THE CHANDALAR-SHEENJEK DISTRICT, ALASKA

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INTRODUCTION

The Chandalar-Sheenjek district, as described in this report, consists of an irregular area of about 6,000 square miles that lies between parallels 66° 28′ and 69° north latitude and meridians 143° 25′ and 147° 35′ west longitude. This area includes mainly the valleys of the Sheenjek River and the East Fork of the Chandalar River from their headwaters in the Brooks Range southward to their debouchures into the Yukon Flats. The index map (fig. 1) shows the position of this area in northern Alaska. Only traverses were made by the writer south of latitude 66° 48′, but the limits of the map have been extended southward to Fort Yukon and Beaver, in order to show the geographic relation of these settlements to the mapped area.

The geologic information given in this report is based principally on field work done by the writer in 1926 and 1927. The topographic map was begun by J. O. Kilmartin in 1926, in the Sheenjek Valley, but 85 per cent of the mapping was done by Gerald FitzGerald during the season of 1927. No surveys earlier than 1926 had been made in the greater part of what is here considered the Chandalar-Sheenjek district, but several geologic reports and topographic maps of contiguous areas that have a direct bearing upon the results outlined in this report are listed below in chronologic order:

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.

Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, pp. 315–338, 1908.

Maddren, A. G., Geologic investigations along the Canada-Alaska boundary: U. S. Geol. Survey Bull. 520, pp. 296–314, 1912.

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

Leffingwell, E. de K., The Canning River region, northern Alaska: U. S. Geol. Survey Prof. Paper 109, 1919.

Mertie, J. B., jr., Geology and gold placers of the Chandalar district, Alaska: U. S. Geol. Survey Bull. 773, pp. 215–263, 1925.

On June 6, 1926, the writer, accompanied by J. O. Kilmartin, topographer, and Earl Hunter and Ray Russell, camp helpers, left Fort Yukon in two Peterborough canoes equipped with outboard motors and proceeded up the Porcupine River to the Sheenjek River and thence up that stream. Geologic and topographic mapping was

FIGURE 1.—Index map showing location of Chandalar-Sheenjek district

begun 90 miles by river from the mouth of the Sheenjek at a point where the hills begin to the north of the Yukon Flats. The expedition continued work up the Sheenjek River, to a point about 160 miles by river above the mouth, where, on account of injuries sustained by Russell and Kilmartin, the work was discontinued, and the party returned to Fort Yukon in the later part of July. As a result of this work, a topographic map and a preliminary geologic report were prepared and published.[1]

As the Geological Survey desired to continue this work, another expedition was outfitted in 1927 but with a different organization. The personnel, as in 1926, consisted of four men, but the expedition was divided into two units of two men each, one of which was to enter the country during the late winter, in order to establish a base camp in the Brooks Range and to lay out caches of supplies for the work of the ensuing summer. Accordingly Gerald FitzGerald, topographic engineer, left Seattle February 26, 1927, and proceeded to Fairbanks. He was joined at Nenana by Fred E. Clark. On March 13 FitzGerald and Clark left Fairbanks by dog team and proceeded by way of Circle to Fort Yukon, where they arrived after seven days' travel. The expedition was outfitted at Fort Yukon. It had originally been planned that the winter party would freight a summer's outfit of supplies and one Peterborough canoe northward into the Brooks Range, but it was found at Fort Yukon that it would be impossible to transport a canoe into the mountains over the narrow toboggan trail used by the natives, which was the only route of entry. Arrangements were then made with natives at Fort Yukon for freighting a part of the supplies of the expedition northward, and about a week afterward eight dog teams, manned by natives and loaded with 2,200 pounds of supplies for the expedition and necessary dog feed, left Fort Yukon and moved this freight northwestward to Caribou House, a distance of 107 miles by trail. On March 30 FitzGerald and Clark also left Fort Yukon with two dog teams and 800 pounds of additional supplies, and on April 4 they arrived at Caribou House. From this point FitzGerald and Clark moved the entire 3,000 pounds of supplies northward to Arctic Village by relaying, and by April 19 the entire outfit was safely landed at Arctic Village, 150 miles by trail from Fort Yukon. This freighting was accomplished in winter, under most trying conditions, for the party was traveling rapidly, with a minimum of camping and personal equipment. Much of the ultimate success of the expedition must be attributed to the successful completion of this winter work.

After arrival at Arctic Village Clark and two natives, with three dog teams, departed on April 25 and moved 1,500 pounds of supplies northeastward into the upper valley of the Sheenjek River, where they made two caches, and returned to Arctic Village by May 4. In the meanwhile FitzGerald continued with the topographic mapping, which he had begun April 4 at Caribou House, and made five

[1] Mertie, J. B., jr., Preliminary report on the Sheenjek River district, Alaska: U. S. Geol. Survey Bull. 797, pp. 99–123, 1928.

side trips by dog team out from Arctic Village. On one of these trips, on which he started May 10, accompanied by Clark, he placed another cache of provisions up the East Fork of the Chandalar River, about 15 miles above Arctic Village. On May 27 the spring break-up occurred on the East Fork at Arctic Village, and thereafter for some time travel by any means was impracticable. Between June 10 and July 15, however, the topographic mapping was continued on three side trips from Arctic Village, dogs being used for the transportation of supplies.

In the meanwhile the writer had arrived at Fort Yukon, and on June 9, accompanied by C. A. Wheeler, in a canoe equipped with an outboard motor, he proceeded down the Yukon to the upper mouth of the Chandalar River and thence up that stream. Progress up the lower part of the Chandalar River, for the first 25 miles, was easy and rapid, but from that point westward progress became slower and more difficult, for the river was then at its highest stage and was therefore swift and full of driftwood and was carrying a large volume of water spread out into numerous overflow channels. Finally the current became too swift to ascend with a motor, and as many of the gravel bars were covered with water continuous lining of the canoe was also impracticable. The party was therefore obliged to stop at several places and wait for falling water, thus losing 15 days, so that the mouth of the East Fork of the Chandalar River was not reached until July 2. Up to this point considerable use had been made of the outboard motor, but in continuing up the East Fork of the Chandalar River most of the progress was made by lining the canoe along gravel bars, the motor being used mostly in making bad crossings and in ascending stretches of the river where no gravel bars were exposed on either side.

On July 9 the party arrived at a point about 3 miles above Lush Creek and 135 miles by river from Fort Yukon but was unable temporarily to go farther because of an injury of the ankle received by the writer. Wheeler then proceeded upstream on foot and made connection July 14 with FitzGerald at Arctic Village. On July 15 FitzGerald and a native came downstream in a canvas canoe and joined the writer at Lush Creek; and the night of July 16 the three men started back to Arctic Village, back packing the necessary equipment for the summer's work, and arrived there in two and a half days. This return trip of 60 miles was made along the ridge that lies between the East Fork of the Chandalar River and the Christian River and enabled the writer to see the rock formations along this part of the route.

On July 19 the united party, consisting of FitzGerald, Clark, Wheeler, and the writer, started northeastward for the upper

Sheenjek River. Six dogs accompanied the party, packing about 150 pounds, and the remainder of the camp and personal equipment and instruments were packed on the backs of the four men, with an average load of 65 pounds to the man. The route followed was eastward from Arctic Village by way of Old John Lake to Johnnie Frank's cabin on the Koness River, thence northeastward to the caches on the Sheenjek, thence westward up the valley of Old Woman Creek and over into the upper valley of the East Fork of the Chandalar River, and thence southward by the East Fork cache to Arctic Village. This trip, which covered a distance of about 200 miles, was made in four weeks and resulted in the topographic and geologic mapping of all of the Koness Valley and the headwaters of the Sheenjek River and the East Fork of the Chandalar River.

On August 20 the party started down the East Fork in two skin boats, obtained from the natives at Arctic Village, and on August 28 it arrived at Lush Creek, where the Peterborough canoe and the canvas canoe had been stored. It proceeded downstream the following day, three men in the Peterborough canoe and one in the canvas canoe, and arrived at the mouth of the East Fork September 5. During this trip downstream the East Fork was mapped on both sides of the valley, from Arctic Village to its mouth, but early snows in the later part of August materially impeded the progress of work in the lower stretches of the river. On September 9 the expedition arrived at Beaver, on the Yukon, and on September 11 FitzGerald and the writer started upstream in the Peterborough canoe for Fort Yukon, where they arrived, ending the season, on September 13.

The members of this expedition are much indebted to numerous people in interior Alaska for hospitality and cordial cooperation. Particularly should be mentioned Mr. Jack Donald, agent for the Northern Commercial Co. at Fort Yukon, and Dr. and Mrs. Grafton Burke, also of Fort Yukon. Mr. L. J. Palmer, of the United States Biological Survey, at Fairbanks, also helped materially by the loan of a sled for the winter trip from Fairbanks to Fort Yukon.

GEOGRAPHY

DRAINAGE

The Chandalar-Sheenjek district (pl. 1) is drained by the East Fork of the Chandalar River and by the Sheenjek and Christian Rivers. The Christian River empties into the main Chandalar River, which drains into the Yukon. The Sheenjek River empties into the Porcupine River, another tributary of the Yukon. Hence all the streams of this region are a part of the Yukon River system and drain the south slopes of the Brooks Range.

The Yukon River from Circle to Fort Hamlin splits into numerous channels and spreads out over a wide flood plain known as the Yukon Flats. From Circle the Yukon flows northwestward for an air-line distance of about 75 miles and then turns southwestward and flows 125 miles farther through these flats. Within this 200-mile stretch all the streams tributary to the Yukon likewise flow through flats in their lower courses. This great flood plain of the Yukon, together with its continuation up the lower courses of the tributary streams, includes an area of about 7,500 square miles, and at Fort Yukon its width from north to south is at least 70 miles.

The Porcupine River, the largest tributary of the Yukon within the flats, enters the Yukon just below Fort Yukon, at the point where the course of the main river veers southwestward. The Porcupine itself flows southwestward, and the Yukon Valley below Fort Yukon appears therefore to be rather a continuation of the Porcupine Valley than of the Yukon Valley above Fort Yukon. The main part of the Porcupine River enters the Yukon several miles below Fort Yukon, but a navigable slough of the Porcupine joins the Yukon about a mile or two below Fort Yukon, and this slough is the route usually taken by small boats in entering the river. The Porcupine flows in its lower course through the Yukon Flats and within that stretch is joined from the southeast by the Black and Little Black Rivers and from the north by the Sheenjek River, which is locally called the Salmon River. These tributary streams also flow through flats in their lower courses.

The Porcupine River, from its mouth upstream for 125 miles, though probably only half that distance in an air line, flows through the flats in large meanders, splitting, particularly at times of high water, into numerous channels and sloughs. The banks, as seen along the outer sides of the meanders, are composed of silt and peat, with here and there bodies of ground ice, and are often undercut by the river current, producing overhanging masses of peat and vegetation, which by caving fall into the river and produce snags and sweepers. These higher banks are usually bordered by timber, mainly spruce. The inner sides of the meanders are generally low sand or gravel bars, and for some distance back from these the flats are covered mainly with willows and alders. At ordinary stages of water the lower Porcupine is a rather sluggish stream, with a current of 2 to 3 miles an hour, but during stages of high water it is considerably swifter, approximating at places a 5-mile current. The current at the mouth of the Porcupine is determined mainly by the stage of water in the Yukon, being particularly sluggish if the Porcupine is at low stage while the Yukon is in flood and rather swift if these conditions are reversed.

The Sheenjek River flows in its lower course through flats of the same character as those above described, and the conditions along the river in this stretch are much the same as those on the Porcupine, except that the Sheenjek is a smaller stream and therefore flows in meanders of smaller amplitude, though no less tortuously, than the Porcupine. Other differences are that the river banks along the Sheenjek are lower than on the Porcupine, and in its lower course fewer and smaller gravel bars are present. In fact, when the Sheenjek is in flood, no gravel bars are visible from the mouth upstream for 60 miles by river, although many such bars are visible in the lower river at low water. Like the Porcupine, the Sheenjek River shows great variation in stream velocity, dependent on the stage of water. At low water the lower Sheenjek is distinctly sluggish, but in flood the current is fairly strong, and at some places a motor boat with considerable power is required for traveling upstream against the current. In general, however, the lower Sheenjek presents no difficulty to motor-boat navigation, except at very high water, when the presence of driftwood, concealed snags, and occasional whirlpools necessitates greater care.

Few riffles occur in the lower Sheenjek River, but these swifter and shallower places become progressively more numerous upstream, so that at ordinary stages of water the upper limit of navigation for a power boat is Carroll's cabin, about 75 miles by river from the mouth. At high water a well-powered motor boat of shallow draft can go 20 miles farther upstream, to Christian's cabin, but within this 20-mile stretch the heavily loaded canoes of the Geological Survey party of 1926, which were propelled by outboard motors, were unable at many places to travel upstream except by lining them along the gravel bars.

In going up the Sheenjek the first sight of hills is obtained about 72 miles by river from the mouth. Here, at the end of a short eastward course, the traveler turns abruptly northward and sees a low wooded ridge that lies east of Christian's cabin. From this point upstream to the hills the river, although still within the flats, changes to a swifter stream, with fewer cut banks and numerous gravel bars on both sides. At Christian's cabin the river swings eastward and approaches closely to the wooded hill above mentioned, which may then be seen to be a low spur, projecting 10 miles or more southward from the main hills. From this place for another 15 miles upstream from Christian's cabin to the hills the river remains essentially a swift braided stream, flowing through flats.

From the southern edge of the hills upstream to the forks of the Sheenjek and for some distance up the west or main fork this river continues to be a swift braided stream, and although more confined than in the flats and straighter in its general course, it splits repeatedly into two or more channels and has numerous high-water overflow sloughs. The walls of the valley, however, are well defined, and the valley floor is a well-wooded flat, characterized by oxbows, lakes, swamps, and muskeg. At one point, about 10 miles in an air line below the mouth of the Koness River, the valley is constricted to a width of less than half a mile, but above this point it widens again to an average width of 2 miles. At the forks of the Sheenjek River, 185 miles by river from the mouth, the course of the main valley turns abruptly westward and then veers northward again to the headwaters.

All the streams that drain southward from the eastern part of the Brooks Range within the Chandalar-Sheenjek region are characterized in their upper courses by a stretch of relatively sluggish water that is followed downstream by rapids. The Sheenjek River is no exception to this rule, and the main river, 10 miles above the forks, changes to a sluggish meandering stream and continues thus for 20 miles upstream. Within this stretch the river is confined largely to a single channel and flows through a wide lake-dotted valley floor with banks of sand and silt. Between this sluggish water and the mouth of the East Fork are rapids, the river flowing swiftly through numerous riffles characterized by large boulders. Upstream from this sluggish stretch of water the river is a typical swift mountain stream, and the gradient steepens to its head.

The only large tributary of the Sheenjek River below the forks is the Koness River, which enters from the west side of the valley about midway between the northern edge of the flats and the forks. The Koness River, though not a large stream at ordinary stages of water, drains a large and diversified area west and northwest of its mouth. In its lower course, where it cuts through the hills to join the Sheenjek, the river flows through a narrow canyon-like valley but is nevertheless a meandering stream bordered by sand and gravel bars, much like the Sheenjek. Farther upstream it splits into a number of tributaries, which flow for the most part in wide, open valleys bordered by rolling hills. One of these tributaries heads to the west in Old John Lake, which lies in a wide valley leading to the East Fork of the Chandalar River. The tributaries from the north head mainly against Monument and Old Woman Creeks, tributaries of the Sheenjek.

The East Fork of the Sheenjek River has not been mapped but is said by prospectors to head about 20 miles northeast of the forks and to be cut off from the Arctic divide by an upper tributary of the Coleen River. A low divide exists between the head of the East Fork of the Sheenjek River and the Coleen River, and an even lower pass is said to separate the head of the East Fork from the main Sheenjek. About 8 or 9 miles below the forks a small tributary of the Sheenjek River, known as Monument Creek, comes in from the southwest, and a little upstream from Table Mountain a larger stream, known as Old Woman Creek, enters the Sheenjek River from the northwest. All the larger tributaries of the Sheenjek River except the East Fork enter from the west, thus rendering the Sheenjek drainage system markedly asymmetric. Along the main river below the forks, for example, it is less than 10 miles in places to the Sheenjek-Coleen watershed, but the East Fork of the Chandalar River, which is the next large stream to the west that flows parallel to the Sheenjek, lies 50 miles distant. Another noteworthy feature of the Sheenjek drainage system is the marked tendency of a number of the tributaries that enter from the west to flow northeastward in approaching the main valley, thus creating a condition resembling "backhand drainage." This feature is believed to be due mainly to the controlling effect of the rock structure.

The East Fork of the Chandalar River and the main Chandalar River below the mouth of the East Fork form the other main drainage system of this area. The Chandalar River enters the Yukon in several channels, which together with the outlets of the Porcupine create a maze of islands along the north side of the Yukon for 50 miles or more below Fort Yukon. The main mouth of the Chandalar is about 40 miles by river below Fort Yukon, but two other good-sized outlets exist farther upstream, and through the upper one, 20 miles below Fork Yukon, the expedition of 1927 entered the Chandalar. Between the upper and lower mouths sloughs lead off to the Yukon, but most of these could be entered only at a very high stage of water. The expedition of 1927 came out of the Chandalar into the Yukon by way of the lower mouth.

The Christian River enters the Chandalar about 25 miles by river above the upper mouth. In this stretch the Chandalar is very sluggish at low water, but in flood stages it has a current of 2 to 3 miles an hour. Above the Christian River for 20 miles the river is swifter and split into numerous channels, through which, even at low water, it is not easy for a stranger to follow the main channel. From this point upstream to the East Fork, a distance of 25 miles, the river is a swift stream but is less split up than farther downstream. The current in the Chandalar River, from the Christian River to the East Fork, runs from 3 to 5 miles an hour at high water, and under these conditions the stream is hard to navigate. Like those of the Sheenjek, the sand bars of the lower river are covered at high water, the river flowing between cut banks, but this zone extends only 20 miles up the Chandalar, as compared with 60 miles up the Sheenjek. Above the Christian River sand and gravel bars are exposed at all

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stages of water, and the river meanders swiftly along, with timbered cut banks of sand and silt on the outer sides of the turns and gravel bars on the insides, which farther back from the river are covered with willows and alders. The natives have no difficulty in navigating the river in motor boats up to Chandalar Village, 45 miles from the upper mouth, at any stage of water, and at high water a well-powered shallow-draft boat could probably go on upstream beyond the mouth of the East Fork, perhaps to the mouth of the Middle Fork. Small shallow-draft steamboats in fact did at one time go up on high water to a point midway between the East and Middle Forks, but loaded canoes of considerable draft with outboard motors can not navigate successfully the 70 miles to the East Fork at high water, because the stream is too swift, and at low water the shallow channels will cause trouble.

Throughout the 70 miles from the East Fork to its mouth the Chandalar flows through the Yukon Flats, a featureless plain devoid of relief. Its current, as well as that of the other streams in the flats, including also the Yukon River, shows clearly that this flood plain is by no means "flat" but has a strong tilt, the main Yukon flood plain sloping strongly southwestward and the flood plains of the tributary streams sloping even more perceptibly toward the Yukon. In traveling up the Chandalar distant hills to the north are first seen a short distance above the Christian River, and at Chandalar Village one channel of the river swings to the north side of its valley and impinges against a gravel bluff about 35 feet high, which is the southward edge of an alluvial bench that rises northward to the hills. Just below the mouth of the East Fork the river swings in to the south side of the valley, against a hard-rock bluff. From the appearance of the two streams at their confluence, the East Fork carries nearly as much water as the main Chandalar above the confluence.

The East Fork of the Chandalar River is a larger river than the Sheenjek, both in drainage area and in amount of water carried, although the Sheenjek, which rises as far north and flows for so many miles through the Yukon Flats to the Porcupine, is perhaps a somewhat longer stream. The air-line length of the East Fork is about 150 miles, but the length by river may be as much as 300 miles. The general course is relatively straight and bears about S. 30° W.; in this respect it is dissimilar to that of the Sheenjek River. The East Fork of the Chandalar may in general be divided into four zones. In the first zone, which extends from the mouth upstream to the Wind River, an air-line distance of 60 miles, the river is much like the Sheenjek, from the northern margins of the flats up to the forks. It flows with a fairly swift current over an alluvium-filled valley floor from 1 to 5 miles wide, in one channel for much of this distance but at numerous places braided into several channels.

The stream gravel is rather coarse everywhere, and at places, particularly where the river cuts into the gravel benches on both sides, the gravel is very coarse and contains numerous large boulders. On account of the large amount of water that flows at flood stage in the spring, it is difficult to line canoes upstream through these braided channels, owing to the necessity for making numerous crossings in the swift current from island to island. Where the river flows in one channel, upstream travel is in general good, and in such places an outboard can be used to advantage. In the lower 10 miles of this stretch the valley walls close in and the stream flows through a narrow gorge over a bed of very coarse gravel and large boulders. The current in this 10 miles, however, is no swifter than above, and as the stream is confined to one channel the boating either upstream or downstream is better than above the gorge. At one place just below the gorge, where the river starts out across the valley floor of the main Chandalar, the stream cuts bedrock and makes rapids for about 100 yards, but these are not especially difficult in downstream travel if care is exercised, and in going upstream, especially at high water, one can line around this stretch through another channel.

In the second zone from the Wind River upstream for 17 miles to a point a few miles above Crow Nest Creek the river has numerous rapids where it flows swiftly over coarse gravel and boulders, and this portion constitutes the worst stretch on the river for boating. It corresponds to the similar stretch on the Sheenjek River between Table Mountain and the forks and may be described as the zone in which the valley gradient is suddenly steepened. This feature resembles superficially the effect produced by a recent lowering of the base-level of a stream, the rapids corresponding to that zone of headward steepening where adjustment between an old and a new base-level is in progress. The location of these rapids on the North, Middle, and East Forks of the Chandalar and on the Sheenjek, however, corresponds with the southern limit of morainal material and is probably determined mainly by the preexisting conditions of glaciation.

Above these rapids stretches the third zone, in which the East Fork for nearly 40 miles in an air line is a sluggish meandering stream, with sand bars and banks of sand and silt. At places where the river has cut laterally into morainal material, gravel and boulders have slumped down to the water level, producing gravel bars, but such places are not characteristic of this part of the river as a whole. The 20-mile stretch on the Sheenjek River above Table

Mountain is strictly analogous to this 40-mile stretch on the East Fork of the Chandalar. In this zone of sluggish water the valley floor of the East Fork is from 5 to 10 miles wide and is a timber-covered lake-dotted flat. Oxbow lakes are well developed, and changes in the drainage channels of some of the tributary streams are also clearly evident.

The fourth zone lies above the sluggish part, extending to the head of the river. Here the river is again a typical mountain stream, with a steadily rising gradient to the Arctic watershed. This stretch of the river is perhaps 50 miles long, as compared with about half that distance for the similar stretch on the Sheenjek. One of the striking features of this upper zone on the East Fork is the presence of a number of bodies of aufeis. One of the largest of these deposits of ice occurs at the lower end of this upper stretch, just above the place where the river ceases to be a sluggish meandering stream. Another notable deposit is developed on the Junjik River, likewise just above the meandering zone of the river. One at a similar site is also known on the upper Sheenjek River, about 30 miles above Old Woman Creek. These ice sheets lie usually in the headwater stream courses, where the streams are split to form a braided network of channels; but it is not clear whether the site of such braided channels has determined the position of the ice, or whether the ice by its formation has caused the braiding of the stream channels. These bodies of ice, which may be 10 feet or more thick and several miles in length, remain usually until late in summer and during a cold season may persist in part throughout the summer.

The East Fork of the Chandalar River, like the Sheenjek River, is markedly asymmetric in its drainage system. The three largest tributaries, named in order upstream, are the Wind River, Crow Nest Creek, and the Junjik River, all of which enter from the west side. The Wind and Junjik Rivers are said by natives to head against one another in a low divide about 30 miles west of the main river. Below the Wind River, however, a tributary of the Middle Fork of the Chandalar River heads within 10 miles of the East Fork. Along the east side of the East Fork no large tributaries enter the river, and the watershed that separates the East Fork from the Christian and Koness Rivers and from the upper part of the Sheenjek River lies everywhere 10 miles or less distant.

The Christian River, the only other stream of any size draining this district, lies between the East Fork of the Chandalar River and the Sheenjek River but is quite different in character from either of those streams. It heads against the Koness River on the north and is therefore cut off from the high mountains of the Arctic watershed and also lies for the most part south of the glaciated portion of this area. From the point where it enters the Chandalar upstream to Christian Village it is said by natives to be little more than a sluggish slough, impeded by log jams, so that it is not suitable for navigation by small boats. Above Christian Village the valley is constricted for some distance into a narrow gorge, but above this gorge the head-water tributaries flare out into wide, open valleys cut in rolling hills.

RELIEF

The Chandalar and Sheenjek Valleys and the intervening territory may naturally be divided into three well-marked physiographic provinces, which from south to north are the Yukon Flats, the piedmont province, and the alpine province. The Christian River, however, flows only through the piedmont province and the Yukon Flats.

The Yukon Flats, through which all three of the above-mentioned streams flow in their lower courses, form a densely timbered alluvial plain, relatively devoid of relief and traversed, especially at high water, by innumerable sloughs of the Yukon and Porcupine Rivers and their tributaries. These flats, which characterize the Yukon River from Circle to Fort Hamlin, extend up the Porcupine River almost to the mouth of the Coleen River and therefore extend also up all the lower tributaries of the Porcupine, including the Black and Little Black Rivers as well as the Sheenjek. These flats in the Chandalar-Sheenjek district have a pronounced slope southward and southwestward, as shown by the gradients of the streams traversing them, and also by the altitude at the northeast and southwest limits of the flats within the Chandalar-Sheenjek district. Thus from the northern margin of the flats on the Sheenjek River southward to Fort Yukon the average gradient of the flats is about 11 feet to the mile. It does not of course follow that the streams in this area have any such average gradient, for many of them follow indirect and winding courses, but this figure does give an approximate idea of the slope of this alluvial plain and shows that it is a " flat " only in the apparent sense of having no prominent topographic landmarks.

The northern border of the Yukon Flats extends from the mouth of the East Fork of the Chandalar River about N. 70° E. toward the Sheenjek and Coleen Rivers. From this line northward for 50 to 70 miles lies a country of rolling hills, which merge northward into the higher mountains of the Brooks Range. This intermediate zone, here called the piedmont province, is of course more sharply defined from the Yukon Flats than from the alpine province to the north, from which it is distinguished in general by lower relief, more gradual slopes, and an absence or smaller degree of glacial erosion. This piedmont province reaches from the mouth of the

East Fork of the Chandalar River upstream to the south side of the group of high mountains west of Arctic Village and from this point extends east-northeastward, passing south of Titus Mountain, at the head of Tritt Creek, and south of Index and Table Mountains, in the upper Sheenjek Valley. Within this stretch the regional relief differs considerably but averages close to 2,000 feet, although the maximum relief is perhaps as much as 4,000 feet. Thus at the mouth of the East Fork of the Chandalar the altitude of the valley bottom is about 800 feet above sea level, and the ridges on each side rise to general altitudes of 2,000 to 3,000 feet, though the highest points attain 4,000 feet. At the upper end of this province on the East Fork, however, the valley floor has an altitude of about 2,000 feet, and the neighboring hills rise to altitudes of 3,000 to 4,000 feet, with higher mountains attaining nearly 5,000 feet. Similarly on the Sheenjek River the valley floor in the piedmont province rises from 1,400 feet at the southern limit to 2,000 feet at the northern limit, and the average crest lines of the ridges rise correspondingly from 3,000 feet to 3,800 feet, though the highest points on the ridges rise perhaps to 4,600 feet. Thus it appears that a surface joining the average crest lines in this piedmont province approximates in form a plane that slopes southwestward from the south front of the Brooks Range to the Yukon Flats and is incised by two trunk valleys that have a fall of similar magnitude.

Certain variations in this general picture should, however, be pointed out. Just as the valleys of the East Fork of the Chandalar and Sheenjek Rivers are asymmetric in their areal limits, so the boundary ridges are likewise noticeably asymmetric in the vertical sense. Thus the ridge along the east side of the Sheenjek River, which forms the watershed between that stream and the Coleen River, is on the average lower than the bounding watershed on the west side of the Sheenjek, and similarly the watershed between the East Fork of the Chandalar and the Christian Rivers is lower than the watershed that lies west of the East Fork. The Christian River, on the other hand, does not flow in a trunk valley and is fairly symmetrical areally. These facts bring to light the anomalous condition that although the average slope of the summits of the crest lines in the piedmont province is southwestward, this old erosional surface, if it is one, is modified by reversals of this slope to a southeasterly direction along the two trunk valleys, thus giving rise to an asymmetrically fluted surface.

Within this piedmont province certain tracts rise conspicuously above the average level of the crest. One of the more prominent of these is Helmet Mountain, which has an altitude of nearly 4,000 feet, about 6 miles northwest of the constricted part of Sheenjek

Valley. The top of Helmet Mountain is a sharp protuberance of igneous rock below which the slopes down to the lower ridge level are rounded, thus simulating the form of a German helmet. Shoulder Mountain, about 6 miles north of the mouth of the Koness River, is another outstanding mountain 4,200 feet high but is flat and mesa-like on top. A third mountain, known as Smoke Mountain, which has an altitude of 5,000 feet, stands west of the East Fork of the Chandalar River, between Crow Nest and Smoke Creeks, and still another mountain, flat on top like Shoulder Mountain, lies 9 miles southwest of Smoke Mountain and rises to an altitude of more than 4,400 feet. Farther down the East Fork, where the river cuts through a gorge into the main Chandalar Valley, a group of hills stands out in relief above the regional crest, and although the maximum altitude of these hills is not as great by 1,000 feet as that of Smoke Mountain, the relative relief is perhaps even greater. One other prominent landmark in this piedmont province should be mentioned, although it lies east of the area here treated. This feature is a symmetrically conical mountain, about 5,000 feet high, which stands east of the Coleen River and is known locally as Spike Mountain. This peak, which stands well south of the front of the alpine province amid much lower hills, is one of the highest mountains in the piedmont province and is therefore visible for many miles in all directions. On account of its striking character and visibility it should make a valuable reference point for tying together adjoining surveys in this general region. Spike Mountain was sighted by FitzGerald and the writer from Index Mountain, a distance between 80 and 100 miles.

The benches of the East Fork of the Chandalar and the Sheenjek River constitute a feature particularly characteristic of the piedmont province and worthy of separate mention. In going up the main Chandalar Valley a prominent terrace may be seen as soon as the hills are visible. This terrace extends upstream from a point about opposite the place where the Christian River issues into the flats. At this point the terrace appears to stand about 600 feet above the valley floor of the Chandalar River, but it becomes progressively lower upstream and is lost to view in the hills just below the mouth of the East Fork. The difference in slope between this terrace and the present river gradient of the Chandalar suggests the presence of an old lake in this valley or at least of an ancient stream with a gradient materially less than that of the present river. Also, at Chandalar Village, as previously stated, one slough of the river cuts into the north wall of its valley, truncating a bench composed of coarse gravel, about 30 or 35 feet high, which continues upstream and appears to be more nearly conformable in gradient with the present stream. Just at the mouth of the East Fork a low gravel bench, about 20 feet above the valley floor, is well developed on the north side of the main Chandalar, and this may in fact be the upstream continuation of the gravel bench at Chandalar Village. In the lower gorge of the East Fork no prominent terraces were noted, but just above the gorge, where the valley widens out, a well-marked bench about 300 feet high occurs on both sides of the valley. Where the East Fork cuts against this bench it is seen to be composed mainly of gravel, though in a few places it is mainly bedrock, with probably a veneer of gravel. This bench continues upstream to a place within a few miles of the Wind River, at more or less this same altitude above the valley floor, and at one or two places in this stretch the river cuts bedrock.

From the upper limit of this bench upstream to Ottertail Creek the East Fork rises 600 feet or more and therefore rises to the top of this bench, which from this point upstream corresponds roughly to the present valley floor. The tributary streams in this stretch also have a system of benches, as exemplified by the gravel deposits that lie between the lower courses of Smoke Creek and the Wind River. In this tract there are several well-marked gravel benches and some minor ones, which rise in all about 600 feet in the 6 miles from the East Fork to the hard-rock hills to the west. Upstream from Ottertail Creek terraces are noticeable at places but appear for the most part to be older terraces, well above the river level. Thus in the hills along the west side of the valley, opposite Arctic Village, four such terraces were noted, and similarly on the east side of Nichenthraw Mountain four rock terraces were seen, of which the next to the highest, about 800 feet above the valley floor, is very well developed.

On the Sheenjek River, where that stream debouches into the flats, a bench 300 feet high is well developed along the west side of the valley, and about 8½ miles in an air line above Christian's cabin the Sheenjek impinges against the west wall of the valley, cutting into this bench and exposing at this point perhaps 50 feet of gravel. This bench continues upstream with diminishing width for several miles to the constricted part of the Sheenjek Valley. Upstream from this point another bench appears, and although this seems to be cut in rock, it doubtless is related genetically to the gravel bench of similar height farther downstream. In addition two higher rock-cut terraces, one at an altitude of about 2,600 to 2,800 feet and the other at about 3,400 feet, are also present in the upper valley. The lower of these features is probably an old river terrace, but the higher one may be due to planating processes that are peculiar to sub-Arctic regions. Similar high benches are also seen on the upper slopes of the group of hills near the mouth of the East Fork.

North of the piedmont province and extending to the Arctic divide and beyond rise the high and rugged mountains that constitute the Brooks Range in this longitude. This area is the alpine province of the Chandalar-Sheenjek district. The expedition of 1927 penetrated 20 miles northward into the alpine province, both on the East Fork of the Chandalar and on the Sheenjek, and about one-sixth of the accompanying map portrays its topography. This mountainous region rises for the most part above timber line and has been extensively glaciated in past times, although in the parts visited no indications of present glaciation exist. This past glaciation has resulted in a typically glacial form of topography, including U-shaped main valleys, truncated spurs, smooth ridge tops, hanging valleys, and roches moutonnées in the southern part and cirques and generally ragged crest lines due to headward glacial sapping in the northern part.

The floors of the trunk valleys in the alpine province lie at altitudes above 2,000 feet, and the tributary valleys are correspondingly higher. The mountain tops range from 4,000 to 8,000 feet in altitude, and some of the peaks along the Arctic divide may even reach an altitude of 9,000 feet. Hence the maximum relief in this part of the district is 6,000 feet or more, and the average relief ranges from 2,000 to 5,000 feet. Many prominent mountains exist in this province, but only a few, particularly those which form prominent landmarks along the southern margin, have been named. Table Mountain, on the Sheenjek, Titus Mountain, at the head of Tritt Creek, and Nichenthraw Mountain, between the East Fork of the Chandalar River and the Junjik River, are some of these. A prominent mountain 16 miles southwest of Table Mountain rises to an altitude of 5,600 feet. This mountain was called Index Mountain by the members of the expedition. In the area 4 miles northwest of Nichenthraw Mountain stands a peak about 5,600 feet high, which was named Yasuda Mountain after Frank Yasuda, who about 30 years ago crossed the Brooks Range from the Arctic side and came down the creek west of this mountain. Another high mountain, 12 miles northwest of Arctic Village, which has an altitude of 6,200 feet, was named Misty Mountain, because of the usual covering of clouds upon it.

CLIMATE

The Chandalar-Sheenjek district has the typical sub-Arctic climate of northern Alaska, consisting of short, fairly warm summers and long, cold winters. The only available climatic records near this district are those made at Fort Yukon, on the Yukon Flats, and manifestly these can not be applied to the piedmont and alpine provinces farther north. Nevertheless these records are of interest in that they apply to part of the area here considered, and it is possible to extrapolate from them to obtain an approximate idea of the climatic conditions in the rest of the area.

At Fort Yukon the records of the United States Weather Bureau indicate an average total precipitation between 7 and 8 inches a year, with an average snowfall of 45 inches. This precipitation is fairly well distributed throughout the year, although a somewhat greater proportion of it appears to occur in the late spring and early summer. September, so far as present records show, appears to have a smaller mean precipitation than any other month. The summer days, particularly in June, July, and early August, are long and moderately warm, and about 45 to 50 days may be expected during the summer when the maximum daily temperature will be 70° or higher, although temperatures as high as 100° have been recorded in late June and early July. The minimum daily temperature may be expected to drop below freezing any time within the nine months from September to May, and freezing weather has been recorded exceptionally even during the three summer months. On the average, however, the daily temperature may be expected to fall below the freezing point during 245 days in the year and below zero during 155 days in the year. The extreme minimum of 70° below zero has been recorded in winter. The Yukon River at Fort Yukon usually freezes over about the last of October, and the ice in the river breaks and begins to move downstream about the middle of May.

In the piedmont and alpine provinces north of Fort Yukon climatic conditions are believed to be essentially similar to those at Fort Yukon, except in the following respects. Maximum summer temperatures are probably lower. It is doubtful if the minimum winter temperatures are much lower than at Fort Yukon, but the winter is longer and the summer shorter, and correlatively the mountain streams freeze earlier in the fall and open later in the spring. The East Fork of the Chandalar, for example, broke at Arctic Village on May 27, 1927, which is about two weeks later than the usual time of the spring break-up on the Yukon at Fort Yukon. No quantitative data on precipitation in the piedmont and alpine provinces are available, but with little doubt the precipitation, both rain and snow, is greater than at Fort Yukon. Still farther north, however, on the north slopes of the Brooks Range, the precipitation probably decreases toward the Arctic Ocean; for most of the rains come up the Yukon Valley from the southwest, and the Brooks Range interposes a barrier that prevents these storm clouds from dropping their moisture on the Arctic slopes. The Arctic Ocean, on the other hand, appears to be too cold to act as a source of moisture-laden winds.

ANIMALS AND PLANTS

The larger game animals of the country are moose, caribou, mountain sheep, and bear. Moose are fairly plentiful, particularly in the swampy lake-dotted stretches of the East Fork of the Chandalar and the Sheenjek River, near the south front of the Brooks Range. Individual caribou and small herds of them were seen and are fairly plentiful, though no very large herds like those in the Yukon-Tanana region roam in this country. Mountain sheep appear to be scarce. Both the black and brown grizzly bear live in this region, and some of the latter attain great size. The smaller mammals, many of which are valuable for their fur, include wolf, wolverine, coyote, fox, lynx, mink, beaver, rabbit, muskrat, ground squirrel, and porcupine. The native game birds of the country are ptarmigan and grouse, but their numbers appear to vary greatly from year to year, both being scarce during the seasons of 1926 and 1927. Numerous varieties of migrating birds, however, visit this country in summer, ducks and geese being then plentiful on the lakes and sluggish sloughs. The streams are well stocked with fish, particularly grayling or Arctic trout and lake trout. Pickerel and whitefish also inhabit these waters. Salmon run up the Porcupine and its tributaries in summer but not in the same degree as on the Yukon.

Spruce is the principal timber in the valley of the Sheenjek; the trees range in size from some 2 feet in diameter in the lower valley to the typical scrubby spruce of the upper wooded slopes. Several varieties of poplar also are common. Birch grows usually in the interior on well-drained lands, commonly hill slopes, but much of the timbered areas of the East Fork of the Chandalar and the Sheenjek River is boggy bottom land, so that birch is rather uncommon. The best birch on the East Fork of the Chandalar River was seen on the gravel benches on the west side, between Crow Nest Creek and the Wind River. Birch is also found in the lower part of the Koness River and on the Sheenjek River. Birch is highly prized by the natives, being used by them for snowshoes and as frames for their skin boats. Willows and alders grow in profusion in the swampy bottom lands, usually as high underbrush. Buck brush, or dwarfed black birch, occurs in this region as a low underbrush but not so plentifully as south of the Yukon. Timber line ranges from 2,000 to 2,500 feet, depending upon local conditions, but in the valleys of the larger streams timber may follow up a main valley to an altitude of 3,000 feet. Figure 2 shows the distribution of timber in the Chandalar-Sheenjek district.

Many varieties of flowering plants mature in this region during the summer. Small but fairly representative collections of the early maturing plants were made by the writer in 1926 and 1927 and sub-

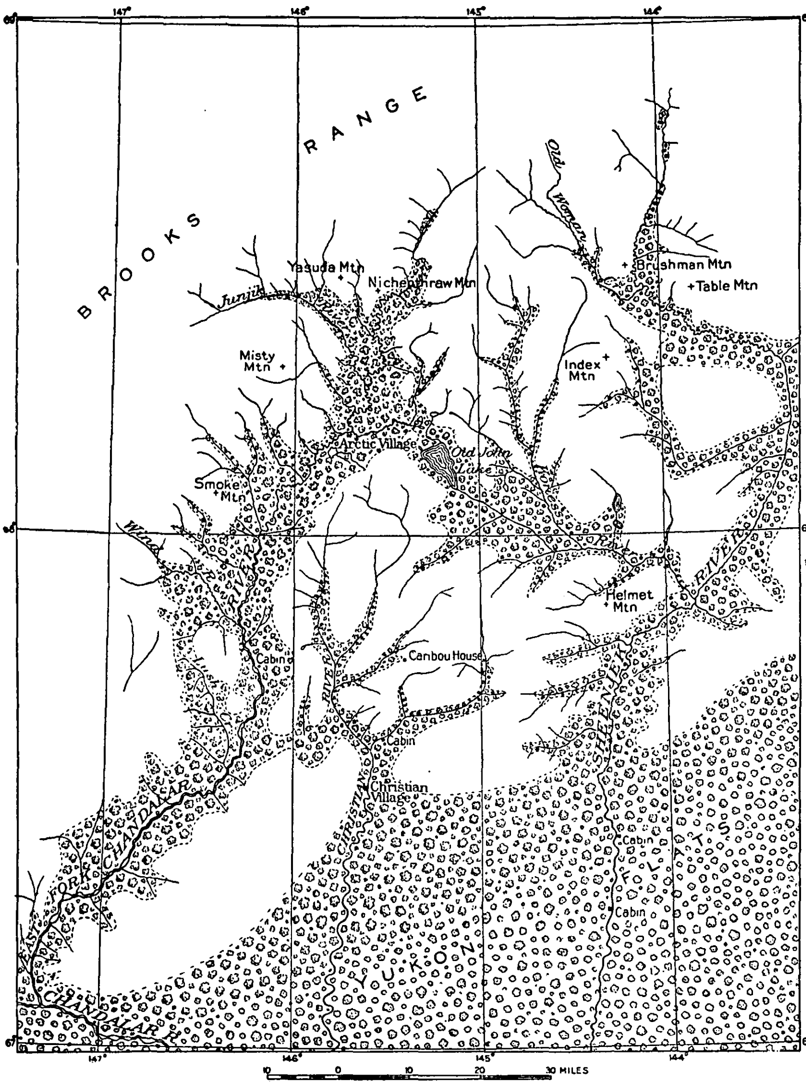

FIGURE 2.—Sketch map showing distribution of timber in the Chandalar-Sheenjek district

mitted to the Smithsonian Institution for identification. This flora, as determined by Dr. Paul C. Standley, is listed below:

Poaceae (grass family):
  Torresia odorata (Linné) Hitchcock. Sweet grass.
Cyperaceae (sedge family):
  Eriophorum callitrix Chamisso. Cotton grass.
Liliaceae (lily family):
  Allium sibiricum Linné. Wild onion.
  Tofieldia palustris Hudson. Scottish asphodel.
  Zygadenus elegans Pursh. Poison camas.

Orchidaceae (orchid family):
Cypripedium guttatum Swartz. Lady's-slipper.
Cypripedium passerinum Richardson.
Habenaria obtusata (Pursh) Richardson.
Salicaceae (willow family):
Salix sp. Willow.
Polygonaceae (buckwheat family):
Polygonum bistorta Linné. Knotweed.
Silenaceae (pink family):
Arenaria capillaris Poiret. Sandwort.
Arenaria macrocarpa Pursh.
Cerastium maximum Linné. Mouse-ear chickweed.
Dianthus repens Patrin.
Silene acaulis Linné. Carpet pink.
Silene repens Patrin.
Stellaria longipes Goldie. Chickweed.
Ranunculaceae (buttercup family):
Aconitum delphinifolium De Candolle. Monkshood.
Anemone multiceps (Greene) Wight.
Caltha palustris var. arctica (R. Brown) Huth. Marsh marigold.
Papaveraceae (poppy family):
Papaver nudicaule Linné. Arctic poppy.
Brassicaceae (mustard family):
Cheirinia cheiranthoides (Linné). Link. Wild wallflower.
Lesquerella arctica (Wormskiold) Watson. Bladder pod.
Sisymbrium humile Ledebour. Water cress.
Parnassiaceae (Parnassia family):
Parnassia kotzebuei Chamisso. Grass of Parnassus.
Saxifragaceae (saxifrage family):
Saxifraga bronchialis Linné. Saxifrage.
Saxifraga tricuspidata Rottboell. Saxifrage.
Rosaceae (rose family):
Dryas drummondii Hooker. Yellow dryad.
Dryas integrifolia Vahl. Dryad.
Dryas octopetala Linné.
Potentilla fructicosa Linné. Shrubby cinquefoil.
Potentilla nivea Linné.
Potentilla pennsylvanica Linné.
Potentilla villosa Pallas.
Rosa acicularis Linné. Wild rose.
Rubus arcticus Linné.
Spirea steveni (Schneider) Rydberg. Meadow sweet.
Fabaceae (bean family):
Astragalus alpinus Linné. Loco weed.
Astragalus gormani Wight.
Astragalus sp.
Hedysarum americanum (Michaux) Britton.
Hedysarum mackenzii Richardson.
Lupinus arcticus Watson. Lupine.
Oxytropis campestris (Linné) De Candolle.
Oxytropis nigrescens (Pallas) Fischer.

Onagraceae (evening primrose family):
- Epilobium angustifolium Linné. Fireweed.
- Epilobium latifolium Linné.

Apiaceae (parsley family):
- Conioselinum gmelini (Chamisso and Schlechtendal) Coulter and Rose. Hemlock parsley.

Ammiaceae (carrot family):
- Bupleurum americanum Coulter and Rose.

Cornaceae (dogwood family):
- Cornus stolonifera Michaux. Red osier dogwood.

Pyrolaceae (Pyrola family):
- Pyrola grandiflora Radius. Wintergreen.
- Pyrola minor Linné.
- Pyrola secunda Linné.

Ericaceae (heath family):
- Arctostaphylos uva-ursi (Linné) Sprengel. Bearberry.
- Ledum decumbens (Aiton) Loddiges. Labrador tea.
- Ledum groenlandicum Oeder.
- Rhododendron lapponicum Linné.

Vacciniaceae (blueberry family):
- Vaccinium vitis-idaea Linné. Bilberry.

Primulaceae (primrose family):
- Androsace chamaejasme Wulfen.

Polemoniaceae (Jacob's ladder family):
- Phlox hoodii Richardson.
- Phlox sibirica Linné.
- Polemonium humile Willdenow. Jacob's ladder.
- Polemonium pulcherrimum Hooker.

Boraginaceae (borage family):
- Eritrichum aretioides (Chamisso) De Candolle.
- Mertensia alaskana Britton. Bluebells.

Scrophulariaceae (figwort family):
- Castilleja tristis Wight. Indian paintbrush.
- Castilleja tristis var. pubens Wight.
- Pedicularis labradorica Panzer. Lousewort.
- Pedicularis sudetica Willdenow.
- Pentstemon gormani Greene. Beard tongue.

Rubiaceae (madder family):
- Galium boreale Linné. Bedstraw.

Caprifoliaceae (honeysuckle family):
- Linnaea borealis Linné. Twinflower.
- Viburnum pauciflorum Pylaie. High-bush cranberry.

Valerianaceae (valerian family):
- Valeriana capitata Pallas. Valerian.

Campanulaceae (harebell family):
- Campanula lasiocarpa Chamisso. Harebell.
- Campanula uniflora Linné.

Asteraceae (aster family):
- Achillea borealis Bongard. Yarrow.
- Arnica alpina (Linné) Olin.
- Arnica nutans Rydberg.
- Aster sibiricus Linné.
- Crepis nana Richardson.

Asteraceae (aster family)—Continued.
- Erigeron caespitosus Nuttall. Fleabane.
- Erigeron hyperboreus Greene.
- Erigeron uniflorus Linné?
- Senecio atropurpureus (Ledebour) Greenman. Groundsel.
- Senecio lugens Richardson.
- Taraxacum ceratophorum (Ledebour) De Candolle. Dandelion.

SETTLEMENTS

Fort Yukon, at the confluence of the Porcupine and Yukon Rivers, and Beaver, about 80 miles by river downstream from Fort Yukon, are the only white settlements in this region. Fort Yukon, the point of entry for the Porcupine Valley, is the center of the fur industry of the upper Yukon, and its population is therefore to some extent nomadic, the trappers being alternately in and out of town. The stable white population consists perhaps of 40 to 50 people, augmented periodically by trappers and prospectors. The United States Signal Corps maintains a radio station at Fort Yukon. One of the local points of interest at Fort Yukon is the Hudson Stuck Memorial Hospital, where the native people of this district are cared for in sickness and are taught the rudiments of sanitation and hygiene, as well as the fundamentals of Christianity. This is the only well-equipped hospital in this region and is therefore also a great benefit to the white people along the upper Yukon.

Beaver is another trading post and trapping center on the Yukon. The population of Beaver, like that of Fort Yukon, is variable but usually consists of a few white men and several native families. Beaver is also the point of entry into the Chandalar mining district, 125 miles to the northwest.

Several native settlements exist in this district, of which the largest is the one at Fort Yukon, where 200 or more natives live. The next largest settlement is at Arctic Village, about midway between the Junjik River and Ottertail Creek, on the East Fork of the Chandalar, where there are about 75 natives. Christian Village, another settlement of perhaps 20 natives, is just below the constricted part of the Christian River valley, where the river discharges into the Yukon flats. Chandalar Village, on the Chandalar about 45 miles by river from its upper mouth, is another native settlement. All these natives are of Indian stock. The native families at Beaver, however, are mainly Eskimos and their descendants, who migrated across the Brooks Range from the Arctic side with Frank Yasuda about 30 years ago.

The only road in this district is a wagon road 75 miles long, from Beaver to Caro, on the Chandalar, over which supplies for the Chandalar mining districts are freighted. A number of winter trails are used by the natives and trappers, however, one of the more frequented of which is the trail from Fort Yukon to Arctic Village by way of Christian Village. The distance from Fort Yukon to Christian Village is 75 miles and to Arctic Village 150 miles.

The Yukon River is the arterial highway of this region. In summer passengers, mail, and freight are carried on the Yukon by a steamboat operated by the American-Yukon Navigation Co., and in winter a regular mail service is maintained by dog teams from Fairbanks to Circle and thence up the Yukon to Eagle and downstream to Fort Yukon and Beaver.

GEOLOGY

OUTLINE

The sedimentary rocks of the Chandalar-Sheenjek district are mainly of Paleozoic age. Six sedimentary formations are shown on the accompanying geologic map (pl. 2), ranging in age from pre-Silurian to Carboniferous. Igneous rocks also are present but are confined mainly to Sheenjek Valley, where they occur as intrusive bodies in the late Devonian or early Mississippian sediments. Tertiary lavas are represented in the southwest corner of the mapped area.

The oldest sedimentary rocks are a group of schists of early Paleozoic and possibly in part of pre-Paleozoic age. These schists are overlain by the Skajit limestone, of Silurian age, and this in turn is followed by a group of rocks that are believed to belong in the Devonian system. Three younger formations are also mapped, of which the lower one is here considered to be of Upper Devonian or early Mississippian age. The intermediate formation is regarded as lower Mississippian. The youngest of these three formations is the Lisburne limestone, of upper Mississippian age. Triassic rocks are known also to exist to the northwest and northeast but have not been recognized as such in this district. To the west Cretaceous rocks also are known to exist south of the Brooks Range, and such rocks may indeed be present in the unmapped country in the south-central part of this area, especially near the Christian River.

SEDIMENTARY ROCKS

EARLY PALEOZOIC AND POSSIBLY OLDER ROCKS

Distribution.—Undifferentiated early Paleozoic rocks crop out along the East Fork of the Chandalar River from the mouth upstream for 50 miles in an air line and continue thence upstream along the west side to Ottertail Creek as a narrow fringe adjoining the Skajit limestone. At Ottertail Creek a local doming brings to the surface an equidimensional area of 30 to 40 square miles, and this dome marks the northern extent of these rocks.

These rocks continue westward at about the same latitude into the valley of the Middle Fork of the Chandalar River and still farther westward into the North Fork, where they have been described and mapped by the writer.[2] To the east, in the Chandalar-Sheenjek district, these undifferentiated Paleozoic rocks appear to be covered by younger rocks, for they are exposed nowhere on the Sheenjek River. Undifferentiated metamorphic rocks north of the Chandalar-Sheenjek district, however, on the north slopes of the Brooks Range, have been described and mapped by Leffingwell[3] under the name Neruokpuk schist. It is therefore probable that all the younger rocks in the Chandalar-Sheenjek district are underlain at depth by these older Paleozoic rocks.

Lithology and structure.—Very few observations of these rocks were made in the lower valley of the East Fork of the Chandalar, because few exposures occur in the valley walls and the tops of the hills in late August were deeply buried by snow. The few data available, however, show that this group is composed mainly of mica schist, quartz-mica schist, and phyllite, the last in places graphitic. Also a few specimens show the presence of more quartzose rocks, approaching quartzite schist and quartzite in character, mainly in the hills near the Chandalar River, at the south side of this belt of rocks. No crystalline limestone was seen, but from the character of those rocks farther west thin bands of this rock may occur. Old vein quartz was also seen, kneaded into the mica schist and phyllite and appearing therefore mainly as thin laminae and flattened lenses along the cleavage planes.

On top of the hill between the lower valley of Lush Creek and the East Fork an interesting sheared conglomerate crops out. This conglomerate is sheared to such an extraordinary degree that its originally fragmental character is scarcely evident in hand specimens. The component pebbles, which seem to be chert and quartz, are from half an inch to 3 inches in length, perhaps one-third to one-half as wide, and from one-sixteenth to one-fourth inch in thickness and are therefore prolate spheroidal in shape but extremely flattened in one dimension. The long axes lie parallel to the dip of the cleavage. Together with the conglomerate at this locality occur long stringers of slate, chert, and vein quartz, as thin as the pebbles above described, showing that these rocks have been disrupted and drawn out into elongated slivers. The cleavage is usually fairly regular, approximating a plane surface, but in places it is wavy and somewhat crenu-

[2] Mertie, J. B., jr., Geology and gold placers of the Chandalar district: U. S. Geol. Survey Bull. 773, pp. 225–228, 1925.

[3] Leffingwell, E. de K., The Canning River region, northern Alaska: U. S. Geol. Survey Prof. Paper 109, pp. 103–105, 1919.

lated. Ordinarily the occurrence of conglomeratic phases of these metamorphic rocks near the northern border of the group might have some stratigraphic significance, but in rocks so greatly metamorphosed their present geographic position probably means little or nothing with reference to stratigraphic interpretation. The nearest approach to limestone in this group of rocks was seen in the center of the dome, on the ridge southwest of Ottertail Creek. The rocks on this ridge are mainly calcareous mica schist, composed essentially of muscovite and calcite, with some more argillaceous types of mica schist.

Sheared greenstone is intermingled with the schist along the ridge east of the mouth of the East Fork of the Chandalar River, and sheared igneous rocks that may originally have been dioritic occur at places in the lower canyon of the East Fork. Hence igneous rocks of intermediate and basic character appear to constitute a part, though a minor part, of this group of rocks, but no information is at hand for interpreting their original mode of occurrence. In general, however, such igneous rocks appear to occur mainly along the southern margin of this group of undifferentiated rocks, thus suggesting that they are very ancient.

No original bedding planes were recognized, and the available stratigraphic data are too meager to permit the tracing of any distinct lithologic horizons areally. Hence the stratigraphic succession of beds is quite unknown. The cleavage, which is the only structure visible, strikes from N. 60° W. to west and dips mainly north at angles of 15° to 25°, although at places it dips south. At the center of the Ottertail Creek dome the cleavage is nearly horizontal and dips very slightly, but this is evidently a minor structure and has little regional significance. It appears probable, from the few data available, that these rocks have been deformed in several stages and have at some time been acted upon by intense lateral pressure applied either from the north, which thus produced the northward-dipping cleavage, or from the reverse direction, which produced conjugate cleavage, of which the northward-dipping cleavage in this area is a part.

Age and correlation.—No fossil evidence is available for assigning these rocks to any part of the geologic column. However, both here and to the west they lie south of the Skajit limestone, which is of Silurian age, and as this limestone appears to dip in general northward and is regionally less metamorphosed, these schistose rocks underlie it stratigraphically. No absolute data are available either to prove or to disprove an unconformity at the base of the Skajit limestone, but the variable nature of the schist along the southern margin of the limestone makes it probable that such an unconformity does in fact exist. Hence it seems best to regard these schists as totally pre-Silurian, rather than possibly Silurian in their upper beds. Similarly the lower age limit is indefinite, but the sequence as a whole resembles more closely the altered Paleozoic rocks of the Yukon-Tanana region than the definitely pre-Cambrian rocks which underlie them. On the other hand, the occurrence of quartzitic rocks in this group, along its southern margin, suggests a downward gradation into pre-Cambrian rocks. In general, therefore, this group of undifferentiated schistose rocks is regarded as mainly of early Paleozoic age, with the possibility of an admixture of pre-Cambrian rocks along the southern margin of the belt.

SILURIAN ROCKS

SKAJIT LIMESTONE

Distribution.—The Skajit limestone crops out along the west side of the East Fork of the Chandalar River from a point about opposite the head of Lush Creek northward at least for 80 miles and continues on in the same direction into the Brooks Range. Just above Nichenthraw Mountain this limestone crosses to the east side of the valley, but its areal extent north and northeast of that point is undetermined. About 35 miles north of Nichenthraw Mountain Leffingwell[4] has mapped a great mass of limestone, which on the basis of fossils found at the west end of the Franklin Mountains and farther down the Canning River he regarded as essentially Carboniferous. Undoubtedly a large part of this limestone is of Carboniferous age, a fact which is further corroborated by the presence of similar limestones at the head of the Sheenjek River, striking off northwestward, in the direction of the head of the Canning River. But another part of the limestone mapped by Leffingwell, particularly the limestone at the crest of the Brooks Range, north of Nichenthraw Mountain, is almost certainly the Skajit limestone, of Silurian age. Evidently two limestone formations, of greatly different age, lie in contact with one another or in close proximity along the crest and north slopes of the Brooks Range.

Lithology and structure.—This formation consists of crystalline and semicrystalline limestone and includes possibly dolomitic beds. In the Chandalar-Sheenjek district the Skajit limestone was seen mostly from a distance and appeared to be white or light gray but mottled in places by red and brown iron stains. The general appearance is also affected considerably by the degree of metamorphism to which the limestone has been subjected, and the general absence of any dark-gray or bluish colors in this district leads to the belief that

[4] Leffingwell, E. de K., op. cit., pp. 108–112.

the limestone has been much deformed and is probably much recrystallized. Commonly the Skajit limestone occurs as heavy beds of massive limestone, much fractured in places and commonly seamed by veins of calcite and less commonly quartz. It therefore differs markedly from the Carboniferous limestone on the Sheenjek River, which is thin bedded and very cherty.

The only structural observations available on the Skajit limestone in the Chandalar-Sheenjek district are those dealing with the attitude of the bedding planes of the limestone at and near the contact with the underlying schist. From the Wind River to Crow Nest Creek long-distance observations show clearly that the limestone beds dip steeply westward and northwestward. Also on Ottertail Creek, where cross structure has created a doming of both the schist and the limestone, the limestone dips away from the schist on the north, west, and southwest sides of the dome. These observations suffice to prove that the Skajit limestone lies stratigraphically above the schist, and as previously stated it is probable that an unconformity separates these two groups of rocks.

The regional structure of the Skajit limestone in this district is somewhat mystifying when compared with its regional structure and trend to the west. This Silurian limestone has been shown in previous publications [5] to extend almost continuously across northern Alaska, from Kotzebue Sound on the west to the Middle Fork of the Chandalar River on the east, and it was believed from that point to swing southeastward to the Porcupine Valley, where a similar limestone of Silurian age is known. Here, on the East Fork of the Chandalar River, however, it appears to veer sharply northward toward the crest of the Brooks Range, and to judge from Leffingwell's work in the valleys east of the Canning River it is not likely to continue eastward along the north side of the Brooks Range. On the other hand, the explorations on the Sheenjek River and information obtained from prospectors relative to the Coleen River indicate that this limestone does not continue eastward along the south side of the Brooks Range. Moreover, it does not appear to plunge under younger formations to the east, for the limestone is bounded by schist on the south in the valley of the East Fork and on the north along the Canning River. This areal distribution of these two groups of rocks suggests the presence of a large northeastward-trending synclinorium, whereby the limestone comes to the surface and ends. With the information at present available this hypothesis is strongly indicated.

[5] Mertie, J. B., jr., Geology and gold places of the Chandalar district, Alaska: U. S. Geol. Survey Bull. 773, pp. 229–233, 1925. Smith, P. S., and Mertie, J. B., jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815 [in preparation].

Manifestly, if such a synclinorium is present, this area is a most unfavorable one in which to attempt any measurement of the thickness of the formation, and as a matter of fact the route of the expedition of 1927 did not lead sufficiently close to this formation to collect any such data, even had the structural conditions been more propitious. Hence all that may be said regarding thickness is to repeat the previous estimate made by the writer, which was based on observations made in the valley of the North Fork of the Chandalar. From those data the stratigraphic thickness was judged to be on the order of 6,000 feet.

Age and correlation.—No determinable fossils were collected from this limestone during the season of 1927, but it is known to be continuous with the Silurian limestone of the Middle and North Forks of the Chandalar River, which in turn continues westward to join the Skajit limestone on the John River. Excellent fossils were collected from the upper part of this limestone by the writer[6] on the North Fork of the Chandalar River in 1923, consisting mainly of a thick-shelled species of *Conchidium*, which was referred by Edwin Kirk, of the U. S. Geological Survey, to the upper Silurian. This of course does not prove that all of this great mass of limestone is of upper Silurian age. In fact, other data suggest that it may include beds of earlier Silurian horizons. But in any event this limestone is certainly of Silurian age and is believed by the writer to be mainly of upper and middle Silurian age.

The name Skajit was not applied to the Silurian limestone on the Middle and North Forks of the Chandalar River when that area was mapped by the writer, owing mainly to the uncertain status of the formational nomenclature at that time, but the correlation of this Silurian limestone with the Skajit formation was made. Recently the old term Skajit formation has been changed to Skajit limestone, by Smith and Mertie,[7] and the term Skajit limestone, now applicable to the limestone here discussed, has been adopted in this report.

DEVONIAN (?) ROCKS

Distribution.—Rocks believed to be mainly of Devonian age are shown on the accompanying geologic map along the east side of the East Fork of the Chandalar River, beginning about 5 miles above Lush Creek and extending north-northeastward to Old John Lake, with two outlying masses on the west side of the valley, one just below the Wind River and the other in the hills west of Arctic

[6] Mertie, J. B., jr., Geology and gold placers of the Chandalar district: U. S. Geol. Survey Bull. 773, p. 232, 1925.

[7] Smith, P. S., and Mertie, J. B., jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815 [in preparation].

Village. The recognition of these rocks and their cartographic delineation as a separate mappable unit are based largely on their lithology, and their areal representation is therefore of necessity somewhat diagrammatic.

Lithology and structure.—Along the low ridge that forms the watershed between the Christian River and the East Fork of the Chandalar River these rocks are exposed as surface rubble and consist mainly of quartzitic sandstone. These are fine-grained light-gray to dark-gray rocks, the component grains of which are chert and quartz, with certain other constituents that on oxidation produce reddish-brown iron-stained bedding planes and similarly colored rusty spots within the rock itself as seen on a fresh fracture. The original grains are clearly evident with a hand lens, but some of the specimens show incipient recrystallization, which produces a somewhat quartzitic texture. Naturally, these harder rocks form the ridges, and the softer members of the group are probably localized mainly in the valleys. Thus along the west wall of the East Fork, just below the mouth of Crow Nest Creek, rocks of the same group are exposed and are seen to consist of thin-bedded sandstone and slate, in beds of variable thickness that repeatedly alternate within short distances. These thin-bedded sandstones are essentially similar to those exposed on the ridge to the east, except that they are more quartzose and if anything more quartzitic. The slates are thin cleaving and dark gray to black. Both the sandstone and slate show ripple marking, and the slate shows minute muddy concretionary forms of irregular outline on the bedding planes. Thin seams of quartz are also prevalent at places as fillings along planes of fracture transverse to the bedding. These rocks strike about due northeast and dip about 70° SE., and the cleavage of the slaty rocks is clearly parallel to the bedding. This attitude of the beds, if it represents their regional structure, indicates that they overlie the schist and the Skajit limestone, which lie along the valley wall to the west.

Along the ridge southeast of Arctic Village and southwest of Old John Lake, where these beds are fairly well exposed, they consist of quartzitic sandstone, similar to that described above, in beds from 4 to 18 inches thick interbedded in the fissile dark-gray to black slate, in part sandy, and some fissile red argillaceous slate. The heavier of these sandstone beds are dark gray but weather to a very light gray. All these beds in this locality strike fairly regularly north to N. 10° E. and dip 30°–40° E.

Similarly, in the hills west of Arctic Village, quartzitic sandstone and shaly beds were seen, the sandstone in beds from 4 to 18 inches thick, which weather out on the steep slopes of the valley wall as great flat slabs. This quartzitic sandstone differs from the conglomeratic quartzite described below in that it is not conglomeratic, is softer and thinner bedded, and has considerable mica, which does not seem to be of secondary origin. The strike of these rocks, however, is N. 60°–80° W., and they differ in this regard from the rocks described above.

The recorded structural observations tend to show that this group of rocks not only overlies the schist and the Skajit limestone but also is separated from the underlying formations by a structural unconformity. Undoubtedly these rocks are much folded, and insufficient work has yet been done to evaluate this folding and other structural features, so that no estimate of thickness is warranted. A considerable thickness, however, perhaps several thousand feet, is indicated by the fact that the areal extent of the outcrops across the strike is at least 10 miles.

Age and correlation.—The rocks of this group are unquestionably post-Silurian, but as fossils have not been found in them, no precise geologic age may be assigned. Lithologically they resemble both the Devonian rocks of the Brooks Range and the Lower Cretaceous rocks of the Yukon Valley. The actual contact between these rocks and the Upper Devonian or early Mississippian rocks to the northeast has not been carefully studied, and insufficient structural data are available along this contact line to state definitely which of the two groups is the older. Their position in the geologic column must therefore be decided on regional geologic data of less specific nature.

On the North Fork of the Chandalar River a conspicuous group of rocks, containing in their lower horizons Middle Devonian fossils were found by the writer[8] overlying and closely adjoining the Skajit limestone, and these rocks appeared to continue eastward in the direction of the Middle and East Forks of the Chandalar River. West of the Chandalar Valley the Devonian sequence, containing in its upper part Upper Devonian fossils, has been mapped by Smith and Mertie[9] in the valley of the Killik River and shown by them to continue westward to Cape Lisburne. It is evident, therefore, that the Devonian is represented by a well-developed sequence of rocks in northern Alaska and may be expected to occur in the Chandalar-Sheenjek region. The rocks of this region, here designated Devonian (?), resemble greatly the Devonian rocks of the North Fork of the Chandalar River and of the Killik River, both in their lithology and in the character and degree of their deformation. Hence strong presumptive evidence exists for their assignment to the Devonian.

The Lower Cretaceous rocks of northern Alaska, on the other hand, have not been found to extend east of the Mosquito Fork of the

[8] Mertie, J. B., jr., Geology and gold placers of the Chandalar district, Alaska: U. S. Geol. Survey Bull. 773, pp. 233–235, 1925.

[9] Smith, P. S., and Mertie, J. B., jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815 [in preparation].

Koyukuk River, although the main Chandalar Valley, toward which they trend, has been mapped geologically both by Schrader and by the writer. Lower Cretaceous rocks, however, are known to the east of the Chandalar-Sheenjek region, in Canadian territory, and also to the southeast, between Circle and Eagle; but both these areas are more than 150 miles distant and appear to represent sedimentation in an arm of the Cretaceous sea that did not communicate directly with the Koyukuk area. The existing evidence, therefore, does not favor the assignment of these rocks to the Mesozoic, although the possible Mesozoic age of part of them is by no means disproved.

Two other groups of rocks, as later described in this report, are believed to lie between these rocks and the Lisburne limestone, and this condition favors their assignment to the early Devonian rather than to the late Devonian. As a matter of fact, however, no Lower Devonian rocks are known to exist anywhere in Alaska, and with this fact in mind the rocks here described are believed to represent either Middle or Upper Devonian horizons, or parts of both.

CARBONIFEROUS SYSTEM

MISSISSIPPIAN SERIES

GENERAL FEATURES

Two formations that are believed to be of Mississippian age and another that is assigned to the Upper Devonian or Mississippian have been shown on the geologic map (pl. 2). The uppermost of these three, known as the Lisburne limestone, is definitely of upper Mississippian age. The two lower ones, in which fossils have not been found, are quite enigmatic in their structural and stratigraphic relations to one another and to the Lisburne limestone, and their assignment to the Mississippian has been made mainly on the basis of their lithology, compared to better-known sections elsewhere. So doubtful, in fact, is the stratigraphic sequence of these two formations that it might have been better to map them collectively as a single group of rocks, as was done with a similar stratigraphic sequence by Smith and the writer[10] farther west in the Brooks Range. The lithology of these two formations, however, is sufficiently dissimilar to make it seem best to differentiate them, even if the boundaries given are only approximate, with the hope that such differentiation will serve as a starting point for any subsequent geologic studies in this and adjoining areas.

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[10] Smith, P. S., and Mertie, J. B., jr., op. cit.

LOWER MISSISSIPPIAN ROCKS

Distribution.—The two lower formations are a quartzite-conglomerate-slate formation and a chert-slate formation. The chert-slate formation is here considered to be either of Upper Devonian or early Mississippian age. It is typically developed on the Sheenjek River, from Outlook Point northward for at least 55 miles, to the mouth of Monument Creek and also in the hills south and southwest of Old Woman Creek. The quartzite-conglomerate-slate formation occurs at Table Mountain, whence it continues northwestward up the northeast side of Old Woman Creek, thence veers southwestward, and extends for 30 miles to Nichenthraw Mountain, on the East Fork of the Chandalar. From Table Mountain this formation also extends southwestward for at least 30 miles to Johnnie Frank's cabin, on the Koness River.

Lithology.—The Sheenjek River may be considered the type locality of the chert-slate formation. The low ridge known as Outlook Point, east of Christian's cabin, is the southernmost exposure of this formation, and there the country rock consists of a massive light-gray chert, cut by numerous dikes of gabbro and diabase. One of the distinguishing characteristics of this formation on the Sheenjek River is the large amount of basic igneous rock associated with it. This mixture of chert, shaly slate, and basic igneous rock continues on up the Sheenjek River and appears to be the only formation represented up to Monument Creek. Helmet Mountain, one of the prominent landmarks of the Sheenjek Valley, is composed of a fine-grained gabbro, but the ridge southeast of Helmet Mountain is composed of light to dark gray chert that weathers white on the surface owing to the development of a thin veneer of opaloid material. This type of weathered surface is characteristic of chert rubble on the tops of ridges in the piedmont province, where the chert has been particularly affected by residual decomposition. Shoulder Mountain, farther up the west side of the Sheenjek, is likewise composed of basic igneous rocks, surrounded on the lower slopes by chert with some interbedded sandstone and argillite. On the west side of the Sheenjek Valley 10 miles above the Koness River the spurs are likewise composed essentially of chert, but near the top of the spur between the Sheenjek River and Monument Creek some thin bands of limestone and calcified chert were also seen. This material is worthy of special description. In the beds where replacement has occurred the boundary line between the chert limestone follows bedding planes in some places, but in others the contact forms an intricate pattern in no way related to bedding. Some of the contacts appear sharp and clean-cut and others indefinite, but in thin sections of this material even the sharp contacts are seen to be only relatively so, being bordered on one side by completely calcified material and on the other by a zone showing incipient calcification of the chert.

Additional evidence of the operation of secondary processes at this locality is found in the numerous euhedral crystals of limonite, pseudomorphic after pyrite, that are scattered about on the surface of the ground. Along the east side of the Sheenjek Valley 13 miles above the Koness River the spurs consist of chert and diabase, but near the crest of the Coleen-Sheenjek watershed a recrystallized chert was found which resembled superficially a gneissoid rock but was determined to be a fine-grained quartzite, replaced to a considerable extent by calcite. Naturally, because of their superior resistance to erosion, the chert and associated basic igneous rocks form most of the ridges and prominent spurs in the lower Sheenjek Valley. This formation, however, is believed to contain a considerable amount of shale and slate. About 20 miles above Christian's cabin, for example, fissile chocolate-colored shaly slate occurs along the west wall of the valley just at the edge of the valley floor, and similar rocks are believed to be extensively developed in the valleys elsewhere.

The area south and southeast of Old Woman Creek, which is mapped as part of the chert-shale formation, is at the southern edge of the alpine province and yields good exposures of these rocks. The southward-facing spurs between the forks of Old Woman Creek, for example, are bare, particularly toward their tops, and the country rock is an intimate mixture of chert, slate, and shale. The chert is gray and black and in part banded, and the slate and shale are largely thin-cleaving brown varieties, though in part green or red. Still farther west, along the contact between the chert-slate and the quartzite-conglomerate-slate formations, the chert and slate are about evenly divided in quantity, and there, at or near the top of the chert-slate formation, is a thin but conspicuous and apparently persistent bed of red slate that is traceable by its brick-red outcrops for at least 3 miles along the strike.

Only at one locality, however, in this northern area of the chert-slate formation were basic igneous intrusives seen in this sedimentary formation. At this locality, on the hill about 5 miles southwest of the mouth of Old Woman Creek, occurs a peculiar assemblage of rocks, consisting of light-gray and greenish chert, black, red, and green slate, thin-bedded sandstone, basalt, and beds of the quartzite and conglomerate typical of the overlying formation. The proximity of the quartzite-conglomerate-slate formation to the south doubtless accounts for the presence of these two types of rocks.

The quartzite-conglomerate-slate formation, as the designation implies, consists mainly of rocks of these three types, but quartzite and conglomerate constitute the prominent and specially diagnostic parts of the sequence. The quartzite is mainly of two kinds, of which the more common is a dark-gray rock composed of rounded grains of chert and quartz that show a certain amount of recrystallization, although in general the rounded outlines of the original grains are still preserved. The less common type is a light-gray quartzitic sandstone, nearly free of chert grains. The darker variety, by an increase in the proportion of chert and an increase in the size of the constituent grains, grades into a conglomeratic rock at several places, the most common variety of which consists of angular, subangular, and rounded grains of vitreous white vein quartz and light-gray and black chert in a matrix which is partly chert and partly quartz. Some of these rocks are essentially chert conglomerate—that is, mainly angular chert pebbles in a chert matrix. Generally, however, both chert and vein quartz constitute the pebbles, and the matrix is quartzitic. When such rocks have dark angular grains of chert and quartz in a lighter-colored quartzose matrix, they resemble superficially granitic rocks and have been mistaken for such by prospectors in this region. Generally the pebbles are not larger than half an inch in diameter, but at some localities, as for example on the mountain 7 miles southwest of Table Mountain, pebbles several inches in size were seen.

The cherty matrix of some of these conglomerates appears to resemble the chert conglomerate at the base of a chert formation in the Livengood district of the Yukon-Tanana region, described by the writer,[11] but the occurrence of quartz in many specimens, both in the pebbles and in the matrix, constitutes a distinguishing feature not seen in the rock of the Livengood district. Moreover, this formation appears to overlie rather than underlie a chert formation, therein differing again from the chert conglomerate at Livengood.

The slate associated with this quartzite and conglomerate is a black variety, almost phyllitic in places, and occurs in numerous bands through the formation, thus separating the more massive rocks into a number of zones. Good exposures occur on top of the mountain east of Nichenthraw Mountain, on the upper part of the East Fork of the Chandalar. Several bands of the slate crop out along the west face of this mountain, interbedded with the quartzite, and an outlying hill of quartzite to the southwest, which forms a roche moutonnée in the valley of the East Fork, is evidently separated from the main valley wall by such a band of slate, which has been gouged out by the old glacier that moved down the valley. The particularly noticeable shearing in this black slate is probably due to the fact that such beds that lie between the massive quartzite and

[11] Mertie, J. B., jr., The gold placers of the Tolovana district: U. S. Geol. Survey Bull. 662, pp. 239–242, 1918.

conglomerate have acted as planes of slipping in the folding of this formation.

Structure.—The chert formation in the piedmont portion of the Sheenjek Valley is not well exposed on the lower slopes of the spurs, and many of the tops are composed of basic igneous rocks. Hence few structural observations are available in this part of the valley. Also, because these rocks are rather incompetent and therefore much deformed, the few scattered observations of strike and dip can have little value in interpreting the larger structural features. So far as the dominant strike or trend of the rocks is concerned, the direction of drainage channels and ridge tops probably gives more real information than the detailed structural observations. As will be seen from Plates 1 and 2, many of the tributaries of the Sheenjek within the piedmont province trend about N. 70° E., and the few available results of observations on the structure of the chert and the directions of elongation of the bodies of intrusive rocks do not depart greatly from that direction. Hence it is inferred that the regional trend of the chert-slate formation in the piedmont province is about N. 70° E. The direction of the prevailing dip can be inferred even less surely than the strike. In fact, the few scattered observations may be said to be practically worthless for affording an understanding of the broader features. The regional geology, however, indicates that younger rocks crop out to the north in the Sheenjek Valley and that older rocks crop out to the south on the East Fork of the Chandalar River. Hence the general dip of the chert-slate formation in this part of the Sheenjek Valley is considered to be northward. Little is known of the type of folding that characterizes these rocks, but the great distance across their strike suggests that there is much duplication of beds at the surface. Furthermore, the net effect of the folding must be such that a low regional dip is produced, even if these beds occur in a basin that lies unconformably upon older rocks. Otherwise, younger rocks should show as unfolded strata or older rocks would be exposed by erosion, unless an inordinately great thickness is assumed for this formation. The few available observations suggest a multiplicity of intricate folds of small amplitude, which duplicate certain beds many times at the surface.

At the northern locality of the chert-slate formation, south and southwest of Old Woman Creek, these rocks strike about N. 60° E. and give rise to a characteristically hummocky landscape, the chert layers forming elongated hummocks and hogbacks on the sides of larger hills. Along the south flanks of the quartzite-conglomerate-slate formation that lies to the north the rocks of the chert-slate formation appear to dip rather constantly southeastward. This structure is puzzling, because it suggests that the chert-slate formation overlies the quartzite-conglomerate-slate formation.

Little is known of the structure of the quartzite-conglomerate-slate formation, particularly as regards its structural relation to the chert-slate formation. At Brushman Mountain the quartzite appears to strike N. 60° E. and dips about 30° NW., and northward this structure seems to remain fairly constant, thus plunging this formation under the Lisburne limestone. Opposite Nichenthraw Mountain, on the East Fork of the Chandalar River, however, the rocks of the quartzite-conglomerate-slate formation strike about N. 50° E. and dip 45° SE. It is fairly certain that these rocks underlie the Lisburne limestone, but obviously much doubt exists whether they overlie or underlie the chert-slate formation.

Age and correlation.—The quartzite-conglomerate-slate formation is a peculiarly distinctive lithologic unit which has been recognized elsewhere in northern Alaska and is fairly well placed stratigraphically. The equivalent of this formation was first observed by Schrader [12] on the headwaters of the Anaktuvuk River and described under the name Stuver "series" and was believed by him to be pre-Devonian in age. Subsequently, in 1923, the writer [13] found many boulders of these quartzitic conglomerates among the stream gravel in the headwaters of the North and Middle Forks of the Chandalar River in such a geologic environment that they were believed to overlie the known Middle Devonian rocks of that area. These rocks were again seen by the writer [14] in 1924 on the Killik River just south of the Lisburne limestone, in a geologic sequence of rocks that seemed to be progressively younger in going from south to north. These data sufficed for a new age assignment for these rocks, and along the Killik River they were grouped with the black shales of the Noatak formation, of Mississippian age, with which they seemed to belong stratigraphically. This evidence, coupled with their apparent position below the Lisburne limestone on the headwaters of the Sheenjek River, is the basis for their assignment in this report to the lower Mississippian.

The age of the chert-slate formation, however, is less definite. Rocks comparable with this formation also were first recognized by Schrader [15] along the North and West Forks of the Chandalar River and described by him under the name West Fork "series." No fossils were found in place in this "series" by Schrader, but he picked up some fossiliferous black flint in the gravel of the Chanda-

[12] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, pp. 60–62, 1904.

[13] Mertie, J. B., jr., Geology and gold placers of the Chandalar district: U. S. Geol. Survey Bull. 773, p. 236, 1925.

[14] Smith, P. S., and Mertie, J. B., jr., op. cit.

[15] 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.

lar River, which he believed was derived from this group of rocks. A list of the fossils contained in these flint pebbles was first published in 1925,[16] and on the basis of these fossils, which included two species of *Syringopora*, *Acervularia*, a cyathophylloid coral, and *Spirifer disjunctus?*, and following the correlation of G. H. Girty, the writer referred the West Fork " series " to the Upper Devonian or Mississippian. The position of the West Fork " series " far south of the alpine province in the Chandalar Valley, where the Devonian and Mississippian rocks are typically developed, was very puzzling at that time, even as it is in the lower Sheenjek Valley, but the writer nevertheless correlated the West Fork " series " with the chert-conglomerate rocks equivalent to the Stuver " series," which at the longitude of the North Fork of the Chandalar River lie apparently at the crest of the Brooks Range. It now seems likely that this correlation was erroneous, but the data in hand still seem to justify the reference of the West Fork " series " to the Upper Devonian or Mississippian, though probably underlying the Stuver " series." It also seems probable that rocks comparable with the West Fork " series " crop out intermittently along the south flanks of the Brooks Range from the North and West Forks of the Chandalar River eastward at least as far as the Sheenjek Valley. Under these conditions, and with no contradictory data at hand, it seems necessary to regard the chert-slate formation of the lower Sheenjek Valley, which is probably the equivalent of the West Fork " series," as Upper Devonian or Mississippian. As regards a choice between the assignments of Upper Devonian and Mississippian, the writer, influenced by the Carboniferous aspect of these corals and the questionable specific determination of the *Spirifer* and also by the known presence of a lower Mississippian chert formation along the Yukon, has been inclined to regard the West Fork " series " and the chert-slate formation of the Sheenjek Valley as a part of the Carboniferous rather than the Devonian system, but this is only an unproved opinion.

On the other hand, if the fossiliferous flints collected as float by Schrader came from some undetermined horizon and not from the West Fork " series," this whole framework of correlation fails. The geologic explorations of recent years in central and northern Alaska have proved the existence of extensive chert formations other than the lower Mississippian chert of the Yukon-Tanana region. One such formation of Triassic age in northwestern Alaska has been described by Smith and the writer,[17] and another of Middle Devonian age

[16] Mertie, J. B. jr., Geology and gold placers of the Chandalar district: U. S. Geol. Survey Bull. 773, p. 237, 1925.
[17] Smith, P. S., and Mertie, J. B., jr., op. cit.

along the Yukon has recently been described by the writer.[18] Therefore, in the absence of fossil evidence a reasonable doubt is cast upon the assignment of the chert-slate formation of the Sheenjek Valley to the late Devonian or early Mississippian. The Upper Triassic chert-shale formation of northwestern Alaska, in particular, is a significant alternative for correlation. Against such a correlation, however, must be cited the fact that the nearest Upper Triassic formations to the Sheenjek Valley are the Shublik formation of the Canning River region, described by Leffingwell,[19] and the Upper Triassic rocks along the international boundary, north of the Porcupine, described by Maddren [20]; and both of these Upper Triassic formations are described as limestone, shale, and sandstone, with no mention whatever of any cherty rocks in the sequence. For lack of any better data the writer therefore correlates the chert-slate formation of the Sheenjek Valley with the basal Mississippian rocks or with the upper part of the Upper Devonian sequence.

UPPER MISSISSIPPIAN ROCKS

LISBURNE LIMESTONE

Distribution.—The Lisburne limestone is found in the Chandalar-Sheenjek district only in the upper Sheenjek Valley, where it crops out in a band from 10 to 15 miles wide that trends perhaps N. 60° W. The easternmost point at which this limestone was seen is on the spur between the forks of the Sheenjek River. From the main Sheenjek River it continues westward into the East Fork of the Chandalar River and on in the same general direction across the crest of the Brooks Range into the valley of the Canning River.

Lithology.—The lithology of the Lisburne limestone is fairly well known from comparative studies farther west, and hence the formation is readily recognized even where fossils are scarce. On the upper Sheenjek it was possible to examine this formation at only one locality. The writer spent one day in the limestone hills on the east side of the river, opposite the camp at the mouth of Old Woman Creek, and the following lithologic data may apply more particularly to the basal part, which was examined in the course of that work, than to the formation as a whole. The limestone in these hills appears from a distance to be rather well bedded, for the lines of stratification are strongly marked on the hillsides. On close inspection this stratification is seen to mark the boundaries of innumerable alternating beds of limestone and chert, the limestone light in

[18] Mertie, J. B., jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816 [in preparation].

[19] Leffingwell, E. de K., op. cit., pp. 115–118.

[20] Maddren, A. G., Geologic investigations along the Canada-Alaska boundary: U. S. Geol. Survey Bull. 520, pp. 312–313, 1912.

color, owing to weathering, and the chert mainly dark, and thus the section has an appearance similar to that of the outcroppings at Calico Bluff. Chert appears to constitute perhaps as much as 50 per cent of the rock, particularly in the hills close to Table Mountain, which represent the basal part of the formation. Farther up the Sheenjek the rocks appear more massive and less laminated and probably contain a much smaller proportion of chert. In addition to the interbedded and interlaminated chert the limestone beds themselves contain much chert, which occurs in indescribably complex shapes and patterns. At one place it simulates a fault breccia; at others the chert patches are rounded, in all sizes from minute fragments up to areas several feet in diameter; again, the chert appears to be zonally grown; and finally, it occurs in colloidal laminae so intricate in shape that they resemble the crenulated layers in a highly contorted schist, although obviously the bedding planes are fairly regular. Most of this chert is black, though a very little light-gray chert was also seen. The limestone is typically a dark-gray to black, finely crystalline variety, though in places coarsely crystalline, and emits a fetid odor where freshly broken. Thin seams of pyrite in places cross the bedding of the limestone. Little or no white crystalline limestone or anything suggesting dolomite was seen, though such limestone is probably present farther up the Sheenjek Valley. A little black slaty shale in beds from an inch to a foot in thickness was also seen in this lower part of the formation. Both the chert and the limestone contain innumerable crinoid stems, but fossil shells are not so numerous at the locality visited.

Structure.—Observations of strike and dip show that the formation is much folded, though apparently not closely appressed. Just northwest of Table Mountain the trend of the limestone appears to be N. 20° W. for a considerable distance, but in the limestone belt as a whole, the regional trend seems to be nearly N. 60° W. Continuous dip slopes, which extend over long distances, together with the regular bedding on the hillsides, indicate that the folding is relatively open, and the great width of the limestone belt suggests much duplication of beds at the surface. Numerous reversals in dip were noted, but the regional dip is presumed to be northward. The northern limit of the limestone on the Sheenjek River was seen and mapped from a distance of 20 miles, but insufficient structural data regarding the whole formation are available with which to make any estimate of the stratigraphic thickness. Obviously, however, the thickness is comparable with that of the Silurian limestone, which was stated to be approximately 6,000 feet.

Age and correlation.—Only a few of the crinoid stems of this formation were collected, because they were not regarded as sufficiently diagnostic to warrant their transportation back to Arctic Village. One imperfect shell and a crinoid head, however, were collected from the base of the Lisburne limestone hills on the east side of the upper Sheenjek Valley, about 4 miles N. 70° W. of the north end of Table Mountain. G. H. Girty, of the United States Geological Survey, makes the following identifications and statement:

27AMt25. Crinoid columnals.
27AMt28. Megistocrinus sp.
27AMt29. Spirifer sp.

The *Spirifer* is an imperfect pedicle valve that has a broad, shallow, and apparently unplicated sinus and numerous lateral plications. Superficially it is marked by delicate but sharp radial striae. Among Carboniferous Spirifers I know of none that possesses this combination of characters, for though some have similar fine superficial striae, they have a plicated fold and sinus, such as *S. logani* and *S. grimesi*. In the Silurian and Devonian, however, a considerable number of Spirifers occur that have these characters. Edwin Kirk, of the United States Geological Survey, to whom these specimens have also been referred, is of the opinion that this fauna is not Devonian, and I can not say that it is not Carboniferous. The character of the matrix certainly suggests the Calico Bluff formation, and the stratigraphic and lithologic evidence presented by Mr. Mertie obviously suggests a Carboniferous age. The most probable geologic age, therefore, is Mississippian. I might add, however, that *Megistocrinus* is not known above the lower Mississippian, and if the Calico Bluff formation is upper Mississippian, as I have thought it to be, the horizon of this collection is not Calico Bluff.

In general, however, the age of the Lisburne limestone is well known, being substantiated by large collections of fossils made farther west in the Brooks Range. The writer [21] has recently assembled all the known faunas of the Lisburne limestone from the Brooks Range, west of the John and Anaktuvuk Rivers, into a list that embraces about 100 genera and perhaps twice as many species. Nearly all these fossils have been determined at different times in the last 25 years by Mr. Girty, and as a result of this work the age is definitely known to be upper Mississippian. The fossils from the upper Sheenjek Valley, however, appear to be of lower Mississippian age, and this determination introduces a serious difficulty in correlation. If it should develop that these fossils were collected from the uppermost beds of the rocks that directly underlie the Lisburne limestone, rather than from the base of the Lisburne limestone itself, the difficulty still persists, because Smith and the writer have shown that the Lisburne limestone to the west is underlain by a pre-Lisburne Mississippian sequence that includes in its upper horizons rocks of upper Mississippian age. In the absence of any known or surmised discontinuity of sedimentation between the Lisburne limestone and the pre-Lisburne Mississippian rocks, the paleontologic determina-

[21] Smith, P. S., and Mertie, J. B., jr., op. cit.

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tions of Messrs. Kirk and Girty indicate that a marked lithologic change takes place along the strike of the Mississippian sequence from west to east, whereby all the upper Mississippian rocks become of calcareous character and as such a part of the Lisburne limestone, while the pre-Lisburne Mississippian rocks become essentially of lower Mississippian age. This inference constitutes a good reason why the term "Noatak formation," as defined at present, should not be extended east of the John River into the region here described.

The nearest point to the Sheenjek Valley where the Lisburne limestone has been recognized is to the northwest, along the north slopes of the Brooks Range, where it has been described and mapped by Leffingwell.[22] Upper Mississippian rocks about 40 miles to the northeast, in the upper valley of Old Crow River, and in the Firth River Valley, have also been described by Maddren,[23] though he did not at that time apply to them the specific designation Lisburne limestone. This formation, so well known in the western part of the Brooks Range, therefore apparently extends for about 600 miles across northern Alaska, from Cape Lisburne to the international boundary, and is recognized geologically as one of the notable horizon markers of the range.

Along the Porcupine River are rocks that contain the upper Mississippian fauna just above the lower ramparts and also farther upstream, just above the mouth of the Coleen River, and have been described by Kindle.[24] Along the Yukon below Eagle the same fauna is also found in the well-known Calico Bluff formation. Both the Yukon and Porcupine occurrences of this upper Mississippian fauna, however, are in rocks that are essentially thin-bedded limestone and shale and include no massive limestone or chert. These rocks are thus a materially different lithologic unit but are correlated paleontologically with the Lisburne limestone.

QUATERNARY DEPOSITS

GENERAL FEATURES

The Quaternary deposits may conveniently be divided into two general types, the separation being made primarily on the basis of age and secondarily on the character of the deposits. The older or Pleistocene deposits originated mainly from glacial erosion during the glacial epoch and from the partial reworking of glacial débris by the streams that issued from the southern terminals of the glaciers. These older deposits, therefore, consist in part

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[22] Leffingwell, E. de K., op. cit., pp. 108–113.

[23] Maddren, A. G., op. cit. pp. 310–312.

[24] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, pp. 330–333, 1907.

of true glacial deposits, or till, and in part of reworked glacial débris, commonly known as outwash deposits. The later unconsolidated deposits consist of sand, gravel, and silt, which have been derived in part from the postglacial weathering and stream transportation of the hard-rock formations and in part from the reworking and transportation of the older Quaternary deposits. The work in the Chandalar-Sheenjek district has not been sufficiently detailed to warrant the separate delineation of these two types of unconsolidated deposits, and therefore on the accompanying map (pl. 2) they have been grouped together as a unit and designated Quaternary deposits.

PLEISTOCENE GLACIATION AND DEPOSITS

The term Pleistocene epoch is commonly used as more or less synonymous with the term "Glacial period," though it is recognized that the glacial epoch in Alaska probably began earlier and certainly continued later than in the northern United States. Parts of southern Alaska, for example, which are still begirt by ice, may be regarded as still within a glacial epoch. The initiation of glacial conditions requires an annual snowfall greater than the annual dissipation by melting of snow and ice. After extensive ice fields have once formed, however, glaciation will persist indefinitely if a balance exists between the annual accumulation and dissipation of ice and will persist for a great length of time even if the annual accumulation is slightly less than the annual dissipation. The conditions that make glaciation possible are either a cold climate, or a heavy snowfall, or both. Parts of central and northern Alaska have a mean annual temperature that is adequate, at the present day, to give rise to glaciation. Nevertheless, these areas are at present essentially unglaciated, and central Alaska remained for the most part unglaciated throughout the Pleistocene epoch. It is therefore probable that changes in precipitation have been a notable factor in the glaciation of northern Alaska, which began early in the Pleistocene and continued throughout that epoch and probably for a considerable length of time in the Recent epoch. The Brooks Range, although extensively glaciated during this period of maximum accumulation of snow and ice, is now almost free of perennial ice, but the effects of the extensive glaciation are still clearly visible.

When a glacial climate has been 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 slowly down into the valleys, commonly 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 sapping 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, picked up again by glacial streams that issue from the ends of the glaciers, and redistributed to a greater or lesser extent farther down the valleys. The original glacial débris is characterized by a complete lack of assortment, boulders and cobbles 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, 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 in northern Alaska the Brooks Range was probably almost entirely covered by ice, which extended both northward and southward down the river valleys for miles and formed at their lower ends individual valley glaciers. This glaciation was essentially alpine in character, although the glaciers in the upper valleys extended high up into the intervalley watershed regions. Thus along the west side of the valley of the East Fork, near Nichenthraw Mountain, huge erratic boulders were seen up to an altitude of 4,800 feet, or 2,000 feet above the valley floor, thus indicating the presence there at one time of a body of ice that had a minimum thickness of 2,000 feet. Nichenthraw Mountain, with a glacial cirque at about the same altitude, offers corroborative evidence of this fact. The Sheenjek Glacier, however, was smaller, having a minimum thickness, at the mouth of Old Woman Creek, of only about 1,400 feet. The glaciers of both the East Fork of the Chandalar and the Sheenjek appear to have thinned rapidly as they emerged from the alpine into the piedmont province. The glacial deposits that remain indicate that the southern limit of the glacier of the East Fork of the Chandalar was somewhere between the Wind River and Lush Creek, about 35 miles below Nichenthraw Mountain; and the Sheenjek Glacier ended at or a short distance below the confluence of the East Fork of the Sheenjek. During the time of maximum glaciation one large distributary of the glacier of the East Fork of the Chandalar was diverted southeastward from a point opposite the mouth of the Junjik River into the wide depression that is now occupied by Old John Lake and the upper Koness drainage. The long ridge that lies between Old John Lake and the East Fork, however, although overridden by ice at the time of maximum glaciation, must have served as an effective barrier as the glaciers began to recede, leaving a great body of stagnant ice in this depression. A similar distributary from the Sheenjek Glacier is believed to have been diverted southward into the upper valley of Monument Creek, to be similarly cut off as the main Sheenjek Glacier receded.

The upper valleys of the East Fork of the Chandalar and the Sheenjek River have the characteristic U-shaped outlines that are produced by glacial erosion. Also, the spurs that extend from the main ridges down into these valleys, especially in the alpine province, have been truncated and oversteepened by glacial action. The smaller tributary valleys, which were not eroded by ice as actively as the main valleys, were left, after the retreat of the ice, as hanging valleys and now have a steep gradient and rapids in their lower parts. The creek that enters the East Fork of the Chandalar east of Nichenthraw Mountain is a good example of a small U-shaped hanging valley, in the lower end of which postglacial stream action has incised a precipitous V-shaped gorge. Beautiful examples of glaciated spurs, elongated in the direction of the main valley by the scouring action of the ice and separated or nearly separated from the main valley walls, are also prominent. Such outlying spurs, or roches moutonnées, are especially prominent in the valley of the East Fork of the Chandalar River upstream from Arctic Village.

Morainal deposits left by the glaciers are now found in the valley of the East Fork of the Chandalar River from Nichenthraw Mountain downstream nearly to Lush Creek and on the Sheenjek River from a point 15 miles above Old Woman Creek down to the forks. These deposits, incidentally, correspond in situation with the sluggish, meandering portions of these two streams and evidently have played a notable part in postglacial stream history. Within these stretches are wide valley floors, with a typical kettle-hole topography and with many lakes in the undrained depressions. Old lake levels, which are still preserved, show that many large lakes were present in the morainal zone after the ice retreated. Thus, at Old John Lake three well-defined benches remain—one at 8 feet above the present lake, a second at 20 feet, and a third at 50 feet. The main stream courses also were sluggish, as at present, and therefore the morainal deposits along the main rivers, as on the East Fork of the Chandalar and the Sheenjek River, are for the most part covered by sand and silt of postglacial fluviatile and lacustrine origin. Only in the lower parts of the morainal deposits, where the rapids occur, is the glacial débris well exposed in the gravel bluffs. The gravel in the bluffs farther downstream, though originally of glacial origin, has been reworked to a considerable degree and is really outwash rather than till.

The dumping of glacial débris in the main valleys evidently created new base-levels for the headwater tributaries, and postglacial stream history is mainly concerned with the readjustment of the drainage channels to these new base-levels. Thus on the East Fork of the Chandalar two zones occur where such adjustments of gradient are in progress. The lower East Fork, from the main Chandalar up to the Wind River, has the normal gradient of a mountain stream. The rapids that extend from this point upstream for 30 miles represent a zone of readjustment to the lower drainage, and this zone of rapids will gradually migrate upstream through the morainal deposits until a uniformly rising stream gradient is established. The other zone of adjustment is at the upper end of the morainal deposits, where the headwater stream abruptly loses its gradient and debouches upon a nearly level valley floor. The headwater stream is depositing a veneer of stream gravel upon the morainal deposits, temporarily raising its lower base-level and at the same time actively eroding upstream to bring the headwater drainage into adjustment with the lower gradient. Hence it may be said that two new base-levels are being established on the East Fork—an upper one, which is relatively temporary, and a lower one, with which the entire East Fork will ultimately be brought into adjustment. Exactly the same process is taking place on the Sheenjek River.

So far as the character of the till and outwash deposits are concerned little need be said. Both types consist of silt, sand, gravel, and boulders and differ from one another mainly in the degree of assortment of the component material and in the degree of rounding which the coarser débris has undergone. The till is largely unsorted, boulders and gravel of all sizes being mixed indiscriminately with sand and clay. The outwash deposits consist of rounded to subangular detritus, according to the amount of transportation, and the gravel and boulder beds are fairly well separated from the finer sediments. Some of the glacial boulders now exposed in the valley of the East Fork, among the outwash deposits, are 5 or 6 feet in diameter, such coarse material being specially plentiful in the lower gorge and also farther upstream where the river has undercut high banks of outwash gravel.

The maximum thickness of the till is hard to estimate, because the East Fork of the Chandalar River does not cut to bedrock at the lower end of the morainal deposits, where the till is best exposed in the bluffs. Farther downstream, however, the river does at places cut bedrock alongside of gravel benches 300 feet high, thus indicating a minimum thickness of that order for the outwash deposits. In the lower end of the morainal zone, however, the glaciers may have gouged downward into the hard-rock valley floor, thus materially lowering the old hard-rock gradient. As the gravel benches in this zone are as high as those farther downstream, the total thickness of till may be considerably in excess of 300 feet in the center of the valley.

RECENT DEPOSITS

The Recent deposits consist of the sand, gravel, silt, carbonaceous deposits, and hillside rubble that form the flood plains and contiguous débris in the present valleys. Such deposits may be classified into three general types, which differ from one another in their physiographic history as well as in their lithologic character. These are (1) the detrital deposits that constitute the alluvial fillings in the present valley floors; (2) the sand, silt, and carbonaceous deposits that constitute the filling in the Yukon Flats and also the detrital veneer over the morainal material farther upstream; and (3) the hillside rubble, or eluvial deposits, that form a covering on the slopes of present valleys.

The deposits of class 1 consist mainly of coarse sand and gravel and subordinately of fine sand and silt and are found along all the swift watercourses of this region. In a mountainous region like the Chandalar-Sheenjek district such deposits should normally be made up of sand and gravel. However, as the main streams are handling reworked glacial débris, in addition to normal stream gravel, this recent alluvium contains in places more or less fine sand, silt, and clay, as well as abnormally large boulders. Such composite débris forms thick alluvial deposits in the lower valleys.

The finer detrital material and carbonaceous deposits of class 2 are found mainly in the Yukon Flats and are probably both fluviatile and lacustrine in origin. A general description of these flats has already been given. The final chapter in their origin has not yet been written, and it is doubtful if a thoroughly satisfactory explanation of this great alluvium-filled depression of the Yukon can be formulated until a reliable topographic map of the flats and the bordering hills has been drawn and detailed geologic studies have been made. Yet, whatever the final explanation may be, it is evident that the encircling hills at Fort Hamlin, at the lower end of the "flats," were the site of a bulwark that controlled for a long period the base-level of the upper Yukon. In the absence of any reliable data that would prove their mode of origin, it is commonly inferred that the Fort Hamlin hills and the Yukon Valley above Fort Hamlin have been involved in differential uplift or depression, whereby the natural grade of the bedrock floor of the Yukon has been changed, so that at Fort Hamlin and for an undetermined distance upstream the bedrock grade of the Yukon is upstream. This condition has produced a great dumping of river deposits above Fort Hamlin, and the long-continued operation of this process has extended such alluvial deposits up into all the streams tributary to the Yukon to points where their naturally high headwater gradients have brought their valley floors above this great alluvial plain.

In the main Chandalar Valley the critical point is some distance above the mouth of the Christian River, where the river changes to a swift braided stream that flows over a flood plain with a fairly strong gradient. The upper stretch of 40 miles, although within the Yukon Flats from the Christian River to the hills, contains alluvial material more characteristic of the mountain gradients. From the Christian River downstream the Chandalar flows as a sluggish stream over a flood plain of appreciably lower slope, and because the river meanders tortuously in this stretch the gradient per stream-mile is still further reduced. Consequently little stream gravel is seen on the river bars below the Christian River, the alluvium being mostly sand and silt. The presence at places of high alluvial banks, which appear to be above the highest stage to which the streams now reach, indicates, however, that the downward movement of sediments, even in the lower valley, exceeds the yearly alluviation by overflow and that the flats as a whole are in process of destruction rather than construction.

The similar critical point on the Sheenjek River is just above Carroll's cabin, likewise in the Yukon Flats, 20 miles from the nearest hills at Outlook Point. The presence of sand and silt in the lower valley is therefore to be expected. The black carbonaceous sediments, seen in many of the river banks in the lower river, also are explicable in terms of present conditions. The numerous log jams and snag flats of the present stream show how carbonaceous material can accumulate in the river mud, and the heavy layers of moss in the forest and brush, back from the river, afford a major source for the peaty deposits seen in the silt.

Similar deposits of fine sand and silt also occur as a veneer over the morainal deposits, both on the East Fork of the Chandalar River and on the Sheenjek River, and such deposits are essentially similar to those seen in the Yukon Flats. One noticeable difference, however, is the lack of snags and log jams and the paucity of carbonaceous material in these upstream deposits of sand and silt, due mainly, of course, to the fact that in these upper stretches timber is smaller and more sparsely distributed. Eluvial deposits are present everywhere on the gentle lower hill slopes in the piedmont province and must constitute a large part of the surficial detritus. For the most part, however, they are covered by heavy layers of vegetal material. Much of the ground back from the main waterways is perpetually frozen, so that solifluxion, nivation, and similar processes must play a significant part in the genesis and movement of such material.

IGNEOUS ROCKS

CHARACTER AND DISTRIBUTION

Igneous rocks are singularly scarce in the Chandalar-Sheenjek district and are confined mostly to the piedmont province of Sheenjek Valley and the main Chandalar Valley. Such rocks may be divided into three general groups, as follows:

1. Greenstone and metadiorite, which form an integral part of the pre-Silurian sequence of metamorphic rocks. A few such rocks were noted, mostly as rubble, in the lower valley of the East Fork of the Chandalar River. The occurrence and general character of such rocks have been mentioned in the description of the early Paleozoic or older rocks, and no separate description will be given.

2. The basic intrusive rocks of Sheenjek Valley, of Carboniferous or Mesozoic age, which are most numerous in the areas occupied by the chert-slate formation.

3. Basaltic lava flows and associated intrusive rocks, of Tertiary age, which are found in the main Chandalar Valley.

CARBONIFEROUS OR MESOZOIC INTRUSIVE ROCKS

Distribution.—The Carboniferous or Mesozoic intrusive rocks, as previously stated, are found mainly in association with the rocks of the chert-slate formation and occur chiefly in the piedmont province of the Sheenjek River, where this formation is typically developed. It would be superfluous to mention all the many localities in the Sheenjek Valley where such intrusive rocks were seen, for almost everywhere they appear to be represented in the chert-slate sequence. On the other hand, no areas of intrusive rocks were observed large enough to warrant their separate delineation. The chert-slate formation and its included igneous rocks are therefore shown on the geologic map as a single pattern. Shoulder Mountain and the summit of Helmet Mountain are two of the more prominent localities of these intrusive rocks.

Petrologic character.—These intrusive rocks are all basic but may in general be classified into four types—gabbro, quartz gabbro, diabase, and basalt. The gabbro, diabase, and basalt are normal rock types and require no particular description. They consist essentially of plagioclase, which has an average composition about that of labradorite, augite, and iron oxides, with more or less accessory apatite. In some of these rocks the pyroxene or plagioclase or both are altered to a degree sufficient to justify the appellation greenstone. In others the component minerals are little altered. The three types mentioned differ from one another mainly in their granularity and texture.

A more specialized type, designated quartz gabbro, is distributed along with the other intrusive rocks at several localities in the valley but occurs typically at Shoulder Mountain. This rock is typically granular but is in places rather exceptionally coarse grained. It consists essentially of plagioclase, quartz, augite, and iron oxides, with accessory apatite, together with secondary minerals, such as sericite, chlorite, biotite, basaltic hornblende, and iron hydroxides. The feldspar is zonally grown, with centers of labradorite and rims of oligoclase. Another striking feature is the presence of peculiar latticed intergrowths of magnetite and biotite. The general idea derived from a microscopic examination of these quartz gabbros is that they have been extensively altered by hydrothermal processes at a late stage of their formation, to which may be attributed the formation of the sericite, biotite, and hornblende and possibly a certain degree of the albitization.

Age.—The age of these intrusive rocks is not exactly known. They clearly intrude the rocks of the chert-slate formation, but the age of that formation also is somewhat in doubt. If, as suggested in this paper, the chert-slate formation is of late Devonian or early Mississippian age, these intrusive rocks can not well be older than Mississippian. On the other hand, these rocks have developed to a greater or less degree a pronounced greenstone habit, in which they differ markedly from the Tertiary volcanic rocks described below. They are therefore believed to have originated prior to the Tertiary period. So far as the evidence in the Sheenjek Valley is concerned, the age of these basic intrusive rocks must therefore be given as Carboniferous or Mesozoic.

If the chert-slate formation is in reality of Mississippian age, these intrusive rocks might well be correlated with the volcanic rocks along the Yukon which constitute the Rampart group, and with the similar intrusive rocks, described by the writer,[25] in the chert formation at Livengood, in the Yukon-Tanana region. Intrusive and extrusive types of basic volcanic rock were widespread during Mississippian time, in both central and southern Alaska, and this correlation seems very suggestive. On the other hand, if the chert-slate formation should be proved to be of Upper Triassic age, it would then seem necessary to correlate these intrusive rocks with the Jurassic volcanism. As against this correlation, however, it must be remembered that the Jurassic volcanism produced also a great variety of granitic and related rocks, none of which appear to be represented in the Sheenjek Valley, nor, in fact, anywhere in the Chandalar-Sheenjek region.

[25] Mertie, J. B., jr., The gold placers of the Tolovana district: U. S. Geol. Survey Bull. 662, p. 243, 1918.

TERTIARY VOLCANIC ROCKS

Distribution.—Basaltic lavas crop out along the south side of the Chandalar River just opposite the mouth of the East Fork, making prominent red bluffs. This is the only occurrence of these rocks within the area covered by this report, but similar rocks, both extrusive and intrusive, are found farther upstream on the north side of the Chandalar River and continue on up the West Fork of the Chandalar. The general distribution of these rocks is therefore about east and west.

Petrologic character.—The lavas opposite the mouth of the East Fork of the Chandalar River are olivine basalts. These rocks, though in places somewhat porphyritic, are for the most part fine grained and nonporphyritic, with a fabric ranging from intersertal to partly glassy. The groundmass consists mainly of labradorite, augite, olivine, and magnetite, with a small amount of apatite. The glassy specimens contain from 5 to 40 per cent of a reddish-brown glass. Where the rock is porphyritic the phenocrysts comprise labradorite and olivine and less commonly also augite. The feldspars and pyroxene in these rocks are quite fresh and unaltered in appearance, and even the olivine is very little serpentinized.

Age.—The age of these lavas is not definitely known. Farther up the Chandalar occur both extrusive and intrusive basalts that are believed to have originated at the same time as the lavas at the mouth of the East Fork. The intrusive phases of these volcanic rocks have been observed by the writer in places where they cut the Mesozoic granodiorite that lies along the south side of the Chandalar River. Hence it is likely that these volcanic rocks originated late in the Mesozoic or in the Tertiary. The fresh, unaltered condition of the lavas at the mouth of the East Fork is a strong indication of their Tertiary age.

ECONOMIC GEOLOGY

Igneous rocks are relatively scarce in the Chandalar-Sheenjek district, and granitic rocks, which commonly are the source of most of the metalliferous deposits in central and northern Alaska, have nowhere been seen. Nevertheless, only a small portion of the 6,000 square miles of this district has been examined in any detail, and the possibility still exists that granitic rocks with attendant mineral deposits may be found.

Metalliferous lodes in this region could hardly be commercially valuable at the present time, because the region is very remote from centers of supply and is devoid of modern transportation facilities. The airplane holds forth the greatest promise of transportation if metalliferous deposits should be discovered and developed here. Such transportation, however, is costly, and only lodes of the bonanza type could possibly be developed under present conditions. Placer deposits, however, require a minimum of equipment and yield quick returns, and the discovery and mining of such deposits offer the only prospect of any metalliferous mining activity in this region in the near future.

The alpine province and the more northerly part of the piedmont province, where the surficial features have been affected by glaciation, constitute the least hopeful area for prospecting for gold placers, because glacial erosion tends to dissipate rather than to concentrate the metals. Moreover, if gold placers existed in this region prior to the glacial epoch, the ensuing glaciation very likely has eroded and scattered such deposits. Finally, it is a striking fact that most of the richer gold placers in interior Alaska have been found in areas of relatively low altitude and relief, where long-continued denudation and uninterrupted alluviation have operated to develop more or less continuous pay streaks. These conditions do not exist in the alpine province of the Chandalar-Sheenjek district, and although gold placers may occur anywhere if the contributing lode material is of sufficiently high grade and sufficiently extensive, the odds against such optimum conditions are great.

So far as the surficial features of the piedmont province are concerned, the conditions for the accumulation of placers are favorable provided the necessary lode deposits are present from which such placers may be concentrated. Granitic rocks and definite evidences of gold mineralization have not been observed by the writer, but the piedmont part of this region requires much more careful inspection before it may be stated that such mineralization has not occurred. To the west workable gold placers are found on the North Fork of the Chandalar River, and to the east gold is found at places on the bars of the Coleen River. The East Fork of the Chandalar River and the Sheenjek River are practically unprospected as yet, and no inherently good reasons exist against the possible occurrence of mineral deposits in this region.

Another interesting mineral deposit of possible value in this region is oil shale. A sample from the Christian River about 75 miles northwest of Fort Yukon, which was submitted to the Geological Survey in 1926, was found to contain a phenomenally high percentage of shale oil. This sample was distilled and examined by E. T. Erickson, of the Geological Survey, and his report is given herewith:

A distillation test made by the Bureau of Mines oil-shale distillation method [26] gave 122 gallons of crude oil per ton. Rate of distillation maintained during the period of active distillation, 0.5 cubic centimeter of distillate per minute. Specific gravity of the crude distillate, 0.864 $\frac{15°C.}{15°C.}$ Setting point of the crude oil, 11° C.

When first distilled, the crude oil was strongly green, a color unlike the amber or dark-brownish colors usually exhibited by crude shale oils. The color of the crude oil, however, darkened considerably upon prolonged contact with air, and the change was accompanied by the separation of a dark substance. The green color, together with the unusually high yield of the crude oil, suggested that the sample might be related to some form of residual petroleum, for the heavier lubricating fractions of certain petroleums are characterized by a similar color. Extraction tests made with chloroform and benzene directly on the sample and also on the sample previously treated with hydrofluoric acid gave no evidence to confirm this suggestion, yielding but slight quantities of soluble material. Hydrocarbon material directly related to petroleum would likely exhibit solubility in these solvents. The slight solubility noted, together with the ash determination of 33.15 per cent, may be considered to classify the sample as oil shale.

The setting point is the temperature at which solidification of the oil occurs, probably through the separation of wax and other hydrocarbon substances. The setting point noted is considerably lower than that given by typical Colorado and Scottish shale oils.

The green color noted may have some significance as to the commercial value of the crude oil for lubricants and may also be of scientific interest in regard to the geologic origin of the colored hydrocarbons of petroleum, as their occurrence in the crude shale oil involves a distillation process.

The locality where this oil shale occurs has not been visited by any geologist, and the character and age of the containing rocks have therefore not been ascertained. Deposits of coal are also reported from the valley of the Christian River, and this fact, together with the occurrence in the same area of oil shale, suggests that Mesozoic rocks may be present in that valley.

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[26] Karrick, L. C., A convenient and reliable retort for assaying oil shales for oil yield: U. S. Bur. Mines Repts. No. 2229, 1921.