THE TOKLAT-TONZONA RIVER REGION

By Stephen R. Capps

INTRODUCTION

LOCATION AND GENERAL CHARACTER

The region here considered lies on the northwest flank of the Alaska Range and extends from the headwaters of the main Toklat River southwestward to the head of Tonzona River, an air-line distance of about 100 miles. In this region the Alaska Range rises abruptly from the lowlands on the northwest. The lowlands are of mild relief, are covered by marshes interspersed through areas of timber, and have few rock exposures. The difficulties of summer travel by pack train in these lowlands are so great and the geologic results to be obtained there are so meager that they have so far received little attention from the geologist. The Alaska Range, by contrast, is in this region practically devoid of timber, rock exposures are excellent, and travel by pack train along the front of the range is easy. Yet the mountain mass is extremely rugged, and all the larger valleys are occupied by great glaciers that push well out toward the mountain front and bar ready access to the higher parts of the mountains. These conditions leave a belt some 15 to 25 miles wide in which the geologic results to be obtained justify the expenditure of time and effort necessary to examine it at present.

The region discussed in this report (pl. 2) lies between parallels 62° 40′ and 63° 25′ north latitude and meridians 149° 50′ and 152° 40′ west longitude and comprises an area of about 2,000 square miles. Toklat River, at the east edge of the region, is about 48 miles west of McKinley Park station on the Alaska Railroad. Most of the area lies within the borders of the Mount McKinley National Park.

PREVIOUS SURVEYS

Until the completion of the Alaska Railroad from Seward to Fairbanks, in 1923, the region on the north flank of the Alaska Range, in the vicinity of Mount McKinley, was difficult of access and was visited by comparatively few persons. Most of those who entered this area were prospectors, hunters, and trappers, who worked southward from the Kantishna mining district, but in general these men left no permanent record of their discoveries. Since 1902 our only accurate knowledge of the region on the northwest slope of the Alaska Range west of Muldrow Glacier has been derived from Brooks's monumental exploration in that year, during which instrumental topographic surveys and systematic geologic observations were carried from Cook Inlet to Rampart by way of Rainy Pass, the north flank of the range, and Nenana River.[1] Although Brooks's expedition brought out an astonishing amount of geologic information from the region traversed, nevertheless it made only a hasty exploration in which the difficulties of long and rapid marches consumed much of the energy of Brooks and his assistants. Later work in other parts of the range has added greatly to our knowledge of the geologic history of this province. Prindle, in 1906, visited the Bonnifield and Kantishna mining districts,[2] and Moffit[3] and Capps[4] have studied adjacent areas, each of these investigations throwing additional light on the stratigraphy and structure of the range.

Several mountaineering expeditions, organized for climbing Mount McKinley, have visited this region and have been followed by publication of narrative accounts of the expeditions and descriptions of the regions traversed.[5] These expeditions have added considerably to our knowledge of the geography of the immediate vicinity of Mount McKinley and have supplied scattered notes on the geology, but none of them was accompanied by a trained geologist, and no areal geologic mapping was attempted.

PRESENT INVESTIGATION

The expedition that gathered the material for this report was organized in 1925 for the purpose of carrying a reconnaissance geologic survey from Toklat River southwestward along the face of the Alaska Range to connect with earlier surveys by the writer in the Toklat and Kantishna districts and to review in greater detail a part of the area visited by Brooks in his hasty explorations in 1902.

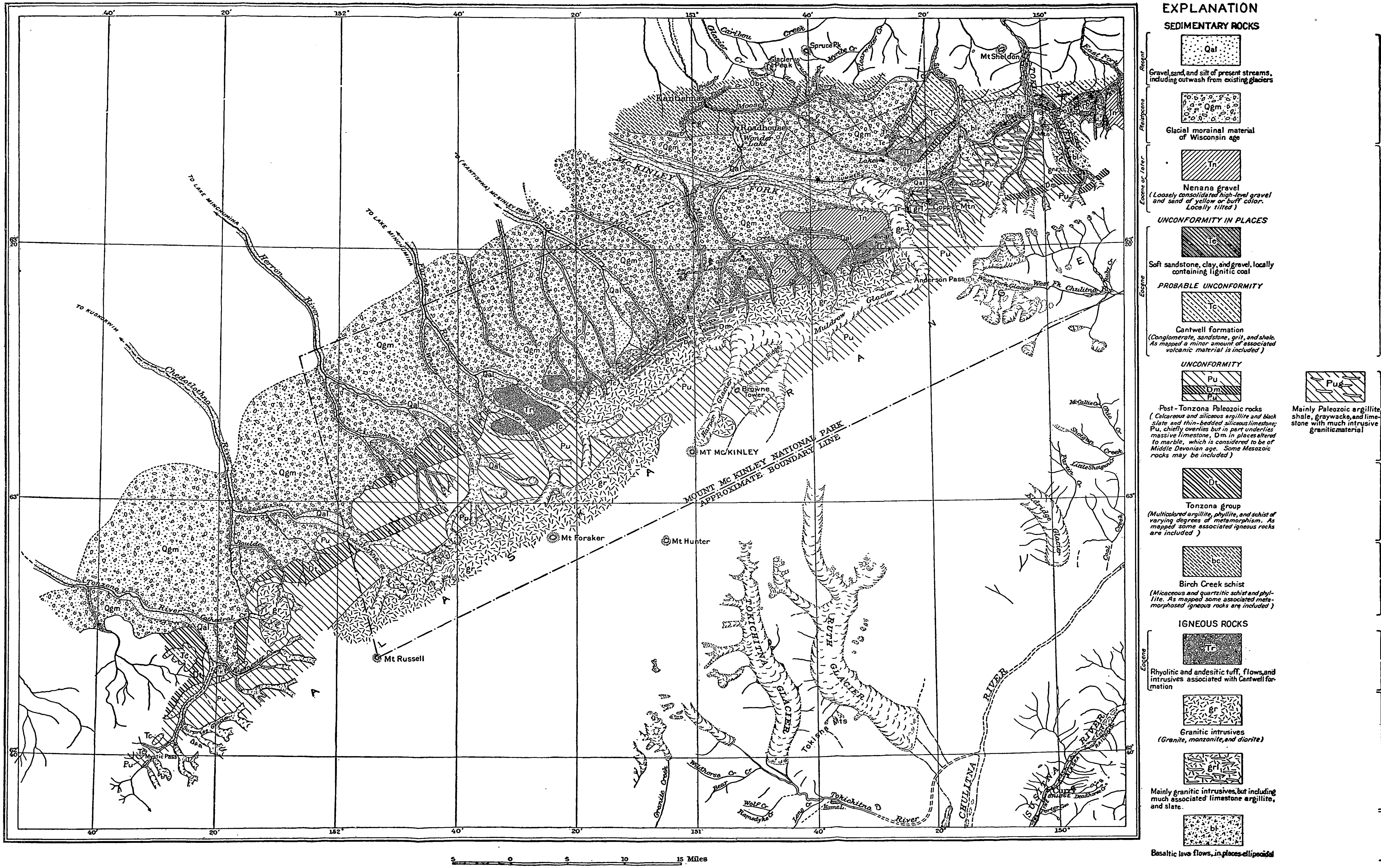
[1] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, 1911.

[2] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, pp. 205–226, 1907.

[3] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, 1915.

[4] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, 1912; The Yentna district: U. S. Geol. Survey Bull. 534, 1913; The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, 1919; Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 207–232, 1919.

[5] Dunn, Robert, The shameless diary of an explorer, Outing Publishing Co., 1907. Cook, F. A., The top of the continent, Doubleday, Page & Co., 1908. Browne, Belmore, The conquest of Mount McKinley, G. P. Putnam's Sons, 1913. Stuck, Hudson, The ascent of Denali, Chas. Scribner's Sons, 1914.



GEOLOGIC MAP OF THE TOKLAT-TONZONA REGION

A short visit was made to the Kantishna mining district at the end of the field season. The party consisted of S. R. Capps, geologist, and two camp hands, Elmer Larson and M. L. Eckart, to both of whom the writer wishes to express his thanks for faithful service. Seven pack horses were used to transport the necessary supplies and equipment. The party left the railroad at McKinley Park station on June 14 and returned to the starting point on September 4. No topographic mapping was attempted, the original topographic map made by D. L. Reaburn, of the Brooks expedition, being used as a base. To this map certain additions were made from sketches by the writer, consisting principally in extending the headward portions of streams and glaciers into areas not seen by Reaburn. Although these sketches were only roughly controlled by compass readings, they nevertheless give a general idea of the drainage in areas which until now have remained blank on published maps.

The writer here wishes to acknowledge courtesies extended by Harry Karstens, of the National Park Service, Thomas A. Marquam, of the McKinley Park Transportation Co., O. M. Grant, of Copper Mountain, and the miners of the Kantishna district, whose hospitality was unfailing.

GEOGRAPHY

DRAINAGE

The region here described lies along the northwest flank of the highest portion of the Alaska Range, and as large areas in the range are above the level of perpetual snow, the main valley heads on both flanks are occupied by glaciers. The crest of the range lies much nearer the northwest than the southeast edge of the range, and this configuration has led to the development of many short parallel valleys descending the northwest slope of the range, each occupied by a small separate glacier, in contrast to the elaborately branching valleys of the Susitna slope, where many smaller ice tongues converge into major trunk glaciers. Muldrow Glacier, which drains the northeast slopes of Mount McKinley, differs conspicuously from both these forms, for it occupies a valley that trends parallel to the axis of the range and receives a number of large tributary ice streams. Muldrow Glacier has a total length of about 44 miles and with its tributaries covers an area of at least 75 square miles. It therefore ranks among the largest half dozen glaciers of the Alaska Range. The other principal glaciers of the region, including Hanna, Straightaway, Foraker, Herron, and Chedotlothna Glaciers, range in length from 11 to 14 miles, and there are a large number of smaller, unnamed glaciers from 8 miles to 1 or 2 miles long.

All the larger streams within this area head in the glaciers of the Alaska Range and therefore are supplied in large part by waters flowing from the melting ice fields. As a consequence the volume of stream discharge is extremely variable, being lowest in the winter and greatest on the long warm days of summer or during warm rains, when the melting of the glaciers and snow fields is most rapid. In the winter stage of low flow the streams run clear, being fed mainly by springs. In summer, by contrast, when the glacial discharge is active, the streams are turbid from a heavy load of gravel, sand, and silt.

As a consequence of the heavy load of glacial débris which they carry and of their great daily and seasonal variation in volume the glacial streams tend to build up extensive valley-floor deposits of gravel and sand, and they generally flow over these deposits in many braided channels. These glacial-outwash deposits consist of coarse boulders near the glaciers, but their materials become progressively finer downstream, and as a result the valley flats narrow, and there is less tendency for the streams to break into smaller channels.

About three-fourths of the area here described lies within the drainage basin of Kantishna River. Toklat River and Stony Creek, its tributary, drain directly to the Kantishna around the east side of the Kantishna Hills. McKinley Fork, the largest tributary of the Kantishna, heads in Muldrow Glacier and is also fed by Clearwater Creek, Muddy River, and Birch Creek. In the area here described McKinley Fork flows in a multitude of channels over a wide gravel flat, and though the total volume of water discharged is considerable, the stream is not navigable even for small power boats. By proper care in choosing a ford it may be crossed on foot between the mouth of Clearwater Creek and Muldrow Glacier in all but extremely high stages of flood. North of the area here shown (pl. 2) this river flows in a northerly direction around the west base of the Kantishna Hills and below the settlement of Roosevelt is navigable in summer for boats of moderate draft.

Foraker, Herron, Chedotlothna, and Tonzona Rivers are supplied mainly by glacial waters, and all have the characteristics of glacial streams, though none of them discharge so much water as McKinley Fork. Foraker and Herron Rivers flow northward to Lake Minchumina and thence drain to the Kantishna. Chedotlothna and Tonzona Rivers are headward tributaries of the Kuskokwim. All these streams can be forded on horseback in ordinary summer stages, but all are large and swift enough to make fording on foot dangerous except during times of low water.

RELIEF

KANTISHNA-KUSKOKWIM LOWLAND

The Alaska Range is bordered on its northern and western flanks by a great lowland of varying width that extends for practically the entire length of the range—from the international boundary on the east to and beyond the great bend of the Kuskokwim on the southwest. This lowland, in the region here described, is occupied by the headward tributaries of Kantishna and Kuskokwim Rivers. It is a great structural depression in which a large quantity of detritus, derived mainly from erosion of the Alaska Range, has been deposited, and its prevailing surface forms are the result of stream and glacial aggradation, with here and there isolated groups or ranges of hard-rock hills rising above the general level of the plain. This lowland has been little studied except around its borders, for the marshy character of the ground, the thick timber and brush, and the many rivers that cross it render summer travel difficult. It is believed likely, however, that at some earlier time, perhaps early in the Pleistocene, it was a single great river basin, drained by a stream that followed the general course of the Tanana to about the mouth of the present Kantishna and thence swung to the southwest across the present divide and into the basin now occupied by the upper Kuskokwim.

The Kantishna-Kuskokwim lowland has in general an altitude of less than 1,000 feet, though in this area its margin along the mountains ranges from 1,600 to 3,000 feet above sea level. This high margin is crossed by many streams that drain radially from the highlands. Farther out in the lowland these streams unite into larger rivers which converge into the Kantishna or the Kuskokwim. The divide between the basins of these great rivers is said to lie between Herron and Chedotlothna Rivers, though from the mountains one's eye can not follow the rivers far enough to determine their final course, and the course of the drainage lines in that unsurveyed area has been wrongly shown on many published maps. The most trustworthy information obtainable is that Chedotlothna River is the easternmost tributary of the Kuskokwim, and that Herron and Foraker Rivers flow to Lake Minchumina and thence to the Kantishna.

ALASKA RANGE

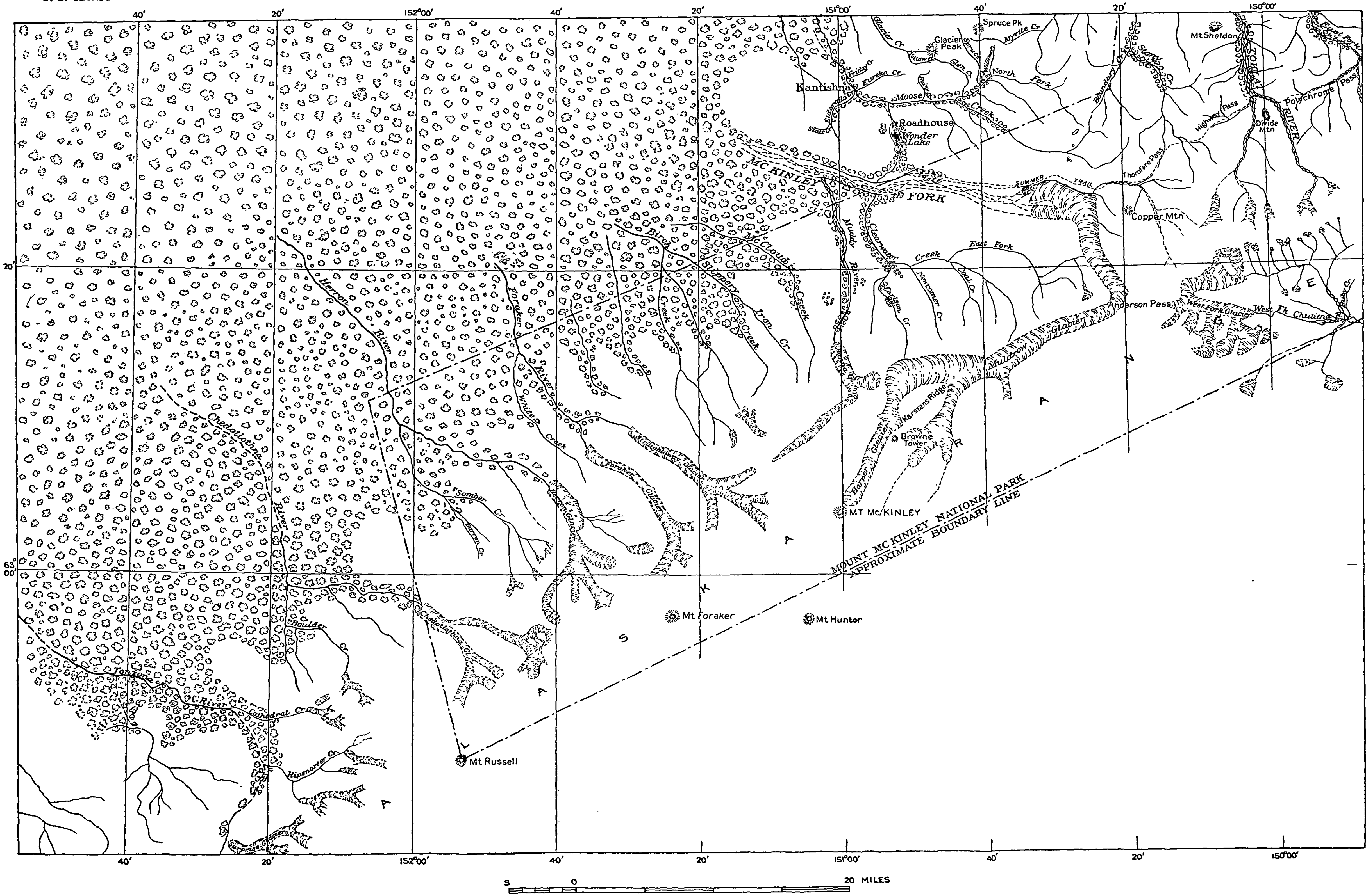
The region between Muldrow Glacier and Tonzona River is noteworthy because, although in this stretch the Alaska Range reaches its greatest height, the mountains rise abruptly from the lowland on the north without any intermediate belt of foothills. Between Muldrow

Glacier and the railroad along Nenana River and, in fact, as far eastward as Delta River the main range is bordered on the north by a considerable foothill belt, and foothills are developed also southwest of Tonzona River. These outlying hills have been described elsewhere.[6] Groups of isolated hills rise above the lowland level, but their structure has not been studied, and it is doubtful if they are structurally and geologically related to the Alaska Range. At any rate they are so separated from it by intervening lowlands that they would not be considered to belong to the Alaska Range geographically. The abrupt front of the range, which rises from the moraine-covered edge of the lowland, is probably the result of both folding and faulting. The nearly straight line of the mountain front suggests a great fault scarp, but the fault could not be directly observed, and the steep dip of the sedimentary beds, in many places as high as 90°, is evidence that in the uplift of the mountain mass a sharp flexure of the rocks took place. The relative importance of faulting and folding in determining the abrupt front of the range has not been determined.

The Alaska Range forms one of the major geographic features of the continent, culminating in Mount McKinley, the loftiest mountain in North America, with an altitude of 20,300 feet. The part of the Alaska Range here under consideration lies at the crown of the great arch described by the axis of the range. At Mount McKinley the axial direction of the range is northeast, and as the range approaches the headwaters of Toklat River it veers to east. Southwest of the mountain the range swings southward and approaches a due south trend at its south end. In this area the range is from 30 to 50 miles wide, but its crest, as roughly indicated by a line drawn through Mounts McKinley, Foraker, and Russell, lies at an average distance of only 12 miles from the Kuskokwim-Kantishna lowland and is therefore much nearer to the northwest than to the southeast border of the range. The abrupt rise from the lowlands on the northwest to the crest of the range gives this magnificent mountain chain an aspect that for sheer steepness and for scenic grandeur can scarcely be matched elsewhere. From places on Hanna Glacier the slopes of Mount McKinley rise from 5,000 to more than 20,000 feet in a horizontal distance of less than 5 miles. The limit of perpetual snow here lies at an altitude of about 7,000 feet, so that the higher parts of the range are concealed by a permanent mantle of ice and snow except on cliffs that are too steep to afford lodgment for it.

All the larger valleys that head back against the crest of the range are occupied by glaciers that push well down toward the mountain

[6] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 13–14, 1919; The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, p. 12, 1912.



SKETCH MAP SHOWING DISTRIBUTION OF TIMBER IN THE TOKLAT-TONZONA REGION front. Muldrow Glacier extends several miles out into the lowland belt, but in the other valleys the ice tongues reach only to the face of the range. The steep slopes of the main range and the glacier-filled valleys make access to the higher mountains difficult, and few persons have penetrated the range more than a short distance. A number of well-equipped mountaineering expeditions have attempted to ascend Mount McKinley, and although at least three parties have reached the higher slopes only a single expedition[7] succeeded in ascending its highest peak. Mounts Foraker, Hunter, and Russell, magnificent peaks of the first magnitude, are as yet unscaled, and a considerable area in the heart of the range is still entirely unexplored.

CLIMATE

No accurate weather records have been taken in this immediate area, but it is known that the climate here is much like that of the general region on the north slope of the Alaska Range. In interior Alaska in general the summers are moderate and the winters cold. The annual precipitation is light, ranging in the Tanana Valley between 8 and 19 inches and averaging about 11 inches, though in the mountains it is doubtless higher. The mean annual temperature at Fairbanks is about 25°, with a range between 86° and —65° F. Along the flank of the Alaska Range the weather is influenced by local conditions. During most of the time in the summer the higher peaks of the range are in clouds, and local showers are frequent. In winter the snowfall is considerable in the mountains but is light north of the range.

VEGETATION

In this region the Alaska Range proper in practically devoid of trees. Timber grows up to altitudes of 2,000 to 2,800 feet and reaches its greatest altitude along the main river valleys, as shown in Plate 3. The entire Kantishna-Kuskokwim lowland below an altitude of about 2,000 feet contains timber, though by no means in a solid stand, for the lowland contains many marshy tracts in which the trees are scattered and scrubby. The principal trees are spruce, cottonwood, birch, and larch, none of which reach large size. Spruce trees exceptionally reach a diameter of 2 feet at the base, but they average much smaller and yield little clear lumber. It is therefore apparent that this timber has value only for rather local uses.

Along the immediate base of the Alaska Range timber for camping purposes is available in only half a dozen of the larger valleys, and the main dependence of the Geological Survey expedition for fuel was on willows and brush. A few miles northwest of the route

[7] Stuck, Hudson, The ascent of Denali, Chas. Scribner's Sons, 1914.

traveled, however, timber is abundant. Small cottonwood trees are locally and willow bushes generally to be found above the highest spruce timber. For any mining operations that may be undertaken in this part of the range it will be necessary to haul wood for fuel and for structural uses for some distance.

Grass is found generally throughout the region, though the traveler will often find it necessary to select his camp site with the problem of horse feed in mind, for there are considerable areas where forage is scarce. The principal forage plants are redtop, "bunch grass," and at a few places "pea vine," a vetch that grows locally on the gravel bars of the streams. Stock can subsist on the local vegetation only between June 1 and September 15, for after the first heavy frosts the grasses lose most of their nutritive value. The region contains several wild edible berries, including currants, raspberries, and blueberries. The blueberries are especially abundant and grow best above timber line at altitudes of 2,000 to 2,800 feet.

Little agriculture has been attempted in the region here described. On Wonder Lake and on Friday Creek, in the Kantishna mining district, gardens have been cultivated successfully at altitudes of 1,600 to 1,800 feet. No doubt similar success with quickly maturing crops could be obtained elsewhere in equally favorable places, but in general the agricultural possibilities of the area along the foot of the Alaska Range are small, though no doubt stock could be grazed there during the summer.

GAME

The northern slope of the Alaska Range from Nenana River westward is notable for the abundance of big game. From McKinley Park station on the Alaska Railroad to Muldrow Glacier the white bighorn sheep abound, and hundreds may be counted on a single day. Between Muldrow Glacier and Tonzona River they are much less numerous, but southwest of the Tonzona they are again plentiful. The entire region is a summer feeding ground for great herds of caribou, which on hot days climb high on the mountains and glaciers to escape the heat and the insects. Moose are much less numerous but are frequently seen in the timbered and brushy valleys. Grizzly bears range throughout the mountains, and black bears in the timbered lowlands. Rabbits and ptarmigan are at times very numerous, but they vary in abundance from year to year. Some furbearing animals occur, notably fox, lynx, mink, and marten. Much of the area here described lies within the limits of the Mount McKinley National Park, where hunting and trapping are forbidden.

This part of Alaska is poorly supplied with fish. Most of the streams, being glacier-fed, are turbid in the summer, and fish avoid them. Streams that are clear contain grayling but not in great abundance. Wonder Lake contains trout, but that is the only locality in this area where trout are known to occur. So far as known, the salmon, which each year migrate up Kuskokwim and Tanana Rivers to spawn, do not come to the headward reaches of these streams.

POPULATION, TRAILS, AND TRANSPORTATION

Except for some 30 miners in the Kantishna district, two prospectors at Copper Mountain, and one on Carlson Creek, this region is unpopulated. A few prospectors visit the area from time to time, and an occasional hunting party crosses it on the way to hunting grounds outside the park. Even the natives rarely visit it, as their villages are in the lowlands along streams from which they can obtain fish. West of Muldrow Glacier and south of McKinley Fork there is a single prospector who may be considered a permanent resident. There are no well-marked trails except those of the wild animals. Travelers to this region in summer come either by trail from the railroad at McKinley Park or up Kantishna River by boat to Roosevelt, some 20 miles north of Kantishna post office, and thence overland. A good wagon road is now under construction westward from McKinley Park station, and some 20 miles was completed by the end of 1925. From the end of the road a good trail for pack horses leads by way of Igloo Creek and Polychrome, Highway, and Thorofare Passes around the end of Muldrow Glacier past Wonder Lake to Kantishna post office. Eventually this trail will be superseded by the extension of the wagon road now being built.

In spite of the entire absence of man-made trails southwest of McKinley Fork, travel by pack train in summer presents no serious difficulties. By following close to the northwest face of the range, generally above timber line, the traveler finds an open country with solid footing for horses and little obstruction from trees or brush. Here, too, the torrential glacier streams, which below unite to form deep rivers, are small enough to be forded on horseback except in flood stages. They are, however, large enough to be difficult and dangerous to cross on foot during the summer.

The Alaska Range itself is high and rugged, and travel into its higher parts and up the glacier-filled valleys, where no fuel for camping is to be found, requires alpine equipment. The lowland below an altitude of 2,000 feet, by contrast, is in general timbered and marshy and is crossed by many rivers too large to ford but too swift and shallow to be navigable except by poling boat or canoe, so that it is to be avoided in summer. In winter, when the streams and marshes are frozen, travel by dog sled is feasible anywhere except in the higher parts of the range.

GEOLOGY

GENERAL OUTLINE

The surface distribution of the rock formations of this area, in so far as they have been differentiated, is shown on the accompanying geologic map. (Pl. 2.) The geologic field work on which this map is based has all been of reconnaissance character, a large area being covered during a short field season, so that it has been possible to outline the geologic units only approximately. Even when the position of the formational boundaries was accurately determined in the field it was often impossible to record the details, for the base map used was made in a hasty exploratory trip in 1902, and no time was available to the topographer for refined mapping of the details of surface form. An additional difficulty confronts the geologist working in this region because of the scarcity of fossils from which the age of the sedimentary beds may be accurately determined, and so likewise the age of the igneous rocks is difficult to determine through their relations to sedimentary beds of known age. The only recognizable organic remains found in any of the rocks during the present investigation were some fragmentary leaf imprints from the Cantwell formation on Tonzona River. No fossil shells were seen. It has therefore been necessary to leave the question of the age of the rocks largely unsettled, though correlations are suggested with beds of similar lithology and known age elsewhere. The tentative age assignments here given are subject to change or modification as fuller information is obtained, and it is certain that some assemblages of beds here grouped together will later be subdivided.

The geologic subdivisions shown on the accompanying map have already been described in reports on this and contiguous areas, and elaborate descriptions are unwarranted here. In the following pages a brief description of each subdivision is given, with reference to more complete published descriptions.

As shown on the geologic map (pl. 2) the pre-Tertiary rocks are divided into eight units, each of which is distinguished by a separate pattern. Each of two of these units is a combination of two others; one is an assemblage in which igneous rocks predominate but which includes also considerable sedimentary material, and the other is a similar assemblage in which the sedimentary beds predominate over igneous rocks. The same sedimentary rocks where comparatively free of intrusive materials are shown by a separate pattern, as are the intrusive rocks where they contain only minor amounts of included sediments.

The oldest formation is undoubtedly the Birch Creek schist, which occurs in this area only along the valley of Moose Creek in the Kantishna mining district. The schists of this formation are unfossiliferous, and their age has not been definitely determined, but from their association elsewhere with fossiliferous sedimentary beds it is known that they antedate the Ordovician period, and they may be of pre-Cambrian age. The rocks that appear to be next younger than the Birch Creek schist are a group of schists and phyllites, grading toward the southwest into less metamorphic argillites. This group, which is known as the Tonzona group, has so far yielded no fossils, but from certain relations Brooks[8] tentatively assigned it to the Lower Devonian or the Silurian, and definite information is still lacking upon which to make a more precise age determination. A third pre-Tertiary group of sediments constitutes the major element of the north flank of the Alaska Range. It is composed dominantly of black blocky argillite and graywacke, with some black slate, some thin-bedded limestone, locally siliceous, and calcareous shale and argillite, all more or less intimately intruded by dioritic rocks. The age of these sediments is not accurately known, but from their association with a massive limestone that elsewhere has yielded Middle Devonian fossils these rocks are known to be in part, at least, of Paleozoic age, and the group probably includes beds some of which are older and some younger than the limestone. It is possible, moreover, that some Mesozoic black argillites and slates are also included in the group as here mapped. Certain massive limestones that occur in the Toklat Basin and near Hanna Glacier are shown by a separate symbol on the map. (Pl. 2.) These limestones are highly metamorphosed and recrystallized, so that any fossils they may have once contained have been destroyed, but they lie along a belt that extends eastward to Nenana River in which limestones with similar lithologic relations have yielded Middle Devonian fossils. The limestones separately mapped in this report are believed to be also of Middle Devonian age.

In addition to the above-mentioned pre-Tertiary sedimentary rocks there are in the Toklat Basin certain areas of greenstone that are probably Mesozoic, and in the Alaska Range large areas of intrusive granitic rocks, mainly diorite. These granitic materials were probably intruded in Jurassic time. They cut the older sediments and in places are so intimately intruded in them that it is impossible to separate them on a map of the scale of Plate 2. In such places they are shown either as areas composed mainly of granitic rocks with some included sediments or as mainly sedimentary rocks with considerable intrusive material.

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[8] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 73–76, 1911.

The Tertiary rocks are here divided into three formations, the oldest of which is the Cantwell formation. This formation is composed mainly of conglomerate, sandstone, and shale and is associated and in part interbedded with some intrusive and extrusive igneous materials composed mainly of volcanic flows and tuffs. Fossil plant remains reported from the Cantwell formation indicate that it is of early Tertiary age. It is succeeded, probably unconformably, by lignite-bearing sandstone and shale such as occur at intervals along the entire northern face of the Alaska Range. These beds are to be correlated with the lignite-bearing beds of the Nenana coal field, which have been determined to be of Eocene age. Above the lignite-bearing Eocene beds is a thick series of high gravel deposits that in this area have been differentiated only in Polychrome and Thorofare Passes and in the basin of Clearwater Creek. These deposits, the Nenana gravel, are believed by the writer to be of Tertiary age, though younger than the coal-bearing formation. They have so far yielded no fossils. The Quaternary deposits as mapped in this region include two broad groups of materials; the older comprises the widespread mantle of glacial drift that generally marks the southeast margin of the lowlands and was deposited by the glaciers during a time when they were expanded much beyond their present size, and the younger consists of the present stream deposits, including the gravel, sand, and silt of the present flood plains of the streams. These younger deposits, to be sure, are largely the outwash of glacier-fed streams and are therefore mainly of glacio-fluvial origin. Other Quaternary deposits, including accumulations of talus and older terrace gravel, are of small areal extent and have not been differentiated on the geologic map.

The following table gives the stratigraphic sequence for this district in so far as it is now known.

Quaternary: Gravel, sand, and silt of present streams; talus accumulations; peat and impure organic deposits, or muck; soils and rock disintegration products in place; deposits of existing glaciers; terrace and bench gravels, some of glacio-fluvial origin; morainal deposits, mainly of Wisconsin age, but possibly including some of pre-Wisconsin age.

Tertiary:

Nenana gravel (loosely consolidated elevated gravel and sand, yellow or buff, locally tilted).

Lignite-bearing formation (generally light-colored soft sandstone, clay, and gravel, little indurated, locally containing lignite). Contains Eocene plants. Locally associated with sediments are lava and tuff.

Cantwell formation (generally dark-colored, indurated conglomerate, grit, sandstone, and shale, with some carbonaceous material). Generally classified as Eocene, although there seems to the writer a possibility that the deposits may be Upper Cretaceous. Associated with the formation are dikes and considerable thicknesses of lava and tuff.

Mesozoic (?) (possibly some of the shales and graywacke beds here grouped with the post-Tonzona Paleozoic rocks are of Mesozoic age):
- Granitic intrusives, mainly diorite.
- Amygdaloidal and ellipsoidal greenstone.

Post-Tonzona Paleozoic rocks:
- Argillite, slate, and graywacke, locally calcareous; thin-bedded limestone, locally siliceous; in places intensely intruded by granitic rocks. This group contains some beds that underlie and some that overlie the Middle Devonian limestone and may even contain beds as young as Mesozoic.
- Middle Devonian limestone: Massive crystalline limestone beds in Toklat Basin and near Hanna Glacier, everywhere highly metamorphosed.
- Paleozoic argillite, phyllite, and schist, varicolored. In general highly metamorphosed to schist. Older than the Middle Devonian limestone.

Devonian or Silurian:
- Tonzona group: Multicolored argillite, phyllite, and schist of varying degrees of metamorphism.

Pre-Ordovician: Birch Creek schist (micaceous and quartzitic schist and phyllite).

STRATIGRAPHY

BIRCH CREEK SCHIST

Character and distribution.—The Birch Creek schist appears in the area here under discussion only as a narrow strip along the valley of Moose Creek, in the Kantishna mining district, although it is the prevailing formation in the Kantishna Hills, just north of this area, and forms an important element of the Alaska Range farther east, occupying a continuous belt that extends from McKinley Fork at least as far eastward as Delta River. The Birch Creek schist of this general region has been described by Brooks,[9] Prindle,[10] and Capps.[11] The prevailing phase includes highly contorted fissile mica schist, quartzite schist, and phyllite in shades of green, brown, and gray. Where fresh and little weathered the rocks appear rather massive, but in weathered exposures they break down into thin flakes, the surfaces of which glisten with mica scales. The degree of schistosity is not uniform, the rocks ranging from highly fissile mica schists to rather massive, poorly cleaving quartzitic beds.

The schist is cut by many quartz veins, most of which are gash veins and stringers that follow the foliation of the schist and have been distorted in the general crumpling and folding that the rocks have undergone. These gash veins, lenses, and stringers are commonly little mineralized but are prevailingly of milky-white massive quartz with no visible sulphide minerals, though in places a little pyrite appears in them. In addition to the twisted gash veins that

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[9] Brooks, A. H., op. cit., pp. 56–60.

[10] Prindle, L. M., The Bonnifield and Kantishna regions: U. S. Geol. Survey Bull. 314, p. 206, 1907.

[11] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 20–22, 1912; The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 26–29, 1919.

follow the cleavage planes of the schist there are in places later quartz veins that cut across the foliation and are mineralized with sulphides and free gold. Some of these later veins are many feet wide, have been traced for several hundred feet, and have a valuable content of gold, silver, and lead. This group of veins has doubtless supplied most of the placer gold to the streams of the Kantishna district, and two mines have produced a considerable tonnage of ore of high grade. Other veins, probably of the same group, contain large bodies of stibnite. The prevailing mineral association in these veins is arsenopyrite, pyrite, galena, sphalerite, stibnite, tetrahedrite, gold, and silver. The schist itself contains some scattered pyrite but has so far not been found to contain metals in minable amounts.

Structure and thickness.—The Birch Creek schist is believed to have consisted originally of sedimentary materials, including shale, sandstone, and a little limestone. As a result of deep burial and intense folding and crumpling at various times these rocks have been completely recrystallized and metamorphosed into the schists we now see. As a result of the very processes that have developed mica schists from previously unaltered sediments the schists have a highly complex structure. This structure includes larger close folds upon which are superimposed smaller folds and close crumpling and contortion, so that no trustworthy estimate can be made of the original thickness of the beds from which the schists were derived. Furthermore, the schists are the oldest rocks in this region, and their base is nowhere exposed. It can only be said that the Birch Creek schist in the Kantishna district is now at least 2,500 feet thick and is probably much thicker. The structure is highly complex in detail, but in a broad way the strike of the foliation is parallel with the axis of the Alaska Range and its dip is steep.

Age and correlation.—Precise information concerning the age of the Birch Creek schist is still lacking, although the formation has been studied in many parts of Alaska and by many observers. The schist lacks fossils from which its age could be accurately determined, and as it is everywhere the oldest formation in the district in which it is found, nothing concerning its age can be deduced from the character of the underlying rocks. In this general region the rocks next younger than the Birch Creek are the argillite and phyllite of the Tatina group, which is tentatively assigned to the Ordovician. If this assignment is accepted it would make the Birch Creek at least pre-Ordovician. In the Yukon-Tanana region, where the Birch Creek is extensively developed, there is a thick series of sediments, the Tatalina group, that lies beneath Lower Ordovician beds and above the Birch Creek schist. The exact age of the Tatalina is still undermined, but it is in part correlated with rocks that are known to include Middle Cambrian fossils, and its presence between Ordovician rocks and the Birch Creek schist lends strong evidence to the conclusion that the Birch Creek may be of pre-Cambrian age.

TONZONA GROUP

Character and distribution.—A group of rocks that has been called the Tonzona group occurs in considerable areas along the northwest front of the Alaska Range. This group as a whole has been rather fully described by Brooks.[12] In the area here considered rocks of this group have been identified from Foraker Glacier to the basin of Tonzona River. In most of that area they consist of glossy thin-cleaving phyllites and schists in shades of red, green, blue, brown, and black, though west of upper Tonzona River they are less metamorphosed and include varicolored argillites and cherts. In the belt of these rocks that extends from Foraker Glacier southwestward to and beyond Barren Creek and in the belt that crosses the Chedotlothna Basin the rocks of this group consist largely of phyllite that has a silky sheen along the cleavage planes, though their texture is fine and no individual crystals could be distinguished with the naked eye. Where sufficiently metamorphosed to exhibit a well-developed schistose structure these rocks are easily identified. In places, however, there are large bodies of black argillaceous material, partly altered to slate and phyllite that resemble certain phases of the post-Tonzona Paleozoic rocks described elsewhere in this report, and in these places the separation of the rocks of the Tonzona group, as shown on the accompanying map, is tentative only. On the east side of the Tonzona Basin south of Cathedral Creek there are certain quartzose schists, associated with black glossy phyllites and slates, that may have resulted from the metamorphism of some siliceous igneous rock. Their degree of metamorphism justifies their inclusion with the Tonzona group, especially as similar rocks occur in this group in the Bonnifield and Kantishna regions. West of upper Tonzona River, in the type area from which the group took its name, the rocks of this group are less metamorphosed than in the areas just mentioned and consist mainly of varicolored argillite with considerable chert.

Structure and thickness.—The structure of the Tonzona group in this region is highly complex. The close folding that developed the schistose structure has so complicated the section that no reliable estimate of the thickness of the beds can be made. In general the strike of the schistosity is roughly parallel with the trend of the

[12] Brooks, A. H., op. cit., pp. 73–76.

range, and the dip is usually high. In most places the bedding of the sediments from which the schists were derived can not be determined, though in localities where there is an alternation of schists of various colors the rocks of a single color may be presumed to represent what was originally a single bed or group of beds, and these also have prevailingly steep dips. West of Tonzona River the Tonzona rocks are less highly metamorphosed, and the structure is more easily decipherable. A section studied by Prindle[13] shows steeply dipping clay shale and grit with some limestone, interbedded with or cut by diabase. Faulting is everywhere common, and faults probably played an important part in determining the shape of the present outcrops of this group. It appears that the group must have an actual thickness in places of several thousand feet. No more definite figure can now be given.

Age and correlation.—No fossils have been found in the rocks of the Tonzona group, and its age can therefore be determined only in a general way. Brooks states that although its age is doubtful it is without doubt younger than his Tatina group, which is, in part at least, probably Ordovician. In the area here discussed it seems certain that the Tonzona rocks are older than the other rocks that appear in close association with them. These associated rocks include the Cantwell formation, which is classified as early Tertiary, and a great group of argillites, shales, slates, thin-bedded limy shales and limestones, and massive limestones. As will be shown later, most of the latter assemblage is believed to be of Paleozoic age, and the massive limestones within it are believed to be Middle Devonian. If, then, the conclusion is correct that the Tonzona rocks are older than the associated Paleozoic beds, they are older than Middle Devonian and younger than the part of the Ordovician that is probably represented by the Tatina group. The present evidence is therefore that the Tonzona lies somewhere between Ordovician and Middle Devonian.

POST-TONZONA PALEOZOIC ROCKS

Distribution and character.—The largest single group of rocks shown on the accompanying map (pl. 2) consists of an undifferentiated assemblage that includes blocky black argillite, slate, calcareous argillite, thin-bedded limestone and shale that are locally silicified, and considerable intrusive igneous material. Undoubtedly this group will be subdivided into a number of formations when it can be studied in detail, for it contains several rather distinct lithologic units. The country occupied by this group lies, however, in the high, rugged part of the Alaska Range, much of which is covered by perpetual snow and in which practically all the valleys are occu-

[13] Brooks, A. H., op. cit., fig. 8, p. 74.

pied by glaciers, so that it is difficult of access. The rocks of this group, furthermore, are all dark colored, so that close examination of exposures is necessary to determine their character.

In a general way it may be stated that this group is composed of argillaceous sediments, with minor amounts of coarser beds and with some thin-bedded limestones. These sediments include black blocky argillite and black slate, locally intimately interbedded with graywacke. Elsewhere the slate or argillite is calcareous and is interbedded with thin-bedded limestone. In still other places both argillite and limestone have been strongly silicified, much of the lime having been removed and replaced by secondary silica. Near the contacts with large bodies of intrusive materials all the sediments have been contact-metamorphosed, and the argillite has become a hard, massive, dense rock, filled with secondary minerals and locally mineralized by sulphides, chief of which is pyrite. It is in this group of sediments, at places near the borders of large granitic intrusive masses or where they have been intimately intruded by dikes and sills as offshoots from the larger intrusive masses, that most of the mineral deposits in this region occur. In certain areas, notably that just east of Muldrow Glacier in the vicinity of Copper Mountain, the volume of granitic intrusive rock injected into this group of sediments approaches that of the intruded sediments. Such places are shown on the accompanying geologic map by a conventional pattern. In other places, notably east and west of Hanna Glacier, the intrusive rock predominates in volume over the sediments, although a large amount of sedimentary material is included within the boundaries of the igneous mass. These areas also have been shown by a conventional pattern.

Structure and thickness.—Only the general structural features of this group of rocks have been worked out, but it is known that these beds have been deformed by mountain-building processes during at least two distinct periods and possibly more. One of these periods was probably late in Mesozoic time, and another occurred during middle or late Tertiary time. Each deformation resulted from folding, faulting, and tilting along approximately the present alinement of the Alaska Range. The beds now present a wide range of structure, which runs from steep monoclinal dips to great major folds upon which secondary smaller folds are superposed, the whole having been more or less complicated by faulting and locally by intricate intrusion. In the upper Toklat Basin this group of rocks, including the Middle Devonian limestone, which is in reality a part of the group, although it is mapped separately, dip steeply to the north beneath the Mesozoic greenstones and the Cantwell formation. No older rocks have been recognized in that locality. Farther west, in the basins of Herron and Chedotlothna Glaciers, these rocks overlie the older Tonzona schists but have been infolded with them. Throughout much of their area, in the rugged snow-covered parts of the range, the structure of this group has not been deciphered.

The complex structure of this group of beds renders difficult any estimate of its thickness, and the problem is further complicated by the fact that in no one locality were both the top and bottom of the group observed. Furthermore, there is generally a profound erosional unconformity between these rocks and the next younger formation with which they are in contact, an unknown thickness of the older group having been removed by erosion. Their wide areal distribution, however, and the great vertical relief of mountains composed wholly or in large part of these rocks indicate that the group must be at least 3,000 feet thick, and it may be much thicker.

Age and correlation.—The best definite evidence of the age of this great rock assemblage is that it includes materials that lie both above and below the limestone that has been assigned to the Middle Devonian. Logically this Middle Devonian limestone is a part of this group, but as it is a distinct lithologic unit and in places could be differentiated from the rest of the group it has been shown by a separate pattern on the accompanying geologic map. The beds beneath the limestone are obviously older than it and are younger than the Tonzona group. Probably they are in part of earlier Devonian age, though some may be as old as Silurian. Obviously also the beds that overlie the limestone are younger than it. The next younger formation in this region is the greenstone that on somewhat doubtful grounds is assigned to the Mesozoic. All that can definitely be stated about this group is that it includes rocks both younger and older than the Middle Devonian limestone, and the group as a whole is thought to be mainly of Paleozoic age. It is proper to note, however, that in lithology parts of this group closely resemble a great series of argillite, slate, and graywacke that is extensively developed on the southeast flank of the Alaska Range, in the Susitna Basin, and that is believed to be of Mesozoic age. Possibly a part of the rocks here assigned to the Paleozoic may be of Mesozoic age. No fossils have been found in these rocks, and fossils are likewise almost entirely absent from the Mesozoic slate and graywacke group of the opposite flank of the range. Further field studies will be necessary before the age limits of this rock group can be determined and before a positive statement can be made that it includes only Paleozoic terranes.

Middle Devonian limestone.—At several places in this region, notably at the headwaters of Toklat River and on either side of Hanna Glacier, there are exposures of massive limestone associated with black argillite, slate, and limy argillaceous sediments. In the Toklat Basin the limestone is interbedded with sedimentary rocks, and some small bodies of granitic intrusive material cut the sedimentary series. The limestone does not occur in a continuous band, as might be expected, but is interrupted by faults and has consequently a patchy distribution. Near Hanna Glacier the limestone and associated sediments have been so extensively intruded by granitic material that they now appear only as great lenses or irregular blocks completely inclosed by intrusive rocks. On the accompanying geologic map (pl. 2) the larger masses of limestone are shown in approximately their true position, but the innumerable irregular bodies of argillite, slate, and thin-bedded limestone that are included in the great intrusive mass are indicated only by a conventional pattern, for neither the scale to be used for the map nor the time available permitted their mapping in the field.

Everywhere, whether interbedded with sediments or inclosed by intrusive rocks, this limestone is crystalline and massive. Bedding planes are indistinct or unrecognizable. At the head of the main Toklat Valley the limestone is really a marble in shades of white, gray, or pale pink. Near Hanna Glacier it is gray to white on freshly broken faces, is completely recrystallized, and has much secondary calcite in veinlets and bunches. Weathered surfaces show evidence of some silicification. No trace of fossils was found in either locality.

The massive limestone in the upper Toklat Basin is much faulted and folded, so that its structure is obscure. The general strike of the faulted blocks is approximately parallel to the trend of the range and the dips are commonly steep. Although bedding planes were not observed in this crystalline limestone, the shape and position of the masses indicate a general northward dip of 70° or more. Because of the complex structure, which includes both faults and close folds, no reliable estimate of the thickness of this formation could be made. Here and there the thickness has apparently been increased by duplication through faulting, but certainly the formation has in places a normal thickness of several hundred feet. Near Hanna Glacier blocks and lenses of limestone that certainly are 400 feet or more thick are bordered by intrusive rocks, so that no measure can be given of their original thickness. These lenses, inclosed in diorite, have various orientations but in general strike southwest and dip at high angles.

No direct evidence of the age of this limestone was found in the present investigation. It is, however, certainly younger than the Tonzona phyllites and argillites, described above, and is older than the Cantwell. The best evidence of its age is that obtained by correlation with other limestones found both east and southwest of this area. In the Tonzona Basin Brooks[14] found a limestone that occupies a position in the range similar to that here under discussion and has similar geologic relations, from which Middle Devonian fossils were collected. Likewise Capps[15] found on upper Sanctuary Creek massive limestone that yielded Middle Devonian fossils. Both these localities are along the strike of the limestone here described, and in both places the limestone has similar geologic associations. Furthermore, no other massive limestone of known age occurs on the north flank of the Alaska Range in this region. There thus seems to be ample justification for correlating the limestone in the Toklat Basin and near Hanna Glacier with the Middle Devonian limestones that occur along the same strike both east and west of this region.

CANTWELL FORMATION

Distribution and character.—The Cantwell formation has an extensive areal development in the Toklat Basin and thence eastward to Nenana River. Farther west, in the region here considered, the Cantwell occurs in relatively small, irregular, and more or less isolated areas along the margin of the range, bordered on the southeast by Paleozoic sediments and granitic intrusive masses and on the northwest mainly by later Tertiary materials and glacial deposits. It is entirely possible, however, that the Cantwell formation may occupy considerable areas in the Kantishna-Kuskokwim lowland beneath the glacial materials and the younger Tertiary sediments.

The general characteristics of the Cantwell formation throughout its known extent on the north slope of the Alaska Range have been adequately described by Brooks[16] and Capps[17] and will be summarized here only briefly. The formation consists predominantly of coarse clastic sediments that grade from beds of coarse conglomerate which contain pebbles 6 inches or more in diameter through finer conglomerates and grits to coarse sandstone and thence into shales. Normally the basal part of the formation is composed of coarse conglomerate, and there is a tendency toward fewer coarse beds and more fine sediments higher in the section, though fairly coarse conglomerate beds occur at intervals far above the base of the formation. Above the prevailing coarse basal phase, which locally has a thickness as great as 200 feet, there is commonly an alternation of sandstone, grit, shale, and conglomerate, the individual beds ranging in thickness from a few inches to many feet. Many

[14] Brooks, A. H., op. cit., pp. 77–78.
[15] Capps, S. R., unpublished notes.
[16] Brooks, A. H., op. cit., pp. 78–83.
[17] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 37–44, 1919.

of the beds are somewhat lenticular, so that the section differs from place to place. The Cantwell sediments range from light gray in some of the conglomerate and sandstone to dark gray and black in the shale. The beds are well indurated and weather into rugged forms. The conglomerate especially is resistant, yields topographic forms of bold relief, and breaks down into coarse angular talus. The shale is much less resistant to erosion.

The Cantwell sediments were laid down mainly as subaerial lacustrine or estuarine deposits. No fossils have been found in this formation except plant remains, and the absence of all forms of aquatic animals indicates that the formation includes no marine sediments. Associated with the Cantwell formation there are in places abundant volcanic materials, including intrusive dikes and sills as well as lava flows and tuffs, that are in part interbedded with the Cantwell formation. These volcanic rocks, which include rhyolite porphyry flows and tuffs, andesite, and diabase, are in many places highly colored, the colors ranging from white and cream through light shades of pink, red, green, and purple to dark green, brown, red, and black, and they give the striking colors to the mountains of Calico and upper Teklanika Basins, to Polychrome Pass, and to the upper valley of Toklat River.

West of Muldrow Glacier, in the region here under discussion, the Cantwell formation likewise consists of conglomerate, sandstone, and shale, but it is here associated with volcanic tuffs and lavas that in places exceed in thickness the Cantwell sediments.

In the eastern headwaters of Clearwater Creek, just west of Muldrow Glacier, is an area of several square miles occupied by vari-colored volcanic rocks, mainly tuffs, but including also intrusive and flow phases. One conspicuous member of this assemblage is a black obsidian that weathers to an opaque green rock. This obsidian also appears at "Green Point," on the east side of Muldrow Glacier some 2 miles south of the Thorofare Creek bar. These volcanic materials overlie typical Cantwell conglomerate, sandstone, and shale. Farther southwest, at the lower ends of Straightaway and Foraker Glaciers, there is another large area in which the basal conglomerate and finer sediments of the Cantwell are overlain by a thick series of tuffs, flows, and intrusive rocks. Still farther southwest, in the basin of Tonzona River, are small isolated areas of Cantwell sediments that are relatively free from volcanic materials.

Structure and thickness.—In general the Cantwell rocks are less severely metamorphosed than either the Tonzona schists or the other Paleozoic sediments with which they are associated. The degree of metamorphism which they underwent depended, however, upon local conditions, and the result differs so greatly from place to place that no broad description is everywhere applicable. East of Broad Pass the formation grades from normal Cantwell sediments to stretched conglomerate and mica schist.[18] In the Toklat Basin the beds, though indurated, are generally found in broad open folds. Locally, however, they are intensely crumpled and plicated. On the headwaters of Clearwater Creek the Cantwell sediments and the associated volcanic materials are of fairly simple structure and are little metamorphosed. Their contact with the granitic rocks on the south is apparently a fault contact, and they are overlain unconformably by either the coal-bearing Tertiary beds, the Nenana gravel, or glacial deposits. In the basins of Straightaway and Foraker Glaciers the dominant structural feature is a great pitching syncline in which the Cantwell sediments lie unconformably upon Tonzona and post-Tonzona Paleozoic rocks and are themselves overlain with apparent conformity by a thick series of the associated volcanic rocks. The irregular outlines of the areas of Cantwell rocks in the Tonzona Basin are the result of faulting and infolding with the older rocks.

Age and correlation.—The only determinable fossils that have been reported from the Cantwell formation consist of a few collections of leaf imprints, although the finer sediments generally contain poorly preserved carbonaceous remains of sticks, twigs, and leaves. Most of these specimens have been determined to be of early Tertiary age. For only one collection was it suggested by the paleontologist that the age might be as old as Upper Cretaceous, but he considered this unlikely. The earliest age assignment for this formation was made by Brooks, in 1902, and his conclusion that the Cantwell formation was of Carboniferous age was based solely on lithologic grounds, for he found no fossils that he thought belonged in this formation.

The uncertainty in regard to the age of the Cantwell involves also the age of the coal-bearing Tertiary beds of the north slope of the Alaska Range. These coal-bearing beds, which have yielded abundant collections of plant remains, have been generally correlated with the Kenai formation of the Cook Inlet region, which is considered to be of Eocene age. Somewhat fragmentary collections from the Cantwell have also been doubtfully referred to the Kenai epoch. Yet on stratigraphic grounds the Cantwell formation is certainly to be considered as older than the coal-bearing Tertiary beds of the north side of the Alaska Range, and it was indurated, deformed, and eroded before the deposition of those beds. It would thus seem evident that either the Cantwell represents an earlier stage of the Eocene than the coal-bearing Tertiary beds, or else it is of Upper Cretaceous age, as has already been suggested. In view of the time interval represented by the deformation and erosion referred to above, it seems to the writer that the Cantwell may be

[18] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, p. 45, 1915.

as old as Upper Cretaceous, though in the lack of conclusive evidence it is here classed as Eocene on the basis of the paleontologic determinations now available.

The volcanic materials associated with the Cantwell formation may be considered of the same general age as the Cantwell, for the surface lavas and tuffs are interbedded with the sediments. In the region here described the main accumulation of the sediments now remaining took place before the chief volcanic activity occurred. Farther east, in the Toklat Basin, the bulk of the volcanic material occurs about in the middle of the Cantwell formation, and the major volcanism was preceded and followed by periods during which sediments were laid down with only a minor admixture of volcanic materials.

TERTIARY COAL-BEARING FORMATION

Character and distribution.—Coal-bearing sediments of Eocene age occur at intervals along the north flank of the Alaska Range from the Kuskokwim Basin to the Alaska-Canada boundary, also on the south side of the range, in the basins of Susitna River and Cook Inlet. In the Cook Inlet region these beds have been called the Kenai formation, and there is little doubt that the coal-bearing Tertiary sediments on the north side of the range are, in part at least, the equivalent of the Kenai, though the exact identity of the two formations has not yet been established, and the sediments on the north slope have as yet received no formation name.

North of the range this formation is best known and reaches its greatest development in the Nenana coal field, where the coals it contains have been mined for several years. Farther west, in the Toklat and Kantishna Basins and on the headwaters of the Kuskokwim, the Tertiary coal-bearing beds occur in small isolated areas on the flanks of the Alaska Range, and although their known surface outcrops are small it is quite possible that they may occupy considerable areas in the great Kantishna-Kuskokwim lowland, concealed beneath a mantle of glacial materials and stream gravel. It is to be expected that a more thorough examination of this region will disclose other outcrops of this formation in addition to those shown on the map (pl. 2).

Most exposures of the Tertiary coal-bearing beds show unconsolidated or only slightly indurated white to cream-colored sand, gray to blue-black clay, and fine conglomerate, with scattered seams and sticks of carbonaceous material and in places with lignite. The lignite is of fair grade, is brown to black, and occurs in beds ranging from an inch or two to 20 feet or more in thickness. In the region here considered this lignite has at present no value for shipment to outside markets, but it has been used locally for domestic purposes and may prove of great value in any mining developments that may take place in the district, especially in localities where wood for fuel is not available.

Occurrences of beds of the coal-bearing formation in Highway Pass and in the pass between Stony Creek and the southeast branch of Moose Creek reveal narrow synclinal basins in which there is an alternation of clay, sand, and gravel containing streaks of carbonaceous material and some considerable beds of a fair grade of lignite. A sloughed bank on the north side of Thorofare Creek, the small stream flowing west from Thorofare Pass, half a mile above its mouth, shows unconsolidated clay and considerable lignite. It is possible that there is at that place a lignite bed of workable thickness.

At the upper main forks of East Fork of Clearwater Creek a mud flow on a steep terrace face shows loose cream-colored sand with fragments of lignite that indicate the presence there of beds of the coal-bearing formation. Likewise on Coal Creek and on a fork of Clearwater Creek between Coal Creek and East Fork there are exposures of this formation. From the East Fork of Coal Creek rises a bluff 75 feet high consisting of tilted and folded beds of sand, shale, and gravel. The sand and shale are unconsolidated, but lenses of the gravel are consolidated so that they weather into coarse angular blocks. At this place there are bunches and beds of lignite as much as 6 inches thick. On the West Fork of Coal Creek several pits have been excavated on the weathered outcrop of a lignite bed. No coal in place was visible at the time of visit, but a large dump at one pit, consisting wholly of weathered fragments of lignite, indicates the presence of a considerable bed of lignite at that place.

No exposures of the coal-bearing Tertiary formation were seen between Coal Creek and Tonzona River, but Brooks[19] mapped two areas farther southwest, between Tonzona and Dillinger Rivers.

Structure and thickness.—The sediments that make up the Tertiary coal-bearing formation were deposited by streams at a time when the area now occupied by the Alaska Range was a region of low relief and of mature drainage, as is indicated by the sediments themselves, which are much finer than those now being carried by streams in the same area. The presence of thick lignite beds indicates that there were long periods during which the accumulation of vegetable remains could go on without being interrupted by the deposition of clastic sediments. The deposition of the coal-bearing formation was terminated by the beginning of growth of the present Alaska Range. The uplift of the mountains steepened the stream gradients, and as a consequence coarse gravel deposits—the

[19] Brooks, A. H., op. cit., pl. 9.

Nenana gravel—were laid down upon the finer coal-bearing sediments, which about this time were tilted and folded. With the continued growth of the range the streams deepened their valleys, and the unconsolidated Tertiary materials were rapidly cut away. Only in places where they were in some manner protected from erosion or where they were folded down below the level of the older hard rocks have the Tertiary sediments remained.

This formation is believed to be generally unconformable upon the underlying rocks. A direct contact between these rocks and the Cantwell has nowhere been observed, but the greater induration of the Cantwell and certain discordances of structure indicate an unconformity. Its structural relations to the younger Nenana gravel are not so well agreed upon. In some places there is a definite recognizable unconformity; in others there appears to be perfect conformity. It is likely that in some places the deposition of the Nenana gravel succeeded that of the coal-bearing formation without interruption, but elsewhere the coal-bearing beds were deformed and eroded before being covered by the Nenana gravel. Certainly the coal-bearing formation was in general involved in the folding, faulting, and uplift of the Alaska Range.

As only isolated bodies of this once widespread formation now remain, and as there is no assurance that the base of the formation at any place was deposited contemporaneously with the base at any other place, it is difficult to estimate the original thickness of the formation. The thickest known remnant is on Healy Creek, east of Nenana River, where a single section shows 1,900 feet of beds. Farther west the remnants of the formation are thinner, and it is doubtful whether in the region here described the formation ever attained so great a thickness. On upper Moose Creek several hundred feet of the formation is exposed. In the basin of Clearwater Creek less than 100 feet was seen at any one locality.

Age and correlation.—The age of the coal-bearing Tertiary formation of the north slope of the Alaska Range has been determined largely from the fossil plants that have been found in it and by correlation with similar beds of known age elsewhere. Plant remains are abundantly present throughout this formation but are commonly found only as lignitized sticks, stems, and imperfect and fragmentary leaf prints. In many places, too, where fairly perfect leaf impressions occur, they are found in incoherent sand and clay that crumble upon digging and are too fragile to be collected for later study and identification. For these reasons the collection of fossil plants from most localities is difficult. At a few places, however, leaf-bearing beds have been found in association with burned-out coal beds, and in the burning of the coal the adjoining clay beds have been baked to a hard, bricklike material, in which the leaf prints are still perfectly preserved. Collections from these places have been identified as definitely of Eocene age and have served to correlate the coal-bearing formation of the north flank of the range with the Eocene deposits of the Susitna Basin and the margins of Cook Inlet. The stratigraphic relations also show that the coal-bearing Tertiary beds are younger than the Cantwell formation and older than the Nenana gravel.

NENANA GRAVEL

Character and distribution.—The Nenana gravel comprises a series of elevated gravel deposits that are widely distributed along the north flank of the Alaska Range. They are extensively developed both immediately east and west of Nenana River, and the deposits in those localities have been described in such detail [20] that a brief summary will suffice here.

The term Nenana gravel has been applied to a thick series of unconsolidated or only loosely cemented material, consisting for the most part of beds of well-rounded, rather coarse gravel, with subordinate beds and lenses of sand. Pebbles the size of cobblestones are common, though there is much finer gravel, and in some places boulders a foot or more in diameter were seen. The pebbles include a wide range of rock types, and the percentage of pebbles of various types differs greatly from place to place. In the aggregate all the older hard-rock formations of the Alaska Range are represented, though, as is to be expected, the harder materials such as quartz, quartzite, conglomerate, and various kinds of igneous rock predominate over the softer and more easily destroyed sedimentary rocks.

A characteristic feature of the Nenana gravel is its yellow or buff color, which indicates that the gravel is old enough to have been rather thoroughly oxidized, whereas the deposits of the last glaciers and of the present streams that in many places overlie the Nenana gravel are gray and little oxidized.

The Nenana gravel, being unconsolidated, yields readily to erosion by glaciers and streams, and the surface forms developed on it by erosion are generally of smooth outlines and gentle slopes, so that good exposures are not common. As a consequence of its smooth surface forms and the mantle of soil and vegetation by which much of it is covered, some areas of this gravel can not be distinguished from certain glacial deposits, and the Nenana gravel may therefore have a wider distribution than is shown on the map.

[20] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 30–34, 1912; The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 51–57, 1919.

In the region here described the Nenana gravel was distinguished and mapped at only a few places. In the basin of Thorofare Creek, north and northeast of Copper Mountain, there are some small ridges and benches of old gravel that are evidently remnants of what was formerly a much more widespread deposit of this material. The basin of Clearwater Creek has considerable areas of Nenana gravel, as shown on Plate 2, and no doubt this formation has a considerable development farther southwest but is generally concealed beneath the prevalent mantle of glacial materials.

Structure.—That the Nenana gravel is a stream deposit is indicated by the character and composition of its materials and by the distribution of the formation. There is no evidence that this region has been generally submerged since Mesozoic time, as all the Tertiary materials, including the Cantwell formation, the coal-bearing formation, and the Nenana gravel, were laid down by streams during periods when the surface stood above sea level. The prevailing coarseness of the Nenana gravel in contrast to the comparative fineness of the sand and clay of the next older coal-bearing formation indicates a renewed uplift of the Alaska Range after a period of relative quiescence, during which the relief of the region was moderate. It is believed that in this uplift the axial portion of the range was elevated enough to give the northward-flowing streams steep gradients, so that they could transport coarse material, but that the areas now occupied by the gravel were still north of the uplifted area. After the deposition of the gravel, locally to a thickness of nearly 2,000 feet, the uplift of the range became more extended and involved the areas earlier covered by the gravel deposits. The gravel and the underlying coal-bearing beds were raised and warped into folds that lay parallel with the mountain axis. During these later stages of uplift and since the elevation of the range to about its present height and area erosion by streams and glaciers has been active, and the loosely coherent gravel has been deeply dissected. From some areas which it formerly covered it has been entirely removed.

In general the Nenana gravel is believed to lie conformably upon the coal-bearing formation in those sections where both are present. Where the coal-bearing beds are absent the gravel lies unconformably upon some of the older formations. Locally what appears to be normal Nenana gravel is unconformable upon the coal-bearing formation, but this can be explained if the gravel so found is considered to represent not the base of the Nenana formation but some higher portion, for the coal formation in places was doubtless involved in the mountain-building movements and eroded during early Nenana time and was covered with gravel later in the Nenana epoch. Certainly in many localities there is apparent conformity between the coal-bearing beds and the overlying Nenana gravel, even though both have been folded and tilted together. It may be said that in general the Nenana gravel is deformed equally with the coal-bearing formation where both occur.

Age and correlation.—From the facts cited it is shown that the Nenana gravel is younger than the coal-bearing Tertiary (Eocene) and older than any glacial deposits that have been recognized in Alaska. Certainly it is older than the deposits of Wisconsin age, and it is probably also older than the pre-Wisconsin glacial deposits. Brooks,[21] who traversed this region in 1902, grouped this gravel with the glacial deposits and considered them all to be of Pleistocene age. As a result of field studies in 1910, the writer gave this formation its name, and considered it to be of Miocene or Pliocene age.[22] Later studies, conducted through three field seasons and extending from Tonzona River eastward to Delta River, have convinced him that the Nenana gravel antedates by a considerable time all the known glacial deposits of the region and that the gravel was deeply oxidized and extensively eroded before the first recognized Pleistocene ice advance. Furthermore, the conformable relations observed at many places between the coal-bearing Tertiary beds and the gravel and the similarity in the extent of the deformation suffered by these two formations indicate that the gravel deposition began soon after the completion of the coal-bearing series and may well have ended the laying down of those finer sediments. The gravel has yielded no fossils upon which an age determination could be based, but the writer believes it to be certainly of Tertiary age and probably almost as old as the coal-bearing formation.

QUATERNARY DEPOSITS

PREGLACIAL CONDITIONS

The area now occupied by the Alaska Range has been the scene of mountain-building movements at intervals since very early geologic time. Our information concerning the climate of this region during these ancient times is meager, but it is probable that during those periods in which the mountain range stood at a considerable altitude there were glaciers in the higher valleys, as there are to-day, and that in the intervening periods when the mountains had been worn down to moderate or low relief the glaciers disappeared. The plants that flourished in early Eocene time give evidence of a temperate climate. The uplift of the present Alaska Range began in Eocene time and has probably been renewed intermittently to this day.

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[21] Brooks, A. H., op. cit., pp. 108–109.

[22] Capps, S. R., The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 30–34, 1912.

GLACIAL CONDITIONS

OLDER GLACIATION

In the beginning of Pleistocene time, when the range had reached approximately its present height and area, a progressive change in climate began, which included a gradual lowering of the mean annual temperature and probably also an increase in precipitation. The mountain glaciers began to expand in area and thickness and to push farther down their valleys. Tributary glaciers joined those in the main trunk valleys, and the ice streams pushed outward to and beyond the mountain front and onto the piedmont plain. After this first great encroachment of glacial ice there were several successive withdrawals and readvances of the ice, marking several stages of glaciation during the glacial epoch.

The complete history of early glacial time in Alaska can not yet be written, if ever, for during the last great glacial advance the vigorous ice streams, moving out into the areas that had earlier been glaciated, recarved the valleys and overrode the existing glacial deposits and thus destroyed much of the evidence of earlier ice advances. There is, however, on the north slope of the Alaska Range definite evidence that there was at least one major ice advance in Pleistocene time that took place before the last great advance of which we have such abundant evidence.[23] In the northern United States and in Canada there were several distinct epochs of glaciation separated by periods of ice withdrawal, and it is quite likely that in Alaska also there were at those times corresponding glacial fluctuations. There is little doubt that the last glaciation in Alaska corresponds with the most recent or Wisconsin stage of glaciation in the United States.

LAST GREAT GLACIATION

There is abundant evidence to indicate the vigor and extent of the Alaskan glaciers during their last great advance, and the general distribution of glacial ice at that time is known, though many details still remain to be worked out. For the part of Alaska here considered the most striking feature of this distribution is the great difference in the areal development of the glaciers on the opposite sides of the Alaska Range. On the southern or Pacific slope the entire area between the crest of the Alaska Range and the coast, except a few of the loftiest peaks and mountain ridges, was buried beneath a huge ice field. On the north slope the glaciers pushed outward only a few miles beyond the mountain front, and a great area in the basins of Tanana, Yukon, and Kuskokwim Rivers was not then nor, so far as we know, at any earlier time invaded by glacial ice. This

[23] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 59–60, 1919.

great difference in ice development on opposite sides of the range can not well be accounted for by assuming a difference in the mean annual temperature of the two regions but is almost certainly due to a difference in the precipitation. It is likely that then, as now, the mountain range acted as a barrier to the moisture-laden winds from the Pacific, and that the moisture was chiefly dropped on the south side of the range, so that the interior region had a comparatively arid climate. A further factor favoring the greater development of the glaciers on the south slope is the asymmetrical position of the divide peaks, which lie much closer to the north front than to the south front of the range. The glaciers that were tributary to the Susitna Basin, therefore, had great headward basins in the high mountains, whereas the high portions of northward-draining valleys are in general short and small.

The extent of glaciation on the north flank of the Alaska Range from the Kantishna region eastward to Delta River has already been described.[24] In the region here treated no accurate mapping of the outer edge of the glaciated area has been done, for the ice extended out into the alluvial lowlands, which in summer are marshy and which lie outside the region of principal concern in the present investigation. It is known, however, that Muldrow Glacier, which is much the largest glacier on the north slope of the range, pushed northwestward at least 30 miles beyond its present terminus, overflowed the divide between McKinley Fork and upper Moose Creek, and sent at least small ice lobes both down Moose Creek and into Stony and Boundary Creeks. Wonder Lake lies in a glacial basin excavated by the ice that moved northward into Moose Creek. The outer limits of this glacier on the northwest have not been defined, but it probably terminated in some such way as is indicated on the geologic map. (Pl. 2.)

West of Muldrow Glacier the mountain front, at the time of the last great ice advance, was bordered by a piedmont ice sheet formed by the coalescing of a large number of valley glaciers whose terminal lobes expanded laterally as the ice streams emerged from the confines of the narrow alpine valleys. This piedmont ice sheet extended outward into the lowland for an average distance of 12 or 15 miles from the mountains. The present surface of the area that was covered by this ice sheet is now marked by large and small boulders, by deposits of glacial till, and by many ponds and lakes. The great lowland of Kantishna and Kuskokwim Rivers farther northwest is believed to have escaped glaciation not only during the last great advance but also during previous stages. So far as is known, the area between

[24] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 56–64, 1919; The Bonnifield region, Alaska: U. S. Geol. Survey Bull. 501, pp. 34–39, 1912.

the Alaska Range on the south and the Brooks Range north of the Yukon has never been invaded by a continental ice sheet and has never been occupied by glacial ice except by a few small valley glaciers that formed on the slopes of isolated mountains.

The existing glaciers in the part of the Alaska Range here described show evidence of rather recent retreat and shrinkage. Muldrow Glacier, although still vigorous, nevertheless has an area at its lower end where for several square miles the ice appears to be melting faster than it is replaced by movement from above. Hanna, Foraker, Herron, and Chedotlothna Glaciers are all in retreat. Straightaway Glacier and the many glaciers tributary to Tonzona River show less evidence of recent shrinkage.

From the indications of recent retreat here and elsewhere in Alaska the inference has often been drawn that the Alaskan glaciers are all shrinking and are on their way to complete disappearance. This conclusion is not justified. There is abundant evidence that many glaciers are as large now as they have been at any time for several centuries, and others have shown important recent advances. The vigor of each glacier is largely determined by the conditions of snowfall and of melting within its own basin, and unequal distribution of the snowfall in any year or series of years may cause some glaciers to advance and others to retreat. The terminus of any glacier is likely to oscillate within certain limits over a period that may seem long as measured in the lifetime of a person, but a period of retreat for any given group of glaciers is likely to be followed in time by a period of readvance.

PRESENT STREAM GRAVEL

The gravel deposits along the present streams, indicated on the accompanying map (pl. 2), have been laid down under conditions essentially like those that now exist in this region. These deposits include only those that occupy the flood plains of the present streams and are subject to overflow in times of flood; as a consequence they appear on the map as long, narrow bands that follow the irregular courses of the streams.

Except Clearwater Creek, a headward tributary of McKinley Fork of Kantishna River from the south, all the larger streams head in glaciers and in consequence are heavily charged with sand, gravel, and mud during the summer season of glacial melting. A part of this load of detritus is deposited along the stream flood plains, building up wide flats of bare gravel and sand, through which the streams flow in many branching channels. The coarser gravel and sand is deposited near the glaciers; farther downstream, where the material being transported consists of finer gravel and mud, the rivers deposit less material, have narrower flood plains, and show much less tendency to branch out into many small channels.

IGNEOUS ROCKS

Igneous rocks occupy large areas within this region and are of wide range in both composition and age. Igneous activity has taken place here at intervals from the pre-Ordovician to the Tertiary, and the only formations that do not contain intrusive or extrusive igneous materials are those of late Tertiary, Pleistocene, and Recent age. The oldest igneous rocks that have been recognized are certain basic greenstones and serpentines that are associated with the Birch Creek schist and have been metamorphosed along with the schist. If these rocks were originally lava flows, as appears likely, they were extruded during the laying down of the sediments that are now altered into schist and so are contemporaneous with the schist and of pre-Ordovician age.

The Tonzona group of sediments is associated and in part interbedded with rocks that were originally rhyolites, rhyolite porphyries, and tuffs but now have been altered into schist. These igneous materials are much less abundant in the region here described than they are farther east in the vicinity of Nenana River, where they have received the name Totatlanika schist.

The most intense igneous activity in this region took place during Mesozoic time and resulted in the intrusion of granitic rocks in large volume and in extensive flows of basaltic lava. The exact periods during which these granitic rocks were intruded and the lavas poured out have not been determined, nor has it been positively learned which were the earlier. Both the granitic rocks and the greenstones cut the great series of sediments here classified as post-Tonzona Paleozoic rocks and are certainly younger than the Paleozoic. Correlation with periods of igneous activity elsewhere in Alaska leads to the suggestion that the main period of volcanism represented by the greenstone flows here was probably in early Mesozoic time, whereas the intrusion of the granitic rocks probably occurred in Jurassic time, or even later in the Mesozoic.

Although basic dikes and sills are present here and there throughout this area, in most places their extent is too small to be shown on a map of the scale of Plate 2. In the upper basin of Toklat River, however, and northwest of Thorofare and Highway Passes there are considerable areas of greenstone that shows flow structure and was therefore poured out upon the surface as lava. The greenstone is apparently more than 2,000 feet thick, ranges in color from dark green to dark brown and deep purple, is commonly amygdular, and in places shows ellipsoidal structure. It lies unconformably beneath the Cantwell formation and appears to be unconformable upon the Paleozoic sediments. No fossils have been found in it, and it is here tentatively assigned to the Triassic.

Granitic rocks, including granite, monzonite, and diorite, are important elements in this part of the Alaska Range. (See pl. 2.) They occur in two large and several smaller areas. One area extends from Muldrow Glacier southwestward to Straightaway Glacier in a belt that is 3 to 4 miles wide and is extended northeastward by a number of smaller outliers. In places the northwest boundary of this granitic belt is a nearly straight line that suggests a fault contact. Elsewhere the main intrusive mass includes increasing quantities of sedimentary materials as its edge is approached until locally the sediments predominate, though cut by great quantities of granitic dikes and sills. This is especially true near Copper Mountain and northeast and southwest of Hanna Glacier.

The second large area of granitic rocks extends from the west base of Mount McKinley southwestward to Mount Russell. Although the presence of granitic rocks in this area is definitely known from the morainal material brought down by the glaciers, and although even at a distance of several miles the granitic areas could be distinguished from the dark-colored bordering sediments, nevertheless these rocks lie in the rugged and almost inaccessible portions of the range, and the writer nowhere actually examined them in place. The part of the range in which they occur is largely unmapped, and the boundary between the granitic materials and the Paleozoic sediments, as shown on Plate 2, is an approximation only. It is certain, however, that they extend southwestward beyond the crest of the range and onto the Susitna slope, for the glaciers on that slope carry great quantities of granitic materials on their surfaces. It is probable that the ability of these hard, crystalline rocks to resist erosion is in large part responsible for the great height of the crest-line peaks in this part of the range.

No definite evidence of the age of the granitic intrusions was obtained in this investigation other than that they cut and are therefore younger than the Middle Devonian limestones and are overlain by and are therefore older than the Cantwell formation. Similar granular intrusives occur in places throughout the Alaska Range and in neighboring regions in the Susitna Basin. In the eastern Talkeetna Mountains their stratigraphic relations show that similar granitic rocks cut Lower Jurassic beds and were intruded before late Middle Jurassic time. On the basis of correlation with these intrusives of the eastern Talkeetna Mountains, a correlation that is admittedly open to question, the granitic intrusives of the region here under consideration are tentatively assigned to the late Lower Jurassic or early Middle Jurassic, but they may be in part as young as Upper Cretaceous.

The next notable igneous activity after the intrusion of the granitic rocks took place during Cantwell time. The deposition of the early coarse clastic sediments of the Cantwell formation was interrupted by a period of volcanism during which a thick series of lava flows and of fragmental volcanic material accumulated in this region. In places this material consisted mainly of rhyolite and andesite lava flows. Elsewhere it was composed largely of fragmental material ejected from volcanoes, and this formed thick beds of tuff interbedded at intervals with flows. Just west of Muldrow Glacier, in the headward basin of Clearwater Creek, several thousand feet of varicolored tuff, with some andesite flows in red, brown, pink, and gray and beds of glossy black obsidian, occupies an area of several square miles. Similar rocks also occur along the lower valleys of Foraker and Straightaway Glaciers, farther west. Included in these volcanic materials are minor quantities of sedimentary rock, deposited during the intervals between volcanic outbursts. At a few places dikes and sills cut the Tertiary coal-bearing formation, and some tuffaceous material is present, but in general it may be said that since the Cantwell epoch there has been little igneous activity in this part of the Alaska Range.

ECONOMIC GEOLOGY

No productive mining has so far been done in the region here under discussion, though several lodes carrying silver, gold, lead, and copper have been staked, and some development work has been done. In the Kantishna district, however, just north of this region, placer mining has been conducted on a moderate scale each year since 1905, and the total output of placer gold to the end of 1925 has been about $556,000. Recently considerable attention has been given to the lode deposits of the district. A large number of lodes have been staked on quartz veins carrying silver, gold, and lead and other lodes carrying promising bodies of antimony ore. One group of claims on Friday Creek has yielded a considerable quantity of high-grade silver ore, though no systematic mining has been done. All the lode prospects and mines of the Kantishna district are on veins that cut the Birch Creek schist. The schist in this area occurs only at the northern margin of the Toklat-Tonzona region and has not been found in the Alaska Range south of the Kantishna district. All the prospects now known along the northwest front of the Alaska Range from Muldrow Glacier southwestward to the basin of Tonzona River lie along the margins of granitic intrusive masses, either in the intrusive itself or in the invaded sediments near the granitic rocks. Furthermore, rather close prospecting has failed to disclose the presence of placer gold in encouraging amounts. The absence of placer gold, however, does not necessarily mean that gold-bearing lodes are not present. Glacial erosion during the last period of glaciation was so severe in the mountains that any alluvial deposits that may have contained placer gold must have been removed and scattered, and north of the mountain front the great quantities of glacial débris would have buried any stream-channel deposits that escaped glacial scour. The chance of finding extensive gold placers in this region is rather slight, although it is possible that if preglacial placers existed here small areas of them might have been preserved by some unusual combination of circumstances.

At Copper Mountain, just east of the end of Muldrow Glacier, is a mineralized area that has attracted considerable attention. It was discovered in 1921 by O. M. Grant and F. B. Jiles, who staked 23 claims on the north slope of Copper Mountain between Muldrow Glacier and Thorofare Creek. The country rock consists of a series of calcareous and siliceous argillites and siliceous limestone intimately intruded by granitic dikes and sills, the intrusive material locally equaling or exceeding in volume the intruded sediments. The sedimentary beds are unfossiliferous, and their age is not certainly known, but the best available evidence indicates that they are Paleozoic. The sediments are much altered and silicified, probably as a result of the intrusion of the granitic material. The geology is complex and has not been worked out in detail, but it is known that in addition to the intricate and irregular distribution of the intrusive rocks there has been considerable faulting at more than one period.

The metallic minerals, which were no doubt introduced as a result of the igneous intrusion, include the sulphides of zinc, lead, iron, and copper, with a varying content of gold and silver. The ores have replaced the calcareous sediments and occur as vein fillings in both the sediments and the granitic intrusives. Sphalerite is much the most abundant sulphide and occurs as massive aggregates almost free of other sulphides or gangue, as a mixture in various proportions with galena or with both galena and chalcopyrite. The sphalerite, where unaccompanied by lead or copper sulphides, is said to carry only a minor content of gold and silver. The galena, by contrast, commonly carries much silver, and assays have been obtained that show more than 200 ounces of silver and $6 to $17 in gold to the ton. The outcrops that show the most copper are on the Caribou and Denver claims. Elsewhere the lead and zinc sulphides predominate.

By the fall of 1925 little more than assessment work had been done on these claims, and except one 90-foot tunnel, all the development work consisted of open cuts, trails, and a camp. There is no doubt that Copper Mountain is extensively mineralized, but the work so far done is inadequate to demonstrate whether or not there are sufficiently large bodies of high-grade ore on it to make mining profitable at present.

A group of claims has been staked by John Anderson on the east side of Thorofare Creek, east of Copper Mountain, on what is reported to be a large body of sphalerite with some galena. Assays are said to show mainly zinc and lead, with only minor quantities of the precious metals.

In the region southwest of Muldrow Glacier a number of lode claims have been staked, principally by H. Carlson and "Slim" Averil. As reported by the owners, most of theses claims are on mineralized lodes that lie near the northern margin of the great granitic intrusive mass and are probably of the same mode of origin as the lodes near Copper Mountain. The principal metals are said to be lead, silver, and copper. No one was on these properties at the time the writer visited the region, and as only assessment work has been done on them he was unable to find most of them. It may be said, however, that all along the margin of the granitic intrusive masses there is widespread evidence of mineralization, mostly by iron sulphide, and it seems quite possible that there may be localities where the more valuable sulphides of lead, zinc, and copper, as well as gold and silver, may be present in sufficient quantity to justify the development of mines, if better transportation becomes available. As has already been stated, the region is at present so difficult of access that only very high grade ore could be mined at a profit.

Aside from those on Copper Mountain, the only lode claim in this region on which any considerable development work has been done is the J and K claim, on Boulder Creek, a stream that joins Chedotlothna River from the south, some 10 miles below Chedotlothna Glacier. The J and K claim, staked in July, 1923, by F. B. Jiles, Ed Knudson, and Jo Cators, lies on the east side of Boulder Creek, about half a mile below the glacier in which that stream heads. The mineralized rock on which prospecting was done occurs in a group of sediments that include blocky slate and argillite, as well as thin-bedded siliceous limestone and chert, probably all of Paleozoic age, that occur in a narrow belt bordered on the north by older Tonzona schist and phyllite and on the south by a mass of granitic intrusive rocks. The area of greatest mineralization lies about 250 yards from the contact of the argillite-slate-limestone group with Tonzona schist, and about a quarter of a mile from the granite contact.

The principal development work on this property consists of an open cut 25 feet long, with a 12-foot face, having a 12-foot shaft in its floor at the edge of the stream bars, and a trench on the bench some 30 feet vertically above the shaft and 40 feet west of it. Practically the entire open cut, the shaft, and the trench are in a body of siderite (iron carbonate), and the dump is composed largely of this material. The lode strikes about N. 80° W. and stands almost vertical. In the cut and on the dump the metallic minerals recognized in addition to the abundant siderite are arsenopyrite, pyrrhotite, pyrite, chalcopyrite, sphalerite, galena, malachite, and coatings of manganese oxide. It is reported that the chief encouragement to the owners was a thin vein of galena bearing much silver, but this was apparently all removed in prospecting. Polished sections of the ore examined under the microscope show that the siderite, now much the most abundant of the metallic minerals, was introduced later than the sulphides. Tetrahedrite has been reported from this property, but none was seen in either the hand specimens or the polished sections.

Some 200 feet southwest of the main workings a 10-foot tunnel discloses a zone of sulphides, mainly arsenopyrite, lying parallel to the vertically dipping bedding. The country rock consists of sedimentary beds that show thorough secondary silicification, and a granitic dike 50 feet thick cuts the sediments some 100 feet southeast of the tunnel.

The general conditions of mineralization at this property are strikingly like those at Copper Mountain, except for the presence of abundant siderite and pyrrhotite. What were once presumably calcareous sediments are cut by granitic dikes that have silicified the sediments and introduced a similar suite of sulphides to that generally found near the borders of granitic intrusive rocks in this region.

It is reported that the streak of rich silver-bearing galena on this property pinched out and that the claims have been abandoned by the original stakers.

In the existing situation in regard to transportation to Copper Mountain and to points farther southwest along the Alaska Range only ore of very high grade can be profitably mined and shipped. On a recent shipment of about 30 tons of ore from the Kantishna district to the smelter at San Francisco transportation charges alone were more than $70 a ton. This ore traveled about 20 miles by sled and the rest of the way by river boat, railroad, and steamship. Transportation to Copper Mountain will be improved on the completion of the wagon road from the railroad at McKinley Park station, now under construction by the Alaska Road Commission, but even with a wagon road an expensive haul of some 60 miles to the railroad will remain. Unless considerable bodies of high-grade ore are found or unless supplies of lower-grade ore large enough to justify a branch line of the railroad are developed, the remote situation of this district will impose a severe handicap upon lode mining. With the possible exception of Copper Mountain, the ore reserves of which have not yet been determined, no lode deposits of sufficient size to justify a railroad to this region have yet been found.

GEOLOGIC INVESTIGATIONS IN NORTHERN ALASKA

By Philip S. Smith

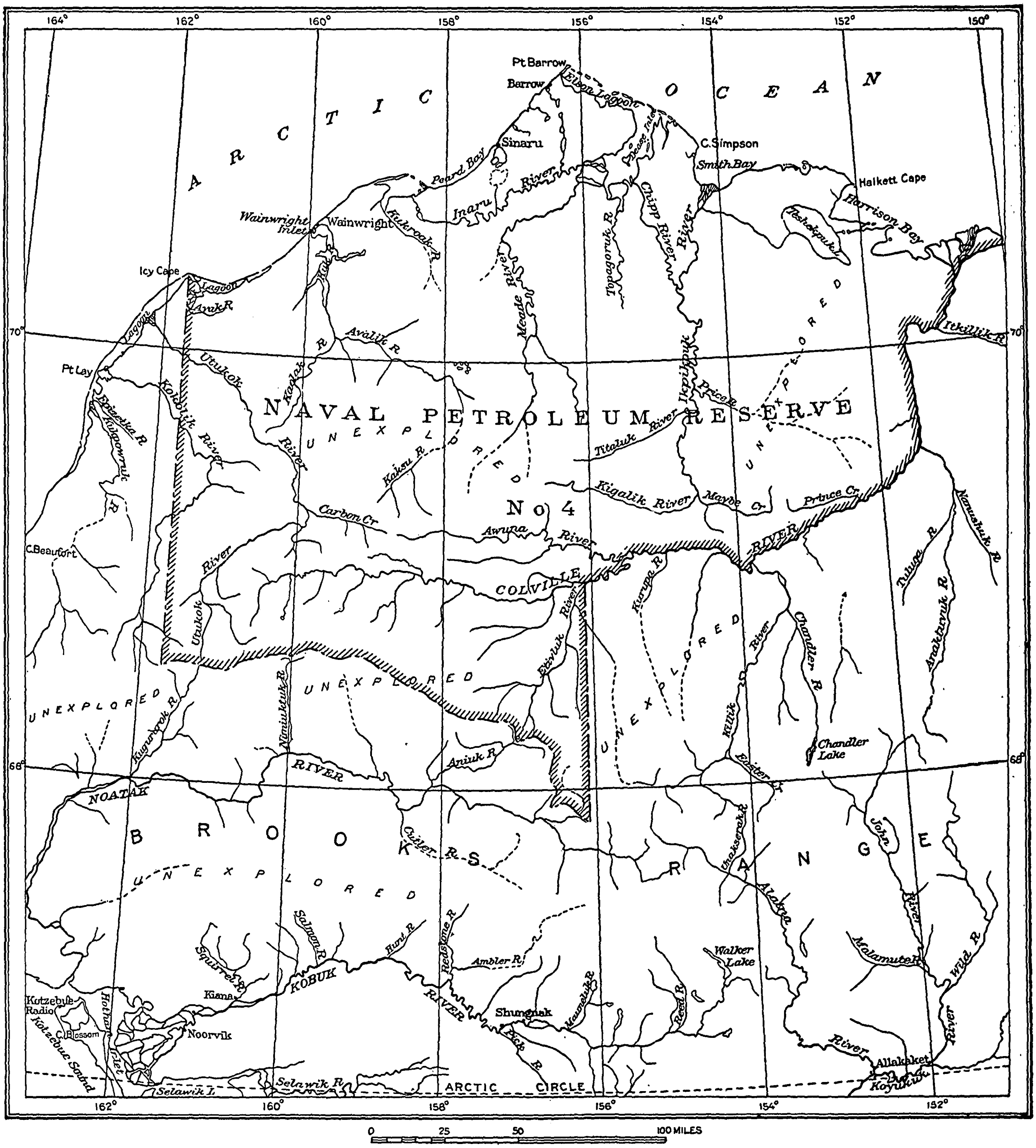
NARRATIVE OF THE EXPEDITION

Geologic investigations in naval petroleum reserve No. 4 were continued in 1925 by a party in charge of Gerald FitzGerald, topographic engineer, with Walter R. Smith, geologist. This party left Washington February 20 and Seattle February 28 and arrived at Nenana, on the Alaska Railroad, March 10. At this place W. R. Blankenship and Fay Delezene, who were to assist in camp duties, joined the party with two dog teams and the necessary equipment for the trail. The party left Nenana March 13 and made the trip along the Nenana-Nome mail trail to the head of Norton Bay and thence to Kotzebue, a distance of about 725 miles, at an average rate of more than 27 miles a day. At Kotzebue necessary supplies and equipment were obtained, as the party would be unable to purchase additional supplies until they returned to the coast in the fall. Several natives and their dog teams were hired to help in freighting some of these supplies into the mountains which form the southern boundary of the reserve and at which the new work of the season was to start.

Leaving Kotzebue on April 15, the party went northward up Noatak River to the Kugururok (see pl. 4), a tributary from the north that enters near longitude 162° W. Topographic surveys were started from landmarks a short distance above Kugururok River, near the canyon of the Noatak, that had been located by C. E. Giffin on an earlier survey, and geologic observations were made so as to tie the new work to that done by Philip S. Smith in 1911.

The party pushed up the Kugururok until the later part of April, when a pass across the mountains was found that led to the drainage basin of the Utukok, a stream on the north side that empties into the Arctic Ocean near Icy Cape. From then on every effort was made to move the camp supplies forward so that they would reach the drainage basin of Colville River before the ice on that stream broke in the spring and at the same time to survey as large a tract of the adjacent territory as possible. Both objects were successfully accomplished. A low pass from the Utukok to the Colville was found, and all supplies placed far enough down the Colville to permit the use of canoes when that stream became free of ice. One of the canoes used by the party had been hauled in from Kotzebue with the other supplies. The second canoe was one that the Geological Survey party under W. T. Foran had been forced to abandon on the Utukok the previous year, when they encountered unexpectedly difficult and long portages.

The ice on the Colville broke so that a canoe was used on May 30, the same date that Killik River, the tributary of the Colville on which the expedition of 1924 made its winter headquarters, had broken the year before. With the opening of the river dog-team work ceased for a while, and the party worked downstream, making numerous back-packing trips into the country 20 miles or more from the river and thus widely extending the area covered by the surveys. On one of these side trips the headwaters of Kaksu River were mapped. This stream is possibly one of the heads of Meade River, but its position is such that it may turn and enter the Ketik or Avalik, which flows into the Kuk, so that further exploration will be required before its true course can be fully determined. During these trips north of the Colville more of the basin of Awuna River, whose lower part was ascended by one of the parties of the expedition of 1924, was mapped. In this way and dropping successively downstream, the party descended the Colville to Etivluk River, a tributary from the south which enters the Colville near longitude 156° and whose lower course was traversed by the Survey party in 1924. At this point, which was reached July 12, junction was made with the surveys of 1924, which had covered most of the eastern part of the basin of the Colville as far east as its tributary the Anaktuvuk. The party under FitzGerald therefore turned southward, ascending the Etivluk and mapping the country on both sides of the stream. During this upstream journey dogs were used with good effect hauling on the tow lines of the boats. By July 25 the party had reached a portion of the stream so small that each day it seemed likely that only a little more progress could be made with the boats. The rainy weather, however, kept the stream at a good stage of water, and by the occasional use of a shovel to widen out narrow points in the channel, the boats were successfully worked upstream. Above the camp of July 27 the stream was little more than a gully cut through the turf, just wide enough for the canoes to pass through and with very little current. This character continued for several miles, to a point 3 miles above the camp of July 28, where the stream was found to issue from a lake about 1½ miles in diameter. This lake proved to be situated almost precisely on the divide between the Colville and



SKETCH MAP OF NORTHWESTERN ALASKA

the Noatak, and a portage of about 1,000 yards from its south end brought the party to a stream tributary to Aniuk River, which flows into the Noatak a little west of longitude 158°. The Aniuk was followed down without much difficulty to its mouth, which was reached August 11 and where the surveys were tied with those made in 1911 by Philip S. Smith and C. E. Giffin.

The party quickly dropped down the Noatak, making practically no stop except for camp at night, and arrived at Kotzebue August 22. Here connection was made with the *Boxer*, and through the courtesy of the Bureau of Education the party was taken to Nome, where, after less than a day's delay, it obtained passage on one of the boats running between Nome and Seattle.

Throughout the region north of the Noatak spruce and other large trees are entirely absent. In fact, the most northern spruce in the region was seen on the Kugururok near latitude 68°, and no spruce was found on the Noatak or any of its northern tributaries east of the Nimiuktuk. In the valleys north of the mountains willows grow at sufficiently close intervals so that with care they can be relied on as a source of camp fuel for small parties of travelers. The area more remote from the streams is covered with grass, lichens, moss, and prostrate bushes. Flowers are nearly everywhere abundant.

Game was found abundantly in the northern part of the area traversed. In the mountains are sheep, and in the plateaus and lowlands north of them caribou was the main source of meat. Fish, principally grayling, were caught in the Colville and Noatak and many of their tributaries. Doubtless they live in many of the other streams, but these were the only ones that were traversed during the season of open water. Birds were also abundant—ptarmigan in the higher country and water birds, such as geese and ducks, in the lower country. Only one bear was seen, and signs of bear were not at all common. Some red fox live in the region, but they did not appear to be nearly as numerous as in the similar region to the east. Natives from the Noatak often go into the Utukok for trapping.

No people live in the region traversed by the party in 1925 after leaving Noatak Mission, on lower Noatak River. Signs of former human visitation were seen at a number of places, but they were made by nomadic parties on trapping expeditions or traveling through the country and did not seem to indicate very long sojourn at any single locality.

TOPOGRAPHIC RESULTS

As a result of these explorations an area of about 6,500 square miles of hitherto unknown country was mapped with the degree of accuracy required by reconnaissance exploratory standards. A much larger area was observed so that its general aspects are known at least sufficiently well to be of considerable assistance in planning further work in the region. Although in general the work is counted as of exploratory standard, most of it was really done in much greater detail. In effect practically all of the topographic work was executed by plane-table and micrometer-traverse methods on a field scale of 1:180,000, though the map which is in course of preparation is being drawn up for publication on a scale of 1:500,000. At frequent intervals during the work observations for latitude and azimuth were made with a transit. When computed these observations coincided with the positions determined by the other methods very closely. The position of the mouth of the Aniuk as determined by this survey coincided so closely with that previously determined by Giffin that probably few points are more than a mile out of position east and west and probably not as much as that north and south. During the winter the novel expedient was used of making the micrometer bases of snow, and placing a colored piece of cloth on the face toward the point from which the next observation back on these bases was to be made. This expedient was resorted to because it was necessary to make signals in a region where timber is entirely absent and where even good-sized bushes are extremely rare, except in the valley bottoms near the streams. It may be of interest to note that a number of the low station marks made of brush and used as micrometer bases by the party that surveyed the Noatak in 1911 were still standing. Elevations were determined throughout the area surveyed, and the relief was sketched with 200-foot contours. The same major topographic division was noted in this region as had been reported in the country farther east—namely, a mountain mass whose higher peaks rise to heights of 4,000 to 5,000 feet above the sea and a rolling plateau country north of the mountains whose summits are usually not much more than 2,000 feet high. The streams have carved rather deep, narrow valleys in the mountains, some of which have evidently been the sites of glaciers in the past, although no glaciers exist there now. In the plateau region the streams flow in beds sunk several hundred feet below the uplands, but the slopes are fairly smooth, and rocky ledges usually crop out only close to the valley floor or on the summits of the ridges.

GEOLOGIC RESULTS

The principal geologic result of the expedition was the recognition and delimitation of rocks belonging to four major geologic divisions—the Mississippian, the Triassic, the Lower Cretaceous, and the Upper Cretaceous. These rocks were found to coincide in general character and relation with rocks of the same age seen by the parties in 1923 and 1924. The Mississippian rocks form most of the higher hills north of the Noatak. They consist of considerably indurated and deformed slates and sandstones overlain by several thousand feet of massive limestone locally called the Lisburne limestone. Overlying this series is a considerable thickness of chert of Triassic age. The cherts are varied in color, some being nearly pure white and others black, green, or red. The alternation of colors in some of the bluffs makes noteworthy and striking landmarks.

No Jurassic rocks were recognized in the area traversed by the party in 1925 and none had been found by the party that surveyed adjacent parts of the reserve in 1924. Overlying the chert but at many places in faulted relation with it are sandstones and shales which are regarded as of Lower Cretaceous age. These rocks are as a rule considerably folded and almost everywhere stand at high angles. They are thoroughly indurated and consist of a monotonous succession of alternating layers of sandstone and shale that disclose no readily recognizable key horizons over any considerable distance. As a consequence it was impossible to make any precise measure of their thickness, but they are several thousand feet thick. Near or at the base of the rocks of this system is a conglomerate which in places has pebbles 6 or 8 inches in diameter but which is usually much finer or is a coarse grit.

Overlying the Lower Cretaceous rocks is a thick series of sandstones and shales which, according to W. R. Smith, are considerably less intensely deformed than the Lower Cretaceous and which at few places in the area studied by him stand at angles higher than 30°. This conclusion is somewhat at variance with the observations of the parties in 1924 and of F. C. Schrader in 1901 on similar rocks, and if it proves to be correct it will be of great stratigraphic significance in throwing light on the age of some of the mountain building and serve as a means of identifying in the field these two formations, which lithologically are practically indistinguishable and can now be separated surely only in places where fossils are found. The Upper Cretaceous rocks contain numerous beds of coal interstratified with the shales and sandstones. Some of the beds are several feet thick, and most of them consist of subbituminous or bituminous coal of good quality. The Upper Cretaceous rocks are everywhere more or less folded, so that anticlines and synclines having their axes trending in general east and west are common. The folding appears to be progressively less and less intense as traced northward from this front of the mountains.

No igneous rocks of the granitic type in place were recognized in the area surveyed. Some boulders and pebbles of granite are present in the unconsolidated deposits on the Aniuk and on the

Etivluk, even as far as its junction with the Colville. According to the interpretation advanced by W. R. Smith, these fragments were probably derived from granitic masses south of the Noatak and transported northward by ancient glaciers and then reworked by the modern streams. Although this interpretation must as yet be regarded as only an interesting suggestion, it has economic significance because most of the known metallic mineral deposits of value in this part of Alaska seem to have a rather close association with igneous intrusive rocks, and if intrusives are not present in this region the probability of finding deposits of valuable metallic minerals here is regarded as not great.

No extensive deposits of unconsolidated sand and gravel were recorded in the area surveyed. The largest bodies of continuous unconsolidated deposits apparently were outwash material from the ancient glaciers. These, however, are more or less confined to the valleys of the larger streams and to their more or less immediate vicinity. So far as evidence is available, it shows that the mountains have at no time in the past been covered by ice caps but were the seat of local valley glaciers that flowed down the former valleys and then, on reaching the limit of the mountains, debouched into small piedmont lobes. No evidence of recent incursion of the sea was found in the area traversed by the party in 1925, and there is no reason to believe that in recent geologic time there were broad movements of depression that resulted in lowering the inland part of the reserve sufficiently to place it at or below sea level.

DATA RELATING TO PETROLEUM

The main object of the expedition was to determine the probability of extensive deposits of oil in this region, and other lines of geologic investigation were subordinated to this end. Until the whole investigation is completed no comprehensive analysis of all the data bearing on the problem will be attempted, and even then probably no public report will be issued until the Government's policy regarding the administration of this tract has been formulated. The more or less obvious results of the work, however, are of such general interest that it has been the practice to make a report of some of the current information in the knowledge that some of the suggestions may require material modification in the light of more complete study or data and that proof of the commercial value of any oil fields that may be discovered can be determined only by actual tests with the drill.

From direct observation the expedition of 1925 furnished few or no additional data to prove the occurrence of petroleum in the region. It has been incontrovertibly shown that petroleum does occur in this reserve, for it is found seeping from the ground near Cape Simpson, on the Arctic coast. The observations made during 1925 have materially delimited the area in which there are rocks similar to those that are supposed to occur near these seepages.

Nothing was observed that tends to modify the opinion already expressed by other geologists that the possible oil-bearing rocks are of Mesozoic age and occur entirely north of the Brooks Range. Although the party of 1925 found some of these Mesozoic rocks infolded or infaulted in the general mountain area that on earlier maps had been indicated as dominantly Paleozoic, these small Mesozoic areas did not appear at all promising structurally for yielding any quantity of oil. No rocks capable of furnishing oil in notable quantity, such as the oil shale obtained in 1924 from the Etivluk, were recognized in other parts of the area traversed in 1925, so that the determination of the stratigraphic limits of the oil deposits is still in doubt. The observations made in 1925, however, corroborate the opinion heretofore expressed that in the large area of Mesozoic rocks structural features competent to trap any oil that may have been produced are widespread. In fact, several large anticlines of great length and considerable closure are shown on the field maps of the geologist. As already stated, the geologist in the party of 1925 has expressed the belief that there was a period of notable deformation between the Upper and Lower Cretaceous, as a result of which the rocks of the earlier period stand at high angles and are considerably more broken and dislocated, therefore not affording as good structure for the retention of any oil that may have originated in or below them.

The work done in 1925 has not solved the question that was raised earlier as to whether certain of the rocks heretofore called Jurassic are in reality different from the rocks which in this area appear to be a continuation of them but which contain Cretaceous fossils. However, the work brought to light additional presumptive evidence that the two may be the same, because, although nearly continuous sections were observed in both the eastern and the western parts of the area, no rocks containing Jurassic fossils were recognized, though Triassic, Lower Cretaceous, and Upper Cretaceous rocks were readily identified. Especial emphasis was placed on the search for Jurassic rocks, as it was realized that the petroleum in the Cook Inlet-Alaska Peninsula region and Katalla-Yakataga region, which contain the only other well-known, definitely proved seepages of oil in Alaska, probably comes from rocks of this age. It was therefore long supposed that these rocks were to be especially sought, but from all the observations so far made the conclusion is suggested that either the Jurassic rocks are not the source of the oil in northern Alaska or, if they are, only a small part of the reserve is likely to be underlain by them within a depth that can reasonably be reached by the drill.

The opinion has already been expressed that unless a very large supply of oil can be demonstrated the development will be so costly that, for practical purposes, the area can not be regarded as a potential source of oil in the near future. The facts at hand are by no means adequate to determine this point, and probably the matter can not be settled without drilling. The recommendation made two years ago that test drilling be done in the vicinity of the oil seepages near Cape Simpson is therefore renewed. It should be distinctly understood, however, that such drilling is not to be undertaken with the aim of producing oil but to prospect and afford geologic data regarding the conditions. A light prospecting drill rig and the necessary crew could be sent during the open season by water within a mile or two of the seepages, so that transportation would not be difficult. The first test holes need not be more than a few hundred feet deep, but the cuttings from them should be carefully examined by a geologist attached to the party, who can then give advice as to the best places to continue prospecting with the drill. When not required to examine the cuttings from the drill the geologist could probably make excursions into the region within a radius of 50 to 75 miles of these seepages for the purpose of gathering more data regarding surface conditions. After the drill has supplied the required geologic data regarding the occurrence of oil in the seepages near Cape Simpson, probably additional field reconnaissances and surveys should be made of those areas where the examinations already made have indicated analogous conditions. In this way drilling and geologic examinations could supplement each other and give data unavailable from either source alone.

If drilling is not undertaken there are still areas that have not been traversed and that might afford definite evidence of oil and thus well repay the cost of cruising them on that chance, as well as supplementing the geologic data already procured. Among these areas where additional reconnaissances of this sort are most needed are the tract lying 50 to 100 miles from the coast and extending in a northeasterly direction between the surveys of 1923 and those of 1925 and another area between the Ikpikpuk and the lower part of Colville River, including Tasekpuk Lake and adjacent country. Plans are already in progress for the survey of the first of these areas, and the field surveys were made during 1926. Although the results can not be expected to compare with those that might be obtained if drill logs were available, these scouting trips should greatly supplement present knowledge of the general geologic conditions of this part of northern Alaska.

DATA RELATING TO OTHER MINERAL RESOURCES

The explorations conducted by the FitzGerald-Smith party in 1925 were mostly south of the areas in which the coal-bearing rocks noted by the parties of 1923 and 1924 occur, and very little of the coal-bearing series with the thicker coal beds was seen. The rocks near the Colville and north of it are the same as those seen by Foran on the Utukok, Epizetka, Kuk, Kaolak, and Kukpowruk, so that little doubt is felt that similar coals also occur in the rocks somewhat higher in the section and somewhat north of the area surveyed in 1925. Some coal was seen, but it is mostly in thin seams and not of commercial thickness, though it appears to be of the same quality as the subbituminous coals characteristic of the Upper Cretaceous. A small exposure of coal was also visited on the Kugururok about 4 or 5 miles above its junction with the Noatak. Possibly this is one of the later Tertiary coals that occupy small isolated basins of no great areal extent and of little commercial importance unless coal is needed locally, such as occur above Squirrel River and at a few other points along the Kobuk.

As has already been stated, the investigations of 1925 were focused on the search for oil, so that relatively little attention was paid to other minerals, and on the whole areas that might contain gold or copper were avoided, as they would hold little chance of being oil bearing. In spite of this condition, however, the gravels were panned at a number of places, and colors of gold were found in some. Practically no tests of the gravels of the Kugururok or the Utukok were made, as the winter conditions that prevailed while the party was in the valleys of these streams made such tests difficult and impracticable in the time available. On the tributary of the Colville named Storm Creek a pan of gravel showed several small bright colors. This stream lies near the contact of the Upper and Lower Cretaceous rocks, but the deposit through which it has cut its course may represent a Tertiary concentration that formed a high bench of outwash from the hills, later re-sorted by the present stream. Some colors of gold were also found in pans taken at intervals down the Colville and in the lower part of the Etivluk north of the limestone. Farther up the Etivluk, although several tests were made, no colors of gold were seen, and on Fay Creek, which at the time appeared to have a good grade and other favorable physical characters, panning tests failed to disclose any gold. Southward from the limestones on the Etivluk to the vicinity of Flora Creek, the large tributary of the Aniuk from the east, no colors of gold were found, though the gravels were panned at several places. South of Flora Creek, however, a pan taken from a high bar showed a number of small colors, and from thence downstream a few colors could be obtained at many places as far as the junction with the Noatak. In spite of the finding of some colors in areas underlain by rocks of Cretaceous age, however, it is believed that they are not promising areas to prospect. Neither are the areas that derived their deposits from the areas occupied solely by the Lisburne limestone. On the other hand, the somewhat metamorphosed rocks of the Noatak sandstone, which forms the country rock toward the southern face of the mountains north of the Noatak, or any of the older schists that may crop out in the region are well worth careful examination.

INDEX

SELECTED LIST OF SURVEY PUBLICATIONS ON ALASKA

[Arranged geographically]

All these publications can be obtained or consulted in the following ways:

1. A certain number of copies are delivered to the Director of the Geological Survey, from whom they can be obtained for a limited period free of charge (except certain maps) on application.

2. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at the price indicated. No copies are available of those marked with an asterisk (*); they may be consulted at many public libraries.

3. Copies of all Government publications are furnished to the principal public libraries throughout the United States, where they can be consulted by those interested.

The maps whose price is stated are sold by the Geological Survey and not by the Superintendent of Documents. On an order for maps amounting to $5 or more at the retail price a discount of 40 per cent is allowed.

GENERAL

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*The geography and geology of Alaska, a summary of existing knowledge, by A. H. Brooks, with a section on climate, by Cleveland Abbe, jr., and a topographic map and description thereof, by R. U. Goode. Professional Paper 45, 1906, 327 pp.

Alaska coal and its utilization. Bulletin 442–J, reprinted 1914. 10 cents.

Mineral industry of Alaska in 1924, by Philip S. Smith. In Bulletin 783–A, 1926, pp. 1–39. Free on application.

Mineral industry of Alaska in 1925, by F. H. Moffit. In Bulletin 792, 1927, pp. 1–39. Free on application.

Railway routes from the Pacific seaboard to Fairbanks, Alaska, by A. H. Brooks. In Bulletin 520, 1912, pp. 45–88. 50 cents.

Geologic features of Alaskan metalliferous lodes, by A. H. Brooks. In Bulletin 480, 1911, pp. 43–93. 40 cents.

The mineral deposits of Alaska, by A. H. Brooks. In Bulletin 592, 1914, pp. 18–44. 60 cents.

The future of gold-placer mining in Alaska, by A. H. Brooks. In Bulletin 622, 1915, pp. 69–79. 30 cents.

The possible use of peat fuel in Alaska, by C. A. Davis. In Bulletin 379, 1909, pp. 63–66. 50 cents.

The preparation and use of peat as a fuel, by C. A. Davis. In Bulletin 442, 1910, pp. 101–132. 40 cents.

*Methods and cost of gravel and placer mining in Alaska, by C. W. Purington. Bulletin 263, 1905, 362 pp. (Abstract in Bulletin 259, 1905, pp. 32–46. 15 cents.)

*Geographic dictionary of Alaska, by Marcus Baker; second edition prepared by James McCormick. Bulletin 299, 1906, 690 pp.

Tin mining in Alaska, by H. M. Eakin. In Bulletin 622, 1915, pp. 81–94. 30 cents.

Antimony deposits of Alaska, by A. H. Brooks. Bulletin 649, 1916, 67 pp. 15 cents.
The use of the panoramic camera in topographic surveying, by J. W. Bagley. Bulletin 657, 1917, 88 pp. 25 cents.
The mineral springs of Alaska, by G. A. Waring. Water-Supply Paper 418, 1917, 114 pp. 25 cents.
Alaska's mineral supplies, by A. H. Brooks. Bulletin 666–P, 14 pp. 5 cents.
The future of Alaska mining, by A. H. Brooks. Bulletin 714–A, reprinted 1921. 25 cents.
Preliminary report on petroleum in Alaska, by G. C. Martin. Bulletin 719, 1921, 83 pp. 50 cents.
The Mesozoic stratigraphy of Alaska, by G. C. Martin. Bulletin 776. 1926, 487 pp. 75 cents.

In preparation

The Upper Cretaceous flora of Alaska, by Arthur Hollick, with a description of the Upper Cretaceous plant-bearing beds, by G. C. Martin.
Tertiary flora of Alaska, by Arthur Hollick.
Igneous geology of Alaska, by J. B. Mertie, jr.

TOPOGRAPHIC MAPS

Map of Alaska (A); scale, 1: 5,000,000; 1927. 10 cents retail or 6 cents wholesale.
*Map of Alaska (B); scale, 1: 1,500,000; 1915.
Map of Alaska (C); scale, 1: 12,000,000; 1916. 1 cent retail or five for 3 cents wholesale.
Map of Alaska showing distribution of mineral deposits; scale, 1: 5,000,000; 1925. 20 cents retail or 12 cents wholesale.
Index map of Alaska, including list of publications; scale, 1: 5,000,000; 1927. Free on application.
Relief map of Alaska (D); scale, 1: 2,500,000; 1923. 50 cents retail or 30 cents wholesale.
Map of Alaska (E); scale, 1: 2,500,000; 1923. 25 cents retail or 15 cents wholesale.

SOUTHEASTERN ALASKA

REPORTS

The Juneau gold belt, Alaska, by A. C. Spencer, pp. 1–137, and A reconnaissance of Admiralty Island, Alaska, by C. W. Wright, pp. 138–154. Bulletin 287, 1906, 161 pp. 75 cents.
Reconnaissance on the Pacific coast from Yakutat to Alsek River, by Eliot Blackwelder. In Bulletin 314, 1907, pp. 82–88. 30 cents.
The building stones and materials of southeastern Alaska, by C. W. Wright. In Bulletin 345, 1908, pp. 116–126. 45 cents.
The Ketchikan and Wrangell mining districts, Alaska, by F. E. and C. W. Wright. Bulletin 347, 1908, 210 pp. 60 cents.
The Yakutat Bay region, Alaska: Physiography and glacial geology, by R. S. Tarr; Areal geology, by R. S. Tarr and B. S. Butler. Professional Paper 64, 1909, 183 pp. 50 cents.
Occurrence of iron ore near Haines, by Adolph Knopf. In Bulletin 442, 1910, pp. 144–146. 40 cents.
Geology of the Berners Bay region, Alaska, by Adolph Knopf. Bulletin 446, 1911, 58 pp. 20 cents.
The Eagle River region, southeastern Alaska, by Adolph Knopf. Bulletin 502, 1912, 61 pp. 25 cents.

The Sitka mining district, Alaska, by Adolph Knopf. Bulletin 504, 1912, 32 pp. 5 cents.

The earthquakes at Yakutat Bay, Alaska, in September, 1899, by R. S. Tarr and Lawrence Martin, with a preface by G. K. Gilbert. Professional Paper 69, 1912, 135 pp. 60 cents.

A barite deposit near Wrangell, by E. F. Burchard. In Bulletin 592, 1914, pp. 109–117. 60 cents.

The geology and ore deposits of Copper Mountain and Kasaan Peninsula, Alaska, by C. W. Wright. Professional Paper 87, 1915, 110 pp. 40 cents.

*The structure and stratigraphy of Gravina and Revillagigedo Islands, Alaska, by Theodore Chapin. In Professional Paper 120, 1918, pp. 83–100.

*The geology and mineral resources of the west coast of Chichagof Island, by R. M. Overbeck. In Bulletin 692, pp. 91–136.

The Porcupine district, by H. M. Eakin. Bulletin 699, 29 pp. 20 cents.

Notes on the Unuk-Salmon River region, by J. B. Mertie, jr. Bulletin 714–B, 1921, pp. 129–142. 10 cents.

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Water-power investigations in southeastern Alaska, by G. H. Canfield. In Bulletin 722, 1922, pp. 75–115. 25 cents.

Ore deposits of the Salmon River district, Portland Canal region, Alaska, by L. G. Westgate. In Bulletin 722, 1922, pp. 117–140. 25 cents.

Mineral deposits of the Wrangell district, by A. F. Buddington. In Bulletin 739, 1923, pp. 51–75. 25 cents.

Mineral resources of southeastern Alaska, by A. F. Buddington. In Bulletin 773, 1925, pp. 71–139. 40 cents.

Mineral investigations in southeastern Alaska in 1924, by A. F. Buddington. In Bulletin 783, 1927, pp. 41–62. 40 cents.

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Geology and ore deposits of the Juneau district, by H. M. Eakin.

Geology and mineral deposits of southeastern Alaska, by A. F. Buddington and Theodore Chapin.

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Juneau gold belt, Alaska; scale 1:250,000; compiled. In Bulletin 287, 1906, 75 cents. Not issued separately.

Juneau special (No. 581A); scale, 1:62,500; 1904, by W. J. Peters. 10 cents retail or 6 cents wholesale.

Berners Bay special (No. 581B); scale, 1:62,500; 1908, by R. B. Oliver. 10 cents retail or 6 cents wholesale. Also contained in Bulletin 446, 1911, 20 cents.

Kasaan Peninsula, Prince of Wales Island (No. 540A); scale, 1:62,500; by D. C. Witherspoon, R. H. Sargent, and J. W. Bagley. 10 cents retail or 6 cents wholesale. Also contained in Professional Paper 87, 1915, 40 cents.

Copper Mountain and vicinity, Prince of Wales Island (No. 540B); scale, 1:62,500; by R. H. Sargent. 10 cents retail or 6 cents wholesale. Also contained in Professional Paper 87, 1915, 40 cents.

Eagle River region; scale, 1:62,500; 1912, by J. W. Bagley, C. E. Giffin, and R. E. Johnson. In Bulletin 502, 25 cents. Not issued separately.

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CONTROLLER BAY, PRINCE WILLIAM SOUND, AND COPPER RIVER REGIONS

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Geology of the central Copper River region, Alaska, by W. C. Mendenhall. Professional Paper 41, 1905, 133 pp. 50 cents.

Geology and mineral resources of Controller Bay region, Alaska, by G. C. Martin. Bulletin 335, 1908, 141 pp. 70 cents.

Mineral resources of the Kotsina-Chitina region, by F. H. Moffit and A. G. Maddren. Bulletin 374, 1909, 103 pp. 40 cents.

Mineral resources of the Nabesna-White River district, by F. H. Moffit and Adolph Knopf; with a section on the Quaternary, by S. R. Capps. Bulletin 417, 1910, 64 pp. 25 cents.

Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska, by U. S. Grant and D. F. Higgins. Bulletin 443, 1910, 89 pp. 45 cents.

Geology and mineral resources of the Nizina district, Alaska, by F. H. Moffit and S. R. Capps. Bulletin 448, 1911, 111 pp. 40 cents.

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Coastal glaciers of Prince William Sound and Kenai Peninsula, Alaska, by U. S. Grant and D. F. Higgins. Bulletin 526, 1913, 75 pp. 30 cents.

The McKinley Lake district, by Theodore Chapin. In Bulletin 542, 1913, pp. 78–80. 25 cents.

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*A water-power reconnaissance in south-central Alaska, by C. E. Ellsworth and R. W. Davenport. Water-Supply Paper 372, 1915, 173 pp.

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Copper deposits of the Latouche and Knight Island districts, Prince William Sound, by B. L. Johnson. In Bulletin 662, 1917, pp. 193–220. 75 cents.

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The upper Chitina Valley, by F. H. Moffit, with a description of the igneous rocks, by R. M. Overbeck. Bulletin 675, 1918, 82 pp. 25 cents.

*Platinum-bearing auriferous gravels of Chistochina River, by Theodore Chapin. In Bulletin 692, 1919, pp. 137–141.

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The metalliferous deposits of Chitina Valley, by F. H. Moffit. In Bulletin 755, 1924, pp. 57–72. 40 cents.

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In preparation

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REPORTS

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*The Mount McKinley region, Alaska, by A. H. Brooks, with descriptions of the igneous rocks and of the Bonnifield and Kantishna districts, by L. M. Prindle. Professional Paper 70, 1911, 234 pp.

A geologic reconnaissance of the Iliamna region, Alaska, by G. C. Martin and F. J. Katz. Bulletin 485, 1912, 138 pp. 35 cents.

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The Yentna district, Alaska, by S. R. Capps. Bulletin 534, 1913, 75 pp. 20 cents.

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The Willow Creek district, by S. R. Capps. Bulletin 607, 1915, 86 pp. 25 cents.

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The Nelchina-Susitna region, by Theodore Chapin. Bulletin 668, 1918, 67 pp. 25 cents.

Platinum-bearing gold placers of Kahiltna Valley, by J. B. Mertie, jr. In Bulletin 692–D, 1919, pp. 233–264. 15 cents.

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*Mining in the Matanuska coal field and the Willow Creek district, by Theodore Chapin. In Bulletin 712, 1920, pp. 131–176.

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The Iniskin Bay district, by F. H. Moffit. In Bulletin 739, 1922, pp. 117–132. 25 cents.

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A ruby-silver prospect in Alaska, by S. R. Capps and M. N. Short. In Bulletin 783, 1927, pp. 89–95. 40 cents.

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The Alaska Railroad route: Seward to Matanuska coal field; scale, 1:250,000; 1924, by J. W. Bagley, T. G. Gerdine, R. H. Sargent, and others. 50 cents retail or 30 cents wholesale.
The Alaska Railroad route: Matanuska coal field to Yanert Fork; scale, 1:250,000; 1924, by J. W. Bagley, T. G. Gerdine, R. H. Sargent, and others. 50 cents retail or 30 cents wholesale.
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REPORTS

A reconnaissance in southwestern Alaska, by J. E. Spurr. In Twentieth Annual Report, pt. 7, 1900, pp. 31–264. $1.80.

*Geology and mineral resources of parts of Alaska Peninsula, by W. W. Atwood. Bulletin 467, 1911, 137 pp.

A geologic reconnaissance of the Iliamna region, Alaska, by G. C. Martin and F. J. Katz. Bulletin 485, 1912, 138 pp. 35 cents.

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The Lake Clark-central Kuskokwin region, by P. S. Smith. Bulletin 655, 1918, 162 pp. 30 cents.

Beach placers of Kodiak Island, Alaska, by A. G. Maddren. In Bulletin 692–E, 1919, pp. 299–319. 5 cents.

Sulphur on Unalaska and Akun islands and near Stepovak Bay, Alaska, by A. G. Maddren. In Bulletin 692–E, 1919, pp. 283–298. 5 cents.

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The Cold Bay-Katmai district, by W. R. Smith. In Bulletin 773, 1925, pp. 183–207. 40 cents.

The outlook for petroleum near Chignik, by G. C. Martin. In Bulletin 773, 1925, pp. 209–213. 40 cents.

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Lake Clark-central Kuskokwim region; scale, 1:250,000; by R. H. Sargent, D. C. Witherspoon, and C. E. Giffin. In Bulletin 655, 1917, 30 cents. Not issued separately.

Cold Bay-Chignik region, Alaska Peninsula; scale, 1:250,000; 1924, by R. K. Lynt and R. H. Sargent (preliminary edition). Free on application.

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The coal resources of the Yukon, Alaska, by A. J. Collier. Bulletin 218, 1903, 71 pp. 15 cents.

The Fortymile quadrangle, Yukon-Tanana region, Alaska, by L. M. Prindle. Bulletin 375, 1909, 52 pp. 30 cents.

Water-supply investigations in Yukon-Tanana region, Alaska, 1907–8 (Fairbanks, Circle, and Rampart districts), by C. C. Covert and C. E. Ellsworth. Water-Supply Paper 228, 1909, 108 pp. 20 cents.

Mineral resources of the Nabesna-White River district, Alaska, by F. H. Moffit and Adolph Knopf, with a section on the Quaternary by S. R. Capps. Bulletin 417, 1910, 64 pp. 25 cents.

The Bonnifield region, Alaska, by S. R. Capps. Bulletin 501, 1912, 162 pp. 20 cents.

A geologic reconnaissance of a part of the Rampart quadrangle, Alaska, by H. M. Eakin. Bulletin 535, 1913, 38 pp. 20 cents.

°A geologic reconnaissance of the Fairbanks quadrangle, Alaska, by L. M. Prindle, with a detailed description of the Fairbanks district, by L. M. Prindle and F. J. Katz, and an account of lode mining near Fairbanks, by P. S. Smith. Bulletin 525, 1913, 220 pp. 55 cents.

The Koyukuk-Chandalar region, Alaska, by A. G. Maddren. Bulletin 532, 1913, 119 pp. 25 cents.

A geologic reconnaissance of the Circle quadrangle, Alaska, by L. M. Prindle. Bulletin 538, 1913, 82 pp. 20 cents.

Surface-water supply of the Yukon-Tanana region, Alaska, by C. E. Ellsworth and R. W. Davenport. Water-Supply Paper 342, 1915, 343 pp. 45 cents.

Quicksilver deposits of the Kuskokwim region, by P. S. Smith and A. G. Maddren. In Bulletin 622, 1915, pp. 272–291. 30 cents.

Gold placers of the lower Kuskokwim, by A. G. Maddren. In Bulletin 622, 1915, pp. 292–360. 30 cents.

An ancient volcanic eruption in the upper Yukon Basin, by S. R. Capps. Professional Paper 95–D, 1915, pp. 59–64. 5 cents.

The Chisana-White River district, Alaska, by S. R. Capps. Bulletin 630, 1916, 130 pp. 20 cents.

The Yukon-Koyukuk region, Alaska, by H. M. Eakin. Bulletin 631, 1916, 88 pp. 20 cents.

The gold placers of the Tolovana district, by J. B. Mertie, jr. In Bulletin 662, 1917, pp. 221–277. 75 cents.

Lode mining in the Fairbanks district, by J. B. Mertie, jr. In Bulletin 662, 1917, pp. 403–424. 75 cents.

Lode deposits near the Nenana coal field, by R. M. Overbeck. In Bulletin 662, 1917, pp. 351–362. 75 cents.

The Lake Clark-central Kuskokwim region, Alaska, by P. S. Smith. Bulletin 655, 1918, 162 pp. 30 cents.

The Cosna-Nowitna region, Alaska, by H. M. Eakin. Bulletin 667, 1918, 54 pp. 25 cents.

The Anvik-Andreafski region, Alaska, by G. L. Harrington. Bulletin 683, 1918, 70 pp. 30 cents.

The Kantishna district, by S. R. Capps. Bulletin 687, 1919, 116 pp. 25 cents.

The Nenana coal field, Alaska, by G. C. Martin. Bulletin 664, 1919, 54 pp. $1.10.

*A molybdenite lode on Healy River, by Theodore Chapin. In Bulletin 692, 1919, p. 329.

*The gold and platinum placers of the Tolstoi district, by G. L. Harrington. In Bulletin 692, 1919, pp. 338–351.

*Mineral resources of the Goodnews Bay region, by G. L. Harrington. In Bulletin 714, 1921, pp. 207–228.

Gold lodes in the upper Kuskokwim region, by G. C. Martin. In Bulletin 722, 1922, pp. 149–161. 25 cents.

Supposed oil seepage in Nenana coal field, by G. C. Martin. In Bulletin 739, 1922, pp. 137–147. 25 cents.

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The Ruby-Kuskokwim region, by J. B. Mertie, jr., and G. L. Harrington. Bulletin 754, 1924, 129 pp. 50 cents.

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The Nixon Fork country, by J. S. Brown. In Bulletin 783, 1927, pp. 97–144. 40 cents.

Silver-lead prospects near Ruby, by J. S. Brown. In Bulletin 783, 1927, pp. 145–150. 40 cents.

The Toklat-Tonzona River greion, by S. R. Capps. In Bulletin 792, 1927, pp. 73–110. Free on application.

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Geology of Fairbanks and Rampart quadrangles, by J. B. Mertie, jr.

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Fairbanks quadrangle (No. 642); scale, 1:250,000; 1911, by T. G. Gerdine, D. C. Witherspoon, R. B. Oliver, and J. W. Bagley. 50 cents retail or 30 cents wholesale. Also in Bulletin 337, 25 cents, and Bulletin 525, 1913, 55 cents.

Fortymile quadrangle (No. 640); scale, 1:250,000; 1902, by E. C. Barnard. 10 cents retail or 6 cents wholesale. Also in Bulletin 375, 1909, 30 cents.

Rampart quadrangle (No. 643); scale, 1:250,000; 1913, by D. C. Witherspoon and R. B. Oliver. 20 cents retail or 12 cents wholesale. Also in Bulletin 337, 25 cents, and part in Bulletin 535, 1913, 20 cents.

Fairbanks special (No. 642A); scale, 1:62,500; 1908, by T. G. Gerdine and R. H. Sargent. 20 cents retail or 12 cents wholesale. Also in Bulletin 525, 1913, 55 cents.

Bonnifield region; scale, 1:250,000; by J. W. Bagley, D. C. Witherspoon, and C. E. Giffin. In Bulletin 501, 1912, 20 cents. Not issued separately.

Iditarod-Ruby region; scale, 1:250,000; by C. G. Anderson, W. S. Post, and others. In Bulletin 578, 1914, 35 cents. Not issued separately.

Middle Kuskokwim and lower Yukon region; scale, 1:500,000; by C. G. Anderson, W. S. Post, and others. In Bulletin 578, 1914, 35 cents. Not issued separately.

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Marshall district; scale, 1:125,000; by R. H. Sargent. In Bulletin 683, 1918, 30 cents. Not issued separately.

Upper Tanana Valley region; scale, 1:125,000; 1922, by D. C. Witherspoon and J. W. Bagley (preliminary edition). Free on application.

Lower Kuskokwim region; scale, 1:500,000; 1921, by A. G. Maddren and R. H. Sargent (preliminary edition). Free on application.

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Innoko-Iditarod region; scale, 1:250,000; 1921, by R. H. Sargent and C. G. Anderson (preliminary edition). Free on application. Also in Bulletin 754, 1924, 50 cents.

Nixon Fork region; scale, 1:250,000; 1926, by R. H. Sargent (preliminary edition). Free on application.

SEWARD PENINSULA

REPORTS

The Fairhaven gold placers of Seward Peninsula, Alaska, by F. H. Moffit. Bulletin 247, 1905, 85 pp. 40 cents.

The gold placers of parts of Seward Peninsula, Alaska, including the Nome, Council, Kougarok, Port Clarence, and Goodhope precincts, by A. J. Collier, F. L. Hess, P. S. Smith, and A. H. Brooks. Bulletin 328, 1908, 343 pp. 70 cents.

Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, Alaska, by P. S. Smith. Bulletin 433, 1910, 227 pp. 40 cents.

A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska, by P. S. Smith and H. M. Eakin. Bulletin 449, 1911, 146 pp. 30 cents.

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Surface water supply of Seward Peninsula, Alaska, by F. F. Henshaw and G. L. Parker, with a sketch of the geography and geology by P. S. Smith and a description of methods of placer mining by A. H. Brooks; including topographic reconnaissance map. Water-Supply Paper 314, 1913, 317 pp. 45 cents.

Iron-ore deposits near Nome, by H. M. Eakin. In Bulletin 622, 1915, pp. 361–365. 30 cents.

*Graphite mining in Seward Peninsula, by G. L. Harrington. In Bulletin 692, 1919, pp. 363–367.

*The gold and platinum placers of the Kiwalik-Koyuk region, by G. L. Harrington. In *Bulletin 692, 1919, pp. 368–400.

Pliocene and Pleistocene fossils from the Arctic coast of Alaska and the auriferous beaches of Nome, Norton Sound, Alaska, by W. H. Dall. Professional Paper 125–C, 1921, 15 pp. 10 cents.

Metalliferous lodes of southern Seward Peninsula, by S. H. Cathcart. In Bulletin 722, 1922, pp. 163–261. 25 cents.

The geology of the York tin deposits, Alaska, by Edward Steidtmann and S. H. Cathcart. Bulletin 733, 1922, 125 pp. 30 cents.

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Seward Peninsula; scale 1:500,000; compiled from work of D. C. Witherspoon, T. G. Gerdine, and others, of the Geological Survey, and all available sources. In Water-Supply Paper 314, 1913, 45 cents. Not issued separately.

Seward Peninsula, northeastern portion, reconnaissance map (No. 655); scale, 1:250,000; 1905, by D. C. Witherspoon and C. E. Hill. 50 cents retail or 30 cents wholesale. Also in Bulletin 247, 1905, 40 cents.

Seward Peninsula, northwestern portion, reconnaissance map (No. 657); scale, 1:250,000; 1907, by T. G. Gerdine and D. C. Witherspoon. 50 cents retail or 30 cents wholesale. Also in Bulletin 328, 1908, 70 cents.

Seward Peninsula, southern portion, reconnaissance map (No. 656); scale, 1:250,000; 1907, by E. C. Barnard, T. G. Gerdine, and others. 50 cents retail or 30 cents wholesale. Also in Bulletin 328, 1908, 70 cents.

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Nulato-Norton Bay region; scale, 1:500,000; by P. S. Smith, H. M. Eakin, and others. In Bulletin 449, 1911, 30 cents. Not issued separately.

Grand Central quadrangle (No. 646A); scale, 1:62,500; 1906, by T. G. Gerdine, R. B. Oliver, and W. R. Hill. 10 cents retail or 6 cents wholesale. Also in Bulletin 533, 1913, 60 cents.

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NORTHERN ALASKA

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Geology and coal resources of the Cape Lisburne region, Alaska, by A. J. Collier. Bulletin 278, 1906, 54 pp. 15 cents.

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The Koyukuk-Chandalar region, Alaska, by A. G. Maddren. Bulletin 532, 1913, 119 pp. 25 cents.

*The Jurassic flora of Cape Lisburne, Alaska, by F. H. Knowlton. In Professional Paper 85, 1914, pp. 39–64.

The Canning River region of northern Alaska, by E. de K. Leffingwell. Professional Paper 109, 1919, 251 pp. 75 cents.

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*A reconnaissance of the Point Barrow region, Alaska, by Sidney Paige and others. Bulletin 772, 1925, 33 pp.

Preliminary statement of recent surveys in northern Alaska, by P. S. Smith, J. B. Mertie, jr., and W. T. Foran. In Bulletin 783, 1927, pp. 151–168. 40 cents.

Geologic investigations in northern Alaska, by P. S. Smith. In Bulletin 792, 1927, pp. 111–120. Free on application.

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Koyukuk River to mouth of Colville River, including John River; scale, 1:1,250,000; by W. J. Peters. In Professional Paper 20, 1904, 40 cents. Not issued separately.

Koyukuk and Chandalar region, reconnaissance map; scale, 1:500,000; by T. G. Gerdine, D. L. Reaburn, D. C. Witherspoon, and A. G. Maddren. In Bulletin 532, 1913, 25 cents. Not issued separately.

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Martin Point to Thetis Island; scale, 1:125,000; by E. de K. Leffingwell. In Professional Paper 109, 1919, 75 cents. Not issued separately.

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Northwestern Alaska; scale, 1:500,000; by Gerald FitzGerald and others.

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