GEOLOGY AND GOLD PLACERS OF THE CHANDALAR DISTRICT

By J. B. Mertie, Jr.

INTRODUCTION

The area here called the Chandalar district lies between meridians 147° and 150° west longitude and mainly between parallels 67° and 68° north latitude, though extending a little north of 68° in the valleys of Dietrich River and the North Fork of Chandalar River. This area includes nearly all of the Chandalar River valley and some of the eastern tributaries of Koyukuk River. Mining operations at present are confined to Little and Big Squaw creeks and to Big Creek, all three of which drain to the North Fork of Chandalar River. The Koyukuk mining district lies to the west of the Chandalar district. (See fig. 8.)

The earliest geologic work in the Chandalar district was done in 1899, when F. C. Schrader[1] and T. G. Gerdine carried a geologic and topographic reconnaissance survey across the Chandalar and Koyukuk valleys. Late in the fall of 1909 A. G. Maddren[2] made a hasty visit to the district, but his work in this area was really only supplementary to more detailed observations in the Koyukuk Valley and added but little to the geologic knowledge of the Chandalar district proper.

The present report is a summary statement of the results of a study of the geology and gold placers of the Chandalar district, made by the writer in 1923. Landing about the middle of June at Beaver, on the Yukon, the party, consisting of a geologist, packer, and cook, proceeded with seven pack horses by the Government road to Caro, on the main Chandalar, thence by trail to the mining district at and around Little Squaw Creek. Leaving a cache at Little Squaw Creek, the party then proceeded northward, visiting the upper valleys of the Middle and North forks of the Chandalar and returning about the first of August to Little Squaw Creek. The second half of the trip consisted of a visit to the lower valley of the

[1] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska, in 1899: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 441–486, 1900.

[2] Maddren, A. G., The Koyukuk-Chandalar region, Alaska: U. S. Geol. Survey Bull. 532, 1913.

North Fork of the Chandalar, including Chandalar Lake and Baby Creek, thence westward in Crooked Creek and southward to the divide between Mosquito Fork of the Koyukuk and West Fork of the Chandalar, thence along the divide between Chandalar and Hodzana and Orenzik rivers to Caro, and returning about the last of August to Beaver. The remainder of the season was devoted to a boat traverse on the Yukon from Beaver to Tanana.

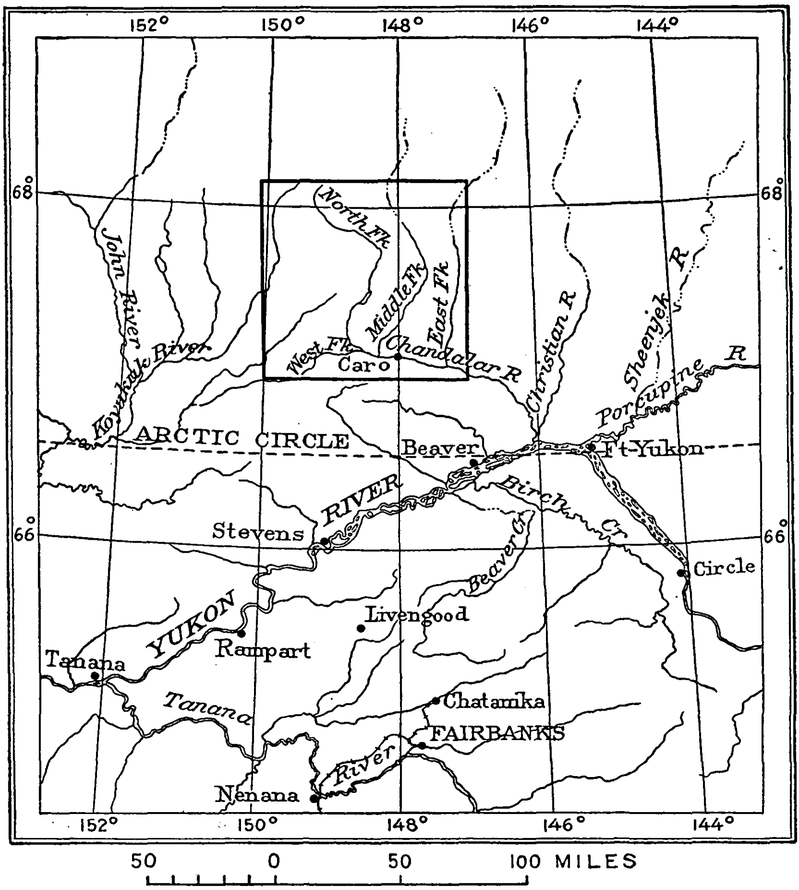


FIGURE 8.—Index map showing location of Chandalar district. Rectangle shows area covered by Plate VI

About 75 days was spent in the Chandalar district, and geologic observations were made in an area of about 4,000 square miles. The topographic map, made in 1899 by Gerdine, was used as a base for plotting geologic notes in part of the area. The writer, however, carried a foot traverse from Beaver to Little Squaw Creek and thence northward on the Middle Fork of the Chandalar, joining with Gerdine's topographic mapping at the forks of the North Fork of the Chandalar. The mapping on Plate VI of the drainage in that part of the area, therefore, is based on this foot traverse, and the same is true of the drainage of the headwaters of the West Fork of the Chandalar. Additional data on the drainage were taken from the topographic and geologic map prepared by Maddren.

The writer takes this opportunity to thank the white people in the Chandalar district for their interest in the work and for their unfailing cordiality and assistance. In particular, thanks are due to Messrs. Frank Yasuda and Charles Schultz, at Beaver, and to Messrs. Harry Patterson and Fred Smith, at Little Squaw Creek, for assistance rendered. The writer also acknowledges with thanks the faithful services rendered by Messrs. Earl Hunter and Clark Abel, the other two members of the party.

GEOGRAPHIC AND ECONOMIC FEATURES

RELIEF AND DRAINAGE

The northern and central parts of the Chandalar district constitute the south flank of the Endicott Range, a part of the Arctic Mountain system, which extends from the international boundary westward to Kotzebue Sound. This portion of the district is a region of rugged mountains, which have been intensely glaciated. The ridges are much dissected, and the crest lines, particularly in the areas of limestone, are irregular, thus making it difficult to follow the divides. The geologic structure of the rocks has played an important part in determining the trend of the ridges and the valleys.

Toward the south end of the district the hills are less sharply dissected, and the crest lines are lower and less rugged. This is particularly true south of Chandalar River, along the divide between the Chandalar and the Hodzana and Orenzik. Here the country begins to show rounded and rolling hills, which resemble those of the Yukon-Tanana region, though here, as in the Yukon-Tanana region, great granitic batholiths form isolated mountains of exceeding roughness. The mountains at the head of the West Fork of the Chandalar exemplify very well this phase of the topography.

The highest mountains, though not the most rugged, occur in the northern part of the district, toward the crest of the Endicott Range. Table Mountain, at the headwaters of the North Fork of the Chandalar, has an altitude of more than 7,000 feet and is about the highest point within the area here mapped. The lowest point is at the southeast corner of the district, in the valley of Chandalar River, where the valley begins to open up into the flats. The altitude here is about 750 feet, so that the maximum relief for the district is about 6,300 feet.

The Chandalar district is drained by Chandalar and Koyukuk rivers, both of which flow southward to the Yukon. Hodzana and Orenzik rivers head against the Chandalar at the south edge of the area mapped but can scarcely be included in the Chandalar district.

Most of the Chandalar district is drained by the West, North, Middle, and East forks of Chandalar River. Dietrich and Bettles rivers, joining to form the Middle Fork of Koyukuk River, together with South Fork and Mosquito Fork of Koyukuk River, drain the western third of the district. Observation during the season of 1923 was confined largely to the North, Middle, and West forks of Chandalar River. North, Middle, and East forks are three streams which are very similar in size and direction of flow and whose valleys are similar in physiographic character. West Fork, which joins North Fork to form the main Chandalar, differs in all three respects from the other forks.

North, Middle, and East forks of Chandalar River are large streams that drain in a general southerly direction from the Endicott Mountains. North Fork is better known than the other two. Heading in the crest of the mountains, against Dietrich River on the west and Middle Fork of the Chandalar on the east, it flows S. 60° E. for about 50 miles and then changes its course abruptly to S. 20° W., in which direction it flows for about 40 miles to the main Chandalar. This abrupt change in direction is undoubtedly controlled by the geologic structure of the country rock. In the upper 30 miles of its course North Fork is a swift mountain stream, flowing over a sand and gravel bed with numerous riffles and fordable almost anywhere on foot at ordinary stages of water. Then, rather abruptly, it enters a silt-filled and lake-dotted valley, through which it meanders tortuously for 35 miles to Chandalar Lake. In this stretch the river is sluggish, deep, and fordable with difficulty. Chandalar Lake is a body of water about 8 miles long and perhaps 1½ miles in average width, which lies in this same silt-filled valley. Below Chandalar Lake, however, the grade increases again and sand and gravel banks appear, and 8 miles below the lake the gradient of the river becomes very steep, forming the Chandalar Rapids, which extend downstream for a quarter of a mile. Below the rapids to the main Chandalar the North Fork is a swift mountain stream of considerable size, flowing over sand and gravel bars.

Middle Fork is much like the North Fork, except that no lake as large as Chandalar Lake is known in its course. It flows more or less parallel to the North Fork, at a distance ranging from 10 to 20 miles, and has a similar bend and a similar silt-filled valley in its middle course. East Fork is reported to have the same general character but was not explored in 1923. Viewed from a distance, however, the topography along the East Fork is less rugged and suggests more the rounded hills of the Yukon-Tanana region, to the south.

Another striking drainage feature is a wide cross valley which, starting from the North Fork of Chandalar River a few miles above Chandalar Lake, extends S. 70° E. to the East Fork. This depression is now occupied by small streams and evidently marks an earlier drainage channel of a larger stream. In common with the North, Middle, and East forks of the Chandalar, however, it has been grooved and deepened by later glacial action.

West Fork of the Chandalar is a smaller, swift-flowing stream from source to mouth. It is fordable almost anywhere at ordinary stages of water. About 10 miles above its mouth it splits into two forks, the smaller of which heads against Mosquito Fork of the Koyukuk and the larger heads against Hodzana River. Neither the West Fork nor the main Chandalar shows the features of glacial erosion that are seen in the valleys of North, Middle, and East forks.

Dietrich and Bettles rivers, the headwater tributaries of the Middle Fork of Koyukuk River, are both swift mountain streams, similar to the upper courses of North and Middle forks of the Chandalar. Their gradient, however, is more or less uniform, neither of them having silt-filled valleys along their middle courses like those of the North and Middle forks. Bettles River flows around the south end of the massive Silurian limestone and shows particularly well the control exercised by geologic structure on the courses of the streams in this district.

The main Chandalar is a swift stream down to the point where it flows out onto the Yukon Flats. It has been navigated by small river steamboats up to a point 7 miles above the mouth of the East Fork.

SETTLEMENTS AND POPULATION

Very few people are now living within the Chandalar district. A few white men and a number of Indians live at the settlement of Caro, on the north side of Chandalar River at the mouth of Flat Creek. The only other white men in the country are at the Little Squaw Creek mining camp, where perhaps 25 or 30 men live during the winter mining season. In addition, several small Indian settlements are scattered throughout the area.

TRAILS AND TRANSPORTATION

Caro is connected with Beaver, on the Yukon, by a wagon road 74 miles long, though in the early part of the summer this road is too wet for wagon transportation, being more suited to pack horses.

(See fig. 9.) Caro is connected with the Little Squaw Creek mining district by two trails. One of these goes up Flat Creek, thence across to Middle Fork, up Middle Fork to Grave Creek, and up Grave Creek to Little Squaw Creek. The other goes northwestward from Caro to Middle Fork and on to Big Creek, thence up

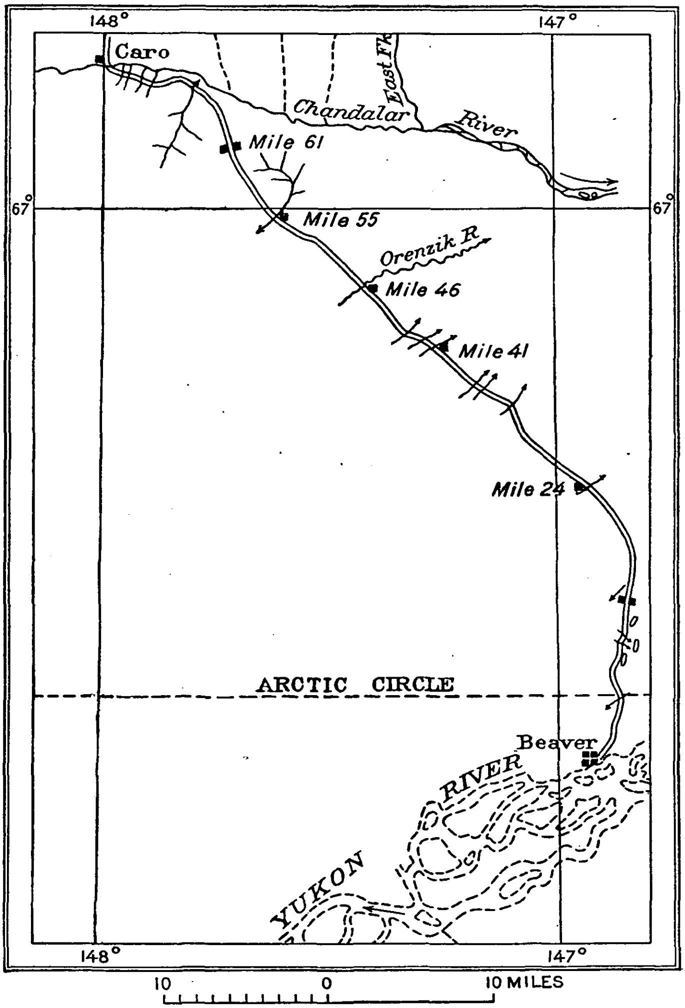


FIGURE 9.—Sketch map showing wagon road and drainage from Beaver to Cairo

Big Creek to its head, and over the divide into Little Squaw Creek. During the summer of 1923 a tram was constructed across Chandalar River at Caro by the Alaska Road Commission.

Supplies for the mining district at Little Squaw Creek are freighted from Beaver to Caro by wagon during the late summer and by dog sleds in winter. Freighting from Caro to the mining camp has so far been done by dog sleds in winter, but a tractor is now at Caro, and winter tractor transportation may soon be attempted.

Beaver receives its supplies largely from Skagway by the White Pass & Yukon Route but in part from Nenana.

CLIMATE

No records of temperature or precipitation have been kept for the Chandalar district, but it is believed that the climatic conditions do not differ very greatly from those in the Koyukuk Valley. According to Maddren,[3] temperatures as low as 70° below zero have been recorded, the average temperature for the three coldest months of winter is 15° below zero, and the average temperature for the three summer months is 55°. Brief records indicate that the annual precipitation in the Koyukuk Valley is between 11 and 12 inches, but it is believed by the writer that the precipitation in the Chandalar district is even less than this.

The summer of 1922 was cold and rainy, and the freeze-up came early, but the summer of 1923 was exceedingly warm and dry, the thermometer registering 90° several times during June, and the autumn was very late. Neither of these two summers really typifies the average summer weather. In general the summers are short and warm, the winters are long and cold, and neither in summer nor in winter is the precipitation heavy. Owing to the absence of any thawing weather in winter, however, all the snow remains, and it often accumulates to a depth of 3 or 4 feet before spring.

VEGETATION AND FORAGE

The lowlands of Chandalar and Koyukuk rivers and their tributaries are timbered with spruce, cottonwood, and birch, together with brushy growths of willow and alder. On the lower courses of the larger streams spruce grows as large as 2 feet in diameter at the base, but over much of the area timber is scarce and small. Timber line ranges from 2,000 to 2,500 feet above sea level, but in some of the main valleys small timber continues upstream to altitudes of 3,000 feet or even higher. Thus timber is found for some distance above the forks of the North Fork of Chandalar River, up to an altitude of perhaps 3,200 feet. The general distribution of timber is shown on the accompanying sketch map (fig. 10).

In this district, as elsewhere in interior Alaska, moss forms the main covering of the ground, and moss and lichens together extend up 1,000 feet or more above timber line. Grass for stock is not plentiful but is sufficient to support pack horses during the sum-

[3] Maddren, A. G., The Koyukuk-Chandalar region, Alaska: U. S. Geol. Survey Bull. 532, p. 27, 1913.

mer. A horsetail rush grows in great profusion in many places and seems to be greatly relished by horses. Many kinds of small plants grow during the summer, but none of these have been collected. Blueberries and low-bush cranberries are usually plentiful, and some high-bush cranberries and red currants are also found.

GAME AND FISH

Caribou, moose, mountain sheep, and bear, both brown and black, are found in the district. Caribou in small bands were seen in 1923,

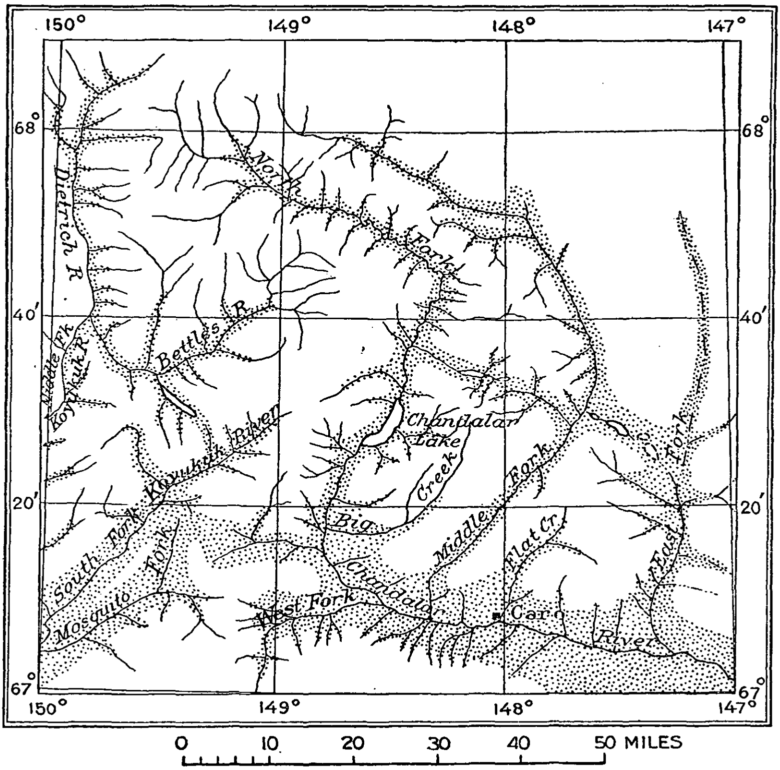


FIGURE 10.—Sketch map showing distribution of timber in Chandalar district

but no great herds like those of the Yukon-Tanana region are present. Mountain sheep appear to be scarce. In the middle courses of the North and Middle forks of Chandalar River, where these streams meander over silt-filled flood plains dotted with lakes, many moose were seen, but not elsewhere. Bear, particularly the great brown bear, are very common, especially in the high mountain groups, such as the granite area at the head of the West Fork of Chandalar River. Ptarmigan and grouse appear to vary greatly in number from year to year, the ptarmigan being fairly abundant in 1923. Ducks and geese also abound on the lakes and rivers, particularly in the fall. Salmon are found in the larger streams, and grayling (Arctic trout), pickerel, lake trout, and whitefish are found in the streams and lakes. Grayling in particular are abundant.

GEOLOGY

OUTLINE

The exact distribution and age of the several geologic formations and the geologic history of the region are as yet imperfectly known, but the major geologic features are now fairly well recognized. The geologic data here given include not only the results of the work of 1923 but also the earlier observations of Schrader and Maddren.

The oldest sedimentary rocks occur at the south end of the district, and, with certain exceptions to be mentioned later, younger rocks appear successively toward the north. Seven sedimentary formations and four igneous formations are shown on the accompanying geologic map (Pl. VI), but some of these are known to be composite groups that will be subdivided by later work.

The oldest sedimentary rocks are a group of quartzite and quartzite schist which crop out along the ridge south of the main Chandalar River. These resemble some of the rocks of the Birch Creek schist of the Yukon-Tanana region, of pre-Ordovician and possibly of pre-Cambrian age, and are referred with certain reservations to that formation.

North of the Birch Creek schist (?) occurs a great thickness of rocks, principally schist and phyllite, which on the basis of their lithology and fossils are referred to the early Paleozoic. These rocks were included by earlier writers as a part of the Birch Creek schist.

The early Paleozoic rocks are adjoined on the north, in the valleys of North and Middle forks of Chandalar River and also in the valleys of Bettles and Dietrich rivers, by a great body of massive crystalline limestone and dolomite, of middle or upper Silurian age.

Still farther north Middle Devonian slates occur, apparently lying unconformably upon the Silurian limestone. The crest of the Endicott Range at this longitude, to judge from the gravels in the stream, is made up of still later rocks, probably of Mississippian age, but these lie beyond the area included in the geologic map.

In the southwestern part of the Chandalar district Upper Devonian or Mississippian rocks occur, lying unconformably upon the older rocks. This occurrence forms one of the exceptions to the general rule that the rock formations are successively younger toward the north.

In the lower Koyukuk Valley, southwest of the Chandalar district, great areas are covered by Upper Cretaceous sandstone and related rocks, and one small lobe of these rocks reaches up into the southwest corner of the Chandalar district. These rocks lie unconformably above all the older rocks of the district. The Quaternary deposits form the seventh geologic unit distinguished on the map. They include, as mapped, both Recent stream deposits and older (Pleistocene) deposits of glacial and glacio-fluviatile origin. They cover large areas in the lower courses of the river valleys, particularly in the valleys of Mosquito Fork and South Fork of the Koyukuk. The Recent stream deposits will eventually be differentiated from the older alluvial deposits, when a more detailed topographic map of the district is made.

Four formations of igneous rocks are shown on the geologic map. The oldest are ancient granitic rocks of gneissoid character, which are exposed typically in the valley of North Fork of Chandalar River at the big bend, though they are also known elsewhere. They intrude the Birch Creek schist (?), the early Paleozoic schist, and possibly the Silurian limestone but are unknown in the Devonian and later rocks. These rocks are believed to be of late Silurian or early Devonian age.

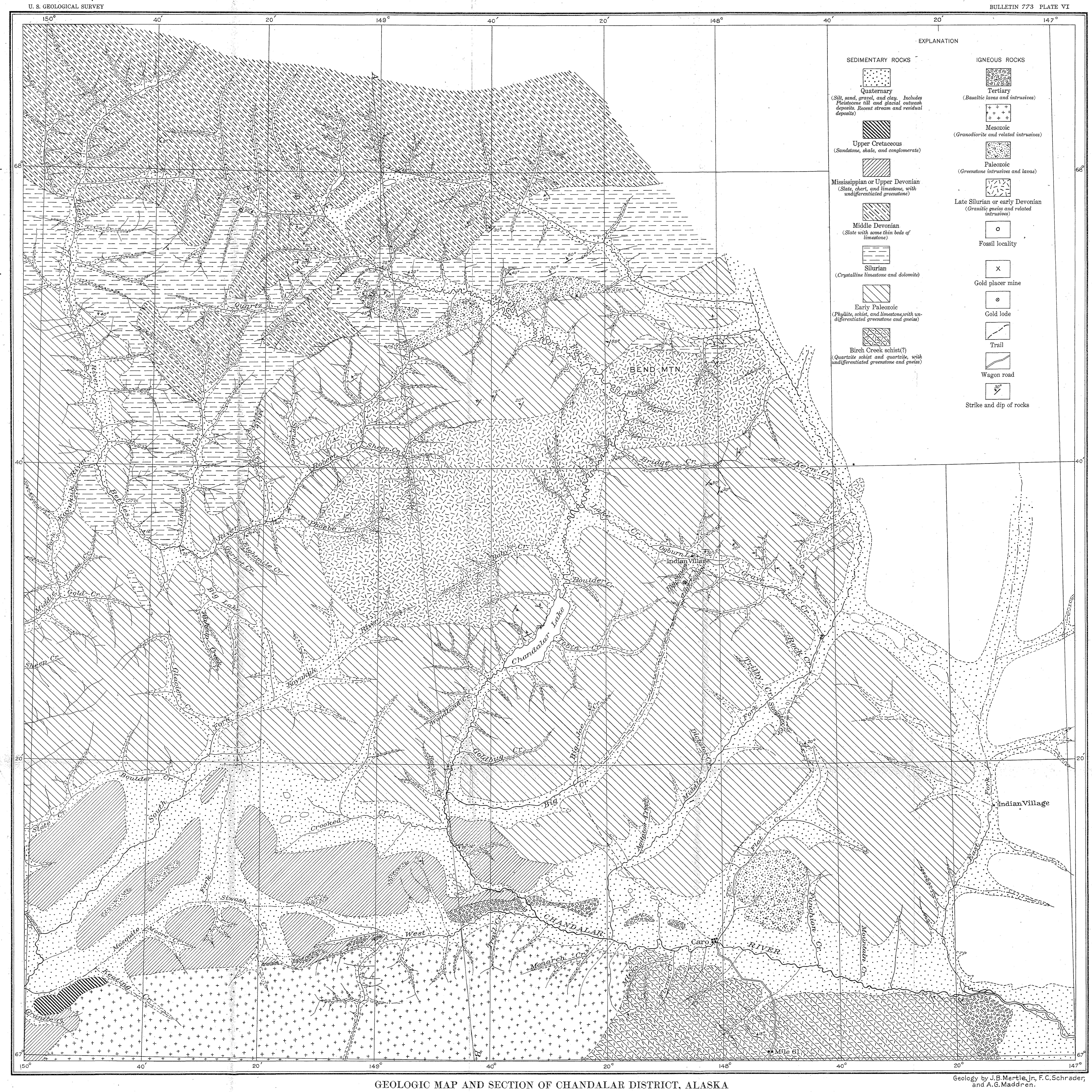
Another formation composed of basic intrusive and perhaps extrusive rocks of greenstone habit is believed to be in part of Mississippian age but in part of early Paleozoic age, possibly Devonian or Silurian, but the necessary data for separating the rocks into two formations are lacking, and they are grouped together as one unit.

In the southwestern part of the district occurs a great massif of Mesozoic granodioritic rocks, which are separately mapped, and in the valleys of Chandalar River and its West Fork are basic lavas and intrusive rocks of Tertiary age.

The Birch Creek schist (?) shows the greatest deformation, but the early Paleozoic schist and the Silurian limestone are also greatly deformed. The most prominent trend line is somewhat east of north, but these three older formations also show the effects of an earlier deformation in which the major axes apparently trended more nearly north. The Devonian and Mississippian rocks are less disturbed than older rocks of a similar degree of competence and do not appear to have partaken of the earlier deformation. The Upper Cretaceous rocks are even less deformed, though they are really not well known in this district.

BIRCH CREEK SCHIST (?)

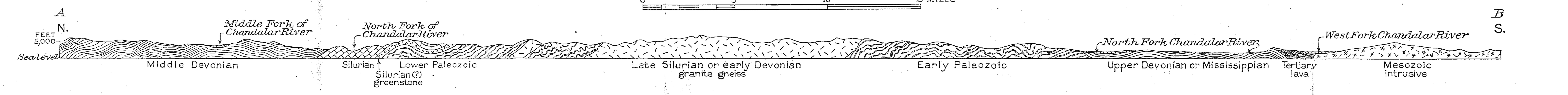
Distribution, lithology, and structure.—The only rocks in the Chandalar district that are believed to be the possible equivalent in age of the Birch Creek schist are those south of the main Chandalar, along the divide between Chandalar and Orenzik rivers. Little



GEOLOGIC MAP AND SECTION OF CHANDALAR DISTRICT, ALASKA

Scale $\frac{1}{250,000}$

0 5 10 15 MILES



study has been given to these rocks, however, the available data consisting of a few observations made by Schrader in 1899 and by the writer in 1923.

These rocks crop out in places along the Beaver-Caro trail, from mile 61 to Schilling Creek, and along the ridge extending to the east and west. In that vicinity they consist chiefly of quartzite schist and quartzite, cut by many veins of massive white quartz. No indication of mineralization was noticed in this quartz. Observations by Schrader on the ridge farther east seem to show that this schist is invaded by the gneissoid granitic rocks of early Paleozoic age.

Few data on the structure of these rocks are available, but what little is known indicates that they dip northward under the younger rocks. They have been much changed by dynamic metamorphism, but the harder members do not seem to be closely folded, though intense crenulation was observed in some of the rocks. Minor folds along the ridge between Chandalar and Orenzik rivers were observed to pitch northeastward, but this is probably a composite structure, resulting from crustal movements during more than one period.

Age and correlation.—No fossils have been found in these rocks, and therefore no absolute evidence is available regarding their age. They underlie a group of younger schists and phyllite in which Silurian fossils have been found and are therefore probably pre-Silurian. Lithologically, however, they resemble some of the rocks of the Yukon-Tanana region that are designated Birch Creek schist and are of pre-Ordovician and possibly of pre-Cambrian age. Solely on lithologic grounds, therefore, these rocks are correlated tentatively with the Birch Creek schist.

EARLY PALEOZOIC ROCKS

Distribution.—The early Paleozoic rocks have a greater areal distribution than any of the other formations mapped in the Chandalar district, owing probably to the fact that under this designation are grouped a great variety and thickness of undifferentiated metamorphic rocks. Beginning at Chandalar River, these rocks extend about 40 miles northward, adjoining to the north the Silurian limestone. The east-west continuity of this vast area is broken at the mouth of the West Fork of Chandalar River, where rocks of Upper Devonian or Mississippian age begin and extend westward in an expanding wedge.

Lithology.—The early Paleozoic rocks consist mainly of mica schist and phyllite, both of which are in places graphitic. In addition, they include quartzose varieties, such as quartz-mica schist and arenaceous phyllite, and some narrow bands of crystalline limestone, from one of which fossils were collected. Locally, in the vicinity of intrusive rocks, particularly near the borders of the Paleozoic granitic intrusives, biotite schist is developed, some of it with garnet and other minerals due to contact metamorphism. Associated with the early Paleozoic schist are bodies of granite gneiss, granitic schist, greenstone, and greenstone schist, all of Paleozoic age. The more conspicuous bodies of these ancient intrusive and extrusive rocks have been mapped as separate formations, but the area here mapped as early Paleozoic doubtless contains numerous bodies of such rocks that have not been seen by the writer.

Structural relations.—Relatively few observations on the geologic structure of these rocks have been made, owing chiefly to the reconnaissance character of the work so far done in this region. These rocks are shown as covering an area of over 2,000 square miles, in which only about twenty observations of strike and dip are recorded. The general trend of the contact of the early Paleozoic rocks with the adjoining rocks, particularly with the Silurian limestone, gives in reality a better idea of the formational trend than these few isolated observations of structural relations; and this contact indicates that the regional trend is about due east, or perhaps a little north of east. (See structure section, Pl. VI.) Similarly, the presence of older rocks to the south and of younger rocks to the north and the absence of data pointing to overthrusting indicate that the general dip is northward.

The scattered observations of strike and dip, however, show plainly that much irregularity exists in the attitude of these rocks. One noteworthy feature is the presence at many localities, particularly along the North Fork of Chandalar River, of an apparent structural trend of about N. 20° E. The significance of this trend is considered later. In addition, the dip observations show reversals which are interpreted as indicating minor anticlines and synclines that modify the larger structural trends. Schrader has noted such a reversal of dip at the rapids of the North Fork of Chandalar River, where the rocks below the rapids dip south and those above the rapids dip north. West of Chandalar Lake and elsewhere similar reversals of dip are common.

The early Paleozoic rocks are in general highly deformed, showing crenulation, close folding, and shearing. In fact, these rocks appear from cursory examination to be more metamorphosed and structurally deformed than the Birch Creek schist (?) to the south, but they are of more argillaceous composition, and their higher degree of deformation is interpreted as due in the main to inferior competency. The great massif of gneissoid granite in their midst, however, may have exerted a supplementary deformational influence.

Other structural features of interest occur, such as faulting and jointing, but few details are available. Faults, or more properly fault zones, are indicated by zones of sheared rock at some places but were not studied carefully. These zones are apparently due to movements when the rocks were deeply buried under a heavy load. On the other hand, fissures filled with quartz, many of them following the cleavage but perhaps quite as many cutting across it, were noted at many places, particularly in the valleys of Grave and Lake creeks and their tributaries. On the ridge south of Grave Creek, a few miles west of the Middle Fork of Chandalar River, the phyllite country rock is greatly jointed, breaking at the surface into elongated slabs about 1 by 3 by 24 inches and larger.

The structural relation of the early Paleozoic rocks to the older rocks to the south is obscure—in fact, practically unknown. By reasoning from analogy an unconformity might be postulated between the two groups of rocks, because that relation appears to exist south of the Yukon, in the Yukon-Tanana region. Too little is known of the stratigraphy and structure of either group in this district, however, to make such a hypothesis very convincing. It is suggested, therefore, as a reasonable possibility rather than a definite conclusion.

On the north, however, the structural relation of the early Paleozoic rocks to the Silurian limestone is better understood. The field evidence points strongly to a conformable relation between the two groups of rocks. This is indicated by the absence of any structural discordance between them, by the similar degree of metamorphism in both groups, and by an apparent lithologic gradation between the two. In approaching the main body of limestone from the south, small bodies of limestone become more common in the early Paleozoic schist. One such body of fairly large size northeast of Bend Mountain is shown on the geologic map. Similarity in the fossils also points to the same conclusion.

Age and correlation.—The rocks here grouped as early Paleozoic schist and phyllite include the rocks named by Schrader the "Rapids" schist and the "Lake" quartzite schist. No lithologic differences, however, were observed that are considered adequate for separating the early Paleozoic schist into two formations, and the distinction has therefore not been made. Schrader considered that the "Rapids" schist underlies the "Lake" quartzite schist, and as the former occurs to the south of the latter and both in a general way dip northward, this conclusion is doubtless true. It is believed, however, that the differences on which this separation was originally made are due largely to local variations in the lithology and degree of metamorphism that will not hold over large areas.

West of the Chandalar district, in the valley of John River, Schrader[4] found a group of rocks consisting mainly of mica schist and quartz-mica schist to which he applied the name Totsen "series." These rocks lie south of the Silurian limestone belt of John River, having the same geographic position relative to the limestone that the early Paleozoic rocks have to the Silurian limestone in the Chandalar district. Nevertheless, he believed that the Totsen "series" or group was younger than the Silurian limestone. The writer disagrees with this interpretation and is strongly inclined to correlate the Totsen group with the early Paleozoic rocks that lie below the Silurian limestone in the Chandalar district.

Schrader considered the "Rapids" schist and the "Lake" quartzite schist, which are included in the rocks here designated early Paleozoic, to be correlative with the Birch Creek schist, and in the absence of any additional data Maddren later accepted this interpretation. In 1923, however, a collection of fossils was made in the very center from north to south of the area occupied by these rocks and necessitated a revision of the earlier ideas regarding their age. These fossils were found in a lens of black yet crystalline limestone, not more than 50 feet thick, interbedded in the phyllitic rocks and separated by only a few feet from a body of the intrusive gneissoid rock. The exact location is about 6 miles N. 30° W. of the junction of Grave Creek with the Middle Fork of Chandalar River, on the summit of the ridge, at an altitude of about 4,000 feet. This location is indicated on the geologic map. The fossils were examined by Edwin Kirk, of the United States Geological Survey, who reports the following forms, which he assigns to the Silurian:

Cladopora sp.
Clorinda? sp. Pentameroid brachiopod. May be same as the species referred to Clorinda in the White Mountains district (Yukon-Tanana region).

One fossil collection in so great a thickness of rocks does not of course determine the age of the entire sequence. The massive limestone to the north, however, is now known to be of Silurian age, though somewhat younger than these rocks, and it is only reasonable to infer that the rocks for an equal distance south of this fossil locality, as far as the Chandalar, are at least not older than Paleozoic, though they may well be older than Silurian. The entire sequence of rocks, therefore, lying between Chandalar River and the massive Silurian limestone is mapped as early Paleozoic.

[4] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, pp. 58–60, 1904.

SILURIAN LIMESTONE

Distribution.—The Silurian limestone crosses the Chandalar district in a general east-west direction just south of the sixty-eighth parallel, forming a belt from 2 to 8 miles wide. The narrowest place in this belt occurs where it crosses the North Fork of Chandalar River. To the east, toward the Middle Fork, the belt becomes much wider; and to the west, very much wider. From the head of Quartz Creek one great lobe of the limestone extends southward for nearly 20 miles to the bend of Bettles River, and some outlying bodies of limestone occur even south of Bettles River. West of Quartz Creek, where the limestone crosses Dietrich River, it appears to have a width comparable with its width at the Middle Fork of Chandalar River. These variations in the areal distribution are considered elsewhere (pp. 230–231).

Lithology.—In general, this formation consists of crystalline and semicrystalline limestone, probably dolomitic at many localities. The usual color, both from a distance and close at hand, is white or light gray, though this grades into darker colors. In some places much red and brown iron staining occurs. At the fossil locality on the upper part of the North Fork of Chandalar River the limestone is almost black and has a strong odor of decomposed organic matter. This condition, however, is exceptional.

The massive limestone is much jointed, and the less massive varieties, particularly near the contact with the older rocks, are in places sheared to the condition of a calcareous schist. The rock is also much fractured in places and veined with calcite and less commonly with quartz.

On the southern border of the limestone belt, where it crosses the North Fork of Chandalar River, a band of sheared greenstone adjoins the limestone, and smaller lenses of this same material are found within the main body of the limestone, indicating a constant association of rocks of these two types. The gneissoid granite to the south is believed to have been intruded after the limestone was deposited, but the two rocks have not been observed anywhere in contact.

Structure and thickness.—The Silurian limestone, because of its easily recognizable contacts and also on account of its conformable relation with the older rocks to the south, is an excellent index of the regional structure of the early Paleozoic rocks. Accurate mapping of this southern contact, together with numerous observations of the bedding of the limestone and a careful evaluation of possible faulting, should yield much information about the orogenic history of the early Paleozoic. Such work, of course, is not accomplished in reconnaissance surveys, but the general trend of this southern contact is sufficiently well known to warrant certain broad generalizations.

The most prominent and universal structure in the rocks of the Chandalar district trends about due east. The youngest of the Paleozoic formations, as well as the oldest, partake of this structure, and it is therefore believed to represent a regional crustal disturbance that occurred after Paleozoic time. Notwithstanding this unmistakable trend, the early Paleozoic rocks on both sides of the North Fork of Chandalar River, both above and below Bend Mountain, show a distinct structure, the average trend of which is about N. 20° E., and the same is true of the Silurian limestone at certain localities. This structure is interpreted as evidence of an older period of folding, which affected the Silurian and pre-Silurian rocks but not the later Devonian rocks.

The hypothesis is therefore suggested that the Silurian and pre-Silurian rocks were folded in early Devonian or late Silurian time, and that all the Paleozoic rocks were again folded in post-Paleozoic time, possibly in more than one stage. The axes of these two sets of folds are believed to make an angle of about 70° with each other. It has been shown that the trend of the later structure is about east and that the regional dip is north. It remains to interpret the areal distribution of the Silurian limestone in terms of an older folding modified by a later folding. Now, while it is true that the later structure is in general monoclinal, with a prevailing northward dip, it is also true that reversals of dip are present, which must be accounted for in any interpretation. Moreover, it is known that faulting has played an important part in determining the areal and topographic form of the limestone. Nevertheless, if a series of anticlines and synclines striking about N. 20° E. are folded in an east-west direction and are welded into an east-west monocline dipping north, the net effect will be an irregular contact line, the old synclines projecting and the old anticlines forming reentrants on the south side. On the north side the reverse will be true, the anticlines forming the projecting lobes and the synclines the reentrants. In the case of the Silurian limestone this effect may be further complicated on the north side by the presence of the adjoining Middle Devonian rocks, which lie unconformably above the limestone. Reversals of dip in the east-west structure will reverse these relations, but probably on a smaller scale, producing secondary lobes and reentrants of minor magnitude. The observed irregularity of the contact lines of the Silurian limestone is interpreted as a result of two such periods of folding, modified of course by faulting. Under this hypothesis the great lobe of Silurian limestone that projects southward from Quartz Creek to the bend of Bettles River may be interpreted broadly as a manifestation of such a composite structure, although it is fully recognized that faulting, particularly on the south edge of this lobe, has also played an important part in the process.

It has been stated that the general trend of the early Paleozoic rocks is east. This is true in the Chandalar district, but observations over a larger area indicate that the easterly trend of the limestone is tangential to the structure of a larger orogenic feature, a crescentic arc that is parallel in a general way to the Alaska Range and to the big bend of Yukon River at Fort Yukon. The evidence for this conclusion consists in the fact that the Silurian limestone of John and Alatna rivers is southwest of the same limestone in Chandalar River, whereas the Silurian limestone of Porcupine River, below the mouth of the Coleen, is southeast of the limestone of the Chandalar district. It is further inferred by a study of the symmetry of this arc that the Chandalar district lies a little west of a line normal to the tangent to the arc at its northern extremity. This fact accounts for the apparent tendency of the later structure to trend somewhat north of east, rather than east, in the Chandalar district.

If this interpretation of the structure of the limestone is accepted, it is manifestly difficult without detailed work to make a trustworthy computation of the thickness of the beds. Obviously the place to measure a section will be at some point where the trends of the older and younger structural features coincide, and such points of course will be found at the noses or ends of the old anticlinal and synclinal folds. The effects of faulting being neglected, such localities will show a minimum north-south distance across the limestone belt. Just east of the North Fork of Chandalar River such a minimum distance between contacts occurs. The average dip at this locality is about 35° N., and with this attitude of the beds the limestone appears to have a thickness of perhaps 6,000 feet.

Age and correlation.—The Silurian limestone was first described by Schrader[5] under the name Bettles "series," but no definite age was assigned to it, although he recognized that this limestone was probably younger than the schists to the south. Later Schrader[6] described under the name Skajit formation another wide belt of limestone and mica schist which crosses John River, about 70 miles to the west of the Chandalar district. Some obscure fossil remains were found in the limestone of the Skajit formation, which indicated that it could not be older than Silurian nor younger than Carboniferous. Schrader inferred from this and certain other evidence that the Skajit formation might be upper Silurian and so designated

[5] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska, in 1899: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, p. 475, 1900.

[6] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, pp. 56–58, 1904.

it in the text of his report. Maddren, however, suggested that both the Bettles "series" and the Skajit formation might be of Carboniferous age.

In 1923 a fossil collection was made by the writer from the limestone in the upper part of the North Fork of Chandalar River. The exact location is on a southern tributary of the North Fork entering about 6 miles from the confluence of the West and North forks of the North Fork, about three-quarters of a mile upstream from the mouth of the tributary. These fossils were identified as *Conchidium?* sp. by Edwin Kirk, of the United States Geological Survey, who reports as follows:

> This may be the same as the *Conchidium?* sp. from the White Mountains of the Yukon-Tanana region. The latter seems to have a relatively thin shell, while this species has one of extraordinary thickness. This may, however, be due to differences in preservation. What appears to be the same genus is found in the upper Silurian of southeastern Alaska.

The fossils collected from the limestone in the White Mountains of the Yukon-Tanana region are regarded by Mr. Kirk as highest middle Silurian. The limestone formation of the Chandalar district is therefore either highest middle Silurian or upper Silurian.

This limestone, as previously stated, is the Bettles "series" of Schrader and is believed to be correlatable with the Skajit formation, to the west, on John River. The Skajit formation also continues westward into the valley of Alatna River, where it was observed by Smith.[7] Smith correlated the Skajit tentatively with the Lisburne limestone, of Mississippian age, but it now seems certain that the Skajit formation and its westward continuation in the Alatna Valley are of Silurian age.

The Silurian limestone of the Chandalar district is correlated in a general way with the buff-colored magnesian limestone that crops out in the Lower Ramparts of Porcupine River, below the mouth of Coleen River, although this limestone was determined by Kindle[8] as middle rather than upper Silurian. It is also correlated with the upper middle Silurian limestone of the White Mountains, south of the Yukon. A part of the Port Clarence limestone of Seward Peninsula, particularly in the Don River valley,[9] is now believed to be middle or upper Silurian, though the main part of the Port Clarence limestone is of Ordovician age. The Silurian limestone may therefore be correlated with the Silurian limestone of Don River, and last of all it may be correlated also in a general way with

[7] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, pp. 61–67, 1913.

[8] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, pp. 324–325, 1908.

[9] Steidtmann, Edward, and Cathcart, S. H., Geology of the York tin deposits, Alaska: U. S. Geol. Survey Bull. 733, p. 23, 1922.

the Silurian limestone of southeastern Alaska, in particular with the upper Silurian limestone of Glacier Bay.

MIDDLE DEVONIAN ROCKS

Distribution.—Middle Devonian rocks begin a short distance south of the 68th parallel, at the northern limit of the Silurian limestone, and continue northward to the limit of the area mapped—that is, for about 10 to 15 miles. These rocks, however, do not extend to the crest of the Endicott Range, for it is known both from the gravel seen at the headwaters of the North Fork of Chandalar River and from data acquired in other ways that younger rocks, probably of Upper Devonian or Mississippian age, crop out at the very crest of the range at this longitude. The Middle Devonian rocks, then, form a belt more or less parallel to the belt of Silurian limestone, extending across the northern limit of the Chandalar district in a general east-west direction.

Two lobes of Middle Devonian rocks, however, project southwestward from the main belt, extending up both sides of Quartz Creek for a distance of 8 or 9 miles. A third area, apparently completely detached from the main belt, lies still farther southwest, forming the divide between Quartz and Limestone creeks. This third area was mapped from a distance, and the boundaries shown on the map are likely to be more or less inaccurate.

Lithology.—The Middle Devonian rocks consist dominantly of slate, with a minor proportion of sandstone and some thin beds of limestone. These rocks form rounded hills up to an altitude of 4,000 feet, and even in the higher mountains up to 6,000 feet they do not produce the ragged seriate crest line characteristic of the Silurian limestone. The slate hills, particularly below an altitude of 5,000 feet, have a mottled yellow and brown appearance, due to the yellow weathering of the slate; above 5,000 feet the hills are black, owing to the presence of relatively unweathered black talus.

The slate in the hills on the northeast side of the Middle Fork of Chandalar River, in the vicinity of the forks of this stream, is literally permeated with vein quartz. Much of this quartz shows the oxidized pyrite cubes that are characteristic of the vein quartz in the vicinity of Little Squaw Creek, and such quartz is probably goldbearing. Quartz veining, in fact, seems to be a distinctive feature of the Middle Devonian slate, though the quartz is not everywhere so plentiful as at the locality above mentioned, nor is it everywhere mineralized.

In the vicinity of the forks of the North Fork of Chandalar River several small bodies or lenses of dark-gray limestone, not of mappable size, are interbedded with the slate. Two such lenses were observed on the spur between the North and West forks of the North Fork of the Chandalar, one of which is cleaved almost to a calcareous slate. Somewhat higher on this spur but stratigraphically below the limestone beds a fossil collection was obtained from the slate. From the forks of the North Fork of the Chandalar down the valley to Quartz Creek the slate seems more than ordinarily metamorphosed and shows phyllitic and schistose phases.

Small bodies of sheared diabasic or basaltic rock of greenstone habit are associated with the Middle Devonian slate at numerous localities. These greenstones occur usually in small bodies, none of mappable size being observed. From their form and general character they are judged to be small intrusive bodies, and most are believed to be of late Paleozoic age.

Structure and thickness.—The Middle Devonian rocks are believed to lie unconformably above the Silurian limestone. This conclusion is borne out by numerous observations on the structure of the two formations along their contact and by the evidence furnished by the fossil collections.

In the vicinity of the fossil locality in the Silurian limestone, previously mentioned, this unconformable relation is particularly well shown. The unconformity is believed to represent one of the major periods of deformation and erosion in the Paleozoic sequence of rocks in this region.

The Middle Devonian slate is intricately folded and crumpled and has evidently presented little resistance to deformational forces. The folds are sharp and many of them are of small magnitude, and in this respect they stand in marked contrast to the more open type of folding that is characteristic of the more competent Silurian limestone. Necessarily, therefore, many reversals of dip occur, indicating numerous folds, only a few of the larger of which have probably been recognized. In general, however, these rocks are believed to dip northward, plunging under younger rocks that form the crest of the Endicott Range. The general strike is east.

The upper stratigraphic limit of the Middle Devonian slate was not reached by the writer, but it is believed to end a very short distance beyond the northern limit shown on the map. Partly on this account, but more particularly on account of the intricate folding and numerous reversals of dip in these rocks, no very trustworthy estimate of the thickness can be made. It is believed, however, that the Middle Devonian slate is between 5,000 and 10,000 feet thick.

Age and correlation.—One fossil collection was made from the Middle Devonian slate. The exact locality is about 2½ miles N. 50° W. from the confluence of the West and North forks of the

North Fork of Chandalar River, on the spur between the two streams at an altitude of about 3,600 feet. These fossils have been examined by Edwin Kirk, of the United States Geological Survey, who pronounces them unquestionably of Middle Devonian age. The forms recognized are as follows:

Striatopora sp.
Diphyphyllum sp.
Cyathophyllum cf. C. caespitosum Goldfuss.
Alveolites sp.
Atrypa reticularis Linné.
Spirifer sp. (type of S. mucronatus Conrad).
Cyrtina cf. C. hamiltonensis Hall.

This fauna is the same as that found by Kindle[10] in the limestone on Porcupine River at the mouth of Salmontrout River. The difference in lithology at these two fossil localities serves to show the possible variation in the character of the Devonian rocks along the strike. It is interesting to note that Kindle also believed that the Middle Devonian rocks of the Porcupine lie unconformably above the Silurian rocks, though his conclusion was based entirely on faunal differences in the two groups of rocks.

The Chandalar and Porcupine valleys are the only two districts in which Middle Devonian rocks have been definitely recognized north of the Yukon. On Yukon River, however, below Woodchopper Creek,[11] is a series of limestone and shale which are unquestionably of Middle Devonian age.

South of the Yukon, in the Yukon-Tanana region, and also south of the Tanana, Middle Devonian rocks are known at numerous localities. The Tonzona group of the Yukon and Tanana valleys is probably in part of Middle Devonian age. The Tonzona group resembles the Middle Devonian slate of the Chandalar district, in that it is dominantly argillaceous and arenaceous, with only a subordinate amount of included limestone. In the valley of Jack River, however, just above its confluence with the Nenana, there is a Middle Devonian limestone which resembles more nearly the Salmon Trout limestone of the Porcupine Valley.

UPPER DEVONIAN OR MISSISSIPPIAN ROCKS

Distribution.—Rocks that are believed to be of Upper Devonian or Mississippian age crop out at the junction of the West Fork and North Fork of Chandalar River and continue westward into the valleys of the South Fork and Mosquito Fork of Koyukuk River.

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[10] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, pp. 327–329, 1908.

[11] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, pp. 279–284, 1908.

Schrader found much chert in the gravel at the mouth of the East Fork of Chandalar River, and it is likely that rocks of the same age are present between Flat Creek and the East Fork and perhaps east of the East Fork, but this district was not visited, and such rocks, if present, have not been mapped.

North of the Middle Devonian rocks at the northern limit of the Chandalar district younger rocks are also probably present, but this region lies beyond the area mapped in 1923. They differ lithologically from the Devonian rocks and so are easily recognized in stream gravel. Gravel of these rocks, including chert and chert conglomerate, was found in 1923 in the headwaters of the North and Middle forks of Chandalar River, and two men who have crossed the Arctic divide have told the writer that the crest at the longitude of the North Fork is formed of a chert conglomerate. It is therefore concluded that younger rocks, possibly in part equivalent to the rocks north of the West Fork of Chandalar River, adjoin the Middle Devonian rocks on the north.

Lithology.—These rocks were first noticed by Schrader west of the junction of the West Fork and North Fork of Chandalar River, and he called them the West Fork "series." According to his description,[12] they consist of fine-grained dark-gray quartzite, black flint, calcareous black shale, and impure limestone, which are cut by greenish dioritic or diabasic dikes that trend northeast, with the structure of the rocks. Later in the same season he recognized the same rocks on Jim Creek, in the valley of the South Fork of Koyukuk River. He also found these rocks just below Rose Creek, the next eastern tributary of the Middle Fork of Koyukuk River below Slate Creek. Maddren,[13] in 1910, made some further observations on these rocks and mapped them as far northeast as Boiler Creek.

Schrader's published description is accurate and carries all the information that is likely to be obtained regarding these rocks in this district, for they occur on low ridges and are recognized mainly from their weathered débris. Few or no structural data are available. The writer examined the base of these rocks on the ridge north of the West Fork and west of the North Fork of Chandalar River, and the only additional information obtained is that the base here consists of a cherty grit, which in the field was mistaken for a tuff. This grit consists of subangular grains of quartz and chert in an iron-stained kaolinic cement. Additional data concerning the intrusive greenstone are given on pages 244–246.

[12] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska, in 1899: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 475–476, 1900.

[13] Maddren, A. G., The Koyukuk-Chandalar region, Alaska: U. S. Geol. Survey Bull. 532, pp. 50–51, 1913.

Structure and thickness.—The structure of these rocks, as stated above, is largely unknown. They appear to trend northeast, to judge from the elongation of the sills and dikes within them, but this trend may be more apparent than real. Without doubt, however, they rest unconformably upon the early Paleozoic rocks, but their stratigraphic and structural relations to the Middle Devonian rocks to the north are unknown.

Age and correlation.—No determinable fossils have been found in place in these rocks. Some fossils were found by Schrader, however, in gravel along the main Chandalar River that are likely to have come from this group of rocks. The localities of these fossils and the report on them by G. H. Girty, made in 1899, are given herewith:

No. 2. Chandalar River 20 miles above mouth: *Syringopora* sp. 2.

No. 5. Chandalar River 48 miles above mouth (17½ miles below East Fork): Cyathophylloid coral.

No. 22. Chandalar River 57 miles above mouth (8½ miles below East Fork): *Syringopora* sp. 1.

No. 47. Chandalar River 98 miles above mouth (1 mile above Middle Fork): *Spirifer, disjunctus* type.

Syringopora is, so far as known, not found above the Carboniferous; therefore specimens 2 and 22 may be referred with little doubt to the Paleozoic. The *Spirifer* of specimen 47 is of a type not found below and in a measure restricted to the Devonian. If, as I suspect, the form is *Spirifer disjunctus* itself or one of its close allies, specimen 47 may pretty safely be referred to the Devonian, probably to the Upper Devonian.

The coral found in specimen 5 probably belongs to the genus *Acervularia*. The age indicated is certainly Paleozoic and probably Devonian.

These determinations should be checked in the light of additional paleontologic data gathered in Alaska in the last 25 years, but the fossils have been lost and are no longer available. With the exception of specimen 47 all these collections might as well be referred to the Mississippian as the Devonian, particularly when it is remembered that the type Mississippian fauna of Alaska, that of the Lisburne limestone, was originally referred to the Devonian. *Spirifer disjunctus*, however, is a form which is said by paleontologists to be characteristic of the Upper Devonian. Moreover, this is not the only collection of *Spirifer disjunctus* made in this region, for Schrader, in 1901, collected it from the Fickett "series" of rocks at two places on John River. It is not likely, therefore, that the determination of specimen 47 is erroneous.

It is necessary to consider the geologic section north of the Skajit formation on John River, in order to arrive at any satisfactory conclusion regarding this West Fork "series." Adjoining the Skajit formation on the north is a great thickness of sediments, of very diverse character, mapped by Schrader under the name Fickett "series." To the north of these beds lies the Lisburne limestone, within which was found a chert conglomerate formation, which he called the Stuver "series." The Fickett "series" was interpreted as Mississippian, the Lisburne as Devonian, and the Stuver as pre-Devonian. It is now known, from later determinations of these fossil collections, that the Lisburne is Mississippian. The Stuver was believed to underlie the Lisburne but is probably either a part of the Mississippian or the base of it. The Fickett "series" probably includes rocks of several ages, from Middle Devonian at the base to Upper Devonian or Mississippian at the top. This would account for the diversity of faunas found within it.

With this section in mind, it seems reasonable to regard the West Fork "series" as equivalent to a part of the Fickett "series." Lithologically the West Fork "series" differs from the Middle Devonian rocks of the Chandalar district in containing chert. On the other hand, it does not appear to have the chert conglomerate of the Stuver "series." It seems best, therefore, to correlate it with the upper part of the Fickett "series," stratigraphically below the chert conglomerate of the Stuver "series." This horizon may be either Upper Devonian or Mississippian.

The chert conglomerate cobbles that are found in the headwaters of the North and Middle forks of Chandalar River are probably derived from the chert conglomerate, or Stuver "series," probably at the base of the Lisburne formation. These cobbles, however, are very hard and resistant to weathering and may have traveled far. It is therefore possible that a formation equivalent to the West Fork "series" may intervene between the northern limit of the Middle Devonian rocks in the Chandalar district and this chert conglomerate formation on the north.

UPPER CRETACEOUS ROCKS

Only one small area of Upper Cretaceous rocks is known in the Chandalar district. This area, which lies at the southwest corner of the district, was not visited by the writer, and the character of the rocks is not known. In general the Upper Cretaceous rocks of the Koyukuk region consist of sandstone, shale, and conglomerate. They have been greatly folded and to some extent faulted, but their structure is relatively simple compared with that of the older Paleozoic rocks. The Upper Cretaceous rocks lie unconformably above all the Paleozoic rocks and probably also above the Mesozoic granodiorite of this region.

QUATERNARY DEPOSITS

The Quaternary deposits consist of unconsolidated silt, sand, and gravel, which now fill the bottoms of the stream valleys and in places extend up onto benches along the sides of the valleys. These deposits are conventionally divided into two types, the division being made primarily on the basis of age and secondarily on the character of the deposits. The older or Pleistocene deposits originated for the most part from glacial erosion during the last period of glaciation in this district, but as found to-day they show that they have in general been reworked by subsequent stream action. The Pleistocene deposits therefore consist in part of true glacial débris, or till, and in part of reworked glacial débris, commonly known as outwash deposits. The latest or Recent deposits consist of sand, gravel, and silt, which have been derived in part from the hard-rock formations by weathering and stream transportation and in part by the reworking and transportation of the older or Pleistocene deposits. On the accompanying map these two types of deposits have been grouped together as a single map unit, designated Quaternary deposits.

PLEISTOCENE GLACIATION AND DEPOSITS

The term Pleistocene epoch is used as more or less synonymous with the term glacial age, though it is well known that the period of glaciation in Alaska began earlier and continued later than in the northern United States. Glaciation requires an annual snowfall greater than the present annual dissipation of snow and ice. Most of the interior of Alaska, notwithstanding its low mean annual temperature, has not been glaciated, because of its relatively light snowfall. Even the Arctic Mountains and Arctic slope, with a somewhat heavier precipitation and lower mean annual temperature than interior Alaska, are not glaciated to any extent at the present time. But a marked increment in one or both of these factors during Pleistocene time caused a severe glaciation of the Arctic Mountains, the effects of which are still clearly visible.

With a glacial climate established, snow accumulates from year to year, and the lower parts of the snow banks gradually congeal to ice. When the weight of superincumbent snow and ice becomes too great the ice begins to flow and creeps slowly down into the valleys, often extending miles beyond the main site of accumulation. This ice movement, which measures usually but a few feet a year, produces a type of erosion quite different from stream erosion. It is primarily a scouring action, accompanied by a sapping action on the main crest lines. The valleys and ridges are scoured smooth, while the main divides just above the flowing ice are converted into ragged crest lines. The ice-borne débris is carried down into the lower valleys and there deposited, where it is picked up again by glacial streams issuing from the ends of the glaciers and redistributed to a greater or less extent farther down the valleys. The original glacial débris is characterized by a complete lack of assortment, boulders and rock fragments of all sizes being mingled indiscriminately with finer débris and clay. The rock débris is unrounded, and many of the cobbles are scoured on one or more sides to produce flat or faceted surfaces. Such material is called till. The partly reworked material, or outwash deposit, preserves to some extent its original form and character, but by prolonged stream action it gradually develops into normal stream sand and gravel.

At the time of maximum glaciation the crest of the Arctic Mountains was probably covered by a continuous ice cap, which probably extended some distance down the Arctic slope before separating into individual valley glaciers. On the south slope, however—for example, in the Chandalar district—the glaciation was mainly of the valley or alpine type, although the glaciers extended high up onto the valley walls. On the divide between the North and Middle forks of Chandalar River, northeast of Bend Mountain, at about latitude 67° 50′, erratic boulders of chert conglomerate were seen by the writer at an altitude of 3,500 feet, showing that the glacial ice at one time extended at least that high at that latitude. Farther south glacial deposits were seen at an altitude of about 2,900 feet on the north side of the valley of Grave Creek. Apparently, then, only the main ridges were quite free from moving ice. The ice tongues of the North, Middle, and East forks of Chandalar River coalesced in the main valley and probably extended to a much lower altitude, almost if not quite to the southeast corner of the district. Other ice streams flowed southwestward into the Koyukuk Valley, forming a great valley glacier that was joined farther down the valley by tributary ice tongues from the north. The ridge south of Chandalar River is not believed to have been extensively glaciated, though the high granitic massif at the head of the West Fork may have generated some small alpine glaciers that flowed off both to the north and south.

The North, Middle, and East forks of Chandalar River, as well as Dietrich and Bettles rivers, show the characteristic U-shaped valleys that are produced by glacial action. The spurs that extend down from the main ridges into the valleys have been truncated at their bases, resulting in oversteepened valley spurs. In keeping with their condition, some of the smaller tributary valleys, particularly those which headed on lower divides and contributed little ice, were unable to cut down their valleys as fast as the glaciers in the main valleys and were therefore left as hanging valleys when the ice retreated. Subsequent stream erosion has cut narrow V-shaped gorges at the lower ends of such valleys, where they join the main valleys. Woodland Creek, which enters the North Fork of the Chandalar from the west, below Chandalar Lake, is an example of such a hanging valley. The valley now occupied by Lake and Grave creeks was apparently a nearly stagnant body of ice in the later stages of the glacial epoch, a kind of back flow from the active glacier of the North and Middle forks of the Chandalar. Little and Big Squaw creeks, on the south side of this valley, therefore, contain glacial deposits, which, as shown later, have had an important influence in determining the position and character of the gold placer deposits in these valleys. Big Creek, which heads against Little Squaw Creek and flows southward, apparently has not been glaciated, as the ridge to its north did not accumulate enough snow to produce independent ice tongues.

Deposits of glacial origin are therefore found in all the main valleys that extend southward from the Arctic Mountains and also in the main Chandalar Valley. Most of these deposits, however, appear to have been reworked to a considerable degree by contemporaneous and later stream action, so that they belong mainly to the class designated outwash deposits. The remnants of such outwash deposits form benches at many places in the valleys, and profiles of them may be seen to advantage where the streams have cut down through them in recent time. Chandalar Lake and the silt and sand filled valley that extends 35 miles upstream above Chandalar Lake are physiographic features that are due to glacial action. A number of older beach lines are preserved as benches along the walls of the valley at Chandalar Lake and continue upstream, indicating that the lake was formerly of larger size and has shrunk progressively since the retreat of the ice. North Fork, however, flows on bedrock in the rapids just below the lake, and it is hard to explain the silt-filled depression above the rapids except as a basin excavated by ice erosion. The reason for this depression may probably be that North Fork originally flowed out to the east through the present valley of Lake and Grave creeks, forming a tributary of the Middle Fork. In that case the present course of the North Fork from Chandalar Lake southward is a postglacial feature, and the site of the rapids was once the head of a northward-flowing tributary of the North Fork that joined it at the present mouth of Lake Creek. This explanation will account for the apparent northward slope of bedrock from the rapids to Lake Creek.

The glacial deposits consist of silt, sand, and gravel and attain a considerable thickness in some of the larger valleys. Even as far north as the valley occupied by Lake and Grave creeks these deposits seem to be more or less sorted, and the gravel is fairly well rounded. Some of the deposits appear to be a true till. The material that forms the false bedrock on Little Squaw Creek seems to be of this character. Schrader has described deposits of till along

Chandalar River which form bluffs 100 to 200 feet high, and he also found similar material on the south side of Chandalar Valley at an altitude of 2,200 feet. In a strict sense, however, this material would be more properly designated outwash deposits, for the gravel and cobbles within it are fairly well rounded. Similar deposits crop out on the north side of the West Fork about 10 miles above its mouth, forming high bluffs along the river.

Another type of deposits formed in the glacial epoch consists of silt and clay. These deposits have been formed in some places by the damming up of unglaciated valleys by glaciers in the trunk valleys, thus causing lakes in which fine sediments were deposited. The silt and clay deposits in the lower parts of Tobin and Big creeks are cited by Maddren [14] as good examples of this type of deposit.

RECENT DEPOSITS

The Recent deposits consist mainly of sand, gravel, and silt and form the flood plains of the present streams. In a mountainous region like the Chandalar district such deposits should normally be mainly sand and gravel, and in fact the material that has been derived directly from the rocks in postglacial time by weathering and stream transportation is chiefly of these kinds. In addition, however, the streams are handling a great deal of the glacial outwash deposits and till, which contain silt and clay as well as the coarser materials. In places, therefore, the Recent alluvium consists of more or less silt. The silt-filled basin in the valley of the North Fork may be cited as an example of silt reworked to some extent by the present streams. Many such deposits on the valley floors are thick.

To the southwest of the Chandalar district, on the South Fork of the Koyukuk, and also to the southeast, on the lower Chandalar, are extensive deposits of silts of Recent age. These are darker in color than the Pleïstocene silts, owing to an admixture of vegetal matter, and those that are very dark are often referred to as "muck." Such silt deposits form bluffs 20 feet or more high along the banks of the streams at some localities. Locally in these silts are found lenses of clear ice.

The Recent deposits include also residual deposits formed by the disintegration of rock in place and weathered material in process of migration down the hill slopes. At the mouths of steep gulches such weathered material may form alluvial fans that project onto the main valley floors.

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[14] Maddren, A. G., The Koyukuk-Chandalar region, Alaska: U. S. Geol. Survey Bull. 532, pp. 64-65, 1913.

IGNEOUS ROCKS

PALEOZOIC GNEISS

Distribution.—The main body of granitic gneiss extends from the Middle Fork of the Chandalar, east of Bend Mountain, southwestward to the head of the South Fork of the Koyukuk, including practically all the valley of Baby Creek and the heads of Sheep and Phoebe creeks. The mapping of the southwestern limit of this formation is not accurate and is likely to be considerably in error. The formation may also continue northeastward beyond the Middle Fork of the Chandalar, but that area was not visited. It is known to have a length of at least 35 miles and a width of 5 to 15 miles. A smaller body is shown northeast of Grave Creek, and another in the upper valley of Robert Creek.

Petrographic character.—In hand specimens the rocks of this formation range from massive granitic rocks through gneiss to a contorted granitic schist. The common type is a speckled gray granitic gneiss, much of which shows a greenish tinge, due to alteration of the dark-colored minerals it contains.

Under the microscope the gneiss is seen to be composed essentially of quartz, albite, and chloritic products and sericite derived from original hornblende, biotite, and feldspar. Calcite and epidote are also common secondary products. The accessory minerals include apatite, titanite, and some iron hydroxides. The albite is fresh in appearance and is believed to be a secondary feldspar. In one of the least altered specimens, collected on Baby Creek, orthoclase and albite occur together in such a relation as to suggest that orthoclase is the original feldspar and that albite is secondary. Another specimen from Baby Creek shows no albite, the feldspar consisting of a mixture of orthoclase and microcline, with little or no plagioclase. In this specimen some original biotite is preserved, thus showing the original rock to be a biotite granite. Other specimens also indicate that the dark minerals of the original rock may have been mainly biotitic. Garnet is present is some specimens.

Another variety of the gneiss is seen at Bend Mountain, on the North Fork of Chandalar River. This phase is likewise composed of quartz and albite but contains a larger proportion of dark minerals, among which both biotite and green hornblende have been identified, though both are more or less altered. Chlorite, epidote, and calcite are the common alteration products. These rocks are interpreted as a dioritic or perhaps kersantitic variety of the biotite granite.

A third variety is a contact phase, perhaps of the country rock rather than the intrusive rock. This was seen at the forks of

Baby Creek. The rock consists of phenocrysts of garnet set in a matrix of sericite, chlorite, calcite, quartz, epidote, and biotite. The garnet shows the consanguinity of this contact rock with the main intrusive mass.

Structure, age, and correlation.—The granitic gneiss and granitic schist have a structure simulating bedding, which apparently is conformable in trend and pitch with the early Paleozoic schist that it intrudes. The state of deformation of both formations is about of the same order, due allowance being made for the superior competency of the granitic rocks. It was fully recognized by Schrader [15] that this granitic gneiss or gneissoid granite was an ancient intrusive body. In fact, he considered it the oldest rock in the district, regarding it as a basal granite. The gneiss was found in 1923, however, intruding Silurian phyllite and limestone, and the fossils listed on page 228 were found only a few feet from the contact of the gneiss with these rocks. The gneiss is therefore not older than Silurian. It has not been observed to intrude the Middle Devonian rocks, nor even the main mass of middle or upper Silurian limestone. This limestone, however, was probably not buried deeply enough at the time of the granitic injection to be intruded. The absence of the gneiss in the Middle Devonian rocks, together with its general ancient aspect, leads to the conclusion that it was injected before the Middle Devonian rocks were laid down. It is believed, therefore, that this granitic gneiss is of late Silurian or early Devonian age.

Areas of granitic gneiss have been found at numerous other localities in Alaska, particularly in the Yukon-Tanana region and in Seward Peninsula, but the geologic section is not sufficiently well known to permit the assignment of a definite age to these areas. It is likely that some of these older granitic rocks may later be found to be contemporaneous with the granitic gneiss of the Chandalar district.

PALEOZOIC GREENSTONE

Distribution.—Greenstone, comprising altered rocks of basic and intermediate composition, occurs as dikes, sills, and possibly flows associated with all the Paleozoic and pre-Paleozoic rocks. At the south side of the Chandalar district such rocks are very intimately associated with the formation mapped as Upper Devonian or Mississippian; and in the northern part of the area similar greenstone, though perhaps more altered, is found as dikes and flows (?) at many localities in the early Paleozoic rocks and the Silurian limestone. It occurs as dikes in the Middle Devonian rocks.

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[15] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 471–472, 1900.

Only the larger areas of these rocks are shown on the geologic map. One prominent greenstone, which probably represents an original flow, flanks the Silurian limestone on its south side, on the North Fork of Chandalar River, and also crops out to the west in the center of an anticline surrounded by the Silurian limestone; another large mass, intrusive in character, is seen between Flat and Funchion creeks; and still other small intrusive bodies occur in the Upper Devonian or Mississippian rocks to the west.

An outcrop of granular greenstone, similar to that east of Flat Creek, also crops out at about mile 16 on the Beaver-Caro road, and a considerable body of such rock apparently continues to the west.

Petrographic character.—The band of greenstone that adjoins the Silurian limestone on the south, along the North Fork of Chandalar River, differs from the other greenstone of the district. It is in reality a greenstone schist and shows no trace of its original fabric. It is best described as a chlorite schist. It is light green in color but varies in appearance in the field, according to whether it is wet or dry. In wet weather the hills composed of this rock are decidedly green, but in dry weather it looks not greatly unlike the Silurian limestone from a distance, except for a slight greenish tone. This rock contains much quartz, in lenses and veinlets, all of which, however, appears to have been crumpled and sheared along with the rock itself. An assay of this quartz, which Schrader had made in 1899, showed 0.42 ounce in gold and 0.14 ounce in silver to the ton.

A second variety of greenstone consists of altered fine-grained basic rocks, which occur as dikes or sills in all the Paleozoic rocks but particularly in the formation described as Upper Devonian or Mississippian. These rocks are usually much altered and commonly schistose, but in a number of specimens collected the original fabric is still preserved. They appear originally to have been chiefly diabase and subordinately basalt, consisting essentially of plagioclase feldspar, augite, and iron oxides. In their present condition they consist largely of chlorite, calcite, sericitic and kaolinic products, and iron hydroxides, accompanied by more or less epidote and secondary quartz. The plagioclase feldspar is altered to these secondary products beyond a chance of determination of its original character, and only in one specimen was some unaltered augite seen.

A third variety of greenstone comprises massive greenish granular rocks of dioritic or gabbroic character. Two areas of these were noted. One of them is outside the Chandalar district, on the Beaver-Caro wagon road at about mile 16. The rock here is at least half plagioclase feldspar, apparently andesine, together with hornblende, a little augite, and quartz. Apatite, magnetite, and ilmenite occur as accessory minerals. The plagioclase feldspar is greatly altered to kaolin and chloritic and sericitic material, and the hornblende is partly altered to biotite and chlorite. This rock is a quartz diorite of greenstone habit. The other occurrence is a large mass of dark-green massive intrusive rock that crops out east of Flat Creek. This rock consists of labradorite, augite, and magnetite and is not greatly altered. The augite is titaniferous. The rock is a gabbro of greenstone habit.

Age and correlation.—The greenstone schist or chlorite schist along the south flank of the Silurian limestone crops out also in the center of an anticline to the west of the North Fork of Chandalar River. It seems, therefore, to follow the lower contact of the limestone and for this reason may be interpreted tentatively as an ancient lava flow. It could, however, be an old intrusive body that runs parallel to the bedding of the limestone. This formation is the same as that described by Schrader[16] under the name "amphibolite schist" and correlated by him with the older rocks of the region.

The altered diabasic and basaltic dikes and sills described as the second variety of greenstones probably include rocks of more than one age, but data are not available for their separation on the basis of age. Some of them are old and may be correlated in a general way with the greenstone schist on the North Fork of Chandalar River. Others, however, particularly those found in the Upper Devonian or Mississippian rocks, are probably of late Paleozoic age and may be correlated in a general way with the basic extrusive and intrusive rocks of the Rampart group, now believed to be of Mississippian age. The quartz diorite and gabbro of greenstone habit above described are also believed to have been intruded at about this same time.

MESOZOIC GRANODIORITE

Distribution.—A large area of granitic rocks occurs south of Chandalar River, extending from a point about opposite the Middle Fork westward to the Mosquito Fork of the Koyukuk. This intrusive mass is about 40 miles long and from 5 to 10 miles wide.

Petrographic character.—A variety of igneous rocks are found within this massif, but the main type is determined as a granodiorite. This rock is dark gray and granular. Much of it is porphyritic, showing phenocrysts of plagioclase and orthoclase. Under the microscope it is seen to consist essentially of quartz, andesine, ortho-

[16] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk rivers, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 472–473, 1900.

clase, biotite, and hornblende. Augite, apatite, and titanite are the accessory minerals. The rock is not altered either by chemical or by dynamic metamorphism and does not at all resemble the Paleozoic granitic rocks, either in petrographic character or in state of preservation. The ratio of andesine to orthoclase is about 3 to 1, so that the rock is designated a granodiorite rather than a quartz diorite or a quartz monzonite.

The granodiorite is cut by aplitic and lamprophyric dikes and larger intrusive bodies, which show a considerable range in petrographic character. One of the typically aplitic intrusives is a light-colored granular rock consisting of quartz and feldspar, the latter predominantly orthoclase and microcline, with some plagioclase. The potash feldspar is graphically intergrown with quartz. Another light-colored product of differentiation consists almost exclusively of feldspar, chiefly microcline with a little plagioclase, quartz, and biotite. This rock closely approaches a syenite. A typical basic differentiate is a granular rock which consists of about two-thirds hornblende and about one-third plagioclase and quartz, with some iron oxides and a little orthoclase. This may be described as a kersantitic variety of the granodiorite.

Observations along the mountain tops south of the West Fork of Chandalar River indicate that the main intrusive rock is granodiorite, but some fairly large bodies of a more granitic type of rock, corresponding chemically to the aplite above described, appear also to be present. These more acidic and also more basic rocks appear to have been injected into the main granodiorite at a late stage in the general process of intrusion.

Age and correlation.—No direct evidence is available regarding the age of these rocks, except that they intrude the latest Paleozoic rocks of the district. They might be either Mesozoic or Tertiary. They resemble the Mesozoic granitic intrusive rocks of the Yukon-Tanana region, however, more than they resemble the Tertiary granitic intrusives of the lower Yukon and Kuskokwim valleys, and for this reason alone they are referred to the Mesozoic.

TERTIARY BASALT

Distribution.—The Tertiary igneous rocks consist of basaltic intrusives and extrusives that crop out in the valleys of the West Fork and the main Chandalar. Beginning at the forks of the West Fork, an elongated dikelike intrusive body extends for 10 miles a little south of west, forming a characteristic trap ridge. In the lower valley of the West Fork lavas occur, and these extend intermittently down Chandalar Valley to the beginning of the flats.

Petrographic character.—The intrusive trap rock is a fine-grained greenish microporphyritic rock, with an intersertal fabric. The microphenocrysts are plagioclase feldspar. The rock was composed originally of plagioclase feldspar, augite, and iron oxides but is now much altered, the plagioclase and pyroxene being changed in large part to chlorite, sericite, and some epidote, while the iron oxides have been converted to iron hydroxides. The rock is determined to be an altered basalt.

The lavas farther east are altered fine-grained trap rocks, many of which are amygdaloidal. One very fine-grained amygdaloidal specimen was seen under the microscope to be composed in large part of a dark-colored volcanic glass, which has been much chloritized. The vesicles are filled with calcite. This is probably a basaltic glass. Other specimens are fine grained but only partly glassy.

Age and correlation.—The exact age of these basaltic intrusive and extrusive rocks is not known. The intrusives cut the Mesozoic granodiorite, however, and the extrusives appear to overlie it. They are therefore believed to be of Tertiary age. Similar Tertiary trap rocks have a wide distribution in interior Alaska but are perhaps best developed in the lower Yukon and Kuskokwim basins.

REGIONAL STRUCTURE

The geologic structure in the Chandalar district is not simple, nor yet as complex as the structure in some other parts of Alaska, as for instance in Seward Peninsula. The rocks have been deposited during a number of different epochs and have been deformed, elevated, and eroded in a number of different cycles, of which, however, the principal ones are believed to have been recognized. The intrusion of granitic rocks on a large scale has taken place in at least two periods during the geologic history, adding further complexity to the structure; and basic intrusions also have played a part in the tectonic history. A complete analysis of the structure of this region can not of course be given, for the small amount of work so far done does not justify a final statement on the many problems involved. A few structural generalizations, however, may serve as a guide for future work in the region.

In many regions structural features are indicated by marked parallelism of the stream valleys. Thus in the Yukon-Tanana region the marked change in the course of Yukon River above and below Fort Yukon is reflected in the stream valleys to the south of the Yukon, and these two directions have always been considered to have a structural meaning. Similarly, in the Silurian and pre-Silurian rocks of the Chandalar district, two well-marked structural directions are indicated by the valley trends, one of which is about N. 20°

E., while the other is about at right angles, or S. 70° E. On the other hand, the strike of the formational contacts does not appear to follow either of these trends, except in minor features, but is about east or perhaps a little north of east. The most prominent of these contacts is the one between the early Paleozoic rocks and the Silurian limestone, and as has been shown this is probably a contact between two conformable formations and must therefore represent on a large scale the general trend of the bedding of the Silurian limestone and the early Paleozoic rocks. Now if a series of rocks are folded and refolded, and the axes of the two systems of folds are inclined to one another, it is to be expected that the later folding will be more prominent, and that the main trend of the depositional contacts will follow the later axial trends. It has been shown also that the Middle Devonian rocks lie unconformably above the Silurian and pre-Silurian rocks and that these Middle Devonian rocks also trend east. It may also be pointed out that the N. 20° E. and S. 70° E. trends of the stream valleys do not appear to continue northward into these Middle Devonian rocks. It is therefore concluded that in post-Devonian time there was a period of deformation which folded the Middle Devonian rocks for the first time and established the east-west trend of the formational contacts as they now appear. But the Silurian and pre-Silurian rocks, which lie unconformably below the Middle Devonian rocks, must have been folded before the latter were deposited and must therefore have suffered deformation during at least two periods. This earlier folding must have taken place in late Silurian or early Devonian time, and the structural trends of the valleys above noted are believed to reflect some of the structural features then produced. It has already been suggested that the N. 20° E. trend in the older rocks represents the axial trend of an older system of folding, and that the southward extension of the Silurian limestone into the bend of Bettles River represents a synclinal fold of this older system that plunges northward, owing to the northward-dipping monocline of post-Devonian age. The S. 70° E. trend in the older rocks is harder to explain. It appears to control the direction of the valley of the North Fork of Chandalar River above Bend Mountain, as well as of the Lake-Grave Creek valley and the main Chandalar Valley. In this connection, however, it should be pointed out that this direction continues to Porcupine River and affects the post-Silurian rocks in that valley. Moreover, a complementary structure trending about S. 70° W. commences in the Chandalar district and continues into the Koyukuk Valley, affecting younger rocks also in that region. Both these structural trends conform in a general way with the trend of Yukon Valley above and below Fort Yukon. The east-west structure of the Silurian limestone is confined to the Chandalar district, for the limestone bends southeastward to the Porcupine Valley and southwestward to the valleys of John and Alatna rivers. From a consideration of these facts it is believed that the east-west axial trend in the Chandalar district is a tangential structure to a great arc, and that the S. 70° E. and S. 70° W. directions indicate the trend of this arc and are a measure of its curvature. These two directions, therefore, are interpreted as elements in the post-Devonian folding, and the east-west trend of the rocks in the Chandalar district is interpreted as the combined result of these two structural trends.

In considering the Birch Creek schist (?), it was suggested that an unconformity might separate these rocks from the early Paleozoic rocks. This hypothesis, however, is proposed only because this relation appears to exist in the Yukon-Tanana region, and it is therefore entirely inferential. No structural data have been collected in the Chandalar district either to prove or disprove the hypothesis.

It remains to suggest some more definite period for the post-Middle Devonian folding. The Upper Devonian or Mississippian rocks in the southwestern part of the Chandalar district appear to have been affected by this same system of deformation and to a similar degree. It seems best, on the whole, to believe that this folding took place at some time in the Mesozoic era, and if so, it was probably more or less synchronous with the intrusion of the Mesozoic granitic rocks. This event is generally believed to have taken place in Jurassic time, and in the absence of any further evidence it is assumed that the post-Middle Devonian folding is of Jurassic age.

Still later deformational movements have affected the rocks of the Chandalar district, for the Tertiary lavas are no longer horizontal, but little is known of these later movements. It is likely, however, that they have not been the source of any new large-scale regional structural features but have acted rather to accentuate the preexisting Mesozoic deformation.

GEOLOGIC HISTORY

The oldest rocks in the Chandalar district are the quartzite schist and quartzite south of Chandalar River. After the deposition of the sediments from which these rocks are derived they were probably folded, elevated, and eroded before the early Paleozoic rocks were deposited. This break in the stratigraphic sequence, however, is inferred and not proved. Then followed the deposition of a great thickness of marine sediments, but the geologic period in which this sedimentation began is not known, though it is known to have continued into Silurian time. If the deposition of these early Paleozoic rocks began in Cambrian or in Ordovician time, it would be surprising if the sequence as mapped does not contain one or more unconformities representing discontinuities in the deposition of the rocks. Such stratigraphic breaks will be recognized only by more detailed studies.

The Silurian or upper part of this sequence of early Paleozoic rocks appears to have graded without a stratigraphic break from deposits of a dominantly marine argillaceous type into marine calcareous deposits, so that in middle or upper Silurian time a great thickness of limestone was laid down. A greenstone schist, which is shown on the geologic map as lying at the base of this Silurian greenstone, may be either an altered flow or an intrusive body, of basic composition. If it is a flow, it shows that a certain amount of volcanic action occurred at the time of the deposition of the Silurian limestone. If it is a dike or sill, the volcanism was of later date.

After the Silurian limestone was deposited the rocks of the district, both Silurian and pre-Silurian, were folded, elevated, and eroded, the first well-recognized break in the sequence of sedimentation being thus produced. It was during this period of deformation and terrestrial conditions that the Paleozoic gneiss is believed to have been intruded into the preexisting rocks. This gneiss, however, has not been observed invading the main belt of Silurian limestone. Its absence may be either a fortuitous circumstance in the localization of the granitic intrusives, or it may be due to the fact that the intrusions took place at too great a depth to reach the limestone. In any event, the age of the gneiss is believed to be either late Silurian or early Devonian.

Subsequently, in Middle Devonian time, the district was again invaded and covered by the sea, and a great thickness of marine argillaceous sediments were laid down, which now form a thick mass of slate. Marine fossils of Upper Devonian age are also found in this district, but the Upper and Middle Devonian rocks have not been observed in contact with one another, so that it is not known whether or not sedimentation continued without interruption from Middle into Upper Devonian time. The Upper Devonian rocks, however, appear to contain slate, chert, and some limestone, indicating that at least there was a difference in the type of sedimentation.

Paleozoic rocks of post-Devonian age were not recognized in the Chandalar district, but in the valley of John River, to the west, there is a series of marine Mississippian rocks, known as the Lisburne limestone, with a chert conglomerate, known as the Stuver "series," at its base. These facts are interpreted as evidence that a break in sedimentation occurred after the latest Devonian rocks were deposited, accompanied by reelevation and possibly erosion. It is not known whether this break in sedimentation was also accompanied by deformation of the Devonian and pre-Devonian rocks.

Pennsylvanian, Permian, Triassic, and Jurassic rocks have not yet been found between the Arctic Mountains and Yukon River, but such rocks are present between the Arctic Mountains and the Arctic Ocean. No evidence is available at present to indicate whether such rocks were deposited and subsequently eroded in the region south of the Arctic Mountains, or whether that region was a land surface during these geologic periods.

Along the Yukon, to the south, great outpourings of basic lava, accompanied by intrusions of basic igneous rocks, took place in Mississippian and possibly in later Carboniferous time. Most of the intrusive greenstones of the Chandalar district are correlated with this period of volcanic activity. Also in Jurassic time a great intrusion of granitic rocks is believed to have taken place, which is now represented by the granodiorite massif south of Chandalar River.

The next recorded period of marine sedimentation south of the Arctic Mountains began in Lower Cretaceous time. The rocks deposited at this time are found in the lower Koyukuk Valley but do not occur in the Chandalar district. More sediments, partly marine and partly estuarine or terrestrial, were laid down in Upper Cretaceous time, but it is not definitely known whether a break in sedimentation occurred between the Lower and Upper Cretaceous. A small area of these Upper Cretaceous rocks is found in the southwestern part of the Chandalar district.

Tertiary sediments are unknown in the Chandalar district, but they may have been deposited and subsequently eroded. If such sediments were deposited, however, it is very likely that they were of estuarine or terrestrial character, similar to the Tertiary conglomerate, sandstone, and shale found elsewhere in interior Alaska. Volcanic action took place in Tertiary time, resulting in lava flows in the Chandalar district and in great intrusions of acidic and basic rocks in southwestern Alaska. The basic lavas of the Chandalar Valley are believed to have been poured out in Tertiary time.

Pleistocene time witnessed the advent of a glacial epoch, as a result of which the high mountains in the Chandalar district were covered with ice caps and the valleys were filled with ice tongues extending outward from these ice caps. The melting of the ice caps and the retreat and final disappearance of the valley glaciers initiated Recent time, which has been characterized by terrestrial conditions and normal stream erosion.

MINERAL RESOURCES

Gold is the only metal that has yet been mined in the Chandalar district and the only one that is likely to be mined in the near future. Gold placer mining is now being done on Little Squaw, Big, and

Big Squaw creeks, but the camp in all is a small one. Both summer and winter placer mining is being carried on. In addition to the placer mining, a crew of four men was engaged during most of the summer of 1923 in prospecting a gold quartz lode on Little Squaw Creek. The character and distribution of mining operations in the Chandalar district in 1923 is shown in the subjoined table:

Mining operations in Chandalar district, 1923

	Drifting		Open-cut work	Prospecting	
	Winter	Summer		Drift	Lode
Little Squaw Creek	1	1		1	1
Big Creek		1	1		
Big Squaw Creek			1		
	1	2	2	1	1

About 30 men in all were engaged in mining work in the district in 1923.

ECONOMIC CONDITIONS

Supplies for this camp are transported from Beaver, on the Yukon, a distance of about 120 miles by trail. A wagon road extends from Beaver to Caro, about 75 miles, but this road can not be traveled by a loaded wagon until about the middle of July, after the high water of spring has subsided and the ground has dried out to some extent. From Caro one trail goes up Flat Creek, then over the Middle Fork of the Chandalar, up the Middle Fork to Grave Creek, and up Grave Creek to Little Squaw and Big creeks. The Big Creek trail goes northwestward to Big Creek and thence up the creek to its head.

The winter rate for freighting supplies from Beaver to Little Squaw Creek is said to be about 15 cents a pound. In reality, a good part of the supplies used at Little Squaw Creek are freighted from Beaver to Caro by wagon late in the summer and by sled from Caro to Little Squaw Creek in winter.

Timber of good size and quality is available in the valleys of Grave, Lake, and Big creeks, but the Little Squaw-Big Creek camp is well above timber line, and the essential firewood and mining timber must be transported a considerable distance, thus being very expensive. On Big Creek cordwood and timber has to be freighted 12 miles upstream in winter by dog teams, and the wood is estimated to cost $50 a cord landed at the mouth of St. Mary's Gulch. This figure is the actual cost of the labor and freighting, the work being done by the placer miners themselves. The length of the summer mining season on Big Creek is determined by the amount of cordwood that can be hauled in winter, rather than by the length of the open season.

Water in sufficient quantity for summer sluicing is available on Little Squaw, Big, and Big Squaw creeks. Winter dumps are taken out on Little Squaw Creek and sluiced in June, when the water is high.

The wages paid to placer miners are $6 a day and board, but men doing work of special kinds, such as winchmen and cooks, receive $7 a day and board.

LITTLE SQUAW CREEK

PHYSIOGRAPHIC HISTORY

Little Squaw Creek is between 3 and 4 miles in length, heads against Big Creek, and flows somewhat east of north, joining the head of Lake Creek above Ogburn Lake. The divide at the head of Little Squaw Creek has an altitude of about 4,800 feet, while the junction of Little Squaw and Lake creeks is at an altitude of about 2,300 feet. The creek therefore has a gradient of 2,500 feet in less than 4 miles, but most of this fall is in the upper part of the creek, above the placer mines. The principal placer-mining operations are about 1½ or 2 miles from the mouth of Little Squaw Creek, and the altitude here is estimated at 3,000 feet.

The physiographic history of Little Squaw Creek can be inferred with considerable assurance. Prior to the advent of the glacial epoch Little Squaw Creek had much the same course as at present and emptied into a large stream that flowed eastward through the present Lake-Grave Creek valley. The valley floor of this trunk stream, however, was higher than the present floor of the Lake-Grave Creek valley, whose lower altitude is due chiefly to subsequent glacial erosion. In the early stages of glaciation the ice in the present Lake-Grave Creek valley probably formed an active glacier, moving slowly downstream. In the later stages, as the ice overflowed the divide south of Chandalar Lake and cut a channel out to the south, the movement of the ice in the Lake-Grave Creek valley probably gradually decreased, and the ice finally became more or less stagnant. As the glaciers retreated and the ice melted, a new trunk stream was established at the lower end of the glacier, in the present North Fork valley, and this stream has been able to retain the upper drainage thus captured by cutting a bedrock channel below Chandalar Lake. In this process the new stream was aided by deposits of glacial material from the melting ice, which were dumped in the Lake-Grave Creek depression.

In the process above sketched the lower part of the preglacial channel of Little Squaw Creek was obliterated by the large glacier scouring along the Lake-Grave Creek or old North Fork valley. The hills to the south, however, including the divide between Little Squaw and Big creeks, did not carry active glaciers, although they probably supported an ice cap of considerable proportions. The preglacial channel of the upper part of Little Squaw Creek was therefore preserved as far downstream as the upper part of the main North Fork glacier. When the glacier retreated it left behind a great mass of morainal deposits, which extended up Little Squaw Creek almost to the upper limit of the glacier. In the postglacial reestablishment of the Little Squaw Creek drainage system these glacial deposits acted at first as a new base-level, over which Little Squaw Creek flowed into the present Lake-Grave Creek valley. Subsequently, as the glacial material was partly removed from the Lake-Grave Creek valley, Little Squaw Creek cut a new postglacial channel down through these glacial deposits in its lower course.

The various stages in this physiographic history are now shown by the character and distribution of the alluvial deposits in the valley of Little Squaw Creek. The creek contains both creek and bench deposits, though these two types of deposits are not everywhere separable, because at places the postglacial channel has cut across the old preglacial channel. In other words, the stream and bench deposits are not distinct and separable by a bedrock rim, as they are, for instance, on Livengood Creek in the Tolovana district. Glacial deposits begin at the upper end of claim No. 3 above Discovery, about 1½ or 2 miles upstream from the mouth of Little Squaw Creek, and continue downstream into the valley of Lake Creek. The old preglacial channel appears to continue downstream under these glacial deposits but probably does not extend very far, because it was doubtless eroded in its lower reaches by glacial action. An early postglacial channel also extends downstream above the glacial deposits, which form a false bedrock for this later gravel. The preglacial alluvial deposits that lie upstream from the glacial deposits and the postglacial deposits that extend out over the glacial deposits have both been mined, but the downstream extent of the preglacial channel under the glacial deposits has not yet been explored by mining operations, though some prospecting has been done for this purpose. On the other hand, the early postglacial channel that lies above the glacial deposits probably also extends for no great distance downstream, because Little Squaw Creek rapidly cut into the glacial gravel and established a later and different channel. These events in the physiographic history of Little Squaw Creek have been the dominating influences in the localization of the gold placer deposits.

GOLD PLACERS

Placer mining and prospecting have been in progress on Little Squaw Creek for a number of years. Figure 11 shows the location of the placer mines on Little Squaw, Big Squaw, and Big creeks. Until a few years ago placer mining on Little Squaw Creek had been confined to the old preglacial channel upstream from the glacial deposits in the valley. This gravel, however, as before stated, is not

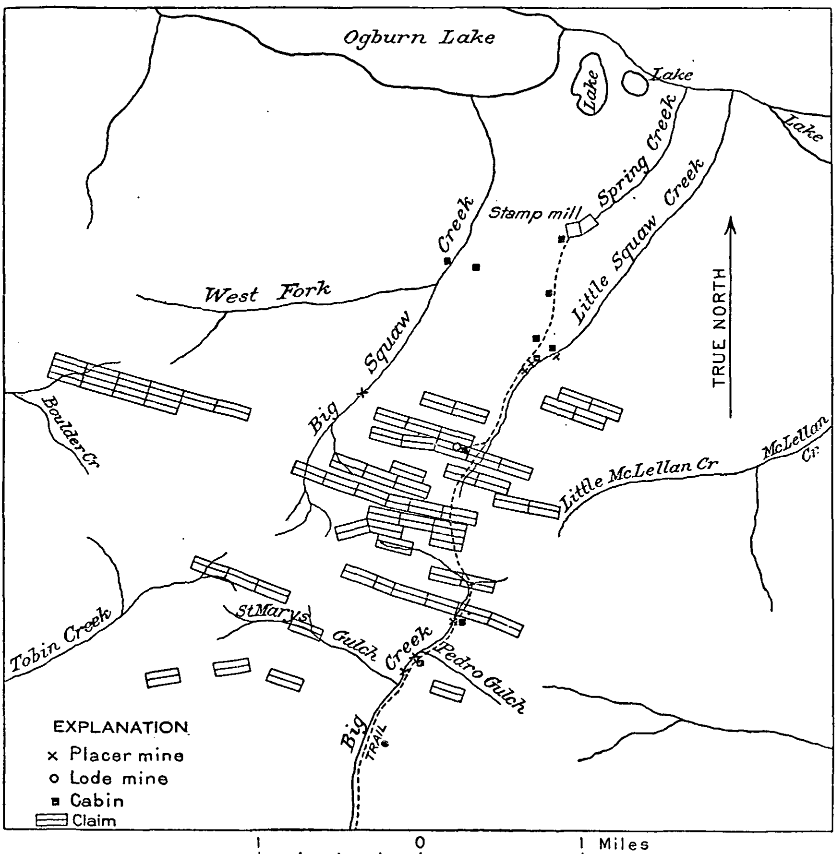

FIGURE 11.—Sketch map showing approximate location of placer mines and lode claims on Little Squaw, Big Squaw, and Big creeks

everywhere sharply separable from the later postglacial deposits. The upper preglacial gravel is now pretty well mined out, but a few years ago, in working the lower end of this gravel, just upstream from the glacial deposits, very rich gold-bearing gravel was struck. In following this rich gravel downstream, the pay streak was found to leave bedrock and continue out over the glacial deposits, which act as a false bedrock. The chief mining operations in Little Squaw Creek are now confined to this early postglacial channel, though some mining is still being done in the old preglacial channel upstream from the glacial deposits.

The bedrock in Little Squaw Creek is a mica schist containing numerous veins of gold-bearing quartz. The schist itself is also mineralized, as shown by the weathered pyrite crystals found in the country rock. The schist is also cut by numerous dikes and perhaps sills of greenstone. The quartz veins and mineralized schist are the proximate source of the gold in the gold placers.

The most extensive placer-mining operations at present on Little Squaw Creek are on claim No. 3 above Discovery, where a gold placer is being mined by drifting in the early postglacial channel, which lies above the glacial till. This deposit is on the west side of the valley at a distance of perhaps 200 feet from the creek. The depth from the surface to the glacial deposits or false bedrock ranges from 55 to 100 feet. The shallow holes are at the upper end of the claim, where the glacial deposits begin, but the variation in depth is due in part to variation in surface configuration and in part to the unevenness of the upper surface of the glacial deposits. Holes have also been sunk through the glacial débris to true bedrock, showing a thickness of 25 to 50 feet of glacial deposits at the upper end of this claim.

The glacial material consists of worn or unworn angular débris, cemented by clay. The large proportion of clay is one of the distinguishing characteristics of this material. Faceted pebbles, some of which show distinct striae due to glacial scouring, are numerous. This material may be classed as a true till. Above the true glacial material comes 10 feet of partly rounded gravel, which is evidently glacial débris that has been reworked to a greater or less extent by stream action. The gold occurs in the upper 6 or 8 feet of this material. Above this zone, and continuing to the surface, is partly rounded material of the same general character, but this is barren of gold from top to bottom. The chief kinds of rock found, both in the till and in the overlying gravel, are schist and greenstone, though the greenstone appears to be more prevalent in the later stream gravel than in the glacial débris. These greenstone cobbles and boulders come from the greenstone intrusions above mentioned, and because of their superior hardness and resistance to erosion they are more numerous than the bedrock distribution appears to justify. Much quartz is also present, both in the gravel and in the till.

Gold, both from this mine and from the preglacial channel upstream, was seen by the writer. Both varieties are said to have the same value, but the gold from the preglacial channel upstream is somewhat darker, coarser, and more waterworn. Nuggets as large as $180 have been found in the preglacial deposits, but none worth over $10 in the early postglacial deposits that lie above the till. A number of assays of gold from the Chandalar district, including the gold from Little Squaw, Big, and Big Squaw creeks, were given to the writer by Mr. Frank Yasuda, of Beaver. These are presented below.

Value of gold from Chandalar district

Sample	Fineness		Value per ounce		Value of silver per ounce at time of assay
	Gold	Silver	Before melting	After melting	
1	0.84975	0.147	$17.30	$17.70	$0.90
2	.84875	.149	17.32	17.65	.69
3	.848	.147	17.05	17.65	.80
4	.84925	.147	17.31	17.65	.61
5	.84925	.148	17.31	17.65	.63
6	.848	.149	17.25	17.62	.63
7	.84875	.148	17.33	17.65	.70
8	.8535	.143	17.34	17.74	.71
9	.849	.148	17.27	17.65	.69
10	.850	.146	17.34	17.71	.95
11	.83575	.159	17.04	17.37	.58
12	.84875	.147	17.27	17.65	.69
Mean	.84823	.1482	17.26	17.64	

The average value of the gold as recovered by the mines is seen to be $17.26 an ounce. This gold passes commercially at Beaver at $17 an ounce, which is a very fair return to the miner, when it is remembered that only 26 cents an ounce is required to cover the express and insurance charges on the gold from Beaver to the mint, as well as the assay charges.

The concentrates recovered in the sluice boxes with the gold on Little Squaw Creek consist chiefly of pyrite, together with smaller amounts of hematite, arsenopyrite, and scheelite (calcium tungstate). A piece of galena was also picked up by one operator in Little Squaw Creek. The hematite occurs in well-banded black tabular crystals, and the scheelite in amber-brown individuals, many of which show crystal outlines. Practically no magnetite occurs in the heavy sands.

Farther upstream, in the old preglacial channel, drift mining on a small scale is being done on claim No. 4 above Discovery, on the west side, about 50 feet from the creek. The depth to bedrock here is 35 feet, of which the lower 5 feet is composed of rounded but lenticular gravel. The shape is due to the preponderance in the gravel of mica schist, which weathers out of bedrock in slablike pieces and becomes disklike rather than spheroidal by stream transportation. The upper 30 feet of gravel is as well or better rounded, owing apparently to a greater admixture of greenstone with the schist. The lower 5 feet is believed to be of preglacial origin. The gold is found almost entirely in 2 or 3 feet of decayed schist bedrock, practically none occurring in the gravel above bedrock. The ground is solidly frozen from the surface to bedrock but is probably unfrozen nearer the creek.

Only drift mining is done on Little Squaw Creek, but the mining on claim No. 3 above Discovery is being done in winter, and that on claim No. 4 above Discovery is being done in summer. The determining factor is the presence or absence of frozen ground. On claim No. 3 the main shaft passes through frozen ground, but the working drifts lead off into unfrozen ground. The bottom of the shaft is therefore filled with water 20 feet deep in summer, but curiously enough this water all drains out in winter, leaving the workings dry. A block of ground 400 by 28 feet, or nearly 11,000 square feet, was mined from a shaft 100 feet deep in claim No. 3 during the winter of 1922–23. All the pay gravel is removed, no pillars being left. Caps and posts are used to support the roof. Where the ground is frozen 7-foot steam points are used for thawing. The plant consists essentially of a boiler and hoist. The gravel is conveyed from the face to the shaft by wheelbarrows, elevated to the surface in an iron bucket, and conveyed by an overhead cable to the gin pole outside and there dumped. This winter dump is sluiced in the spring. Probably a dozen men were employed at this property during the winter of 1922–23.

The work being done on claim No. 4 at the time of the writer's visit was more in the nature of prospecting. The gravel was being elevated to the surface in a bucket by means of a wooden windlass worked by one man. One other man was at work underground.

Still another shaft was sunk by two men during the summer of 1923 on the east side of Little Squaw Creek, about half a mile below the shaft on claim No. 3 above Discovery. This work was being done primarily to discover, if possible, whether the old preglacial channel below the glacial till extends that far downstream. The shaft was sunk 70 feet, apparently to bedrock, and some fine colors of gold were found. More work was expected to be done here during the winter of 1923–24.

BIG SQUAW CREEK

Big Squaw Creek lies about a mile west of Little Squaw Creek and drains into Lake Ogburn. Its physiographic history and general character are similar to those of Little Squaw Creek. Near the head of Big Squaw Creek one man has been mining in a small way for a number of years. During the summer of 1923 a narrow cut, about 6 feet wide, was opened up and from 3 to 4 feet of coarse gravel was shoveled into small sluice boxes. The bedrock here is schist, the cleavage of which strikes N. 55° W. and dips 20° N. The gravel is subangular and includes many large boulders of greenstone and slabs of schist. The surface of the bedrock is very irregular, and the gold occurs both in the gravel and on the bedrock. The gold is coarse and little worn. The heavy minerals of the concentrates include pyrite and arsenopyrite, and one piece of stibnite also was observed. As bearing on the source of the gold, one oxidized crystal of pyrite was seen at this locality, which was about half gold, the gold apparently having been intergrown originally with the pyrite.

BIG CREEK

Big Creek, unlike Little Squaw and Big Squaw creeks, has not been glaciated, and the deposits in its valley belong to the normal type of stream gravel. Clay and silt occur at the lower end of Big Creek, but the gold placers now being mined are at the extreme head of Big Creek. Figure 11 shows the location of the gold placers on Big Creek. Two placer-mining plants were operated on this creek during the summer of 1923.

The upper plant, on claim No. 1 above Discovery, consisted of an open cut with an automatic splash dam and shear boards in the cut to direct the water. The pay streak is about 40 feet wide and consists of a body of fairly coarse gravel averaging about 15 feet thick. Mining operations are being conducted directly in the present stream beds, evidently in gravel of recent age. The country rock of Big Creek above this plant is schist cut by dikes of greenstone. One such dike crosses the creek in the cut and gives rise to numerous large boulders. Just above the open cut some gold quartz veins cut across the creek in a direction about N. 70° W., and numerous other quartz veins are found in the hills near by. These seem to be the main source of the gold on Big Creek. The relation of the gold in the open cut to the quartz veins upstream is particularly evident, as the good placer ground begins downstream from these veins. The concentrates, recovered with the gold, consist mainly of pyrite but include hematite, limonite, monazite (cerium phosphate), scheelite (calcium tungstate), rutile, and arsenopyrite. The monazite is particularly interesting, because it is the first recorded occurrence of this mineral in Alaska. It occurs as small amber-colored grains, the largest of which measure 2 millimeters in diameter. This mineral, though primarily a cerium phosphate, contains also the elements lanthanum, yttrium, erbium, and thorium and is the source of the cerium and thorium compounds that are used in the manufacture of incandescent gas mantles. The occurrence on Big Creek has no economic significance, because the monazite is not sufficiently plentiful nor sufficiently concentrated to be recovered.

On claim No. 5 below Discovery summer drift mining was in progress in 1923. The gravel here is 22 feet thick, and the gold is concentrated in the lower 3 to 5 feet, with very little gold on bedrock. The bedrock is schist, with a very irregular surface. None of the gravel is well rounded, but the lowest 3 to 5 feet is more rounded than the overlying gravel. Many large boulders of greenstone, as much as 3 feet in diameter, occur in the pay gravel and cause trouble in mining. The gold seems to be most plentiful in the lower foot of gravel, which has a sandy matrix and is stained reddish by iron. The gold is fairly coarse and rather ragged. The largest nugget found in 1923 was worth about $5. The concentrates or heavy sands recovered in the sluice boxes with the gold are the same as those found on claim No. 3, upstream, including also the monazite. A block of ground 85 by 125 feet was worked during the summer of 1923. The gravel is wheeled in a barrow to the shaft, hoisted, and dumped in the regular way. The plant consists of a 14-horsepower boiler, hoist, and self-dumping bucket. In thawing 8-foot steam points are used, and pillars are left to support the roof. Only frozen ground is worked. Eight men were at work at this plant.

GOLD LODES AND MINERALIZATION

Numerous gold quartz veins are found at the heads of Little Squaw, Big Squaw, Boulder, Tobin, Big, and McLellan creeks. A sketch map showing the location of the principal lode claims that have been staked was loaned to the writer by Mr. Harry Patterson, of the Chandalar Mining Co., and used in preparing Figure 11.

These quartz veins have been known and staked for 15 years or more, and considerable prospecting and sampling of them has been done. Many open cuts and a few shafts and tunnels have been made in prospecting these veins, but most of these have now caved so that little may be seen except at the surface. A small stamp mill was erected near Little Squaw Creek in 1910.

The principal work in progress at the present time is being done by the Chandalar Mining Co., on the Little Squaw group of claims, in the upper basin of Little Squaw Creek. On the west side of Little Squaw Creek, at an altitude of about 3,800 feet, a tunnel has been driven 150 feet along one of these quartz veins, and at the end of the tunnel a winze has been sunk about 60 feet on the vein. The cleavage of the schist country rock at the mouth of this tunnel strikes N. 5° W. and dips about 15° E., and the vein cuts across the cleavage, striking N. 75° E. and dipping 80° S. The quartz is about 4 feet thick at the portal of the tunnel but varies considerably in thickness. At the 60-foot level in the winze the dip of the vein changes to about 60° and the vein itself consists of several quartz stringers, with much arsenopyrite; but some later work in this winze, after the writer's visit, is said to have shown the vein widening out again. In the tunnel it is apparent that movement has taken place along the footwall, after the quartz was deposited. It is likely that these quartz veins are variable in thickness, and they may also be faulted off at places by later movements.

The gold occurs free in the quartz, locally with arsenopyrite and its green alteration product, scorodite. Some of the gold quartz is of very high grade, but it should not be expected that all the vein will be of this character. The gold probably occurs in rich ore shoots, and in the exploitation of such a mine due allowance must be made for much unprofitable mining and for deadwork in prospecting the vein for new ore shoots. The ore shoots may average $40 to $50 in gold to the ton, but the quartz veins as a whole are much leaner.

A number of the quartz veins in this district were visited, including those on the Overlook, Eneveloe, Woodchuck, Golden Eagle, Summit, Little Mikado, Tonopah, Eclipse, and Crystal claims. Little can be seen at most of these properties, except the direction of the veins and, at some of them, the thickness. On the Little Mikado claim, at the head of Tobin Creek, a shaft was sunk 100 feet deep some years ago but is now caved in. Some distance down the hillside a crosscut was run 160 feet but apparently failed to intersect the main vein.

In general the gold quartz of these veins is white, in places iron-stained, and much of it shows cavities into which crystals of quartz project. Much of the quartz is crushed, and some of it is apparently recrystallized. One of the effects of later movement in the veins is the development of a sort of sheeting in the quartz, which runs parallel to the walls of the veins. Thin seams of altered arsenopyrite lie along many of these sheared fractures, emphasizing to the eye this parallel shearing. It appears that much of the movement within and parallel to these veins has taken place after the mineralization. The commonest sulphide in the quartz is arsenopyrite, but some stibnite, galena, and sphalerite also are found. The quartz on the Little Mikado claim is more massive and closer textured and contains more pyrite than arsenopyrite. Siderite also was observed in some of the vein quartz. The country rock in the neighborhood of the quartz veins also shows the effects of mineralization in numerous oxidized pyrite crystals.

The general trend of the stronger quartz veins ranges from N. 75° E. to N. 60° W., but no general system of veining was discovered. Some of the veins dip to the north and some to the south. Many of the veins intersect the cleavage of the schist, but some appear to follow the cleavage.

It is evident that the gold in the placers on Little Squaw, Big Squaw, and Big creeks has been derived in large measure from the gold quartz veins in the basins of these creeks. The source of the quartz veins, however, is a more involved though not less important problem. The discovery of minerals like monazite and rutile in the concentrates on Big Creek may have some bearing on the question. As Big Creek and the mountains at the head of it have not been overridden by glaciers, these minerals are certainly derived from a bedrock source within the drainage basin of Big Creek; and from the known occurrence of these minerals, particularly monazite, it is believed that this bedrock source is some highly acidic granitic rock, possibly of pegmatitic character. Gold quartz veins, too, are commonly believed to be connected genetically with the intrusion of granitic rocks, but it does not follow that these veins and the monazite are both derived from the same granitic rocks. This genetic relationship is suggested, however, and the suggestion may serve as a basis for further studies in this district.

Granitic rocks of Paleozoic and Mesozoic age are found in the Chandalar district, but only the Paleozoic type, a granitic gneiss, occurs in the vicinity of the Little Squaw-Big Creek mining district. The nearest known Mesozoic granitic rocks (granodiorite) are 30 miles to the southwest, whereas granitic gneiss, though not in bodies of mappable size, is known on the north side of the valley of Lake Creek, about 4 or 5 miles distant. It is possible that some small bodies of the gneiss may also be present in the upper basin of Big Creek, but none are known at present. It remains to be determined, therefore, first whether the quartz veins and the monazite are related genetically, and second, what was the age or ages of the mineralization that produced them. These questions will be answered only by more detailed studies.

METAL PRODUCTION

The production of gold and silver in the Chandalar district, from 1906 to the present time, is shown in the accompanying table.

Placer gold and silver produced in the Chandalar district, 1906–1923

Year	Gold		Silver		Year	Gold		Silver	
	Fine ounces	Value	Fine ounces	Value		Fine ounces	Value	Fine ounces	Value
1906–1912	2,902.50	$60,000	416	$241	1918	628.88	$13,000	96	$96
1913	266.06	5,500	38	23	1919	483.75	10,000	79	88
1914	241.87	5,000	35	19	1920	870.75	18,000	125	136
1915	241.87	5,000	35	18	1921	1,451.25	30,000	197	197
1916	435.37	9,000	62	41	1922	4,015.12	83,000	574	574
1917	725.63	15,000	104	86	1923	2,031.75	42,000	288	236

INDEX

RECENT SURVEY PUBLICATIONS ON ALASKA.

[Arranged geographically. A complete list can be had on application.]

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 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 prices 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.

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Map of Alaska (A); scale, 1:5,000,000; 1920, by A. H. Brooks. 10 cents retail or 6 cents wholesale.

*Map of Alaska (B); scale, 1:1,500,000; 1915, by A. H. Brooks and R. H. Sargent.

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; by A. H. Brooks. 20 cents retail or 12 cents wholesale. New editions included in Bulletins 642 (35 cents), 662 (75 cents), and 714–A (25 cents).

Index map of Alaska, including list of publications; scale, 1:5,000,000; by A. H. Brooks. Free on application.

Relief map of Alaska (D); scale, 1:2,500,000; 1923, by A. H. Brooks and R. H. Sargent. 50 cents retail or 30 cents wholesale.

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The Ketchikan district, by Theodore Chapin.

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Juneau special (No. 581A); scale, 1:62,500; by W. J. Peters. 10 cents retail or 6 cents wholesale.
Berners Bay special (No. 581B); scale, 1:62,500; by R. B. Oliver. 10 cents retail or 6 cents wholesale. Also contained in Bulletin 446, 20 cents.
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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, 40 cents.
Eagle River region (No. 581C); scale, 1:62,500; by J. W. Bagley, C. E. Giffin, and R. E. Johnson. In Bulletin 502, 25 cents. Not issued separately.
Juneau and vicinity (No. 581D); scale, 1:24,000; contour interval, 50 feet; by D. C. Witherspoon. 20 cents.

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The Bering River coal fields; scale, 1:62,500; by G. C. Martin. 25 cents retail or 15 cents wholesale.

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The Broad Pass region; scale, 1:250,000; by J. W. Bagley. In Bulletin 608, 25 cents. Not issued separately.

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Nelchina-Susitna region; scale, 1:250,000; by J. W. Bagley. In Bulletin 668, 25 cents. Not issued separately.

Iniskin-Chinitna Peninsula, Cook Inlet region; scale, 1:62,500; by C. P. McKinley, D. C. Witherspoon, and Gerald Fitz Gerald (preliminary edition). Free on application.

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

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

Rampart quadrangle (No. 643); scale, 1:250,000; 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, 20 cents.

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

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

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

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

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

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Casadepaga quadrangle (No. 646C); scale, 1:62,500; by T. G. Gerdine, W. B. Corse, and B. A. Yoder. 10 cents retail or 6 cents wholesale. Also in Bulletin 433, 40 cents.

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

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

Northwestern part of Naval Petroleum Reserve No. 4, Alaska; scale, 1:500,000; by E. C. Guerin, Gerald Fitz Gerald, and J. E. Whitaker (preliminary edition). Free on application. Surveyed for Department of the Navy.

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