixed at places with more or less reworked silt, are now being laid down in the present valleys. Some of these deposits lie directly upon bedrock, but in places, where all of the preexisting silt has not been removed from the drainage channels, these coarser sediments occur as "inlaid" gravel in the silt.

In addition, however, to the Recent gravel and the hillside or eluvial deposits, the residual alluvial deposits on the summits of the ridges and the flatter parts of the spurs are products of another process of considerable magnitude. In central Alaska the ground in general is permanently frozen, except near the larger streams, where running water tends to keep the ground unfrozen for some

distance back from the banks. Hence the usual condition of a water table and a zone of active weathering above the water table is hardly exemplified in this region, as the subsurface water is in general frozen. Likewise the solvent and depositional effects of circulating water are almost lacking, and the chemical effect of oxygen and carbon dioxide are sharply restricted. Residual deposits should therefore be formed more by mechanical processes, such as fracture and spalling, due to alternate freezing and thawing, than by chemical disintegration of the bedrock. This statement holds true for most of central Alaska, but both in the Ruby-Poorman district and in the Kaiyuh Hills there is at some localities good evidence of pronounced chemical alteration of the bedrock. The granitic rocks show particularly well this type of weathering in the lower ridges and spurs. This condition may be due to deep preglacial weathering, or it may be the result of local conditions that have resulted in unfrozen ground and the consequent circulation of ground water. Regardless of the cause, the surficial bedrock of this region, particularly the granitic bedrock, seems abnormally affected by chemical disintegration, with the result that residual deposits form a considerable part of the alluvial sheet and add materially to the volume of hillside or eluvial deposits that are moved downward into the valleys.

GRANITIC ROCKS

DISTRIBUTION

Only one body of granitic rocks was found in the Kaiyuh Hills. This crops out on a spur near the head of one of the eastern tributaries of the west fork of the Kluklaklatna River.

Other granitic rocks occur at several localities in the Ruby-Poorman district, notably in the valley of Flint Creek, where two good-sized areas have been mapped. Two smaller areas of intrusive rocks have also been mapped in the vicinity of Poorman.

PETROGRAPHIC CHARACTER

The granitic rocks at the southwest end of the Kaiyuh Hills show mainly as surface rubble along the top of a long, nearly flat spur that descends to the west fork of the Kluklaklatna River. They are greatly decomposed, and although some specimens appear to be relatively fresh, they all show under the microscope the effects of prolonged weathering.

These altered granitic rocks are composed essentially of quartz, plagioclase feldspar, microcline, and biotite. The plagioclase feldspar, however, is nearly opaque from alteration, and its specific character is indeterminate. Its principal alteration products are sericite and chloritic and kaolinic minerals of undetermined character. Most of the microcline is relatively fresh and unaltered.

Apatite and some iron oxides also occur as accessory minerals. If all the greatly altered feldspar of this rock is plagioclase feldspar, the proportion of this mineral seems rather too great to regard this rock as a granite. On the other hand, the amounts of microcline and biotite suggest that the rock contains a considerable proportion of potassium, which relates it to the granite family. In view of the indeterminate nature of the plagioclase feldspar it seems unwarranted to give the rock a specific petrographic designation, but in any case it can hardly be more basic than a biotite granodiorite.

The granitic rocks in the valley of Flint Creek, in the Ruby district, are similar to those above described but differ in that microcline is their dominant feldspar. The structure of some of this feldspar, however, is such as to suggest a submicrographic intergrowth of microcline and albite, so that the mineral may in reality be anorthoclase. The plagioclase feldspar is generally grown around acidic oligoclase, with a rather well defined albitic border. The albitic rims also show graphic intergrowths with quartz. The central part of the plagioclase is more or less sericitized. The dark mineral of the rock is biotite, but some specimens contain no dark minerals.

The intrusive rocks near Poorman crop out in two small areas. In an earlier report on the Ruby-Kuskokwim region [12] these rocks were mapped as undifferentiated intrusive rocks, as the information regarding them was not regarded as adequate for their closer determination. No further information has been obtained, and these rocks are here included with the other granitic rocks of this area, though possibly they may be of later origin.

AGE AND CORRELATION

No stratigraphic data are available for determining closely the geologic age of the granitic rocks of the Kaiyuh Hills and of the Ruby district. They intrude the crystalline schists, but they are believed to be very much younger than those rocks. On the other hand, granitic pebbles of similar rocks were found in the Upper Cretaceous conglomerates in the low hills west of the west fork of the Kluklaklatna River, thus suggesting, though not proving, that the granitic rocks are probably older than Upper Cretaceous.

In central Alaska two generations of granitic rocks are believed to exist, though other unrecognized periods of granitic intrusion may also have occurred. The older granitic rocks of these two types are believed from several lines of collateral evidence to have been untruded sometime during the Mesozoic era. The younger granitic

[12] Mertie, J. B., Jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pl. 3, 1924.

rocks are of Tertiary age. These granitic rocks of two different ages also have certain petrographic characteristics which suggest that some of them may be differentiable, even where the necessary stratigraphic data for determining their relative ages are lacking. These petrographic differences are stated in some detail in another publication,[13] and inasmuch as the younger granitic rocks have not been recognized in the Kaiyuh Hills or in the Ruby district, it is unnecessary to analyze these differences in this report. It suffices to state that the older granitic rocks are commonly either granites or quartz diorites of normal character, whereas the younger granitic rocks are typically quartz monzonites. From the foregoing descriptions it is evident that the granitic rocks of the Kaiyuh Hills and the Ruby district are correlative petrographically with the older granitic rocks; and for this reason they are considered to be probably of Mesozoic rather than Tertiary age, but their Mesozoic age is far from being definitely proved.

TERTIARY LAVAS

Tertiary lavas are not known to occur in the Kaiyuh Hills, but the accompanying geologic map shows one area of such rocks about 4 miles east of Poorman. Large areas in which the country rock is composed essentially of these lavas occur on the South Fork of the Sulatna River and in the upper valleys of the Lost and Nowitna Rivers.

No particular description of these rocks is necessary in the present report, as they lie for the most part southeast of the area shown on the geologic map, and more particularly as they are not known to have any special economic significance. They are fine-grained dark-gray to black lavas, ranging in character from basalt to pyroxene andesite. These rocks are similar in composition to the Carboniferous (?) volcanic rocks of the Kaiyuh Hills but are many millions of years younger and do not show any considerable degree of alteration.

MINERAL DEPOSITS

The Kaiyuh Hills have not been thoroughly prospected, but to judge from the geologic conditions there, as compared with those which are found in the Ruby district, it is possible that metalliferous lodes and placers may be present. In fact, indications of gold mineralization were observed at the southwest end of the hills by the Survey party of 1934; and in earlier years one silver-lead lode was found along the north flank of the Kaiyuh Hills and was worked for a short period.

[13] Mertie, J. B., Jr., The Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 872 (in press).

GOLD

No gold lodes or placers of workable grade have yet been discovered in the Kaiyuh Hills, yet the geologic conditions are essentially similar to those which exist in the Ruby district, where rich gold placers have been worked for many years. The country rock, both in the Kaiyuh Hills and in the Ruby district, consists mainly of crystalline schists and Carboniferous volcanic rocks, but it is a noteworthy fact that in the Ruby district the rich gold placers have been found only in the areas where the country rock has been invaded by granitic rocks. Thus in the vicinity of Long, where rich placers occur, granitic rocks crop out in the valley of Flint Creek and on the divide between Flint and Long Creeks, and it is probable that other bodies of such rocks also exist in the same vicinity at no great distance below the surface. In this district, as in some others where mineralization has been caused by granitic rocks, the relation between the gold placers and the granitic masses is not always a direct one—that is, streams containing gold placers do not necessarily head directly in areas where the country rock is of granitic character. This condition is exemplified by the gold placers in the upper valley of Long Creek. There the gold mineralization apparently has been of a more diffuse type, so that the gold quartz veins and other gold-bearing rocks may occur at some distance, on the surface, from the known croppings of granitic rocks. Under such conditions the granitic rocks serve as a general indication of possible mineralization but do not always indicate the exact stream or streams on which gold placers are most likely to be found.

The Kaiyuh Hills should likewise be considered from this point of view. On the accompanying geologic map only one area of granitic rocks is shown, though this does not mean that only one such area exists, as the exigencies of reconnaissance mapping do not permit the examination of all the various ridges and spurs within a mapped region. This mapped area of granitic rocks is at the head of one of the eastern tributaries of the west fork of the Kluklaklatna River; and in the stream that heads against this eastern tributary and flows southeastward to the other fork of the Kluklaklatna some fine colors of gold were panned by the Survey expedition of 1934. Some indications of gold mineralization are therefore apparent in this area. Farther downstream on the Kluklaklatna River, beyond the Kaiyuh Hills, gold has also been known to exist for many years, as this fact was recorded by Maddren[14] 25 years ago. It would seem, therefore, from the data at present available, that the southwest end of the Kaiyuh Hills is more likely to show gold lodes and gold placers than the central or northeastern part.

[14] Maddren, A. G., The Innoko gold-placer district, Alaska: U. S. Geol. Survey Bull. 410, p. 23, 1910.

On the southeast side of the Yukon River opposite Thompson, about 70 miles downstream from Kaltag, a group of low hills may be seen from the river. These hills were not visited by the Survey party of 1934 but are somewhat similar in appearance to the low hills between the headwaters of the Kluklaklatna and the Yukon. Mr. A. Muller, of Kaltag, gave to the writer some small specimens of vein quartz and of the adjacent country rocks that occur in these hills. The vein material was found to consist of vein quartz containing numerous anhedral grains and clumps of molybdenite. The country rock proved to be a fine-grained rhyolite porphyry, showing phenocrysts of plagioclase and biotite, with less orthoclase and quartz, in a fine-grained groundmass consisting essentially of orthoclase, quartz, a little plagioclase, and muscovite. The rock also contained considerable pyrite. The plagioclase feldspar is too greatly altered for determination, but the proportion of potash feldspar indicates strongly that this rock is the fine-grained equivalent of a granite. The age of this granitic rock and of the associated mineralization is indeterminate, but the occurrence serves to emphasize the possibility that some of the other bodies of granitic rocks that are present in this region may have some importance as sources of lode or placer deposits.

SILVER-LEAD

Silver-lead ores have been found both in the Kaiyuh Hills and in the Ruby district. In the Kaiyuh Hills a silver-lead deposit, known as the Perseverance lode, was discovered in September 1918, on the headwaters of Bishop Creek. The exact locality has not been recorded, but according to a description given by G. C. Martin [15] the lode was found along the west slope of the ridge between Bishop and Kalakaket Creeks. The approximate location is shown on the accompanying geologic map. A summer trail, from a point 2 or 3 miles below the lower end of Louden Slough, led from the Yukon River up the above-mentioned ridge to the property.

The country rock in the vicinity of this lode is said to have consisted of quartzose, micaceous, and chloritic schists and limestone, but at the site of the ore deposit the country rock is schist, with a dominant structure that strikes northeast. A belt of limestone was said by Martin to cross Bishop Creek about half a mile above the mine, and this limestone is probably correlative with a similar limestone in the Kaiyuh Hills, about 15 miles to the southwest. (See pp. 157–158.)

The ore was first discovered as float but was subsequently found in place and was mined in a small way. The workings are said to

[15] Brooks, A. H., Mineral resources of Alaska, 1921: U. S. Geol. Survey Bull. 739, pp. 38–39, 1923.

have shown an irregular body of ore, with a maximum thickness of 2 to 3 feet, interrupted by masses and bands of country rock that was either barren or of low ore content. The ore was silver-bearing galena. The Perseverance lode was operated under lease during the winter of 1920–21 and was also worked in 1922, producing a total of about 225 tons of ore, of which about half was shipped to the Selby smelter and the remainder to Bradley, Idaho. These shipments are reported to have averaged 73 percent of lead and 104 ounces of silver to the ton. The ore was freighted by sled to Galena in winter, at a cost of $30 a ton. The freight rate from Galena to Seattle by way of St. Michael was $27.50 a ton, thus making a total cost of $57.50 a ton from the mine to Seattle. Mining operations are said to have been discontinued because of these high rates of transportation.

Another lode, called the "Valley claim", not far from the Perseverance lode, was prospected and worked by the owners at about the same time, but any ore produced from it was probably included in the shipments from the Perseverance lode.

A similar deposit of silver-lead ore was found 20 years or more ago along the north slopes of Beaver Creek, in the Ruby district, about 14 miles south of Ruby and 2 miles east of the old "Fourteen-mile" roadhouse. This property has been described in some detail by Brown,[16] and it is sufficient here to state briefly the general characteristics of the deposit. The wall rock is mainly a micaceous and more or less carbonaceous quartz schist, containing numerous small lenses and stringers of vein quartz, although some slaty and cherty rocks are also present. The strike of the ore body is said to have been N. 25°–30° E., and the dip 60°–80° SE. This dominant structure, it will be observed, is similar to that found at the Perseverance lode and also to the trend of the limestone in the Kaiyuh Hills, southwest of that lode. The main vein at this locality cropped out for a width of 15 feet, but at the bottom of a 40-foot shaft it was found to have a width of about 8 feet, lying between walls of schist. At the surface the deposit was marked by a limonitic cap rock, and even at the bottom of the shaft the ore was much oxidized, consisting essentially of limonite carrying irregular masses and stringers of galena, together with more or less cerusite. The ore also contained irregular horses of country rock. This ore, unlike that shipped from the Perseverance lode, was not of very high grade, as the best assay obtained is said to have contained only 32 ounces of silver to the ton, together with a trace of gold.

Other croppings of ore were located in this vicinity, and a tunnel and some drifts were driven to explore some of these deposits, but

[16] Brown, J. S., Silver-lead prospects near Ruby, Alaska: U. S. Geol. Survey Bull. 783, pp. 145–150, 1926.

no considerable body of high-grade ore was found, although one assay of vein material over a width of 1 or 2 feet is said to have shown a content of 82 ounces of silver to the ton.

FUTURE PROSPECTING

Indications of gold mineralization exist at the southwest end of the Kaiyuh Hills, and a silver-lead lode has been discovered and worked along the north flank of these hills. It has also been shown that the geologic conditions are similar to those which exist in the Ruby district, where rich placers have been worked and where silver-lead lodes have also been found. It therefore appears that some further prospecting may be justified in the Kaiyuh Hills, though no definite assurance can be given that gold lodes or placers or other silver-lead lodes will be discovered.

With regard to gold mineralization, it has been shown that granitic rocks are the ultimate sources of gold in this region, though the gold itself usually occurs in veins of quartz, which may or may not be close to the granitic rocks. The general vicinity of such bodies of granitic rocks, however, is the best site for prospecting for gold lodes, and the streams draining areas that are occupied in whole or in part by granitic rocks or are closely adjacent to bodies of granitic rocks are the most favorable sites for the occurrence of gold placers. In using these criteria, however, some care must be exercised, as granitic rocks may occur a short distance below the surface, so that they are not visible, and yet may be close enough to the surface to have produced gold lodes or placers. At such localities, however, the existence of underlying granitic rocks is likely to be indicated by the presence of either rhyolitic dikes or quartz veins and possibly by contact metamorphism.

No granitic rocks or indications of such rocks were observed at the northeast end of the Kaiyuh Hills, but there is no definite proof of their absence. Such rocks occur at the southwest end of the hills, and this fact, although it does not rule out other areas, makes this part of the Kaiyuh Hills a more favorable site for gold prospecting. It should again be emphasized, however, that the single mapped area of granitic rocks is not the only possible site for prospecting. The adjacent region is likely to have similar areas of granitic rocks, which have not been mapped, and a careful search for all such areas should be the first aim of prospectors.

Silver-lead lodes are known both in the Kaiyuh Hills and in the Ruby district, but the ore bodies are small, and the amount of high-grade ore so far found appears to be meager. These ore bodies have been found only in areas where the country rock consists of the ancient crystalline schists, but this is probably due more to favorable physical characteristics of these rocks, such as cleavage planes,

rather than to their chemical composition. Such cleavage planes, probably extending downward for a long distance, afforded relatively accessible channels for the upward migration of ore-bearing solutions. The greenstones, on the other hand, are more massive rocks, which lack such channels for moving solutions. The areas of schistose rocks within the Kaiyuh Hills therefore in general present more favorable sites for the occurrence both of silver-lead and of gold lodes than areas where the country rock is greenstone. The Kaiyuh Hills have not yet been well prospected, and it is possible that larger and richer deposits of silver-lead ores that would repay development may later be discovered. Yet it should be stated, in view of the great difference that now exists between the prices of silver and gold, that prospecting for gold is more likely to be a profitable undertaking.

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