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MINERAL RESOURCES

OF THE

NABESNA-WHITE RIVER DISTRICT

ALASKA

BY

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WITH

A SECTION ON THE QUATERNARY

BY

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PREFACE.

By Alfred H. Brooks.

The Copper River basin and the adjacent parts of the Yukon basin contain two known mineral-bearing zones, lying respectively on or adjacent to the southern and to the northern slope of the Wrangell Mountains. The southern belt, which has been called the Kotsina-Chitina region and includes chiefly copper-bearing lodes with some gold placers, is about 100 miles from the coast; the northern belt, here termed the Nabesna-White region, which includes both auriferous and copper-bearing lodes, lies about 70 to 100 miles farther inland. This second belt, which is here under discussion, can at present be reached from tide water only by a rather circuitous route, between 200 and 300 miles in length. The construction of a railway up Copper River, now (1909) in progress, has greatly stimulated mining activities in both fields, but for the present, at least, will furnish transportation facilities only for the southern district.

This Nabesna-White River region, first explored by Peters and Brooks in 1899, was more carefully surveyed in 1902 by Schrader and Witherspoon. A considerable part of the district, however, still remained unmapped, and the work of mapping it was undertaken in 1908, with the results here presented. Mr. Schrader published an account of the mineral resources of this district soon after the field work was finished and also began the preparation of a more elaborate report on the geology, which, unfortunately, because of the pressure of other work, he was unable to complete. Mr. Schrader's notes have been freely drawn upon by Messrs. Moffit and Knopf, who, however, in the course of their study of the ore deposits, covered most of the field previously investigated and mapped a considerable additional area. The topographic surveys by Mr. Witherspoon were extended in 1908 by Mr. Capps so as to include the upper White River basin, and the resulting map is here published as Plate I.

Though many claims have been located in this field the amount of actual excavating done is relatively small. It is consequently too soon to pass final judgment on the extent and value of most of the ore bodies found, and the following report is therefore largely a record of the facts observed in the field. An analysis of the many important problems relating to the ore bodies and the general geology is deferred until more detailed information is available.

The important economic conclusion of this investigation is that the copper deposits are associated with amygdaloidal basalts of Carboniferous age—an association like that in the Chitina region. Of particular significance is the presence of some primary native copper in the amygdaloids, while in the Chitina region only secondary native copper deposits have been found. Another type of mineralization here described is that of the copper sulphide deposits and auriferous quartz veins of metamorphic contact zones of intrusive dioritic rocks. This indicates that ore bodies occur in this field in the same genetic relations as do those in southeastern Alaska described by Mr. Wright.

Among the determinations here chronicled bearing on general geologic problems are the synclinal structure of the Wrangell Mountains and the extensive faulting along the northern margin of this syncline, as well as the large development of upper Carboniferous rocks, including a large amount of volcanic material. Of significance also is the determination of the Mesozoic age of the intrusives, which helps to strengthen the view that they belong to the same period as the batholiths of the Coast Range in southeastern Alaska and British Columbia.

MINERAL RESOURCES OF THE NABESNA-WHITE RIVER DISTRICT, ALASKA.

By Fred H. Moffit and Adolph Knopf.

HISTORY OF EXPLORATION.

The following report is based on the work of a topographic and geologic reconnaissance survey made in the summer of 1908 in the area including the northeastern slopes of the Wrangell Mountains

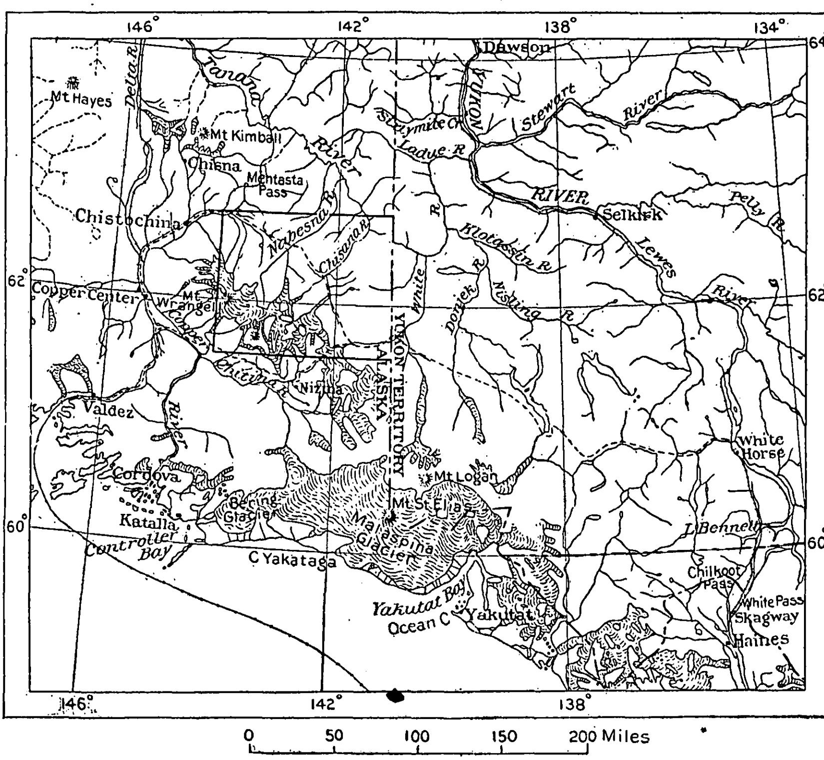


Figure 1.—Outline map of Alaska, showing area covered by Plates I and II (in pocket) and routes of approach.

and the adjacent Nutzotin Mountains—an area extending southeastward from the head of Copper River to the international boundary in the vicinity of Mount Natazhat. (See fig. 1.)

The work, an extension of previous similar surveys made by the United States Geological Survey, was undertaken primarily to determine what progress had been made in developing the mineral resources of the district and to gather information concerning ores and their occurrence that would aid in that development. It involved an examination of all localities where copper and gold have been found previous to 1908, as well as the extension of earlier geologic and topographic surveys.

The party engaged in the work consisted of three men doing geologic and topographic mapping and four others acting as packers and camp assistants. Most of the geologic investigation was made by the senior authors of this report, but they were assisted during the earlier part of the summer by S. R. Capps, whose time after August 1 was given to topographic mapping in the White River Valley. A pack train of eleven horses was used to carry the party and its equipment to the field of work, where a base camp with supplies for the summer's needs had been established at "Sargent's cabin," on Nabesna River, in February, 1908. This base camp was established to avoid the expense and loss of time incident to packing supplies over bad trails in summer and made it possible for the party to leave Valdez with only enough provisions for the trip to Nabesna River. Field work began at "Sargent's cabin" July 8 and ended on White River August 25, when the party crossed Skolai Pass to the Copper River side of the Wrangell Mountains on its return trip to Valdez. Thus a total of only forty-seven days was given to work in the field, and the surveys, which cover an area of nearly 2,000 square miles, must be regarded as purely reconnaissance in character.

The region was first visited by white men in 1891, when Frederick Schwatka, C. W. Hayes, of the United States Geological Survey, and Mark Russell made their way from Selkirk, on Lewes River, to White River, which they followed to its head, and, crossing Skolai Pass, descended Chitina and Copper rivers to the coast. In 1899 W. J. Peters and Alfred H. Brooks, during the course of an exploring expedition extending from Pyramid Harbor to the Yukon, crossed White River at a point west of the international boundary and followed the base of the Wrangell Mountains northwestward to the head of Nabesna River, whence they continued their exploration northeastward across the Tanana to Eagle. During the same year Oscar Rohn, with one companion, A. H. McNeer, under direction of the War Department, crossed the Wrangell Mountains from the Chitina River valley by way of Nizina and Tanana or Chisana glaciers to the head tributary of Tanana River, now known as Chisana River, whence he proceeded northwestward to the head of Copper River, on his way to the coast. Two years later (1902) Frank C. Schrader and D. C. Witherspoon, of the United States Geological

Survey, concluded a geologic and topographic reconnaissance, in the course of which they mapped that portion of the area under consideration lying northwest of Euchre Mountain. As a result of the investigations by these four expeditions, the first three of which must be regarded as purely exploratory, a broader knowledge of the geographic and geologic features of the region has been gained. The published reports resulting from these investigations are the following:

HAYES, C. W. An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, 1892, pp. 117–162, pls. 18–20.

BROOKS, ALFRED H. A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the upper White and Tanana rivers: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1899–1900, pp. 333–391.

ROHN, OSCAR. A reconnaissance of the Chitina River and Skolai Mountains, Alaska: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, pp. 393–445.

MENDENHALL, WALTER C., and SCHRADER, FRANK C. The mineral resources of the Mount Wrangell district, Alaska: Prof. Paper U. S. Geol. Survey No. 15, 1903.

The area investigated in 1908 overlaps that mapped by Schrader and Witherspoon in 1902 in the portion lying between Nabesna and Chisana rivers, and the writers of this report desire to express their indebtedness to Mr. Schrader for the use of his notes and manuscript maps of this area, examined by both parties, and also of the area including the northeast slopes of Mount Wrangell, which (except in the vicinity of Monte Cristo Creek and the mouth of Jacksina River) was examined by Mr. Schrader only. The writers desire further to express their appreciation of the aid given them and the interest shown in their work by the prospectors whom they met during the summer, and particularly to R. H. Sargent and James Galen for the use of their storehouse and cabin and for other favors that contributed largely to the success of the season's work.

GEOGRAPHY AND OTHER FEATURES.

LOCATION OF THE DISTRICT.

The portion of the Wrangell Mountain region that receives first consideration in this paper lies almost wholly within the rectangle formed by parallels 61° 30′ and 62° 30′ north latitude and meridians 141° and 143° 20′ west longitude. (See Pls. I and II, in pocket.) It is limited on the east by the international boundary line and on the south and west by the crest of a mountain chain extending northwest from Mount Natazhat, near the boundary line, to Mount Sanford, the highest peak of the Wrangell group. The principal diameter of the area is the northwest-southeast diagonal of the rectangle indicated above, which corresponds in direction with the trend of the mountains also.

TOPOGRAPHY.

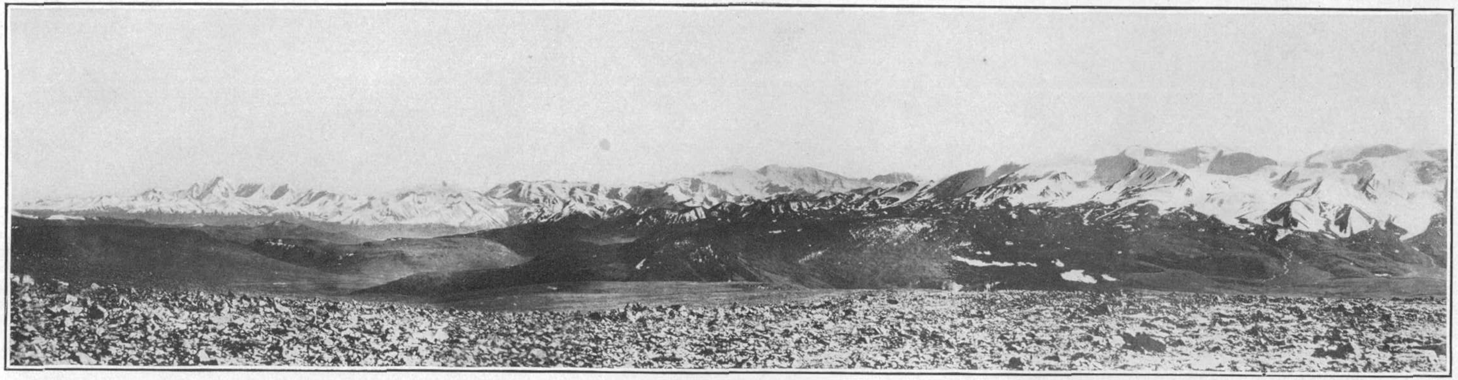
For purposes of description the area may be considered as consisting of two topographic units, the Wrangell and St. Elias mountains on the southwest and the Nutzotin Mountains on the northeast, these two parts being separated by a depression, much better defined in some localities than in others, that extends southeastward from the head of Copper River to White River and thence eastward, as White River valley, into Canadian territory.

The topography of the Wrangell region is exceedingly rugged. The Wrangell Mountains themselves are Alpine in character. They occupy an intermediate position between the adjacent St. Elias and Chugach mountains on the south and the Nutzotins on the northeast, and form a distinct group, which, however, merges into the St. Elias Range in the headwater region of Chitina and White rivers. (See Pl. III, *A*.) Mount Wrangell (elevation, 14,005 feet) holds a central place in the group of peaks to which it gives its name, yet, while perhaps the most imposing, it is not the greatest among them. This group reaches its highest point in Mount Sanford, 16,200 feet above the sea, or 14,000 feet above Copper River on the north, but there are at least five other peaks that rise to elevations greater than 12,000 feet and hundreds that range from 7,000 to 10,000 feet. Their higher portions are covered by a vast snow field, from which scores of valley glaciers descend and form the headwater sources of practically all the important streams of the region. The watershed connecting Mount Wrangell with the St. Elias Range is broken through at only one place. This depression, known as Skolai Pass, lies between the heads of Nizina and White rivers and affords the only route across the divide that does not present almost unsurmountable difficulties.

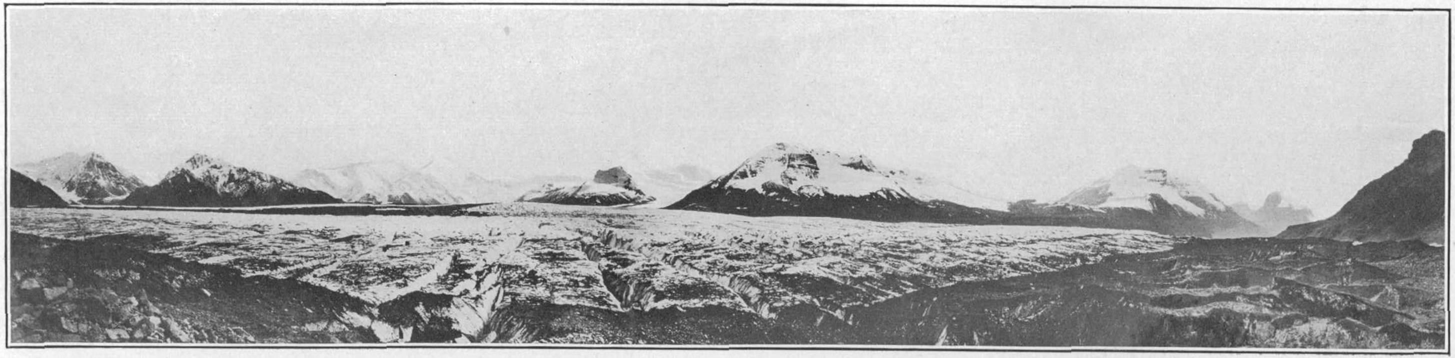
The Nutzotin Mountains reach their highest point in Mount Allen, 10,420 feet above the sea. On the whole they are lower but no less rugged than the Wrangell Mountains, ranging in height from 6,000 to 8,000 or 9,000 feet. They include no extensive snow fields and their few valley glaciers are small and unimportant. On the northwest they merge into the Mentasta Mountains, of the Alaskan Range, and on the southeast they give place to the lower, less rugged, and flat-topped mountains that characterize the country immediately north of White River.

DRAINAGE.

Four principal streams have their origin on the northeast slopes of the Wrangell Mountains. Named in order from northwest to southeast they are Copper River, Nabesna and Chisana rivers, which unite to form Tanana River, and White River. Copper River heads in Copper



A. ST. ELIAS AND WRANGELL MOUNTAINS ABOUT THE HEAD OF WHITE RIVER.



B. RUSSELL GLACIER.

Glacier, on the north slope of Mount Wrangell, and after following a course which is first north, then west, then south, empties into the Pacific Ocean. Its valley offers the most practicable all-American route into the Nabesna region. Nabesna River and Chisana River head, respectively, in Nabesna and Chisana glaciers, the two largest glaciers in the Wrangell Mountain group. The two streams flow in deep canyon-like valleys directly through the Nutzotin Mountains to the Tanana lowlands, where they unite to form Tanana River. Tributaries of Nabesna and Chisana rivers have formed valleys between the Wrangell and Nutzotin mountains, which join the main river valleys nearly at right angles and afford the only routes of travel within the mountain region between the heads of Copper and White rivers. These tributary streams lie in the depression between the two mountain groups to which reference has already been made.

White River heads in Russell Glacier,[a] the ice mass filling Skolai Pass, and after flowing almost directly east to the boundary line turns north and joins the Yukon about 75 miles above Dawson. The White River valley is much wider and more open than the valleys of Nabesna and Chisana rivers, for although it is limited on the south by the lofty snow-covered mountains of the Skolai-Natazhat group, the broad summits of the mountains on the north are for the most part less than 3,000 feet above the river.

The flood plains of these three streams, Nabesna, Chisana, and White rivers, are broad gravel flats ranging in width from less than a mile to several miles, and extending from the feet of the glaciers to the lowlands east of the Nutzotin Mountains. In places they are covered with timber, but in general they are bare wastes of gravel over which the swift detritus-laden glacial streams continually shift their courses.

The streams of the Nabesna-White River district, as previously stated, derive their water supply chiefly from the snow fields of the Wrangell-Skolai group of mountains. Like all glacier streams they are exceedingly changeable in the amount of water they carry, rising and falling with daily variation as well as that depending on season and the irregularities of precipitation. They are heavily burdened with débris brought to them by the glaciers, and it is by the deposition of their overload that the wide gravel flats of the valley floors have been built up. A knowledge of the daily stream variation may be of great value to the traveler in this region, since it enables him to minimize the chance of loss and danger by choosing the most favorable time—from 8 to 10 a. m.—for crossing streams.

[a] Named after I. C. Russell.

TRAILS AND TRANSPORTATION.

The Nabesna-White River region may be approached from any one of three directions—from the northwest, the east, or the southwest. (See fig. 1.)

Travelers bound for Nabesna River usually follow a trail that leaves the government military trail from Valdez to Eagle near the mouth of Slana River. This trail ascends Copper River to Batzulnetas, whence it continues southeastward to the heads of Jack and Platinum creeks, either of which streams leads directly to Nabesna River, although Platinum Creek offers the better route for summer travel. After leaving Batzulnetas the trail bears to the east and traverses the ridge northeast of Tanada Creek. This portion of it may be hard to pick up, but when once found it can be followed with scarcely any difficulty except that in places it is exceedingly swampy, though possibly no worse than some stretches of the military trail between Tonsina and Copper Center or between the Gakona and Chistochina. The distance from Slana River to "Sargent's cabin," on Nabesna River at the mouth of Camp Creek, is approximately 40 miles by way of Platinum Creek and a few miles farther by way Jack Creek.

The customary route of travel for prospectors entering the White River Valley is either through Canadian territory from the Yukon or, less commonly, over Skolai Pass from the Chitina Valley on the southwest. There is a choice of two Canadian routes, depending on the means of transportation it is desired to use. One may either ascend White River in a small boat or follow the overland trail from White Horse, by way of Kluane Lake. The trail from White Horse is probably the easiest and best way of reaching either the White or the Nabesna with stock in summer if ease of traveling only is considered. A wagon road extends from White Horse to Kluane Lake, a distance of 142 miles, and thence a good trail, approximately 120 miles long, leads to Canyon City, on the north side of White River a few miles below the boundary line. Many prospectors bring supplies up White River from Dawson in small boats, and most of them leave the country by boat or by raft in the fall, since it affords them an easy and quick method of reaching the Yukon. The distance from Canyon City to the Yukon by river is approximately 150 miles.

The route over Skolai Pass from the Chitina Valley is difficult for horses and is not frequently traveled. It is used by a few prospectors who have claims in both the Chitina and White valleys, and who cross over from the south to do assessment work. During the earlier days of its use the western end of this trail crossed Nizina Glacier from a point on the west side about 4 miles above the head of Nizina River to the mouth of Skolai Creek, whose north bank it followed eastward to the pass. The trail along Skolai Creek is not now used, for Nizina Glacier is so traversed by crevasses as to be practically impassable, and though horses have been taken high on the mountain around the east side of the small lake formed by the damming of Skolai Creek by Nizina Glacier, the climb is so difficult that it has been undertaken but a few times.

Travelers from the Chitina Valley now ascend Chitistone River to its head and go over a broad, high pass with abrupt northern descent to the foot of Russell Glacier, which occupies Skolai Pass and must be crossed in order to reach the White.

In 1891, when Hayes and Schwatka crossed Skolai Pass, the surface of Russell Glacier sloped smoothly down to the gravel flats of Skolai Creek, and no difficulty was encountered in leaving the ice, but in 1908 the glacier's edge was a wall of ice not less than 25 feet high at its lowest point, and two or three times that in many places. (See Pl. IV, *B*.) From six to eight hours' time is required to cross the glacier, and the whole distance from Chitistone River to White River can be traversed in one day by those familiar with the route. Ordinarily, however, the greater part of two days' time is required to make the trip. The Chitistone trail should not be attempted with heavily loaded horses.

The trail from Nabesna River to White River, whose course will be clearly understood on reference to the map (Pl. I or II), lies in the depression between the Wrangell and Nutzotin mountains and follows the valleys of Cooper, Notch (or Trail), Gehoenda, and Solo creeks. The distance is about 60 miles, and no great obstacles to travel are encountered. Beyond Solo Creek the gravel bars south of White River afford an easy means of travel between Solo cabin and the boundary line. During August, 1908, no difficulty was experienced in fording the river with horses at any point that looked favorable, but there are times when crossing is difficult and dangerous, if not impossible.

Supplies required for use in the Nabesna-White River region should be taken in over the snow in winter unless it is intended to ship them up White River in boats. Supplies used on Nabesna River are brought from Valdez, but most of the prospectors on the White buy their provisions and equipment in Dawson and bring them up the river in the spring. The cost of winter freighting (1908) either from Valdez to Nabesna River or from White Horse to Canyon City is probably not less than 35 cents a pound under favorable conditions, and may be considerably higher.

CLIMATE.

Climatic conditions in the Nabesna-White River region are those of central Alaska as modified by the altitude and the mountainous nature of the country. The region is separated from the Pacific by a broad belt of lofty mountains, and is therefore outside the immediate influence of the ocean with its tendency to increase precipitation and minimize the variations in temperature.

No records of precipitation and temperature are available, and it is not probable that any have been kept. In a general way, however, it may be said that the rainfall is moderate in summer and the winter snows are not excessive. The summers, judged by that of 1908, are cool. Two inches of snow fell in the valleys on July 22 and remained on the lower mountains for a week or more. This snowfall was followed on August 1 by a lighter snow, which lay on the ground only one day. Such snows, however, were considered exceptional.

VEGETATION.

Grass for horses is available in favorable localities in the latter part of May or early in June, and later in the season is abundant, especially on the river bars near Nabesna Glacier, the mouth of Jack Creek, and the head of White River. In many other places, on the contrary, grass is scarce, and it is difficult to keep working stock in good condition. Horses have been left to winter on White River for several years with few losses, and it is said that if they are strong and in good condition when winter sets in the chances are that they will come out all right in the spring, but a much more favorable wintering locality is the region of Kluane Lake. Prospectors using horses leave Nabesna River for Valdez about August 25, or not later than September 1, while those on White River remain till October without danger of lack of feed on the trail to White Horse. The working season on White River is thus considerably longer than that on the Nabesna or anywhere in the Copper River basin.

Spruce timber grows on all the valley floors up to elevations ranging from 4,000 to 5,000 feet, and on the mountain sides to practically the same elevations, though timber line is usually lower at the lower ends of valleys than at the upper ends, and in places is no higher than 3,500 feet. The best timber seen during the summer was on the flats east of Chisana River near Euchre Mountain, where a saw pit had been erected and boat material had been cut. Trees 18 to 20 inches or more at the butt are common here. There is also some very good timber on the head of Nabesna River and on White River.

GAME.

Game is plentiful throughout the Nabesna-White River area. Sheep can be found at the heads of almost any of the streams. In the early spring they feed in the main valleys, but as the summer advances they work farther and farther back into the higher mountains, seeming to choose especially the vicinity of glaciers, and rarely come back to the valleys except as they cross from one mountain to another. They furnish the prospector with a meat supply that rarely fails, yet it is said that their number is decreasing. Caribou, although not present in such great numbers as in the Yukon-Tanana country, are frequently seen on the low hills north of White River. They are the least difficult of any of the game to procure, since their curiosity overcomes their fear of danger and they will follow a horse or watch a man till the scent gives them warning. Moose range the flats bordering White River in considerable numbers, and are occasionally seen on Nabesna and Chisana rivers, though there is less feeding ground for them there. Black and grizzly bears are sufficiently numerous to make it unsafe to leave a cache unprotected for more than a day or two, and they have been known to disturb provisions while the owner slept close by. The natives take a quantity of furs each year—fox, lynx, martin, mink, and wolverine—which they trade to the white men for provisions, clothing, and ammunition. A few ptarmigan are found in the higher untimbered valleys, and occasionally grouse are seen on the timbered flats.

NATIVES.

The total native population of the area extending from the head of Copper River to the White is probably not far from 45 or 50. The natives are divided between three villages, if such they may be called, one at Batzulnetas, on Copper River; one on Nabesna River, at the mouth of Cooper Creek; and a third on Cross Creek, opposite the mouth of Notch Creek, in the Chisana Valley. The Batzulnetas and Nabesna natives rely on the white men for a considerable portion of their food, but the Chisana natives are more independent. Their more isolated position has brought them less in contact with white men, and they have retained their own manner of living to a greater extent. They depend almost entirely on game for food and lay up a good supply each fall for the winter's needs. All the natives wear clothes obtained from white men, except moccasins, which they make themselves, but they prefer the white man's footwear. Under the influence of white men they have become inveterate beggars, always asking for tea or tobacco, for which, as well as for flour and cloth, they will trade meat or leather goods, when they have them.

GEOLOGY.

GENERAL FEATURES.

The geologic map (Pl. II, in pocket) represents the distribution of the principal formations associated with the copper-bearing rocks of the Nabesna-White River region. With a few exceptions the formation boundaries indicated have sketch value only. More detailed field study would result in a subdivision of several of the older formations and without doubt some of the areas that have been included in one formation on the map contain smaller areas that should be differentiated, but their separation was not possible under the conditions of the work and some of them could not be shown on a map of the scale employed. That portion of the map representing the area west of Nabesna River and Nabesna Glacier is entirely the work of Schrader, with the exception of a narrow strip extending south from the glacier to the mouth of Jack Creek and up that stream. This narrow strip and the area between Nabesna and Chisana rivers was examined by both parties. Schrader's manuscript map of this part of the district is reproduced in substantially the form he prepared it, the changes made being those occasioned by the discovery of fossils in localities not visited by him and by the representation of all the granitic rocks by one color.

Both igneous and sedimentary rocks are present in the Nabesna-White River region. In a broad way it may be said that the rocks of the Wrangell Mountains are prevailingly of volcanic origin, although they are associated with important water-laid members, and that those of the Nutzotin Mountains are prevailingly sedimentary, although intrusive igneous rocks are locally prominent. It thus appears that the depression between these two mountain groups separates an area on the southwest that is characterized chiefly by deposits that are the result of volcanic activity from one on the northeast that is characterised chiefly by accumulations due to sedimentation. The following table gives the important features of the stratigraphic column in so far as it is known:

Quaternary	Gravels, till, and other unconsolidated deposits.
Tertiary	Volcanic rocks. Lignite-bearing formation, including shales, sandstones, lignite beds, etc.
Jurassic	Shales of Jacksina Creek. Shales, slates, and graywackes of the Nutzotin Mountains.
Triassic	Thin-bedded limestone of Cooper Creek.
Carboniferous or later	Lavas and pyroclastic beds—tuffs, volcanic breccias, etc. Shales of Skolai Pass.
Carboniferous	Massive limestone. Shales with some tuffs and lava flows. Basic lavas and pyroclastic beds, with some shale and limestone beds.

This table is made up from data collected at various places, for the succession of rocks given is not known to be complete in a continuous section at any one locality.

All the rock formations, including not only those of Carboniferous and Mesozoic age but the Tertiary deposits as well, are cut by dikes and sills of basic igneous rocks, mostly of a basaltic or diabasic nature. The Carboniferous sediments have been further intruded by large masses of quartz diorite and by diorite porphyries and andesites. Whether these granitic and more siliceous porphyritic intrusives extend into the Triassic and Jurassic sediments was not definitely determined, but it is probable that they are at least pre-Jurassic.

DESCRIPTION OF THE FORMATIONS.

CARBONIFEROUS ROCKS.

CHARACTER AND DISTRIBUTION.

The oldest rocks recognized in the region are of Carboniferous age. The series of beds here referred to the Carboniferous shows great variation in the character of its members, for it is in part sedimentary, in part igneous, and includes interbedded shales, limestones, lava flows, tuffs, volcanic breccias, and conglomerates intruded by basalt, andesite, diorite, and in at least one locality by dacite. This series of beds, mostly of volcanic origin, has been folded and faulted but shows no pronounced alteration except where it has been intruded by igneous rocks. A schistose structure is rarely if ever seen. The fragmental volcanic material was laid down in water, for the tuffs and breccias are interstratified with shale and limestone beds and at many localities contain fossils. It is known that the lavas also, or at least a part of them, were poured out and cooled under water.

Neither the top nor the bottom of the Carboniferous series has been determined, but the principal features of the intervening members will now be described. The lowest recognized portion includes shales and occasional thin limestone beds interstratified with dark amygdaloidal lava flows, volcanic breccias, and tuffs. Upon this, in undisturbed sequence, lies the most conspicuous member of the Carboniferous sediments, a massive limestone which north of White River has a minimum thickness of 200 feet and, as described by Hayes,[a] is 500 feet thick in Skolai Pass.

Above the massive limestone are shales and a great thickness of tuffs, breccias, and lava flows, the age of which has not been determined but which are provisionally assigned to the Carboniferous because of their association and seeming conformity with the known Carboniferous rocks. The shales overlying the massive limestone in Skolai Pass, where they are more favorably exposed for examination than in any other known place, have a thickness of nearly 300 feet but include a few thin sills of diabase and in their upper part are interbedded with fine tuffs. No fossils were found in the shales.

The total thickness of Carboniferous rocks exposed in the Nabesna-White district is unknown. The Carboniferous Mankomen forma-

[a] Hayes, C. W., An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, 1892, p. 140.

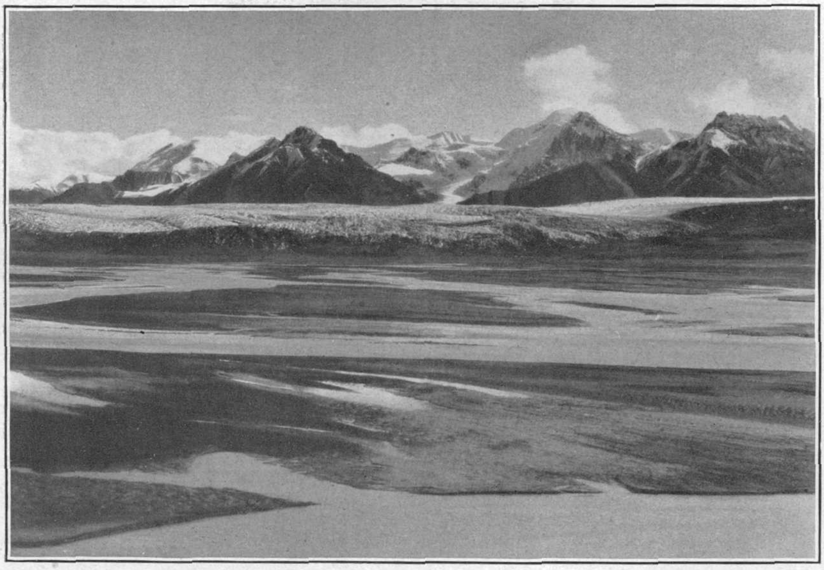
tion in the headwater region of Chistochina and Slana rivers, northwest of this district, has a thickness of nearly 7,000 feet. Probably at least 3,000 or 4,000 feet of Carboniferous slates and volcanic beds are exposed on Nabesna River and they may possibly attain a thickness as great as that of the Mankomen.

The massive Carboniferous limestone is best exposed about the head of Kletsan Creek and at Skolai Pass, but is found also on Cross Creek, at Cooper Pass, and in the region at the head of Nabesna River, including Jack Creek. (See Pl. IV, *A*.) The age determination of that seen on Jack Creek, to which Schrader gave the name Nabesna limestone, is not based on evidence afforded by fossils, and is therefore open to question, although there is little doubt that it is correctly referred to the Carboniferous.

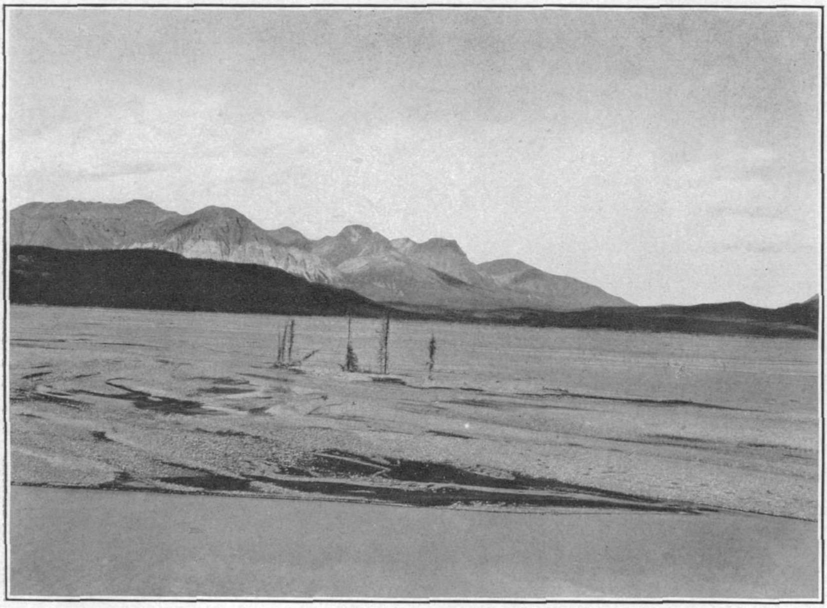
The exposures of the massive limestone occur in such a way as to leave almost no doubt that they once constituted a continuous formation, but faulting and intrusion have so destroyed their continuity that isolated and widely separated limestone masses surrounded by igneous rocks and shales are frequently encountered. The limestone is gray or bluish gray in color, but locally has been altered to a coarse white marble as a result of changes brought about by contact with hot igneous intrusives. Its conspicuous appearance is due to the prominent cliffs in which it is exposed and to the sharp contrast in color between it and the dark shales and lava flows with which it is interbedded. Except where altered it is abundantly fossiliferous, especially in the headwater region of White River, and is characterized by a fauna of great paleontologic interest.

Reference to the geologic map (Pl. II) will show that the Carboniferous rocks occur in the slopes of the St. Elias and Wrangell mountains in a narrow belt extending from the boundary line westward to Skolai Pass and thence northwestward to the head of Copper River and in another area, not so well defined, north of White River, near the boundary line. The importance of the Carboniferous belt lies largely in the fact that the rocks forming it carry the copper deposits of the district, but in examining the map it must be kept in mind that not all of the Carboniferous rocks carry copper and that areas of younger deposits are doubtless included in the belt indicated. Some of the northern tributaries of White River, such as North Fork, show by the bowlders in their gravel bars that their headwaters flow over Carboniferous limestone, but time was not available for determining its location.

From the description it is seen that the beds of the Carboniferous series may be referred to three subdivisions, the upper and lower comprising chiefly shales, lava flows, and pyroclastics, and the middle including only the massive limestone. This series of sedimentary and volcanic beds was intruded in an intricate way by igneous rocks and



A. WEST END OF RUSSELL GLACIER AT HEAD OF SKOLAI CREEK.



B. MOUNTAINS BETWEEN JACK AND JACKSINA CREEKS.

has undergone much faulting, so that the continuity of individual members, such as the heavy limestone, is at many places interrupted, leaving portions of them with no apparent relationship to one another. Furthermore they have been folded and in many places dip at high angles, yet the folding, although locally pronounced, is not so conspicuous as it is in some of the younger sediments.

LITHOLOGY.

The Carboniferous shales for the most part are dense and hard and are of various colors, principally black, gray, or bluish. When exposed to the weather some of them slack or break down into soft, crumbling masses bearing little resemblance to the original rock. This is well shown on the gravel bars of the streams coming into White River from the south, where the shale bowlders weather into heaps of small, angular fragments whose former character is shown by cores of unaltered rock and the fossils they contain. Locally the beds are intensely folded and resemble the Triassic shales of the Chitina Valley. Some of them, more particularly those underlying the massive limestone, are highly fossiliferous and include thin limestone beds that also carry fossils.

The volcanic rocks associated with the shales consist of water-laid tuffs and breccias and basaltic and andesitic lava flows. For convenience the tuffs and breccias have been called pyroclastic beds in the table on page 16 and are occasionally referred to in the text as pyroclastics. They are composed of fragmental material ejected during periods of volcanic activity, and except for their volcanic origin, are like the shales in the manner of their formation—that is, in having been deposited under water. They resemble sandstones and conglomerates in appearance, although the material composing them is little, if at all, waterworn. They differ from each other principally in the size of the fragments composing them, the breccias containing coarser material than the tuffs. The tuffs and breccias are gray, brownish gray, or yellowish gray in color and are lighter than most of the shales and lava flows. At one locality their weathered surface is black, the color being due to the presence of manganese oxide. Their position between shale and limestone beds and their number indicate that the volcanic outbursts giving rise to them were many times repeated and continued through a long period of time.

The Carboniferous volcanic rocks are generally of some dull, subdued color and contrast in this respect with the bright, fresh appearance of the recent lavas of the region. Greens, browns, and reds are the tints most prevalent. In texture these rocks range from highly porphyritic sheets studded with numerous white feldspar crystals to fine-grained dense lavas. Probably their most persistent and striking feature is their amygdaloidal character. The fillings of the amygdules consist of zeolites, calcite, chlorite, epidote, and chalcedony. Of these minerals, the white zeolites and calcite are most conspicuous and over considerable areas form as much as 25 per cent of the bulk of the inclosing rocks. In places the zeolitic filling of former steam cavities is arranged in fine radial aggregates of columns, which have been determined to be thomsonite. Doubtless other varities of zeolite occur in the region, but have not been discriminated.

Petrographically the lavas are essentially plagioclase-augite aggregates, more or less thoroughly altered. In some specimens it is possible that a small amount of olivine was originally present.

AGE AND CORRELATION.

The age of the beds referred to the Carboniferous in the Nabesna-White River district is definitely established by the fossils collected from them. The shales, limestones, and in places the tuffs contain the remains of a fauna that show they were deposited in later Carboniferous time and are related, not to the Carboniferous of eastern and central United States, but to that of Russia. Fossils were obtained from about fifteen localities, scattered all the way from Nabesna River to the boundary line, and in most places were found to be abundant. The limestone of Skolai Pass, particularly, furnished collections that were limited only by the means of carrying them away. This abundance of animal remains in the massive limestone and the underlying shales is in contrast with the seeming scarcity in the upper shales, yet the examination of the upper shales was not thorough enough to justify a statement that they are non-fossiliferous, or even poorly fossiliferous.

The collections of fossils were submitted to George H. Girty, whose report follows. The specimens are referred to in the descriptions by their numbers as catalogued in the National Museum.

All the collections are clearly Carboniferous and all represent the Russian Gschelian fauna except as noted below. They show several more or less distinct facies, but all are more nearly related to the Gschelian than to any fauna known to me. The Russian fauna itself has been divided into several zones and the Alaskan collections probably show greater differences from one another than if a large number of species were contained in each.

One might say that lots 7099a and 7099b represent a different and possibly older facies than the Gschelian, but if lot 7099c belongs to the same horizon it contains a striking species which, so far as I am aware, is peculiar to that horizon. It recurs in 7109. But this collection also contains *Productus* aff. *wallacianus*, which is found in 7094 and other collections, and *Martinia* aff. *semiglobosa*, which is found in 7108 and 7104. The latter collection contains the striking spherical sponge which is also in lot 7097. Similarly, if an attempt is made to follow out the relations of any other lot that seems to have a peculiar facies it is found that the relations ramify so as to include the whole collection, more or less. The only exception, perhaps, is found in lot 7107, which contains two species that are not observed elsewhere in the collection and that are so similar to types found in our own Mississippian as to suggest that they are at least lower rather than upper Carboniferous. *Reticularia*, for instance, is not known to me above the Mississippian in the United States, but I dare do no more for the present than to call attention to this occurrence without drawing any inference from it.

The following collections were made at the localities indicated:

Bond Creek:
- Lot 7094—
  - Campophyllum? sp.
  - Lophophyllum? sp.
  - Rhombopora? sp.
  - Productus semireticulatus Martin.
  - Productus aff. wallacianus Derby?
  - Camarophoria aff. crumena Martin.
- Lot 7095—
  - Productus semireticulatus Martin.
  - Rhombopora? sp.
  - Camarophoria aff. crumena Martin?

Nabesna Glacier:
- Lot 7096—
  - Spirifer arcticus Houghton.

Camp Creek:
- Lot 7103—
  - Campophyllum sp.
  - Clisiophyllum? sp.
  - Camarophoria aff. crumena Martin.

Cooper Creek:
- Lot 7097—
  - Sponge (same as 7104).
- Lot 7104—
  - Sponge.
  - Derbya? n. sp.
  - Martinia aff. semiglobosa Tschernyschew.

Lime Creek:
- Lot 7108—
  - Productus semireticulatus Morton.
  - Productus aff. humboldti D'Orbigny.
  - Productus aff. koninckianus De Verneuil.
  - Productus sp.
  - Camarophoria aff. crumena Martin.
  - Squamularia aff. perplexa McChesney.
- Lot 7108a—
  - Martinia aff. semiglobosa Tschernyschew.

North Fork White River:
- Lot 7098—
  - Spirifer arcticus Houghton.

Middle Fork White River:
- Lot 7106—
  - Rhombopora sp.
  - Productus aff. gruenewaldti Krotow.
  - Spiriferina sp.
- Lot 7101h—
  - Productus sp.

Skolai Pass, north side:

Lot 7102—

Productus cora D'Orbigny.

Lot 7102a—

Productus cora D'Orbigny.

Lot 7102b—

Productus aff. longispinus Sowerby.
Cliothyridina aff. roissyana Keyserling.

Lot 7102c—

Productus cora D'Orbigny.

Lot 7102d—

Productus sp.
Aviculipecten sp.

Lot 7102e—

Chonetes aff. flemingi var. verneuilianus Norwood and Pratten.
Productus cora D'Orbigny.
Productus aff. irginæ Stuckenberg.
Productus sp.
Cliothyridina aff. roissyana Keyserling?
Dielasma aff. bovidens Morton.
Aviculipecten aff. curticardinalis Hall and Whitefield.
Aviculipecten aff. occidentalis Shumard.

Lot 7102f—

Spirifer arcticus Houghton.

Lot 7102g—

Productus aff. longispinus Sowerby.
Spirifer arcticus Houghton?

Lot 7102h—

Productus aff. gruenewaldti Krotow.
Productus aff. timanicus Stuckenberg.
Squamularia aff. perplexa McChesney.

Edge of Skolai moraine.

Chonetes aff. flemingi var. verneuilianus Norwood and Pratten.
Productus cora D'Orbigny.
Productus aff. humboldti D'Orbigny.
Productus aff. longus Tschernyschew non Meek.
Camarophoria aff. kutorgæ Tschernyschew.
Rynchopora sp.
Dielasma aff. bovidens Morton.
Spirifer aff. fasciger Keyserling.
Spirifer aff. cameratus Tschernyschew non Morton.
Squamularia aff. perplexa McChesney.
Spiriferina aff. pyramidata Tschernyschew.
Platyceras? sp.

Moraine Creek, Skolai Pass:

Lot 7105—

Lophophyllum? sp.
Spirifer arcticus Houghton.

Skolai Pass, south side, 2 miles east of Moraine Creek:

Lot 7109—

Productus aff. wallacianus Derby?
Camarophoria aff. sella Kutorga.
Martinia aff. semiglobosa Tschernyschew.
Spiriferna sp.

South side White River, 10 miles east of Skolai Pass:

Lot 7099—

Chonetes aff. flemingi var. verneuilianus Norwood and Pratten.
Productus sp.
Orthotichia? n. sp.
Lima aff. retifera Shumard.
Sedgwickia? sp.

Lot 7099a—

Stenopora? sp.
Derbya? sp.
Chonetes aff. flemingi var. verneuilianus Norwood and Pratten?
Marginifera? aff. wabashensis Norwood and Pratten.
Schizophoria? aff. supracarbonica Tschernyschew.
Rhynchopora sp.
Spirifer aff. keokuk Hall.
Spirifer aff. nikitini Tschernyschew.
Squamularia aff. perplexa McChesney.
Pleurotomaria sp.

Lot 7099b—

Martinia? sp.
Parallelodon sp.
Pleurotomaria sp.

Lot 7099c—

Camarophoria aff. sella Kutorga.

Holmes Creek:

Lot 7100—

Stenopora sp.
Productus aff. fasciatus Kutorga.
Productus aff. pseudaculeatus Krotow.
Camarophoria aff. kutorgæ Tschernyschew.

Lot 7100a—

Productus aff. fasciatus Kutorga.
Squamularia? sp.

Lot 7100b—

Lima aff. retifera Shumard.

Lot 7100c—

Squamularia aff. perplexa McChesney.

Lot 7100d—

Campophyllum sp.

Lot 7100e—

Campophyllum? sp.

Lot 7100f—

Productus aff. fasciatus Kutorga.
Camarophoria aff. crumena Martin.
Spirifer sp.

Lot 7100g—

Spirifer aff. nikitini Tschernyschew.

Lot 7100h—

Marginifera? aff. wabashensis Norwood and Pratten.
Productus sp.
Camarophoria aff. crumena Martin.
Spirifer arcticus Houghton?

Lot 7100k—

Spirifer arcticus Houghton?

Holmes Creek—Continued.
- Lot 7100m—
  - Lophophyllum? sp.
- Lot 7100n—
  - Productus sp.
- Lot 7100p—
  - Rhombopora? sp.
  - Productus aff. wallacianus Derby?
  - Spirifer arcticus Houghton.
- Lot 7100r—
  - Productus (2) sp.
  - Spirifer aff. nikitini Tschernyschew.
- Lot 7100s—
  - Rhombopora sp.
  - Productus aff. mammatus Keyserling.

Kletsan Creek:
- Lot 7101—
  - Chaetetes sp.
  - Chonetes flemingi var. verneuilianus Norwood and Pratten.
  - Productus sp.
  - Rhynchopora sp.
  - Cliothyridina aff. roissyana Keyserling.
- Lot 7101a—
  - Marginifera? aff. wabashensis Norwood and Pratten.
  - Productus aff. gruenewaldti Krotow.
- Lot 7101b—
  - Productus aff. gruenewaldti Krotow.
  - Schizophoria? aff. supracarbonica Tschernyschew.
- Lot 7101c—
  - Platyceras aff. parvum Swallow.
- Lot 7101d—
  - Chonetes aff. flemingi var. verneuilianus Norwood and Pratten.
  - Productus aff. fasciatus Kutorga.
  - Productus aff. aagardi Toula?
  - Marginifera aff. wabashensis Norwood and Pratten.
  - Productus aff. wallacianus Derby?
  - Enteletes hemiplicatus Hall.
  - Camarophoria aff. crumena Martin.
  - Cliothyridina aff. roissyana Keyserling?
- Lot 7101e—
  - Spirifer aff. nikitini Tschernyschew?
- Lot 7101f—
  - Spirifer aff. nikitini Tschernyschew?
- Lot 7101g—
  - Lophophyllum? sp

Eureka Creek:
- Lot 7107—
  - Productus aff. alternatus Norwood and Pratten.
  - Reticularia aff. setigera Hall.

Carboniferous deposits are found in Alaska at many localities—from the Porcupine basin in southeastern Alaska, through the upper Yukon and Tanana valleys, to Bering Strait and the Arctic slope—but the Carboniferous of the Nabesna-White district is more closely related to that of the upper Copper River, the upper Yukon and Tanana rivers, and the Porcupine basin than to that of the northern districts.

The Nutzotin Mountains are directly continuous with the mountains of the Alaska Range to the northwest, and the probable equivalence of the Carboniferous formations of the upper Copper River and of the Nabesna-White district would be suggested by this fact, even if the correlation were not established by the evidence of fossils. Upper Carboniferous deposits are represented in the headwater region of Copper River by the Mankomen formation.[a] This formation is a series of sediments, between 6,000 and 7,000 feet thick, composed of sandstones, shales, limestones, and tuffaceous beds with included lava flows and intruded sheets. These beds were originally described as Permian, but should be correlated, on both structural and fossil evidence, with the beds along White River, and would now be called upper Carboniferous. The Mankomen formation, as described by Mendenhall, "falls naturally into two divisions—an upper, prevailingly calcareous division, which includes somewhat more than half the total thickness, and a lower, prevailingly arenaceous and tuffaceous division, over 2,000 feet thick." Two principal limestones are present in the upper part of the Mankomen formation. The lower, a white, massive limestone about 500 feet thick, is separated from the upper, which is about 600 feet thick, by several hundred feet of shale. This upper limestone is made up of thin beds and is highly fossiliferous, much more so than any other parts of the section examined. Fossils were collected at several horizons from the base to the top of the Mankomen section, and the correlation with the White River section is made on their evidence. The Mankomen resembles the Nabesna-White Carboniferous section in the presence of much volcanic material, in which respect both differ from the corresponding Yukon Carboniferous.

A massive limestone, having a maximum thickness of more than 2,000 feet, is found in the Chitina Valley and reaches its greatest development on Chitistone River, which heads near Skolai Pass. This formation is known as the Chitistone limestone and was correlated by Schrader and Spencer in their report in 1901 on the geology of the Chitina Valley[b] with the Carboniferous limestone of White River. They found no determinable fossils in the Chitistone limestone, and the correlation was based on stratigraphic evidence and lithologic similarity. After studying the Carboniferous formations of the upper

[a] Mendenhall, Walter C., The geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1906, pp. 40-52.

[b] Schrader, Frank C., and Spencer, Arthur C., The geology and mineral resources of a portion of the Copper River district, Alaska: Special publication U. S. Geol. Survey, 1901, p. 46. See also Bull. U. S. Geol. Survey No. 374, p. 27.

Copper River valley, Mendenhall[a] questioned this correlation, his objections being based on the seeming absence of fossils in the Chitistone limestone, on its conformable relation to the overlying Triassic sediments, and on its freedom from basic intrusives, all of these features being contrary to the character of the Carboniferous sediments of the Mankomen formation. Later work,[b] however, proved the Chitistone limestone to be of Triassic age, but it is suggested that the Nikolai greenstone, which conformably underlies the Chitistone limestone in the Chitina Valley, may probably be the equivalent of some of the upper lava flows referred to the Carboniferous in White River valley. Proof for this correlation is lacking and will remain so until the upper limit of the Carboniferous is determined, but the seeming transition, without interruption, from Carboniferous to Triassic deposits in the Yukon Valley suggests the possibility of such a condition holding at the head of White River and that an unconformity between Carboniferous and Triassic deposition may not occur there. Whether the volcanic beds occurring between the massive limestones of the White and Chitina valleys should be referred to the Carboniferous or Triassic may be difficult if not impossible to determine.

The Carboniferous beds of the upper Yukon have been described recently by Brooks and Kindle,[c] who show that in the Yukon Valley, the section is complete from the Devonian to the Triassic and may be divided into an upper and lower member, called the Calico Bluff and Nation River formations, of lower and upper Carboniferous age, respectively. The Calico Bluff formation rests conformably on Devonian sediments, but is separated by an unconformity from the overlying Nation River formation. The Nation River formation, in turn, is unconformably overlain by a heavy upper Carboniferous limestone, on which rests Mesozoic sediments. From this it appears that in the upper Yukon basin the changes from Devonian sedimentation to Carboniferous and from Carboniferous to Mesozoic took place without interruption, but that there were two breaks in the process of deposition within the Carboniferous. At the top of the Nation River formation is a massive limestone of which it is said:[d]

The uppermost member of the Carboniferous is a white subcrystalline limestone with a minimum thickness of at least 200 feet, which carries fossils assigned by Doctor Girty to the upper Carboniferous. This terrane was first assigned to the upper Carboniferous by Schuchert and later placed in the Permian on the basis of more complete collections. It will be shown below that they have been correlated with the so-called

[a] Mendenhall, Walter C., The geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1906, p. 51.

[b] Moffit, Fred. H and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: Bull. U. S. Geol. Survey No. 374, 1908, p. 26.

[c] Brooks, Alfred H. and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Bull. Geol. Soc. America, vol. 19, 1908, pp. 291-304.

[d] Idem, p. 295.

Permian rocks of southeastern Alaska and White and Copper rivers, but though Doctor Girty is inclined to accept this correlation he believes that they should all be called upper Carboniferous rather than Permian.

Of the fossils collected from this limestone Girty says:[a]

> This fauna is unlike anything known in central and eastern North America and appears to be rather closely allied to that of the Gschelstufe of the Ural Mountains. Probably the fauna of the Hueco, Weber, and Aubrey formations of western United States will be found more or less closely related. In Alaska it has been collected in Pybus Bay and on Kuiu Island.

Sediments that are probably Carboniferous in age have been found on the middle White River,[b] but the fossil collections from them were not large and their position in the geologic column is not yet definitely fixed. Brooks says of these rocks:

> A heavy conglomerate and argillite series in the White River region, termed the Wellesley formation, was provisionally assigned to the Carboniferous or Devonian on the basis of a few invertebrate fossils. It seems quite possible that this may be a synchronous deposit with the Nation River.

MESOZOIC ROCKS.

The Mesozoic sediments in the Nabesna-White district, so far identified, belong to the Triassic and Jurassic systems, but a few fossils of doubtful Cretaceous age indicate the probable presence of Cretaceous sediments also. Mesozoic time, as represented by the rocks of the Nutzotin Mountains, where the Mesozoic deposits are best developed, is distinguished from Carboniferous time by the cessation of that volcanic activity which gave origin to the great thickness of lava flows, breccias, and tuffs associated with the Carboniferous slates and limestones and which began again in Tertiary time. The Mesozoic sediments are chiefly banded slates, graywackes, and conglomerates of a character indicating that the conditions of deposition were variable and that erosion and deposition proceeded rapidly.

The known Triassic sediments of the Nabesna-White district include a single limestone formation which, although not so thick as the Carboniferous limestone, is so similar to it in general appearance as to be easily confused with it, and which can be distinguished with certainty only by an examination of the fossils. This limestone was seen in the vicinity of Cooper Pass, where it is associated with the massive Carboniferous limestone. It outcrops on the hill between the two main branches of Cooper Creek and again between the forks of Notch and Wilson creeks. In this vicinity the Carboniferous and Mesozoic beds have been closely folded and dip at high angles, in

[a] Idem, p. 297.

[b] Brooks, Alfred H., A reconnaissance in the White and Tanana river basins: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, pp. 471-472.

places as much as 90°. They have also been faulted and intruded by dioritic and dark porphyritic dikes, so that neither the relation of the Triassic limestone to adjacent sediments nor its thickness were determined. It is believed, however, that the Triassic limestone is much thinner than the Carboniferous limestone, and that it is more thinly bedded.

Fossils were found in the limestone at Cooper Creek and also at the mouth of Wilson Creek, but no collections were made at the latter locality, for the shell remains showed only on the weathered surface and it was difficult to procure determinable specimens. The age of the limestone on Wilson Creek, therefore, is not fixed beyond doubt. The fossils found on Cooper Creek were identified by T. W. Stanton, and are described with the Jurassic fossils below.

The outcrops on Cooper Pass and Notch Creek furnish the first indication of the presence of the Chitistone limestone north of the Wrangell Mountains, yet the evidence afforded by the few fossils collected is not strong enough to prove the exact equivalence of the two limestone formations, although both are upper Triassic.

The Jurassic system is represented in the Nabesna-White district by banded shales or slates, graywacke, and conglomerate. With these are associated sandstone and limestone in minor amount. This group of rocks is not well delimited, and, as will be seen later, probably includes some Triassic sediments and possibly some of Cretaceous age.

Jurassic fossils were collected from thin, banded gray and black shales on the east side of Notch Creek opposite the mouth of Wilson Creek and from dark shales on the west side of Jacksina Creek, 4 miles above its mouth. Schrader found a few imperfect Jurassic fossils on the east side of Nabesna River almost directly opposite the locality last named.

All the Mesozoic fossils collected from the Cooper Pass and Jack Creek localities were submitted to T. W. Stanton who gave the following report on them:

Two horizons are represented in this small collection—the Upper Triassic in the lot numbered 5721, from Cooper Creek, and the lot numbered 5724, from the same locality, and the Upper Jurassic in lot 5722, from Trail and Notch Creeks, and in lot 5723 from the mouth of Jacksina Creek.

The fossils recognized in the different lots are as follows:

Mouth of Jacksina Creek:

Lot 5723—

Aucella sp., related to A. bronni Rouiller

Horizon, Upper Jurassic.

Limestone between the forks of Cooper Creek:

Lot 5721—

Pseudomonotis subcircularis (Gabb).

Horizon, Upper Triassic.

Trail of Notch Creek:
Lot 5722—
Aucella sp., related to A. bronni Rouiller.
Horizon, Upper Jurassic.
Cooper Pass:
Lot 5724—
Pseudomonotis subcircularis (Gabb).
Horizon, Upper Triassic.

A few shells collected by J. D. Irving in the vicinity of Beaver Creek in 1907 were also submitted to Mr. Stanton and were described by him as follows:

The specimens all belong apparently to a single species of *Aucella* and though they are much compressed and considerably distorted they seem to be of the type of *Aucella crassicollis* Keyserling, which is referred to the Lower Cretaceous. The horizon is probably about the same as that of the *Aucella* bed from which Mr. Mendenhall collected on Matanuska River.[a] Whether the fossils belong to the species mentioned or not they are certainly *Aucella* and the age is therefore Lower Cretaceous or Upper Jurassic.

It is, therefore, possible that all three systems of the Mesozoic section are represented in the Wrangell district but inasmuch as the determination of the fossils doubtfully referred to the lower Cretaceous has not yet been verified no place is given to the Cretaceous in the stratigraphic column. Yet the probability that Cretaceous sediments are present is recognized.

The Nutzotin Mountains, so far as known within the area under consideration, are composed chiefly of banded slates or shales, with which there is interbedded a large proportion of graywacke and a smaller amount of conglomerate, sandstone, and thin limestones, all of which are provisionally referred to the Mesozoic, but at the southeast end of the chain this series of beds gives way to Carboniferous and Tertiary sediments. It is possible that the Carboniferous may also be represented in the Nutzotin Mountains of the middle and northern parts of the district, but no evidence of its occurrence there was obtained and, in fact, it is not believed to be present. The walls of Nabesna and Chisana canyons give favorable conditions for a study of sections across the chain, and in neither of these canyons were any rocks found except those already named nor was anything seen that suggested the Carboniferous, as it is known in other parts of the district. There was, however, a resemblance to the Valdez "series" of the Chugach Mountains.

The rocks on Nabesna and Chisana rivers are hard, banded slates, gray and black or bluish black in color, which in places show a brownish rusty weathered surface. Beds of graywacke, ranging in thickness from a few inches to many feet, are interbedded with the

[a] Mendenhall, Walter C., A reconnaissance from Resurrection Bay to Tanana River, Alaska, in 1898. Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1900, p. 309.

slates, and in some localities the banded appearance of the rocks is due not to differences in color of the slate beds but to thin alternating slate and graywacke beds, which differ not only in color but also in hardness and in resistance to weathering, so that one stands out before the other. Brownish feldspathic sandstones are occasionally met. Beds of conglomerate are locally important, although they constitute only a minor part of the sedimentary series. Near the mouth of Cooper Creek a coarse conglomerate bed contains well-rounded pebbles or cobbles up to 8 inches in diameter. It is composed of fragments of diorite, andesite, and limestone, and is associated with a considerable amount of hard, fine conglomerate, pieces of which may be found in many creek beds in other localities.

The slate and graywacke series of the Nutzotin Mountains is closely folded, so that in many places beds whose prevailing strike is northwest-southeast stand on edge or are overturned and probably are several times repeated in the sections examined. No estimate of their thickness was made, but the section at Chisana Canyon is about 18 miles long and the sediments are doubtless to be measured in thousands rather than hundreds of feet. Intrusives are not of frequent occurrence, although dark porphyritic dikes, much altered, cut both the Triassic limestone and the Jurassic slates in localities from which fossils were collected. On the other hand, small veins of calcite and quartz are abundant and form a noticeable portion of the gravels in the stream beds of the Nutzotin Mountains.

Mesozoic rocks play an important part in the geology of the Mount Wrangell region. In the Chitina Valley they attain a thickness thought to be as great as 6,000 feet,[a] and their areal distribution there is greater than that of any other single formation. They include the Chitistone limestone, with a maximum thickness possibly as great as 2,000 feet,[b] on which rest 1,000 feet of interbedded black shales and thin limestones overlain by probably 3,000 feet of black shales with occasional thin limestone beds, all of which, including the Chitistone formation, are of Triassic age. Attention is drawn to the Chitistone limestone, for, as has already been stated in the discussion of the Carboniferous, it was at first correlated with the massive limestone of White River and assigned to the Carboniferous, but has since been shown to be Triassic and is therefore to be associated in age with the overlying limestone and shales. After an interval of uplift and erosion the Triassic limestone and shale formations were again partly or wholly submerged and on them was

[a] Moffit, Fred H., and Maddren, Alfred G., Mineral resources of the Kotsina-Chitina region, Alaska: Bull. U. S. Geol. Survey No. 374, 1908, pp. 26, 28.

[b] Since this paper was written a detailed investigation of the Nizina River district has shown that the Chitistone limestone attains a thickness of at least 3,000 feet in the Nizina Valley and that the thickness of the Jurassic (Kennicott) sediments is much greater than has been supposed, possibly more than 6,000 feet.

deposited a "variable series of conglomerates, sandstones, limestones, and shales" belonging to the "doubtful series lying at the top of the Jurassic or at the base of the Cretaceous"[a] and known as the Kennicott formation.

The Middle Jurassic and lower Upper Jurassic, such as that of the Matanuska Valley and other parts of Alaska, has not yet been found here.

The Kennicott formation is made up of coarse conglomerate, sandstone, and shale, and either was not so widely distributed as the Triassic formations or has since been largely removed by erosion, for it is found only in isolated areas which, however, are widely scattered.

There is small resemblance lithologically between the Mesozoic sediments on the south side of the Wrangell Mountains and those on the east. No limestone comparable with the Chitistone limestone in thickness or areal extent was found in the Nabesna-White district, yet the Triassic fossil, *Pseudomonotis subcircularis* (Gabb), collected from the limestone at Cooper Creek, and from the Chitistone limestone at several localities, bears evidence for the correlation of the two. No Triassic limestone-shale formation, like that of the Chitina Valley, is known east of the Wrangell Mountains. The beds of the Nutzotin chain that resemble it most are seemingly of much less thickness and, moreover, contain Upper Jurassic fossils in the locality where they were most carefully examined. The slate-graywacke series of the Nutzotin Mountains has no counterpart in the Wrangell Mountains in the Chitina Valley, and if it corresponds with any part of the Triassic or Jurassic strata found there the correlation must be based on paleontologic and not on lithologic grounds. These differences are seen in the following correlation table, showing the relation of the formations on the east and south sides of the Wrangell Mountains:

Correlation of the formations on the east and south sides of the Wrangell Mountains.

Era.	System.	East side of Wrangell Mountains.	South side of Wrangell Mountains.
Cenozoic.	Quaternary.	Stream and glacial gravel, sand, etc.	Stream and glacial gravel, sand, etc.
	Tertiary (Eocene).	Volcanics, shales, sandstones, lignite. Unconformity.	Volcanics, lignite-bearing beds. Unconformity.
Mesozoic.	Cretaceous ?	Shales, etc., in Beaver Creek region.	
	Upper Jurassic.	Slates, graywackes, and conglomerates of the Nutzotin Mountains.	Kennicott formation. Unconformity.
	Upper Triassic.	Limestone of Cooper Pass.	Limestone-shale formation. Chitistone limestone.
Paleozoic.	Upper Carboniferous.	Limestone, slates, and volcanics.	

a Op. cit., pp. 30 and 31.

It seems evident from what has been said that the conditions under which the Mesozoic beds in these two portions of the Wrangell Mountain district were laid down must have been widely different. These differences can not be regarded as proved, for there are doubts concerning the age of much of the sediments composing the Nutzotin Mountains, but if the Nutzotin sediments are largely Jurassic rather than Triassic, as seems more probable, the principal points of contrast are the greater development of Triassic sediments in the Chitina Valley and a probable greater development of Jurassic sediments in the Nutzotin Mountains. Viewed still more closely the known Triassic rocks east of the Wrangell Mountains consist of limestone, while those of the Chitina Valley include not only a heavy limestone bed but a much greater thickness of interbedded thin limestone and shale beds and fine black shales. The Jurassic of the Nutzotin Mountains on the whole shows greater variation in material than the Kennicott formation. With its shales are associated a large amount of graywacke and some coarse conglomerate, but its conglomerate beds in general are less prominent, besides being harder and composed of finer material than those of the Chitina Valley.

TERTIARY ROCKS.

EOCENE (?) SEDIMENTS.

A formation consisting of soft, thin-bedded shales and sandstones, associated with large amounts of well-rounded conglomerate composed mainly of diorite cobbles, occurs in the region of Coal Creek, north of White River, near the international boundary. The area in which these rocks are exposed is small, but there is some probability that they underlie the volcanic cappings of the mesas which form prominent features of this part of the White River region.

The strata lie nearly horizontal and rest upon older rocks which stand on edge. In places they are lignitiferous, and petrified wood of exogenous character is common as float in gulches cutting the formation.

The resemblance of these rocks to those of similar patches scattered throughout the Yukon basin [a] leaves little doubt as to their Tertiary and probably Kenai age. Rocks of identical character occur near the head of Chitistone River, and, like those of the White River region, are covered by a heavy series of volcanic flows.

TERTIARY LAVAS.

The surface flows and associated pyroclastics that are piled up to form the volcanoes of the Wrangell Mountains were called the Wrangell lavas by Mendenhall, who made geologic studies on the western

[a] Collier, A. J., Coal resources of the Yukon, Alaska: Bull. U. S. Geol. Survey No. 218, 1903, p. 19.

slopes of the range.[a] Rocks of the same kind are rather widely distributed on the northeastern slopes, and form the bed rock of the large glacier fields mantling the upper portion of the mountains. As Mendenhall has described the lavas in detail, both microscopically and by chemical analyses, it will be necessary only to advert briefly to their essential features. In the northern part of the area under discussion the lavas and accompanying fragmental rocks were piled up as a series of superimposed sheets lying nearly horizontal, and the entire volcanic accumulation was thus given the aspect of evenly stratified beds that dip gently away from extrusive vents situated in the region of Wrangell and Sanford. In these lava sheets columnar structure is common and variety of color is notable. Gray and black are the predominant tones, but the pink and brick-red of weathered phases, especially of the highly vesicular lavas, are perhaps more striking.

The lavas consist largely of pyroxene andesites, commonly containing hypersthene, of olivine basalts, and, less abundantly, of dacites. In texture they range from glassy to holocrystalline. There appears to be a complete series of transitional forms from siliceous andesites to olivine basalts, but the hurried character of the reconnaissance made unfortunately allowed no time for inquiry as to the nature of the eruptive sequence.

It was shown by Mendenhall, in the report already cited, that in the northern portion of the Wrangell Mountains the floods of lava obliterated an ancient topography whose relief in places exceeded 3,000 feet. For the region to the southeast he has accepted the statements of Schrader and Spencer that the volcanics rest on an erosion surface of Tertiary age, and he concludes that the eruptive activity of the Wrangell Mountains has lasted from a time near the close of the Eocene up to the present.[b]

It is to be expected that in a series of lavas outpoured during so long an interval of time some differences between the earlier and the later volcanics might be manifest. The most obvious differences that have been detected appear to consist of the somewhat greater freshness of the later lavas and the greater prevalence in them of obsidians and glassy varieties, rather than of any changes affecting the chemical character of the material erupted.

Two typical specimens of the lavas collected by Schrader have been subjected to chemical analysis in the laboratory of the Survey.[c] One, from the Jacksina drainage, on the north slope of Mount Sanford, is an ash-gray hypersthene andesite with aphanitic groundmass.

[a] Mendenhall, W. C., Geology of the central Copper River region, Alaska: Prof. Paper U. S. Geol. Survey No. 41, 1905, p. 54.

[b] Op. cit., p. 57.

[c] These have already been tabulated by F. W. Clarke in Bull. U. S. Geol. Survey No. 228, 1904, p. 271.

Under the microscope it is seen to contain a large number of glassy plagioclase phenocrysts, which range in composition from Ab_1An_1 to Ab_2An_1. Many of them inclose numerous apatite needles. Hypersthene forms sporadic phenocrysts in the shape of small, stout prisms. The groundmass consists of a feebly polarizing cryptocrystalline aggregate, throughout which grains of magnetite are fairly abundant.

Analysis of hypersthene andesite.

[George Steiger, analyst.]

SiO_2	67.04	TiO_2	0.51
Al_2O_3	16.71	ZrO_2	.05
Fe_2O_3	1.46	CO_2	None.
FeO	2.08	P_2O_5	.27
MgO	1.09	SO_3, S, Cr_2O_3, NiO	None.
CaO	3.26	MnO	.16
Na_2O	5.07	BaO	.03
K_2O	1.84	SrO	Trace.
H_2O-	.08		
H_2O+	.51		100.16

The calculated norm is:

Quartz	21.96	Magnetite	2.09
Orthoclase	10.58	Ilmenite	.91
Albite	42.90	Apatite	.62
Anorthite	14.35		
Corundum	1.22		99.43
Hypersthene	4.80		

According to the quantitative classification this rock falls into the dosodic subrang lassenose of rang 2, order 4 of the persalanes, a large subrang including mainly quartz-bearing rocks—granites, rhyolites, and dacites.

The other specimen selected for analysis was taken from a point on Copper River about 7 miles below the foot of Copper Glacier. This is a light-gray aphanitic rock with scattered phenocrysts of glassy feldspar. When examined microscopically it is found that the large porphyritic feldspars are unstriated, and their small axial angle indicates that they are probably sanidine, which shows in places a submicroscopic lamellation, undoubtedly due to cryptoperthitic intergrowths. The smaller feldspar phenocrysts consist of narrowly striated oligoclase-albite (Ab_6An_1). Augite is rare as a porphyritic constituent, but is dusted all through the section in minute grains. The groundmass is cryptocrystalline and carries some accessory magnetite and apatite.

Analysis of lava from head of Copper River.

[George Steiger, analyst.]

SiO_2	70.94	TiO_2	.30
Al_2O_3	13.96	ZrO_2	.05
Fe_2O_3	1.74	CO_2	None.
FeO	1.69	P_2O_5	.10
MgO	.12	SO_3,S,Cr_2O_3,NiO	None.
CaO	1.13	MnO	.15
Na_2O	5.64	BaO	.06
K_2O	4.03	SrO	Trace.
H_2O-	.09		
H_2O+	.45		100.45

From this the following norm is derived:

Quartz	20.76	Wollastonite	.58
Orthoclase	23.91	Magnetite	2.25
Albite	47.16	Ilmenite	.61
Anorthite	1.11		
Diopside	3.13		99.51

According to this calculation the rock is a kallerudose, in dosodic subrang of the peralkalic rang, order 4, of the persalanes. That subrang includes rhyolites, grorudites, and soda granites of the prevailing classification.

The occurrence of such an alkalic rock among the large volume of normal lime-alkali lavas erupted from the Wrangell Mountains, which are part of the great petrographic province regarded by Spurr as encircling the Pacific Ocean,[a] is worthy of note and has bearing upon certain questions of considerable petrogenic importance.[b]

At the head of Chitistone River a great accumulation of horizontally bedded volcanics form the castellated summits of the mountains. Along the trail above Chitistone Canyon, at an altitude of about 6,000 feet, they rest upon a formation consisting of bluish-weathering shales and soft gray sandstones. Certain phases of the shales are highly carbonaceous and locally contain small amounts of lignite. Near the top of the sedimentary section there is a stratum of coarse volcanic breccia, 75 feet thick, composed of fragments of porphyry, amygdaloidal lava, and lignitiferous sandstone. This is overlain conformably by 8 feet of bluish shale, upon which rests a series of stratiform lavas piled up to a thickness considerably exceeding 1,000 feet. These observations prove that the beginning of volcanic activity put an end to sedimentation and that the lavas do not everywhere rest upon a surface of erosion, as assumed by Schrader and Spencer. The basal portion of the lowermost lava sheet is highly amygdaloidal, the amygdules being filled with chalcedony, and con-

[a] Spurr, J. E., Geology of the Tonopah mining district, Nevada: Prof. Paper U. S. Geol. Survey No. 42, 1905, p. 275.

[b] Cross, Whitman, Trachyte on the island of Hawaii: Jou. Geology, vol. 12, 1904, p. 520.

siderable local alteration has taken place, so that specimens from such localities closely resemble the Carboniferous amygdaloids of the White River country. Unaltered portions, however, consist of a fine-grained iron-gray basalt with large glassy porphyritic feldspars, which are notably tabular in habit. Many of the overlying lavas are similarly characterized by a conspicuous development of numerous large amber-colored labradorite feldspars.

In the open country immediately north of White River there are a number of prominent mesas, which are capped by nearly horizontal flows of lavas. In that one locally known as Pingpong Mountain a columar structure is finely displayed above the cut banks of White River. The rocks of the mesas prove to belong to a number of varieties and types, gray porphyritic andesite, dark glassy hypersthene-augite andesite, and basalt being among those noted.

Whether these lavas were erupted from the volcanic vents of the Wrangell Mountains is not known. It appears quite probable, from the fact that large andesitic dikes cut the underlying lignitiferous formation, that they may have been extruded from local conduits.

QUATERNARY DEPOSITS AND GLACIATION.

By STEPHEN R. CAPPS.

DISTRIBUTION AND CHARACTER.

The Quaternary deposits of this region are for the most part confined to the valleys of the larger streams. They consist of gravels and of bowlder clays, almost all of which are directly or indirectly due to glaciation. Glaciers have existed continuously from Pleistocene time to the present, and glaciofluvial deposition has been uninterrupted during this period. It is therefore evident that a discussion of Quaternary deposits involves also a description of the glacial conditions during Quaternary time, and the two are therefore treated under a single heading. Each of the more important valley glaciers heads in one of two great ice caps, one in the Wrangell and the other in the St. Elias Mountains. These centers of distribution are discussed in the following paragraphs.

CENTERS OF GLACIATION.

A very important feature of the Wrangell Mountains is the great ice cap that occupies the crest of the range and that has its greatest development in the region around Mount Wrangell. (See Pl. II.) From the periphery of this great feeding ground valley glaciers extend in all directions down the more important drainage lines. In the Wrangell Mountains beyond the edge of the great ice cap there are numerous localities where the elevation is sufficient to start small glaciers. Small ice tongues of this type occur between the

Copper and Nabesna glaciers and in the mountains east of the upper Nabesna River.

Second in importance to the Mount Wrangell distributing center is the ice cap which occupies the St. Elias Mountains south of White River. Little is known of this ice field except of the area along its northern border. As far as can be seen from the White River valley, all of the main range that lies west of the international boundary and south of White River is capped with ice above an elevation of about 7,500 feet. As in the Wrangell Mountains, all the important valleys that head back into the range are occupied by valley glaciers.

A few small glaciers have survived in the more favorably situated valleys of the Nutzotin Mountains between Chisana River and Suslota Pass. The largest of these is not more than 3 miles long.

INFLUENCE OF PRESENT GLACIERS ON THEIR VALLEYS.

The existing glaciers are now exerting a most important influence on the shapes of their valleys. By rasping, plucking, and undermining the rock the ice removes great quantities of material from the valleys in which it is confined. The result of this erosion is seen in the characteristic shapes of the gorges in which it has been effective. Instead of the usual V-shaped stream-cut valleys seen in rugged youthful mountains there are everywhere valleys with broad U-shaped cross sections. The ice tends also to steepen the valley gradient toward the glacier head and to reduce it toward the foot of the glacier. There is also a notable absence of sharp angular surfaces or protrusions of the bed rock, for all such projections are worn away by the ice.

Glaciers have also an important influence on the topography of the valleys below the ice edge. All the material that a glacier carries, either inclosed in the ice or on its surface, is ultimately borne toward the terminus and dropped there or at the sides of the glacier or beneath it as the ice melts away. This material accumulates in the valleys as moraine deposits consisting of a heterogeneous mixture of angular or partly rounded rock fragments with fine clays. The included bowlders may bear glacial scratches or striæ.

At times of rapid melting the glacial streams carry large volumes of water and are able to transport a great amount of the débris brought down by the ice. Much of the material may be carried for a long distance from the glacier, or it may be dropped within a short distance. The daily fluctuation in the volume of the streams is an important factor in the transportation and the deposition of the débris.

Both the moraines and the stream-laid gravels form important topographic features in the valleys below the glaciers. The moraines near edges of the ice are, as a rule, most prominent, for those at the terminus of the glacier are readily cut away and destroyed by the streams. The outwash gravels are in many places of great extent, and broad gravel bars, with anastomosing streams, cover the valley floors of nearly all the glacier-fed drainage ways.

FORMER GLACIATION.

There is abundant evidence that at no distant geologic period the glaciers in this region were much larger than they are now. The valleys have been broadened and deepened and show a marked U shape in cross section far below the limits of the present ice. Furthermore, the rock surfaces are striated and there are deposits of glacial till at many places. In the Nabesna Valley the ice at the time of its maximum extent probably reached a point 40 or 50 miles northeast of the edge of the present glacier. At that time the glacier was about 100 miles long from its terminus to the top of Mount Wrangell, where it headed. Other glaciers of this region were also larger and longer than they are now.

In the Chisana Valley, at Euchre Mountain, moraines and erratic bowlders occur up to the 6,600-foot level, or 2,500 feet above the terminus of the present glacier, and in the low col west of this mountain there must have been at least 1,200 feet of ice that moved northward. Euchre Mountain at that time was an island standing about 1,000 feet above the surface of the surrounding glacier.

From the Wrangell Mountains the earlier glacier spread northwestward to the south base of the Nutzotin Mountains, and two tongues, in the valleys of Nabesna and Chisana rivers, pushed directly across these mountains to their north base and there spread out in broad, spatulate lobes. Tributary valleys from both ranges supplied ice to these two tongues. From the St. Elias Mountains the main outlet for the glacial ice was the valley of White River.

An attempt has been made in figure 2, which is based on somewhat incomplete data, to show the extent of the glaciers in this region at the time of their maximum extension. The glaciated area includes all of the Wrangell, Nutzotin, and Skolai mountains. The Nutzotin Mountains were probably at no time entirely covered with ice, but only the highest peaks and ridges projected above the glacier, and the total area of these projecting points was very small.

GLACIATION OF THE WRANGELL MOUNTAINS.

The present distribution of glacial ice in this region is shown on Plate II. The great ice field along the crest of the range supplies many small valley glaciers and two large ones in the Nabesna and Chisana valleys. The Nabesna Glacier is fed by about 40 cirques between Mount Wrangell and Regal Mountain, a distance of 43 miles.

Its total length from Mount Wrangell to its terminus is about 55 miles, and its area is approximately 400 square miles.

The Chisana Glacier, locally called the Shushana, receives the ice from that part of the range which lies east of the Nabesna drainage system, and in many of the cirques the ice is continuous across the divide with the glaciers of the Nabesna, while to the south it is continuous over the divide with the Rohn and Nizina glaciers. The Chisana ice field is 30 miles long and has an area of 135 square miles.

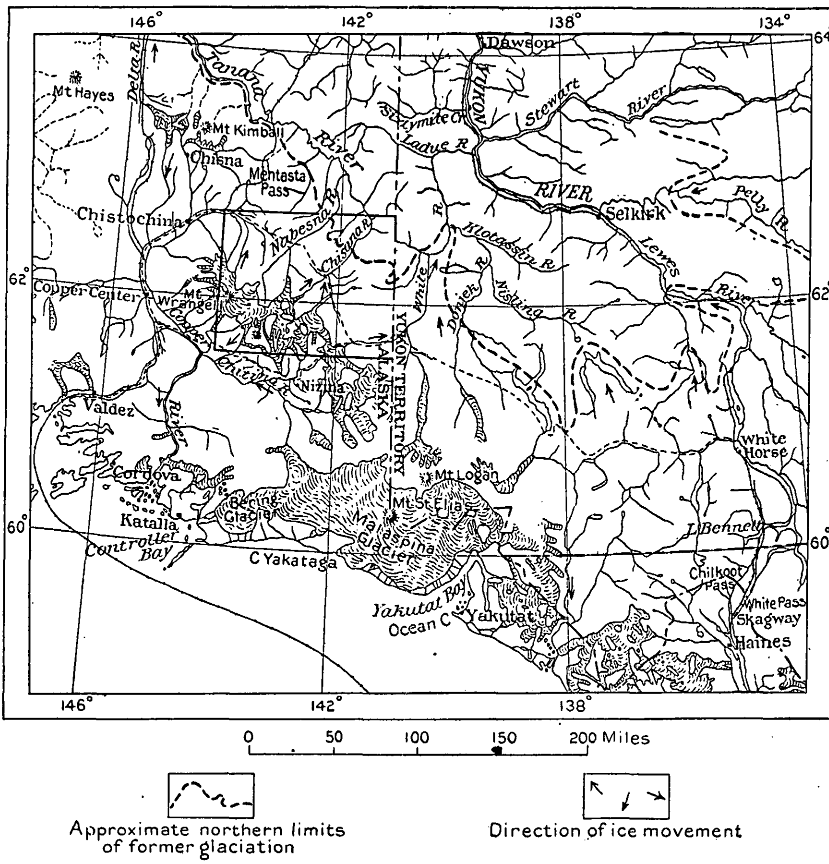


FIGURE 2.—Sketch map showing northern limit of glaciation in the Nabesna-White region.

At the lower ends of most of the valley glaciers there are rough-surfaced terminal moraines composed of fragmental material left by the ice. The most conspicuous of these is the moraine in the Nabesna Valley, which covers the valley floor for 2 miles below the ice edge, except the narrow valleys on the east and west, through which the waters of the melting glacier escape to the north. The surface of the moraine consists of a series of hummocks and kettles, many of which contain lakelets. No well-established drainage lines were observed.

The Chisana Valley is peculiar in that it contains few or no distinct terminal moraine deposits.

All the valleys that head in glaciers are floored with gravel beds. The glaciers constantly supply detritus to the streams and many valleys have been filled to a considerable depth by the glacial outwash. In the Nabesna Valley the bars are from 1 to 3 miles wide and the river anastomoses over much of this flat at periods of high water. The gravels are also conspicuous in the Chisana Valley. As far north as the mouths of Cross (Copper) and Chavolda creeks the bars are composed largely of fine gravels and sands. Below the mouth of Cross Creek the gravels become much coarser, as this creek discharges coarse gravels. The valley through the Nutzotin Mountains is a narrow U-shaped gorge, and the waters flow in a few large channels. Within the gorge there is the usual succession of gravels, coarse above but becoming progressively finer downstream.

Terraces of stream-laid gravels are seen at various places along the larger valleys and are particularly prominent in the Nabesna Valley between Bond and California creeks, where at their upstream end they reach an elevation of 200 feet above the river and slope gradually downward to the north to merge at Bond Creek with the gravel bars which the river is now building. Conspicuous terrace deposits also occur at several points along the valleys of the Chisana and its tributaries. In the region east of Euchre Mountain, including the lower portions of Bow, Gehoenda, and Chathenda creek valleys, there is a broad area of gravel deposits in which these streams have entrenched themselves. The area now covered by these gravels was formerly occupied by the Chisana Glacier. As the glacier decreased in size the ice edge gradually shrank back toward the west and exposed this region while it was still of sufficient thickness in the main Chisana Valley to form an obstruction to the streams from the east. Under these conditions the creeks rapidly built up their valleys with alluvial material. It is even possible that temporary lakes were formed behind the ice dam. An exposure along Gehoenda Creek for several miles above its mouth shows fine stratified gravels and silts, interbedded with coarser materials. The rather perfect stratification of the finer materials suggests that these beds are of lacustrine origin.

GLACIATION OF THE ST. ELIAS MOUNTAINS.

The St. Elias Mountains south of White River are snow capped in much the same way as the Wrangell Mountains. Most of the mountain range is unexplored, however, and the extent and area of the ice field is unknown. All the more important tributary valleys to the north are occupied by valley glaciers, the largest and best known of which is Russell Glacier (see Pl. III, *B*), at the head of White River. The main lobe of ice in the head of the White Valley is between 6 and 7 miles long and about 2½ miles wide, and most of the ice moves in a northeast direction. A small crescentic lobe, however, moves westward into the head of Skolai Creek. Important ice tongues also occupy the heads of Holmes and Traver creeks.

The terminal moraine of Russell Glacier forms a great lobe at the head of White River. It was impossible to determine the line where the glacier ice ends and the terminal moraine begins, as the two blend imperceptibly. A considerable area of the ice is moraine covered, and there is doubtless much ice inclosed in the moraine deposits. The moraine is a confused jumble of fine material and rock fragments of all sizes and shapes. Drainage lines have been developed only along its edges.

The gravel deposits now being laid down in that part of the White River valley that lies west of the international boundary are very extensive. The area of deposition varies in width from about 2 miles, just below the glacier, to about 9 miles, south of Mount Natazhat. For the first 10 miles below the glacier the valley is flat from side to side and is for the most part bare of vegetation. East of Pingpong Mountain White River itself occupies only a narrow

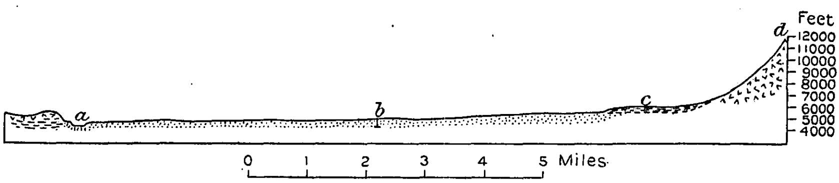


FIGURE 3.—North-south section across White River valley about 5½ miles west of the international boundary. *a*, White River; *b*, alluvial fan; *c*, small glacier; *d*, peak 2 miles west of Mount Natazhat.

valley close to the base of a rock ridge. The remainder of the broad valley to the south slopes upward toward the mountains, and consists of a compound alluvial fan built up by the tributaries from the south. The present course of the White River has been determined by this alluvial fan, which has crowded the river northward against the base of Pingpong Mountain.

Figure 3 is a diagrammatic cross section of the White Valley 5 miles west of the boundary. If we can assume that the wide valley north of Mount Natazhat was eroded by the great glacier to an average depth equal to the present level of White River (*a*), then the valley filling of alluvial gravel must be more than 400 feet thick in the center of the old valley (*b*). Since White River was nowhere observed to have cut its valley down to bed rock, and since the bed-rock level at *b* is probably lower than at *a*, the thickness of the gravels in the deepest portions of the old valley may greatly exceed 400 feet.

In the White River valley remnants of high terraces were noted only on the north side of the river. For about 2 miles below the mouth of Lime Creek canyon there is a bench of coarse gravels from 30 to 50 feet high. Farther east, along the south base of the Pingpong Mountain ridge, the river bluff shows a 50-foot cut. Of this section the lower 35 feet are composed of coarse, rudely stratified gravels. Above this are 15 feet of blue glacial till. Locally the gravel beds immediately below the till are much distorted and crumpled, showing that after the gravels were deposited the glacier advanced over them, disturbing their bedding and depositing a sheet of till. There may be gravels of the same age south of White River, but the present tributaries from the mountains to the south are so actively engaged in building alluvial fans that any remnants of higher terrace gravels that might have existed on that side of the river have been cut away or covered up by more recent deposits.

North and west of Solo Creek there is a broad, flat area covered with outwash gravels, which were laid down under much the same conditions as were those east of the Chisana Glacier. Here the receding ice in the White River valley left bare a broad area which normally drained into White River. The drainage here was impeded by the valley glacier, which must have occupied the valley long after the higher area to the north was deglaciated. During this period of obstructed drainage extensive gravel beds were laid down, which abutted against the ice to the south and spread northward and filled the old drainage channels. The filling went on to such an extent that some of the streams found a lower outlet to the northeast and still flow in that direction. Solo Creek has now cut a considerable gorge through the gravels and into the underlying rock, and is gradually recapturing for the head of White River the drainage lost during early glacial times.

Between North Fork and Pingpong Mountain a broad flat has a gravel covering due to the same causes as those which brought about the deposition of the gravels of Solo Creek. Ptarmigan Lake would normally drain into White River to the south, but its waters found an outlet by way of Beaver Creek at the time the glacial ice in the White River valley formed a barrier to drainage in that direction.

VOLCANIC ASH.

Since the trip of Schwatka [a] down the Yukon in 1883 it has been known that an area in northern British Columbia is covered with a deposit of white volcanic ash. Later observations have shown this area to be of great extent and to extend westward into Alaska. Brooks found the ash on the Yukon at a point about halfway between Circle and Fortymile; Hayes [b] reported it near the head of White

[a] Schwatka, Frederick, Along Alaska's great river, 1885, p. 196.
[b] Hayes, C. W., Nat. Geog. Mag., vol. 4, 1892, p. 146.

River; and J. Keele found it to continue eastward to a point 50 miles beyond the Yukon-Mackenzie divide, in the valley of Gravel River. In the area covered by this report the ash occurs as far west as the headwaters of Chisana River, where it forms a layer, from 4 to 10 inches thick, beneath a few inches of soil. Farther east the thickness of the ash bed increases. In the north bank of White River near the mouth of North Fork there is a layer of ash, 2 to 2½ feet thick, overlain by 6 to 8 feet and underlain by at least 20 feet of peat. (See Pl. V, *A*.) In the peat are many spruce stumps, standing upright, which show conclusively that the peat was formed from vegetable matter that grew at the place where it now occurs. The ash here is much coarser than that in the Chisana Valley and contains more hornblende. The bottom portion is also coarser than the top. On the mountains near the international boundary, on the south side of White River, the lower slopes are covered with great drifts of this white pumice which, from a short distance, are scarcely distinguishable from snowdrifts. (See Pl. V, *B*.) Hayes and Brooks report that these beds attain, in some places, a thickness of 75 to 100 feet. Many of the individual fragments in this neighborhood are large, pieces 5 inches in diameter being occasionally seen, and it is evident that the crater from which the ash was ejected can be at no great distance, probably in the St. Elias Range to the south. At one locality on Holmes Creek two separate beds of ash were observed. The lower bed, of fine ash, 2 to 3 inches thick, was overlain by 2 inches of peat. Over this was 2 to 3 inches of coarse pumice, with fragments up to 1½ inches in diameter. This in turn was overlain by a few feet of peat. It is not clear whether these beds represent two distinct eruptions of ash or whether the upper layer was washed to its present position a considerable time after the ash was ejected.

The "ash" is a white frothy glass, light enough to float on water. The larger fragments of the pumice inclose numerous small hexagonal plates of biotite, short prisms of hornblende a millimeter in length, and less conspicuous crystals of glassy feldspar. In thin section the hornblendes, which are deeply pleochroic in tones of brown, show ideally perfect cross sections and terminated prisms; the biotites also are finely developed and hold some inclusions of apatite. The feldspars are less perfectly crystallized. Both unstriated and lamellated varieties are present, but all possess indices notably higher than balsam. Zonal banding is not uncommon. Optical tests on striated Carlsbad twins prove that the feldspars belong to a species somewhat more calcic than Ab_1An_1. They inclose some minute foils of biotite. Grains of magnetite occur sporadically. The matrix holding these phenocrysts is a pumiceous glass, clear and colorless, with a marked drawn-out, twisted, and fluidal appearance. Some of the phenocrysts show that they were broken by movements of the surrounding glass. According to the microscopical determination the ash is an andesitic pumice.[a]

GRANULAR INTRUSIVE ROCKS.

OCCURRENCE AND CHARACTER.

At numerous localities throughout the region granitic rocks appear, forming isolated masses of no very great size. The most extensive exposures are at the head of Fourmile Creek, north of White River, and at the head of Cooper Creek. Many small masses occur along the front of the St. Elias Mountains, on the south side of White River. This rock is also well displayed along the canyon walls of Monte Cristo Creek in its lower course, and was therefore called by Schrader[b] the Monte Cristo diorite.

The typical rock, which is commonly of a gray color, consists of a medium-grained granular aggregate of hornblende, biotite, and feldspar. Inasmuch as under the microscope the feldspar is found to be mainly andesine, and quartz is discovered to be present as an interstitial filling between the other minerals, the rock may be accurately designated a quartz diorite.

AGE.

At most places manifold evidence can be obtained that the quartz diorite intrudes the older rocks. The massive limestone cliffs between Jack and Jacksina creeks are pierced by a large number of offshoots from the main quartz diorite mass, and an energetic contact metamorphism has been produced, causing the development of garnet rocks and chalcopyrite lenses. Much the same conditions prevail at Cooper Pass, a locality at which Carboniferous fossils were collected from the limestone. It is possible that the diorite also intrudes the Triassic rocks at that place. A similar belt of diorite intrudes the Carboniferous rocks in the ridge overlooking the Generk, on the south side of White River, a few miles below the international boundary.

The upper limit of the quartz diorite has not been determined thus definitely. It is known, however, that Upper Jurassic conglomerates on Chisana River inclose cobbles of diorite, and as the associated grit beds contain much detrital volcanic material, evidently derived from the near-by Carboniferous formation, it is reasonable to believe that the diorites were intruded prior to Upper Jurassic time. They are therefore contemporaneous in a broad way with the batholithic intrusions common in the Talkeetna Mountains and the Alaska Range. This contemporaneity is becoming increasingly apparent with the

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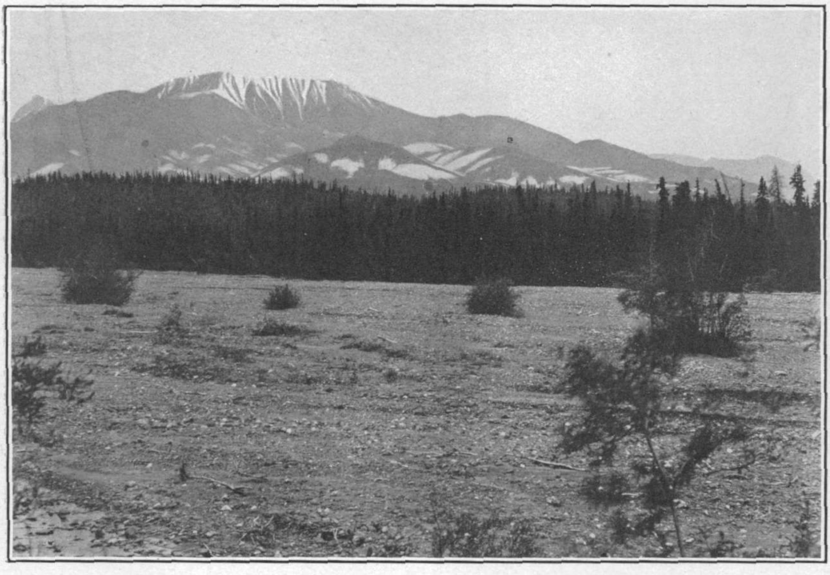
[a] Petrographic description by Adolph Knopf.

[b] Mendenhall, W. C., and Schrader, F. C., Mineral resources of the Mount Wrangell district, Alaska: Prof. Paper U. S. Geol. Survey No. 15, 1903, p. 34.

A. VOLCANIC ASH INTERBEDDED WITH PEAT.

North side of White River near North Fork.



B. VOLCANIC ASH.

Lower slopes of mountains near Mount Natazhat.

progress of geologic investigations in Alaska. The correlation of such batholithic masses with those of British Columbia was first extended northward by Dawson[a] to those of Stikine River and Chilkoot Pass, and later by Brooks[b] to those occurring along an axis of intrusion from Chilkoot Pass to Nabesna River.

ASSOCIATED INTRUSIVE ROCKS.

Various rocks of porphyritic character occur as intrusive masses throughout the region; but as they are hardly of more than local interest they will not be described in detail.

On Monte Cristo Creek there are large exposures of andesite porphyry intruded into the quartz diorite. The rock shows numerous feldspars (andesine-labradorite), which form perhaps 50 per cent of its bulk, and some hornblende phenocrysts embedded in a gray-greenish matrix that is irresolvable by the eye. Other places at which this rock was noted are in the hills near the mouth of Bond Creek, on Nabesna River, and at the head of Cross Creek, where it invades the Carboniferous formation.

In the vicinity of Orange Hill in the upper part of Nabesna Valley, some intrusions of quartz diorite porphyry of highly siliceous appearance cut both the quartz diorite and the stratified rocks. It is a light-colored rock whose most characteristic feature is the presence of numerous large phenocrysts of quartz, many of which exceed half an inch in size. Dark minerals are practically absent, only small sporadic flakes of biotite being detectable. The microscope shows that the feldspars belong to the species andesine and that the groundmass, which is not readily perceptible to the unaided eye, is a microgranular assemblage of quartz and feldspar.

In addition to the siliceous intrusives, dikes and sills of diabase are common, but appear to be limited mainly to the areas of sedimentary rocks, especially to those of Carboniferous age. They are dark, heavy rocks, coarsely crystalline, nearly granular in texture, and are for the most part of fresh, unaltered appearance. Microscopically they are found to consist essentially of augite and plagioclase in typical ophitic arrangement, with a tendency toward a gabbroic texture in the coarser-grained varieties.

STRUCTURE.

Most of the structural relations of the various formations have been presented in the descriptions already given, but for the sake of clearness the important facts are here repeated.

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[a] Dawson, G. M., Yukon district and British Columbia: Geol. Survey Canada, vol. 13, 1887-88, pt. 1, p. 31 B.

[b] Brooks, A. H., Reconnaissance from Pyramid Harbor to Eagle City, Alaska: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 7, 1901, p. 361.

All the rock formations, with the possible exception of some of the younger volcanic lavas, have been either folded or tilted, so that they no longer retain their original position as laid down. This folding is greatest in the Paleozoic and Mesozoic beds, but it does not appear that the Carboniferous sediments and lavas have undergone greater deformation than those of the Triassic and Jurassic. On the contrary, the interbedded slates and graywackes composing the Nutzotin Mountains appear to have suffered greater deformation than the older rocks adjacent on the west and south.

The prevailing trend of the folds is northwest-southeast, as is also that of the major faults that accompanied folding. Local deviations from this prevailing strike are numerous, however. The massive Carboniferous limestone withstood deformation more successfully than the associated slates and pyroclastics; in its best exposures, both in the mountains south of White River and on Nabesna River, it lies nearly horizontal or dips into the mountains at comparatively low angles. It has yielded by faulting rather than by folding, yet minor flexures may be seen in many places. On the other hand, the slates and associated volcanics, particularly the slates, both Paleozoic and Mesozoic, have been closely folded, as is well seen in the region of Skolai Pass and in the canyons of Nabesna and Chisana rivers. Locally the shales or slates have taken on an imperfect cleavage and in some places are slightly schistose.

Faults are numerous in the district, and the displacements on some of them are probably to be measured in thousands rather than hundreds of feet. The abrupt change from rugged mountains to rolling plateau on the northeast side of the Nutzotin Range is probably the result of faulting, which has been suggested also to explain the attitude of the coast range to the interior plateau in other places.[a] The steep northeast face of the mountains seems best explained as a fault scarp resulting from uplift of the mountain area above the lowland. This feature, however, may have been brought about by a sharp flexure along the front of the range without rupture and displacement.

Another large fault probably occurs between the Paleozoic and Mesozoic rocks in the depression between the Wrangell and Nutzotin mountains and may in part account for that depression. Indications of this fault were seen in the vicinity of Cooper and Notch creeks. No fault contact was observed there, but the fact that the Triassic limestone is found only locally between the Carboniferous and Jurassic beds suggests the presence of a fault, although an unconformable relation of Jurassic to underlying sediments would also account for the absence of the limestone. Minor faults are numerous, as is shown

[a] Brooks, Alfred H., Geography and geology of Alaska: Prof. Paper U. S. Geol. Survey, No. 45, p. 294.

by many displacements of the massive Carboniferous limestone, and doubtless faults occur in many places where their presence was not detected.

Intrusions of igneous rocks, such as the diorite, diorite porphyries, and basalts, have further complicated the structural relations of the formations invaded. They do not occur abundantly in the Mesozoic sediments, but the Carboniferous limestone, shales, and volcanics are in many places cut by them, and their field relations can be determined only by detailed study.

In section A–B of Plate II the meager data at hand have been used to interpret the structure of the portion of the Wrangell and Nutzotin mountains included on the geologic map. The section, which is perpendicular to the general strike of the formations, extends from the crest of the Wrangell group northeastward to the Tanana lowlands. Carboniferous rocks and the diorite intrusions in them probably occupy nearly a third of the central part of the section. They are folded and faulted and dip below the later lava flows of the Wrangell Mountains. The Nutzotin Mountains, to the northeast, are believed to present a complicated synclinal structure that is included on the southwest and northeast by fault planes. The Mesozoic rocks show more intense folding but less faulting than the Carboniferous formations. The slate and graywacke strata of the Nutzotin Mountains are vertical in many places, and in the vicinity of the fault that separates them from the Carboniferous rocks this position is especially noticeable.

Lava flows of Tertiary and later age lie almost horizontally on the older Carboniferous formations in the southwest part of the section. They have been but slightly tilted to the south. On the south side of the Wrangell Mountains they rest on Mesozoic rocks, which dip beneath them at low angles. This fact, considered in connection with the attitude of the Carboniferous beds, suggests that the Wrangell Mountains may be of synclinal structure, but the evidence is not conclusive. This suggestion would indicate that the Wrangell and Nutzotin mountains are two synclinal structures separated from each other by a fault that brings the Carboniferous up against the Mesozoic formations.

GEOLOGIC HISTORY.

The earliest records of the geologic history of the province are found in the Carboniferous rocks, which show that marine conditions prevailed throughout the region but that the normal course of sedimentation was repeatedly interrupted by the extrusion of andesitic and basaltic lavas and the ejection of tuffs and breccias. Where the accumulation of ordinary clastic sediments went on undisturbedly, sandstones, shales, and limestones were laid down, and now bear evidence, in their wealth of fossil remains, that the seas teemed with life, among which huge zaphrentoid corals flourished in great abundance.

The marine occupation appears to have persisted until early Mesozoic time, for a series of thin-bedded limestones were deposited during the Triassic period.

Presumably the close of the Triassic was marked by the intrusions of quartz diorites and the various porphyries associated with them. By later Jurassic time the region had been sufficiently eroded to uncover the granitic rocks, which contributed material to the feldspathic sandstones, shales, and grits then accumulating. These sediments, which are *Aucella* bearing, have been subsequently metamorphosed to graywackes and slates and closely folded. In this condition they resemble the rocks of the Valdez "series," a resemblance already noted by Schrader and by Brooks.[a]

The Tertiary period was one of long-continued subaerial volcanic activity. During its early part, however, some lignitic sandstones, shales, and conglomerates were laid down in scattered basins, but these were subsequently flooded over by lavas. The flows attain their maximum thickness in the Wrangell Mountains, where they were poured out from definite volcanic centers. Eruptive activity has continued at many of these vents up to recent time, and is still in progress at Mount Wrangell.

The more recent events in the geologic history of the district are chiefly those that have to do with the production of present land forms.

The commonly accepted views of the physiography of Alaska as a whole are those of Spencer[b] and Brooks[c] who have indicated the broader topographic features and discussed their relations to those of the adjacent Yukon Territory and British Columbia, but have left to future study the filling in of details and the solution of many problems. These views are in part an expansion and a modification of those presented by earlier workers, especially Hayes and Dawson.

The four great geographic provinces of Alaska are the Pacific Mountain system, the Central Plateau region, the Rocky Mountain system, and the Arctic coast region. It was stated in the section on geography that, for purposes of description, that part of the Nabesna-White region under consideration may be regarded as consisting of two topographic units, the Wrangell Mountains on the southwest and the Nutzotin Mountains on the northeast. This distinction finds expression in the manner of origin of the two mountain groups

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[a] Prof. Paper U. S. Geol. Survey No. 45, 1906, p. 230.

[b] Spencer, Arthur C., Pacific mountain systems in British Columbia and Alaska: Bull. Geol. Soc. America, vol. 14, 1903, pp. 117-132.

[c] Brooks, Alfred H., The geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, pp. 267 et seq., more particularly pp. 292-296.

as well as in their form and in the fact of their separation by a more or less well-defined depression, since the Wrangell Mountains owe their existence in large part to the outpouring of lavas which accumulated faster than the process of degradation was able to remove them, while the Nutzotin Mountains are the product of uplift and erosion.

The Wrangell and Nutzotin mountains are parts of the Pacific Mountain system. West of Mount St. Elias the St. Elias Range is divided into two branches, one of which, the Chugach Mountains, extends westward and merges into the Kenai Mountains, while the other, the Nutzotin Mountains, extends northwestward and forms a connecting link with the Alaska Range. The Wrangell Mountains occupy an intermediate position between these two forks of the St. Elias Range. Geologically these mountain groups are young, yet the erosion that has taken place within their area is proof of vast age if that age is measured in periods of years rather than by comparison with the geologic time scale.

In the more generally accepted explanation that has been advanced to account for the present topography of Alaska the Pacific Mountain system and the Central Plateau region are considered to have been developed from an old peneplanated land surface that has been elevated and warped—perhaps faulted—in such a way as to allow the rejuvenated streams to produce the present land forms.

The evidence advanced to show that the Pacific Mountain system has been carved in whole or in part from an old planated land surface in the manner indicated is found chiefly in the presence of antecedent rivers flowing in narrow canyons through the ranges, and in the general accordance in elevation of the mountain summits and their mergence in some regions with the Yukon Plateau, for nowhere within the mountains themselves have remnants of the old plateau been found. This last statement is not true of the Yukon Plateau region, however, for although the streams have incised their valleys deeply below the old land surface the broad, flat, interstream areas clearly show that surface to have been a plain, or rather a peneplain, whose plainlike character has been altered but not destroyed.

When one examines the Nutzotin Mountains and that part of the St. Elias Range immediately southeast of them for confirmation of the outline of topographic development just given he is immediately impressed with the abrupt change from rugged mountain to rolling lowland as it is seen along the northeastern side of these ranges. Not only do the mountains rise steeply like a wall from the plain, but the change from one kind of topography to the other takes place without intermediate gradations. There is nothing in the present topography to suggest that these two land forms have originated from one plain and therefore it seems almost necessary to suppose that the northeast face of the mountains is a fault scarp and that the mountains themselves have been raised relatively a distance of several thousand feet above the lowland, for it is hardly conceivable that tilting and erosion of a land surface could alone have produced the relation of lowland to mountain that has been described.

The Nutzotin Mountains are a young group which has risen across an antecedent drainage system. Nabesna, Chisana, and probably White rivers cut entirely through them in constricted valleys, and a number of the headwater tributaries of the Nabesna even reach back into the Copper River plateau. In the region north of White River, near the international boundary, certain streams, which, like Rabbit Creek, debouch upon alluvial flats, flow in narrow canyons in their lower courses and are interrupted by falls in their upper courses. The canyons open out into relatively broad valleys. Such physiographic features indicate that the range is still in progress of uplift along its northeastern flank.

Sometime after the planation of the land mass or during its later stages the outpouring of the Wrangell lava began and its extrusion was continued a long time, for in places the younger flows overlie recent unconsolidated gravel deposits. Thus the great mass of extrusive rocks overlying the sedimentary and older volcanic beds of the Wrangell Mountains was gradually piled up despite the fact that water and frost must have been actively engaged in tearing them down.

The results of normal stream erosion were augmented by the subarctic conditions, such as frequent and rapid changes of temperature, and particularly by severe glaciation. The mountain valleys were deepened and broadened by the ice streams and the Wrangell lava as well as the sediments of the Nutzotin Mountains took on the rugged character of to-day.

Important changes in drainage were brought about also, but they will only be referred to, since data for their complete discussion is not at hand. Most important of these was the diversion of a part of the upper Alsek drainage, including the upper White and Tanana rivers, to the Yukon.[a] The reason for this change has not been established, but Brooks suggests that it may be due to the northwestward tilting of the old Yukon Plateau, or possibly to the damming of the southeastward-flowing streams during the greatest northerly advance of the ice sheets from the coast ranges which cut off their outlet to the Pacific and forced them to seek a new one into Bering Sea.

Many minor drainage changes also occurred, particularly in the region just north of White River, where a number of old, broad valleys,

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[a] Brooks, Alfred H., Geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. 45, 1906, p. 294.

whose former relations are not understood, were produced. These valleys are seen in the vicinity of Solo Creek, of Pingpong Mountain, and in the area adjacent to the international boundary. Their waters have been diverted, and valleys that must have been produced by streams of considerable size are now occupied by lakes or small creeks. Some of these changes were doubtless the work of glaciers, but it is reasonable to suppose that others were dependent on the greater stream diversions referred to previously.

The most conspicuous of recent changes in the topography of the Nabesna-White district were produced by glacial ice, as already described in connection with the account of the recent unconsolidated deposits. These changes for the most part consisted in a modification of preexisting topographic features, such as the broadening of valleys or the building of terraces, but the modification has been so great in many places as to obscure the earlier forms, so that now the evidences of glacial erosion predominate.

MINERAL RESOURCES.

INTRODUCTION.

The mineral resources that have attracted the attention of the prospector in the upper White-Nabesna region are copper and gold, and, in an incidental way, zinc, lead, and lignite. The probable occurrence of native copper has long been surmised from the reports of the Indians. As early as 1891, the year in which the upper White River country was first penetrated by an exploring party of three men, one of whom was C. W. Hayes of the United States Geological Survey, astonishing accounts of the enormous quantities of native copper found in that region were told to the members of the expedition while at Fort Selkirk, on the head of the Yukon.[a] It was reported that copper nuggets up to the size of a log cabin might be found. During the trip up White River and over Skolai Pass, which was made by back-packing, and which consequently allowed but a casual examination of the line of travel, little was seen that lent support to the exaggerated statements of the Indians. It was definitely ascertained, however, that some placer copper was present in the stream gravels of Kletsan Creek near the international boundary.

From 1898 onward, in response to Indian reports which in popular esteem had invested the upper White River country with mineral wealth proportionate to its remoteness and inaccessibility, prospectors kept coming into the region in search of native copper and gold.

The first published description of copper as a prospective resource was given by Brooks,[b] who hastily traversed this belt in 1899 as

[a] Hayes, C. W., An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, 1892, pp. 117-162.

[b] Brooks, A. H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the upper White and Tanana rivers: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, p. 382.

geologist accompanying the Peters exploring expedition and who came to the conclusion from the abundance of copper indications "that this upper region is one that is worthy of careful investigation by the prospector and the capitalist."

In 1902 a placer-gold stampede brought an influx of prospectors into the upper White River country, but as no paying quantity of precious metal was discovered the majority soon left for more promising fields. The few that stayed turned their attention to the copper resources of the region, being incited to this search by the current Indian reports of large deposits of native metal.

In 1905 reports of rich deposits of metallic copper in the headwater region of Nabesna River were widely circulated in the public press, but examination in the field shows that those statements were not warranted by the discoveries that had been made. Such exaggerated accounts are almost always an injury rather than a benefit to a mining region, yet at times they hold out the hope that finally leads to success. The search for copper and gold has been continued to the present time by a small group of prospectors, who have sought by legitimate means to develop a mining district rather than to promote mining companies, and most of the discovered prospects have been found as a result of their efforts. A good deal of money has been spent and a few prospects that merit further expenditure are known. It is believed that the search for other deposits besides these is warranted by the results so far achieved.

COPPER.

GENERAL CONDITIONS OF OCCURRENCE.

The reported presence of native copper in vast quantities was, as already pointed out, the original incentive that drew the pioneer to the White-Nabesna region. Prospecting in search of these deposits has shown that copper in its bed-rock sources is widely distributed in the form of sulphides (chalcocite, bornite, and chalcopyrite), and on the basis of the facts revealed by the little development work that has been done it may be stated that most of the native copper found in the region is an oxidation product of those sulphides. Some primary native copper, however, has undoubtedly been discovered. In mode of occurrence the copper ore shows two different habits, geologically distinct. In one, so far the better known, it occurs associated with the Carboniferous basaltic amygdaloids; in the other it is found in limestone at or near the contact with the dioritic intrusives.

Native copper occurs as nuggets in the gravels of many of the streams, and green-coated lumps of metal up to 5 pounds or more in weight are occasionally found in the wash of creeks draining areas of amygdaloid bed rock. This stream copper was the source from which the Indians obtained their supply when it was an object of barter among them. From the accounts of Hayes and Brooks, Kletsan Creek appears to have been the placer locality best known to the natives.

Metallic copper occurs also in the surface croppings of sulphide deposits in the amygdaloids, where it is undoubtedly an oxidation product of the sulphides that appear in depth. In such places it is directly associated with the dark-red oxide (cuprite) and more or less green carbonate. At the prospect known as "Discovery," on White River in Canadian territory a few miles below the international boundary, a slab of native copper averaging 8 by 4 feet by 4 inches thick and weighing nearly 6,000 pounds has been uncovered in the slide rock. A number of other sheets of copper, some of them weighing several hundred pounds, have been found in the near vicinity. On account of the stimulus that this find has exerted on the prospecting of the adjacent American territory the occurrence merits some description in this report. Stripping of the bed rock near the great nugget has exposed a face of green basaltic amygdaloid 20 feet high and 15 feet wide and shows that the rock is traversed by numerous seams of native copper along fractures and slickensides. Toward the bottom of the open cut stringers of chalcocite begin to appear. About 150 feet from this prospect an opening on another but independent occurrence shows stringers of cuprite with admixed copper, stringers of glance and calcite, and chalcopyrite disseminated through the amygdaloid country rock. From these features it is clear that the metallic copper of this deposit is a superficial oxidation product of sulphides, that its downward extension is small, and that the prevailing sulphide at greater depth will probably turn out to be chalcopyrite.

At a few localities native copper is associated with certain highly amygdaloidal portions of the Carboniferous basalts and intergrown with the white minerals that fill the former steam cavities in the ancient lava flows. Slaggy-looking portions produced by the weathering and removal of the amygdules from the lava, and amygdaloid that is cut by small irregular veinlets filled with the same minerals as those forming the amygdules appear to be the most favorable places for metallic copper. The copper in the vesicles and stringers is associated with calcite and delicately spherulitic prehnite, but in some of the veinlets calcite, prehnite, quartz, a black lacquer-like mineral, partly combustible, and chalcocite, instead of metallic copper, are associated together.

At a number of places throughout the region narrow stringers of chalcocite cutting the ancient basalts are encountered, but so far as known they have no great persistence. Near the head of Cross Creek, locally known as Copper Creek, a thin quartz-chalcopyrite vein cutting the bedded volcanics has been discovered. At other localities some irregularly disseminated sulphides, in some places chalcocite, in others bornite, occur in the basalts, but these do not appear to be connected with definite vein or lode systems and are consequently of an unencouraging character. Oxidation of these sulphides and disintegration of the containing rock give rise to the nuggets of cuprite and native copper that are found in the talus slopes at several localities in the region.

In contrast to these occurrences, which, as shown by the foregoing discussion, are limited to the ancient basalt flows, copper is found as bornite and as chalcopyrite intergrown with contact-metamorphic rock in limestone adjoining diorite intrusives. In deposits of this type the ore mineral is associated with garnet, coarsely crystalline calcite, epidote, specular hematite, and scattered flakes of molybdenite. The garnet is commonly crystallized in dodecahedrons and is intimately intergrown with the bornite and chalcopyrite. On account of its weight, and especially its appearance, which is not unlike that of cassiterite, it was mistaken for tin ore by some of the early prospectors. Only two deposits of this character were seen in place, but evidences of energetic contact metamorphism were detected at a number of other localities. An extensive contact zone has been produced along the junction of the diorite and the massive limestone exposed on the ridge west of Copper Pass. Various contact metamorphic rocks, pyritiferous as a rule, are present in this zone, and these rocks on oxidizing give rise to large iron-stained outcrops that contrast strongly with the surrounding white limestone. In connection with the discussion of the contact-metamorphic deposits it may be stated that the writers were shown some specimens of copper ore containing abundant large octahedrons of magnetite and blebs of chalcopyrite in a gangue of coarse calc spar. This ore was undoubtedly obtained near the contact of an intrusive diorite with limestone, but whether commercially valuable ore bodies of similar character exist in this region, which is so remote from transportation facilities, is yet to be demonstrated, in view of the fact that copper deposits of contact-metamorphic origin are characteristically bunchy and of low grade.

NABESNA RIVER.

Near the head of Nabesna River and below Nikonda Creek some work has been done on a prospect (the Shamrock claim) which is situated 2,000 feet above the floor of the valley. The stripping of the talus from the base of the massive Carboniferous limestone has disclosed a large, irregular body of massive garnet rock containing some disseminated bornite and chalcopyrite. As a rarity a little molybdenite can be detected. Veinlets of garnet traverse the surrounding coarsely crystalline white limestone. At the time of examination the best exposure of visible ore was a body of solid bornite 4 or 5 inches thick and perhaps a foot long.

On Jacksina Creek the same limestone is intruded by diorite and cut by a large number of diorite dikes. Considerable contact metamorphism has resulted and large garnet masses, locally rich in chalcopyrite, were produced. The metamorphic action was of selective character, certain limestone beds being converted into garnet, whereas others were changed to tabular masses of white silicates. These relations are exposed with diagrammatic clearness in the limestone cliffs. The copper-bearing rock, in typical specimens, consists of garnet (much of it finely crystallized in dodecahedral form), calcite, chalcopyrite, and some specular hematite. The present indications show that the ore occurs rather in a number of scattered bunches than in a single large workable deposit.

CHISANA RIVER.

At the head of Cross Creek, several miles above the lower end of the glacier, a thin quartz-chalcopyrite vein cuts the andesitic lavas and breccias, but almost all that is known of it is derived from an inspection of fragments of ore found in a talus slope 600 feet high. A little galena is associated with the copper mineral. In the same vicinity some outcrops of zinc ore, a resinous sphalerite with scattered galena, have been found, but the exposures are poor on account of the covering of slide rock.

Native copper can be found in some of the streams in the amygdaloid area between Cross Creek and the Chisana. There are also indefinite Indian reports that rich deposits of native metal occur in the mountains bordering Chisana Glacier, but the exact locality has not yet been discovered.

WHITE RIVER.

At the head of the Middle Fork of White River, a large tributary entering from the northwest 5 miles below the head of the main stream, some claims have been staked on outcrops of rock carrying native copper. Two small open cuts, 1,450 feet above the stream, were seen on the Copper King claim. The country rock at this locality consists of stratiform basalts of Carboniferous age intercalated with beds of breccia and brick-red tuffs, striking N. 85° E. (magnetic) and dipping 18° into the mountain. Native copper is apparently limited in its occurrence to a certain definite volcanic sheet—a reddish lava that is locally amygdaloidal to a high degree. For 200 feet along the outcrop of this sheet, metallic copper intergrown with prehnite, calcite, and zeolites can be found here and there in encouraging amounts. The cupriferous portion of the amygdaloid appears to be about 6 feet thick, but as almost no development work has been done on the property figures of this kind have little value. The copper occurs as irregular reticulating masses of metal several inches long and as small lumps and minute particles embedded in the minerals that fill or line the former vesicles in the lava flow. In places these minerals either ramify in small veinlets through the body of the rock surrounding the amygdules or form irregular masses, and such places are eminently favorable for metallic copper.

This is the only deposit seen during the summer in which the native copper appears to be of undoubted primary origin. If the ore on the surface has any downward extension, a fact that can be established only by actual exploration, it can be predicted with a high degree of confidence that metallic copper also will persist downward. To this extent the surface indications are distinctly favorable. Some doubt as to the probable amount of ore may perhaps be entertained, in view of the character of the deposit. Native copper associated with zeolites filling amygdules in basaltic lavas is found throughout the world in widely separated localities—the Faroe Islands, the trans-Baikal region, Brazil, Queensland, and Lake Superior—yet only the Lake Superior region has yielded ore bodies of commercial value.

On Moraine Creek, a small stream in a glacier-filled valley on the east side of Russell Glacier, a number of claims were staked during 1907 and 1908. The bed rock here also consists of green and reddish amygdaloids with associated breccias striking N. 85° W. (magnetic), but dipping 55° S., an angle considerably steeper than on Middle Fork. In some places the upper portion of a lava sheet is more highly amygdaloidal than the rest of the flow. Malachite-stained fragments of rock can readily be found in the talus slopes. Copper occurs in place in small seams cutting the amygdaloid, the veinlets consisting of finely developed spherules of prehnite intergrown with calcite and flecked with red metal and chalcocite. Thin sections show small, clean grains of copper embedded in both prehnite and calcite; some chalcocite occurs similarly. A small amount of native copper is associated with a little hydrated iron oxide, and this copper may have been derived from the reduction of the chalcocite.

The amygdaloids are also traversed by small drusy stringers composed of quartz and prehnite and containing chalcocite and a black, combustible mineral. At another point on Moraine Creek the lava, beside containing white amygdules of zeolite, carries irregular blebs of chalcocite, which give the rock somewhat the appearance of a glance-bearing amygdaloid. Such development work as has been done on Moraine Creek indicates that the amygdaloidal phases of the basalts here, too, are the most favorable and are likely to be found along the contacts of successive lava flows. As the superimposed sheets of lava commonly differ in color and texture the contacts can easily be located.

Near the head of White River the same Carboniferous volcanics form the west wall of the valley. They consist of basaltic tuffs, breccias, amygdaloids, and porphyritic sheets, dipping 10° N. The colors of the lavas are dark red-brown and greens. A number of prospects have been located on chalcocite croppings a few miles below the edge of the moraine of Russell Glacier. In the main these outcrops consist of chalcocite. At one prospect a thin glance stringer, an inch or so thick, cuts vertically across the nearly horizontal volcanics. It is adjoined by sheared amygdaloid walls, and veinlets of white earthy material ramify through the adjacent rock to great distances. A few hundred feet below this locality, on what is thought to be the same vein, is another open cut on a glance stringer about 3 inches wide, largely solid sulphide, which is intergrown to some extent with a zeolite mineral of a specific gravity of 2.27, probably laumontite. The cliff above the cutting shows that the stringer pinches out vertically within 6 feet.

On Rabbit Creek, at a point near the international boundary, about 7 miles north of White River, an adit 20 feet long has been driven on a shattered zone in basalts, presumably of Carboniferous age, like those prevailing throughout the region. At the mouth of the adit the zone, which is about 40 feet wide, is iron stained and variegated with blue and green carbonates of copper. The unoxidized rock carries sparsely disseminated chalcopyrite.

The copper deposits on Kletsan Creek were not visited, on account of lack of time at the end of the field season. The placer copper, according to Brooks,[a] "as far as observed, is confined to a distance of about half a mile above the point where the creek leaves its rocky canyon." It is traceable up to the glacier from which the creek is discharged. In 1902, a number of years after this examination, which was necessarily of a hasty character, some attempt was made by Mr. James Lindsey to test the placer-copper possibilities of the locality. On account of the glacial ice and snow in the high ranges at the head of the creek and a number of other adverse conditions unfavorable conclusions were reached. Some bed-rock occurrences of native copper were described by Brooks[b] as consisting of an irregular system of veins traversing joints in the greenstones. The filling of the veinlets consists of calcite, and careful search showed that some of them carried native copper. The deposits on which prospecting is being done at present consist, however, of chalcocite, as seen from specimens purporting to have come from Kletsan Creek. It is stated that a good trail has been built from Generk River to the deposits and that considerable work has been done on them.

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[a] Op. cit., p. 381. [b] Op. cit., pp. 380-381.

GOLD.

Prospecting for gold in the region is confined to lode deposits, as the placer gold in the streams occurs only in unremunerative amounts. The stampede from Dawson in 1902 was directed toward Beaver Creek and its tributaries, in the vicinity of the international boundary, and the surrounding territory was soon staked far and wide by the stampeders. A few holes put down in the gravel bench of Beaver Creek are now the only visible signs of former activity. It is reported by participants in the stampede that some coarse colors of gold were found in the creek gravels. The wash of the streams is rather coarse, consisting mainly of well-rounded cobbles and bowlders of diorite, and the bench gravels also are coarse, as, for example, in the 50-foot bench of Beaver Creek, where bowlders of diorite up to 6 feet in diameter are not uncommon.

NABESNA RIVER.

At the Royal Development Company's property on Jacksina Creek a number of cuts have been opened on a gossan derived partly from the oxidation of a pyritized sheared diorite and partly from the oxidation of the adjoining pyritized contact-metamorphosed limestone. The trend of the deposit is N. 45° E. (magnetic), and it ranges in width from 4 to 15 feet. The surface ore consists in part of cellular quartz, iron stained and carrying free gold. A three-stamp mill was erected in 1906 and about 60 tons of surface ore was crushed, yielding, it is reported, $12 a ton in gold. During the summer of 1908 the mill was not in operation, inasmuch as the work of the season was directed toward crosscutting the deposit about 200 feet below the outcrop. At the time of visit (middle of July) the crosscut was expected to strike ore within 25 feet. Three men were employed on the property.

At Orange Hill, in the upper Nabesna Valley, considerable ground has been staked for gold. The "hill" consists mainly of a quartz diorite boss projecting through the gravel of the valley floor and is cut by innumerable small quartz stringers, some of them carrying pyrite and a few carrying molybdenite. Oxidation of the iron sulphide has stained the diorite a brilliant yellowish red, whence the name of the hill. A series of twenty assays of samples collected by Schrader[a] from Orange Hill and from similarly mineralized diorite on Monte Cristo Creek yielded only negligible quantities of gold, with a maximum value of 40 cents to the ton.

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[a] Prof. Paper U. S. Geol. Survey No. 15, 1903, p. 44.

WHITE RIVER.

Near the base of the gravel bench on Beaver Creek, about 1 mile upstream from the mouth of Ptarmigan Creek, an outcrop of sulphide ore 2½ feet by 5 feet in surface exposure protrudes through the gravel. It consists of solid pyrrhotite admixed with a little chalcopyrite and minor amounts of quartz and is reported to carry $18 to $40 a ton in gold. An adit 30 feet long has been driven 10 feet east of the outcrop, but encounters no ore, showing only shattered diorite country rock traversed by narrow quartz seams. As the gravel bench is overgrown with moss, the single cropping furnishes the little that is known concerning the lode. About 200 feet downstream the bluffs show that the diorite is intrusive into hard massive shales.

At the head of Eureka Creek, near the international boundary, a number of strong quartz ledges have been discovered. Eureka Creek is about 30 miles north of the mouth of the upper canyon of White River, where a small settlement (Canyon City) has grown up on the north bank of the stream.

The bed rock at the head of Eureka Creek consists of shales interstratified with limestones and dark violet andesitic breccias. Locally the limestones are highly tuffaceous and are crowded with fossils of Carboniferous age. A lenticular bed of limestone 200 feet in maximum thickness and several thousand feet long forms bold crags that project above the more easily weathering shales inclosing it. The strata stand practically on edge and trend N. 87° E. (magnetic). The sedimentary rocks are pierced by a large number of dikes of porphyry and other intrusives, of which at least four varieties were seen during the very hasty reconnaissance of the region. These include green dioritic and andesitic porphyries and, in the vicinity of the Violet claim, a more siliceous porphyry containing small feldspars and quartzes embedded in a flinty-looking matrix. From the prevalence of diorite bowlders in the gravel of Eureka Creek it can safely be inferred that irruptive masses of diorite similar to those found in neighboring areas are present in this vicinity.

The quartz lodes form prominent outcrops that range in thickness from 4 to 12 feet, many of them traceable for considerable distances. As a rule the quartz is nearly barren to the eye, showing only a small amount of chalcopyrite and surface stains of azurite. The values are believed to lie in gold, but information on this point is as yet meager. The most development work, however, has been done on the Eureka claim, where an argentiferous galena-sphalerite ore has been discovered. Values close to $30 a ton are claimed. The mineralization follows a zone of crushing 6 to 8 feet wide, apparently in a porphyry dike crosscutting the shale country rock. The trend of the deposit is N. 25° W. and the dip 74° E. An adit 60 feet long has been driven on the lode.

On the other side of the divide, at the head of Eureka Creek, a small stream named Anaconda Creek flows eastward to Beaver Creek. Near its head, on what is known as the Beaver claim, a quartz lode has been staked. It ranges in thickness from 6 to 12 feet of solid quartz and strikes north and south, crosscutting the stratification of the country rock. A number of large outcrops expose the ledge for several hundred feet, and it probably extends for several thousand feet. Chalcopyrite and azurite are the only visible ore minerals. Assays are reported to have yielded $1.50 a ton in gold and 1½ per cent of copper. It is possible that the apex of an ore shoot carrying profitable amounts of gold may yet be found in veins of this size and persistence, and with this possibility in view further prospecting is certainly to be recommended.

Near the head of Fourmile Creek, a large western tributary of Eureka Creek, a considerable number of quartz outcrops have been discovered, and some of these, it is stated, give encouraging returns in gold from the panning of the crushed ore. Along the crest of the ridge, 2,500 feet above the stream, a great number of quartz veins, from 8 to 30 feet thick, are exposed. The Jumbo quartz vein, approximately 30 feet thick, forms towering pinnacles emerging through the slopes of loose talus. It represents a zone of brecciation and silicification and includes large angular fragments of country rock several feet in diameter. The quartz shows to the naked eye nothing but small sporadic amounts of chalcopyrite. The wall rock of this great quartz mass is a siliceous feldspar porphyry which forms a large intrusion in the surrounding shales and argillites. The porphyry itself is cut by green dikes, through which are scattered numerous large crystals of hornblende, 2 to 3 inches in diameter.

The Husky lode is situated in a more accessible place than the Jumbo. The cropping forms a 15-foot stream bluff on the north side of Fourmile Creek and shows that the lode is a zone of silicification, approximately 30 feet wide, in a crushed feldspar porphyry. The top of the bluff reveals the fact that considerable unsilicified porphyry occurs within the lode. Only one wall of the lode is exposed, and this is not sharply defined, but is a zone of imperceptible transition from quartz to unsilicified porphyry. The lode carries a small tenor of chalcopyrite and an undetermined amount of gold.

Along the middle course of Fourmile Creek some desultory prospecting has been done in the tributaries entering from the south. The geologic features are essentially similar to those on Eureka Creek. Intrusive masses of a gray medium-grained hornblende-biotite diorite appear, and large areas of this rock are shattered and reticulated with veinlets of gypsum, a very unusual mode of occurrence for that mineral. The gypsum is fine-grained crystalline, and many of the stringers carry considerable pyrite, but are of no economic importance.

LIGNITE.

A formation consisting of sandstones, shales, and conglomerate, lying nearly horizontal, is developed in the region of Coal Creek near the international boundary, but its areal distribution is not known. Fragments of lignite can be found in the slide rock of stream cutting on Coal Creek, but at the point examined did not appear to come from thick or continuous beds. In addition to these unfavorable features the strata are pierced by large vertical dikes of basalt. Toward the head of Coal Creek the lignite-bearing formation appears to be covered with a heavy series of volcanic flows. Petrified wood is common as float in the gulches cutting the formation. The lignite has a woody fibrous texture, but on cross fracture shows a brilliant black glossy surface. The subjoined analysis, furnished by the courtesy of Mr. John Sinclair, shows that it is well within the lignite class of coals.

Analysis of lignite from Coal Creek.

[Athelstan Day, analyst.]

Moisture	14. 85
Volatile matter	47. 20
Fixed carbon	29. 15
Ash	8. 80
	100. 00

CONCLUSION.

In some respects the White-Nabesna region can be more easily prospected than many other parts of Alaska on account of the relative abundance of bed-rock exposures. Most of the showings of ore found thus far are situated well up on the mountain sides, generally beneath walls of rock cliffs and above the encumbering talus slopes. This condition is, of course, to be expected in a region that is incompletely prospected, but it entails the disadvantage that the prospects are located far above timber line, and some of them many miles from it. The greater number of the copper prospects are found in the Carboniferous basaltic amygdaloids, a relation which is also essentially true for those of the Chitina country. The geologic investigation of the region has established the fact that these volcanic rocks are widely distributed and underlie the greater part of the Wrangell Mountains. Much of this territory, however, is unfortunately not accessible on account of its numerous glaciers and extensive ice fields.

The main interest of the White-Nabesna region has centered in the occurrences of native copper. No phenomenal ore bodies have yet been discovered, but it has been shown that some primary native copper occurs in the amygdules of zeolitic amygdaloids, a mode of occurrence unknown on the Chitina side of the Wrangell Mountains. This discovery is sufficiently encouraging to warrant further development, and it is to be hoped that the nature and extent of the deposit will soon be demonstrated.

From the descriptions given in the preceding pages it will be apparent that a lode-quartz region of some promise has been discovered in the Nutzotin Mountains near the international boundary and that as yet it has been but imperfectly explored by the prospector. It has been shown that the intrusion of quartz diorite produced a number of contact-metamorphic bodies of copper sulphides, and the occurrence on Jacksina Creek suggests that the magma was also capable of effecting an auriferous mineralization. From the meager data at hand it is perhaps unsafe to venture on generalizations, yet it is probable that the quartz veins are genetically related to the intrusion of the post-Carboniferous quartz diorites and that, therefore, the intruded areas are those most likely to be mineral bearing. Such areas are known to occur throughout the Nutzotin Mountains at a number of localities, especially along their northeastern flanks. Brooks has mapped a large area of granular intrusive on the lower Nabesna. It is probable that in the vicinity of such masses the search for lode quartz may be prosecuted with the most hope of success.

The important facts to be borne in mind by prospectors in the Nabesna-White district may be summarized as follows:

The copper ores are associated with the lava flows that accompanied the deposition of the Carboniferous sediments, and therefore the areas where the Carboniferous rocks occur are the most favorable places for prospecting. The Mesozoic formations of the Nutzotin Mountains have not been found to be copper bearing, and from their nature offer little promise to the copper prospector. In searching for copper in areas of amygdaloidal lavas the contacts of successive flows should be carefully examined. The vicinity of the diorite and diorite porphyry intrusions should be examined for contact-metamorphic deposits. Auriferous veins have been found in the rocks of both the Carboniferous and the Mesozoic formations, but the greater number of occurrences are within the Carboniferous areas. The gold is believed to be genetically related to the intrusion of the diorites and diorite porphyries, and therefore areas where these granular intrusives occur should be carefully examined, especially where contact metamorphic minerals, such as garnet, are present.

In this region erosion proceeds rapidly and has practically kept pace with oxidation, so that the oxidized surface zone is very shallow. The ores so far discovered are enriched oxidized ores. For these two reasons it is not to be expected that the deposits will increase materially in richness with depth, but, on the other hand, it should rather be expected that they may become of lower grade at a comparatively short distance below the surface.

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