# THE TATONDUK-NATION DISTRICT, ALASKA

By J. B. Mertie, Jr.

ABSTRACT

The Tatonduk-Nation district occupies a triangular area of about 600 square miles that forms the southern end of the Yukon-Porcupine region, in east-central Alaska. The Yukon River, which runs N. 60° W. along the south side of this district, delimits the Yukon-Porcupine region on the north from the Yukon-Tanana region to the south. The Yukon-Tanana region contains numerous towns and mining camps and in earlier years has been completely covered by reconnaissance topographic and geologic surveys. The Yukon-Porcupine region, on the other hand, is almost uninhabited and as yet unsurveyed. This report presents the results of geologic studies in the southern part of this region, where the geologic section is unusually complete. No topographic base was available for preparing a geologic map, but the results of the work have been plotted on a reconnaissance drainage base that serves to show general geologic relationships.

Geologically, as well as geographically, the Yukon River in this part of Alaska forms a significant boundary, for south of the river are great granitic batholiths of Mesozoic age, whereas north of the river such intrusive bodies are absent. Likewise, south of the river the pre-Cambrian rocks have been profoundly metamorphosed, and even rocks as young as Devonian have locally been rendered schistose. North of the river, on the other hand, rocks considered to be pre-Cambrian occur practically unaltered. Conditions of sedimentation have also been different north of the river, for the pre-Cambrian dolomite, red beds, and lavas and the Cambrian and Ordovician limestone have no known counterparts elsewhere in Alaska. In addition, sedimentary rocks of every geologic system except the Jurassic are found in the same general vicinity, so that the Tatonduk-Nation district affords an unusual opportunity for compiling a complete geologic section. The Carboniferous and younger rocks of this section, however, have been described by the writer[1] in some detail in an earlier publication, and therefore in this bulletin emphasis has been laid upon the less well known lower Paleozoic and pre-Cambrian rocks of this district.

The oldest rocks in Alaska, known as the Birch Creek schist and considered by the writer to be the basal part of the pre-Cambrian sequence, are not present in this district. The oldest rocks exposed consist of an assemblage of sediments and lavas called the Tindir group, which are known on stratigraphic grounds to be older than Middle Cambrian and which are believed by the writer to be probably of Algonkian age. The Tindir group is divided into seven units, designated by letters and described as follows:

Unit A. Principally thin-bedded limestone. Top of sequence.

Unit B. Principally siliceous dolomite and shale, with beds of dolomitic conglomerate near the base.

[1] Mertie, J. B., jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 84–148, 1930.

Unit C. Upper red beds, consisting of hematitic dolomite, shale, flint, tuff, and lava, with a red basal conglomerate.

Unit D. Amygdaloidal and ellipsoidal lavas of greenstone habit.

Unit E. Thin-bedded dolomite, shale, argillite, and quartzite, with here and there beds of more massive dolomite and quartzite. Also basic dikes and sills, flows, and a prominent horizon of red beds.

Unit F. Massive magnesian limestone and dolomite.

Unit G. An incompletely differentiated group of thin-bedded dolomite and argillaceous rocks that includes also a horizon of lava and an equally well-defined horizon of red beds. A part of these rocks is believed to overlie unit F.

Partial analyses show that most of the carbonate rocks of unit B and presumably similar underlying rocks are essentially siliceous dolomites. Red beds like those of unit C have not been found elsewhere in Alaska, and a detailed stratigraphic section is therefore given. Most of these rocks contain from 3 to 5 per cent of hematite, and some contain 25 per cent or more. Most of them are also highly siliceous, four analyses showing from 36 to 72 per cent of silica. Irrespective of their original character, the rocks of unit C are therefore dominately siliceous and hematitic. The rocks of unit D are mainly amygdaloidal and ellipsoidal basalts and associated pyroclastics of greenstone habit. In unit D and similarly in unit G a horizon of red beds immediately overlies a horizon of lava, and these lavas are believed to be the source of the iron found in the overlying red beds.

The upper rocks of the Tindir group underlie early Middle Cambrian rocks without any recognizable discordance in structure. Open folding, modified by later fault displacements, characterizes these upper beds. The lower beds are more intricately folded, but this may be a matter of local variation rather than an indication of greater metamorphism. The total thickness of the Tindir rocks is estimated by the author to be between 20,000 and 25,000 feet.

The Cambrian section is divided into four parts, as follows:

1. Upper Cambrian limestone that grades upward, without any noticeable stratigraphic or lithologic break, into Ordovician limestone.
2. An upper plate of Middle Cambrian limestone.
3. A thin formation of slate and quartzite.
4. A lower plate of Middle Cambrian limestone.

The principal contribution of the author to the Cambrian stratigraphy has been the recognition of the Middle Cambrian beds, which have been identified both by stratigraphy and by fossil collections. Both the Middle and Upper Cambrian rocks of the Tatonduk River lie in an anticline that plunges southeastward to the Yukon River. The Middle Cambrian rocks are believed to have a thickness of 1,300 feet and the Upper Cambrian limestone about 2,000 feet.

The Ordovician rocks consist of about 1,000 feet of limestone, essentially similar to the underlying Upper Cambrian limestone, and 250 feet or more of graptolitic shale, which appears to be of approximately the same age as the limestone.

The Silurian rocks have not been well differentiated in the Tatonduk-Nation district, but fossil collections show that both middle and late Silurian are present. They are correlative with the Skajit limestone of northern Alaska and with the similar middle Silurian limestone of the White Mountains, south of the Yukon.

As a result of studies in this and other parts of Alaska, the writer presents a generalized Devonian section, composed of four groups of rocks, of which three are found in this district. This sequence is as follows:

1. Upper Devonian, characterized by *Spirifer disjunctus* and other invertebrates. These rocks are found in the Brooks Range, of northern Alaska, and on Prince of Wales and Chichagof Islands, in southeastern Alaska.

2. High Middle Devonian, typified by siliceous and slaty beds in the Tatonduk-Nation district and by the Woodchopper volcanics farther down the Yukon.

3. Middle Devonian proper, exemplified by thin-bedded limestone and shale, found in many parts of Alaska, including the Tatonduk-Nation district.

4. Salmontrout limestone, of lowest Middle Devonian age, typically on the Porcupine River, and also in the Tatonduk-Nation district.

Five Carboniferous formations, together with Triassic, Cretaceous, and Tertiary rocks and Quaternary unconsolidated deposits, are also described, but these formations are more fully discussed in an earlier publication, and the author has merely presented a summary of the post-Devonian formations, amplified by new material of later date. The chief of these additions are certain collections of invertebrates and plants that raise significant questions in Carboniferous statigraphy.

The principal igneous rocks of this district are the Tindir lavas and intrusive rocks, which are for the most part normal basaltic rocks, ranging in granularity from holocrystalline to glassy. Some of the intrusive types contain a small percentage of orthoclase and quartz. Undifferentiated greenstone from the highly altered rocks south of the Yukon is also described. These rocks, though much more altered than the Tindir lavas, are probably Devonian in age.

## INTRODUCTION

The Tatonduk-Nation district covers a triangular area of about 600 square miles, bounded on the east by the boundary between Alaska and Canada, on the northwest by the Nation River, and on the southwest by the Yukon River. It lies mainly between longitude 141° and 141° 40′ and latitude 64° 45′ and 65° 30′. This district is in reality the southern end of a much larger geographic province known as the Yukon-Porcupine region, which lies between the international boundary and the Yukon and the Porcupine Rivers and embraces an area of about 11,000 square miles. The index map (fig. 11) shows the position of the Tatonduk-Nation district in east-central Alaska.

The Yukon-Porcupine region as a whole has not yet been mapped, but reconnaissance surveys were made along its borders in earlier years. Along the Porcupine the only noteworthy geologic work that has yet been done is the traverse made by E. M. Kindle [2] in 1906. Further notes regarding the geologic section along the Porcupine River were also made by A. G. Maddren, formerly of the United States Geological Survey, in 1911. Numerous geologists have studied the geologic section along the Yukon from the international boundary downstream to Circle, and the results of these surveys have recently been summarized by the writer.[3] A topographic and geo-

[2] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, pp. 315–328, 1908.

[3] Mertie, J. B., jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, 1930.

logic map of a strip extending 2 to 3 miles on each side of the international boundary between the Yukon and the Porcupine Rivers, was made in 1911 and 1912. The topographic map was published by the International Boundary Commission on a scale of 1:62,500, and the geologic map of the same strip was published by D. D. Cairnes,[4] of the Canadian Geological Survey, on a scale of 1:125,000.

The preparation of a reconnaissance topographic and geologic map of the entire Yukon-Porcupine region is one of the current projects

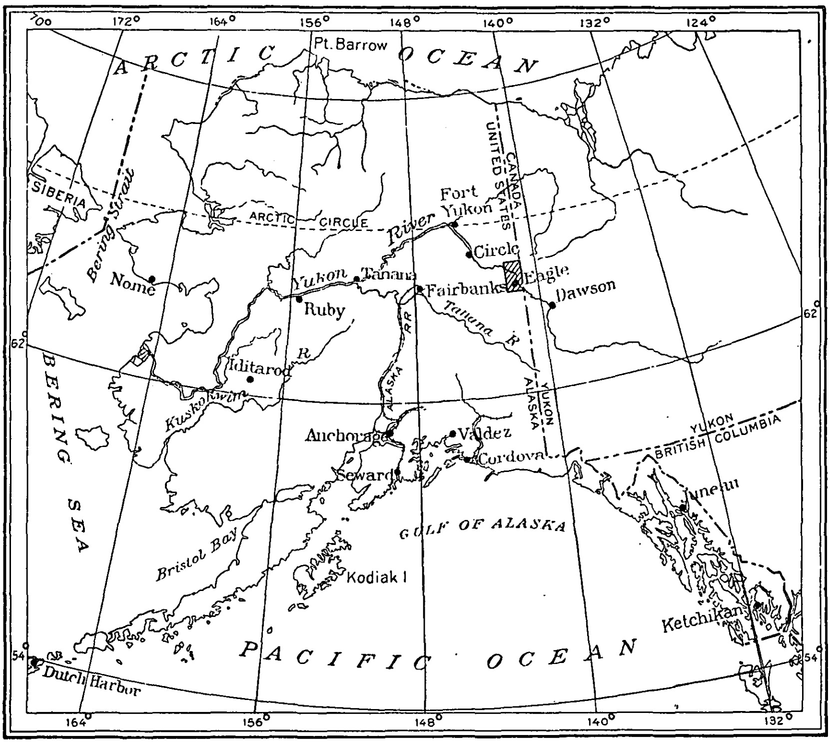


FIGURE 11.—Index map showing location of Tatonduk-Nation district (shaded area)

of the United States Geological Survey, and the accompanying map of the Tatonduk-Nation district represents an initial step in this project. From previous studies along the north bank of the Yukon the geologic section of the Tatonduk-Nation district was believed to be unusually complete and worthy of special attention. Therefore, although no topographic map was available for plotting the results of a geologic survey, it seemed desirable to study this section for the value that would subsequently accrue in connection with the areal mapping of the Yukon-Porcupine region. As some base was needed, however, upon which to plot the distribution of the geologic forma-

[4] Cairnes, D. D., The Yukon-Alaska international boundary between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, 1914.

tions, a sketch map of the drainage was prepared in the field by using plane-table triangulation for control. The map accompanying this report is not comparable in accuracy with the usual reconnaissance surveys in Alaska on a scale of 1:250,000 and is undoubtedly both incomplete and inaccurate in detail, but it serves nevertheless as a medium for showing the major drainage and the general distribution of the rocks.

The writer takes this opportunity to acknowledge with thanks the able geologic assistance rendered by Mr. A. E. Waters, jr., of Baltimore, Md., during the field season of 1930.

## GEOGRAPHY

### DRAINAGE AND RELIEF

The Tatonduk and Nation Rivers are the two principal streams of this district. The name Tatonduk, according to Ogilvie,[5] is the phonetic transcription of an Indian name meaning Broken Stone River. It was spelled Tatondu by Schwatka[6] and Tatonduc by Ogilvie, but the spelling Tatonduk was adopted by the International Boundary Commission. Locally the name Sheep Creek is now applied.

The Tatonduk River heads against the Peel River drainage in Yukon Territory and flows in a general southwesterly direction for about 50 miles, emptying into the Yukon River about 30 miles downstream from the international boundary. Although in general the Tatonduk Valley trends southwestward, the course of the river changes abruptly at numerous points, probably under the control of rock structure. The Tatonduk River is also characterized by several canyons, of which the most difficult to traverse is situated in Yukon Territory about 15 or 20 miles from its headwaters. About 14 miles from its mouth the main stream is joined by a large tributary from the southeast. This point is commonly designated as the forks. From the forks the Tatonduk River flows northwest for 3 or 4 miles, crossing the international boundary in this stretch, and then veers gradually westward to the Yukon.

About 11 miles of the lower part of the Tatonduk Valley lies in Alaska. A short distance west of the international boundary the river enters a straight, narrow gorge, from 50 to 100 feet wide, with walls rising abruptly on both sides for several hundred feet. Within this stretch the stream is deep and gravel bars are absent, so that travel with pack horses is impossible and even foot travel is diffi-

[5] Ogilvie, William, Exploratory survey of part of the Lewes, Tat-on-duc, Porcupine, Bell, Trout, Peel, and Mackenzie Rivers: Canada Dept. Interior Ann. Rept. for 1889, pt. 8, sec. 3, 1890.

[6] Schwatka, Frederick, Report of a military reconnaissance in Alaska made in 1883, p. 47, sheet 7, Washington, Government Printing Office, 1885.

cult. The south shore affords the best route through the canyon. Ogilvie, who traveled through this gorge in winter, referred to it as one of the grandest sights he ever saw, and it does indeed constitute one of the striking scenic features of this district. Below this canyon the valley floor gradually widens out, and the river as it approaches the Yukon flows over a wide gravel bar, with numerous sloughs and overflow channels. Near the Yukon the valley floor is half a mile or more wide, and the valley itself in this lower stretch, from watershed to watershed, is from 5 to 8 miles wide.

The Tatonduk River, throughout most of its course, has a high gradient and is a swift mountain stream. At low stages of water it may be forded on foot at numerous places between the boundary and the Yukon, and on such riffles it is too shallow for power boats. At high water it can not be forded anywhere below the boundary, even on horseback, and although deep enough at such times for a motor boat, a great deal of power would be required to drive a boat upstream against its current. Just before it debouches into the Yukon, the Tatonduk River splits into a number of distributaries, and these have built a gravel delta out into the Yukon.

Between the boundary and the Yukon several small tributaries enter the Tatonduk River. On the south side, about 5 miles from the Yukon, a small tributary enters from the south. This stream, which the members of the expedition of 1930 called Thicket Creek, is about 4 miles long and may be followed with pack horses all the way to its head. As on the other tributaries of the Tatonduk River, however, the winter snow and overflow ice linger until the middle of June or later, making the footing difficult, at places, for horses. The largest tributary of the Tatonduk River in Alaska enters from the north a short distance above the mouth of Thicket Creek. This stream, though constricted to a narrow outlet, has several upper tributaries of appreciable size, and its upper drainage valley therefore flares outward into a good-sized drainage basin. The central or main branch can be traveled to its head by pack horses, and constitutes a short cut from the Tatonduk River northward into the valley of Hard Luck Creek. This tributary was designated as Pass Creek. A third tributary of the Tatonduk River, called Funnel Creek, heads in the high limestone range north of the Tatonduk River and flows southward to join that stream about a mile below the international boundary. This tributary, through the lower two-thirds of its course, flows in a narrow gorge that from a distance looks impassable for horses. Its lower part, near the Tatonduk River, does have several short stretches through which a pack horse could hardly be led, but from a point about a mile above its mouth a good pack trail was cut all the way to its head by the boundary survey party of 1910 and

1911. This pack trail connects with the valley of the Tatonduk River, through a low, wooded pass. A fourth tributary of the Tatonduk River, worthy of mention, heads near the boundary triangulation station called "Chief" and flows for about 3 miles through a narrow limestone gorge to the Tatonduk. This stream was not traversed by the writer, but a good idea of its general character was obtained from the station "Chief." These four tributaries of the Tatonduk are here described in somewhat greater detail than their size appears to warrant, but as the Tatonduk River is a natural route of entry into the Ogilvie Range, and as these streams afford the only lateral routes of access to the north and south, their description seems desirable for the benefit of travelers in this district.

The Nation River, the other large tributary of the Yukon within this district, enters the Yukon 22 miles below the Tatonduk River. The course of the Yukon between the Tatonduk and Nation Rivers is much straighter than between the boundary and the Tatonduk River, so that the distance by river between these two streams more closely approaches the air-line distance. The Nation River, according to Schwatka,[7] was known originally as the Tahkandik River, but Spurr[8] later spelled the name Tahkandit. Within a few years after the time of Spurr's traverse, however, this stream became known locally as the Nation River, and this name has now become the fixed usage. The name Tahkandit was also used by Spurr to designate a sedimentary series, which, however, later work showed to be too inclusive. Spurr's Tahkandit "series" has therefore been redefined and the name restricted to the upper (limestone) part of Spurr's unit, which has been named Tahkandit limestone by the writer,[9] thus preserving the original Indian place name.

The Nation River has not yet been surveyed by the United States Geological Survey, but from the higher mountain tops of this district most of its valley, from the international boundary to the Yukon, may be seen. It crosses the boundary a little north of latitude 65° 30′ and flows in a westerly direction but veers gradually to the southwest, giving a general southwesterly course to its valley in Alaska. At the boundary its valley floor is about half a mile wide, but a few miles below the boundary the valley bottom opens up to a width of 5 miles or more. Near the Yukon the valley is again constricted, and at its mouth the valley floor of the Nation River is again about half a mile wide.

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[7] Schwatka, Frederick, op. cit., p. 47, sheet 8.

[8] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, pl. 38, pp. 252–253, 1898.

[9] Mertie, J. B., jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 121–122, 1930.

The valley of the Nation River in Alaska is markedly asymmetric. Its tributaries from the northwest, heading against the Kandik River (Charlie Creek) are short, apparently not exceeding 6 or 8 miles in length, and the Nation River itself hugs the northwest wall of its valley from the boundary to its mouth. The tributaries entering from the southeast, on the other hand, are good-sized streams that head well to the southeast in Yukon Territory. The wide valley floor of the Nation River in this intermediate stretch lies entirely southeast of the river channel. The general appearance of this valley suggests strongly that the channel of the Nation River has migrated laterally northwestward during the Quaternary period.

The tributaries of the Nation River that enter from the east and southeast drain a major part of the Tatonduk-Nation district. These tributaries, named in order from the Yukon northeastward, are Hard Luck, Waterfall, Tindir, Ettrain, and Jungle Creeks. The name Waterfall was applied by the members of the expedition of 1930 to the heretofore unnamed creek between Tindir and Hard Luck Creeks. The name Harrington Creek was used by Cairnes[10] to designate Hard Luck Creek, but the official name earlier applied to this creek by the International Boundary Commission is retained in this report. A small tributary of the Nation River, about 11 miles in length, lies between Hard Luck Creek and the Yukon River. This stream at present is unnamed.

The direction of the course of the Nation River with respect to the international boundary progressively shortens the Alaska portions of its southeast tributaries from the Yukon northeastward. Partly on account of the wide valley of the Nation River below the boundary, the Alaska portions of the valleys of Jungle and Ettrain Creeks really form a part of the Nation River flats. Tindir Creek runs for about 5 miles through a mountainous country west of the boundary and then flows out into these featureless flats. Waterfall Creek, which flows for about 10 miles within the mountainous region, has a deep, narrow, canyonlike valley for 6 miles northwest of the boundary, succeeded downstream by a short but precipitous gorge with waterfalls. Pack-train travel is impossible through this gorge, but the upper valley of Waterfall Creek is a good pack-train route.

The principal tributary of the Nation River in this district is Hard Luck Creek. At the boundary Hard Luck Creek is a meandering stream, flowing in a narrow valley, the floor of which is about a quarter of a mile wide. A mile and a half below the boundary it enters a steep-walled gorge, which continues downstream for

[10] Cairnes, D. D., The Yukon-Alaska international boundary between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, map 140-A, 1914.

a mile. At the lower end of this gorge Hard Luck Creek is joined by a small tributary from the northeast, up which strikes the boundary trail. From the lower end of the gorge downstream the valley of Hard Luck Creek gradually widens, but for the first 6 or 7 miles below the gorge the stream is sharply incised in its valley floor, giving rise to a narrow alluvial channel perhaps 50 feet below the average level of the valley proper. About 9 miles below the boundary another limestone reef, similar to the one just below the boundary, causes another constriction of the valley for a short distance. Below this point the benchlike character of the main valley floor persists for several miles farther downstream, after which the valley floor and the river alluvium gradually coalesce, the valley finally opening out into the flats of the Nation River, about 20 miles below the boundary. Hard Luck Creek, from its meandering zone at the boundary all the way to the place where it enters the Nation flats, has but a thin veneer of gravel in its channel and cuts bedrock intermittently throughout these 20 miles.

Cathedral Creek, the principal tributary of Hard Luck Creek, enters about 7 miles below the international boundary. At the confluence it carries more water than Hard Luck Creek, and its valley differs markedly from that of Hard Luck Creek. At the boundary and for 2 or 3 miles downstream Cathedral Creek flows in a canyon similar to the canyon of Hard Luck Creek. In this stretch the stream flows a little south of west, but below this point its course changes abruptly to south-southwest, and the valley is wide open. Just above its mouth, Cathedral Creek again enters a narrow and picturesque gorge that extends to its mouth. In this lower gorge the stream flows swiftly in a narrow channel over a bedrock of hard quartzite, with large boulders of the same material in the stream bed. A trail along the east side of the gorge, however, permits pack horses to travel through this stretch without difficulty.

The principal streams on the south side of the Yukon within this district, named in order downstream from the boundary, are Mission Creek, the Seventymile River, Trout Creek, Michigan Creek, and Fourth of July Creek. Mission Creek, which enters the Yukon River just below Eagle, was in McConnell's time [11] called by its Indian name Tatotlindu River, and Eagle Bluff, at the mouth of Mission Creek, was known as Tatottlee Butte. No work was done on the south side of the Yukon during 1930, and as these streams have been described in earlier publications, no further description is necessary in this bulletin. The courses of Trout, Michigan, and

[11] McConnell, R. G., Report on an exploration in the Yukon and Mackenzie Basins, Northwest Territories: Canada Geol. and Nat. Hist. Survey Ann. Rept. for 1888–89, vol. 4, 1890.

Fourth of July Creeks are merely sketched, and their positions are not to be taken as accurately represented.

The east-central part of the Tatonduk-Nation district is characterized by rugged topography and great relief. This part of the district is in reality the western end of the Ogilvie Range, a group of mountains that extends westward from Yukon Territory into Alaska and terminates a few miles west of the international boundary. These mountains rise to altitudes of 5,000 feet or more above sea level, and as timber line lies between 2,500 and 3,000 feet, their tops and interconnecting ridges lie for the most part above timber line. Much of the bedrock in the Ogilvie Range consists of limestone and dolomite, and such rocks, in the subarctic climate of this region, tend to produce a rugged crest line. The general aspect of the Ogilvie Range is therefore that of bare light-colored mountains, with sharp crest lines, precipitous slopes, and deeply dissected narrow valleys that extend down into the timbered zone. The Yukon River crosses the international boundary at 879 feet above sea level, and probably flows at an altitude of about 835 feet at the mouth of Tatonduk River. Triangulation station "Skook," on the international boundary, has an altitude of 5,083 feet and is the highest known point in this district. "Skook" is 9 miles from the mouth of the Tatonduk River, so that the maximum relief for the district is about 4,150 feet.

Few of the mountain peaks in the Ogilvie Range have received formal geographic names, but the members of the International Boundary Commission gave field designations to many prominent peaks and buttes which they occupied as triangulation stations. Along the boundary strip, between the Nation and Yukon Rivers, 62 such prominences have thus been designated. Of these, Casca, Nation, Hiyu, Skook, Squaw, Chief, Crow, Hug, and Strata, named in order from north to south, are shown on the accompanying geologic map. "Hug" was also called McCann Hill by Cairnes,[12] after W. S. McCann, one of the geologic assistants of the boundary party of 1912. "Strata" is the triangulation station at the summit of Calico Bluff, on the Yukon. Another hill, between Waterfall and Hard Luck Creek, was similarly designated by the writer as "Little Nation." These names are here applied only for purposes of geographic and geologic description.

Northward and westward from the Ogilvie Range, the relief gradually diminishes, as the ridges become lower and more rounded in outline. The proportion of timbered country also becomes greater, and about halfway between the boundary and the Nation River, in the valley of Hard Luck Creek, timber covers all but the highest

[12] Cairnes, D. D., op. cit., map 140-A.

points, giving an entirely different aspect to the country. Likewise the Yukon Valley, between the mouths of the Tatonduk and Nation Rivers and on down the Yukon to Circle, is largely a timbered country and therefore more difficult for geologic work than the Ogilvie Range.

### SETTLEMENTS AND POPULATION

Eagle, the principal settlement of this district, is an incorporated town on the west bank of the Yukon, about 6 miles below the international boundary. The town site of Eagle is the best along the upper Yukon in Alaska, and as early as 1883, when Schwatka [13] made his trip down the Yukon, a white trader named F. Mercier had a trading post at this site, which was known as Belle-Isle. As this bluff was believed by Schwatka to mark the international boundary, he named it Boundary Butte, but it is now known as Eagle Bluff. At that time an Indian village called Klat-ol-klin, or Johns Village, was located on the same bank of the river, upstream from Belle-Isle.

From Belle-Isle grew the town of Eagle, and the Indian village still persists. Eagle is now the supply point for the Fortymile, Seventymile, and American Creek districts and for local points down the Yukon as far as Nation. The population of Eagle, according to the Fifteenth Census, is 54, but the population varies seasonally, as miners and trappers, whose homes are really in Eagle, come from and go to outlying districts in connection with their work. According to the same authority, the population of the Indian village upstream from Eagle is 78.

The only other settlement in this district is at Nation, which is on the south bank of the Yukon, about 3 miles below the mouth of the Nation River. Summer placer mining is in progress on Fourth of July Creek, south of Nation, and a few miners and trappers are permanently located at this point.

### TRAILS AND TRANSPORTATION

The Yukon River is the principal avenue of transportation for this region. In summer the Pacific & Arctic Railway & Navigation Co. maintains a fortnightly steamboat schedule on the river, from the head of navigation at Whitehorse, Yukon Territory, to Tanana, and thence up the Tanana River to the crossing of the Alaska Railroad at Nenana. Most of the supplies and mail for Eagle and its vicinity come by steamship from Seattle to Skagway, thence over the railroad of the White Pass & Yukon Route to Whitehorse, and down the Yukon. The Alaska Railroad does not serve this section of Alaska, and charges for freight and passenger transportation

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[13] Schwatka, Frederick, op. cit., p. 41.

from Seattle to Eagle, though reasonable for the haul, are nevertheless high. Thus, for carload lots, the freight rate on different commodities in 1930 ranged from $53 to $92 a ton, or from 2.6 to 4.6 cents a pound, with rates 12 to 14 per cent higher on less-than-carload lots.

In winter the mail is carried on horse and dog sleds on the Yukon River, and, as in summer, Eagle receives its mail from upstream.

No settlements have been established north of the Yukon, in the area under consideration, and therefore no roads or winter trails have been built. A summer trail, however, was built and used by the members of the International Boundary Commission from the mouth of the Tatonduk River into the boundary strip and thence northward. This trail follows up the Tatonduk River to a point about 2 miles west of the boundary, crosses northward over a low timber-covered saddle into Funnel Creek, and ascends Funnel Creek to its head, thence drops down into Hard Luck Creek and continues down that stream for a mile and a half. At this point the boundary trail goes northeastward up a tributary valley, called Pleasant Creek, and crosses the hills into Cathedral Creek Valley a short distance west of the boundary. An alternative and better route follows on down Hard Luck Creek to its junction with Cathedral Creek and up Cathedral Creek to the other trail. After proceeding up a steep spur out of Cathedral Creek, the trail next drops over into a small tributary of Cathedral Creek, from the head of which it follows over the hills around the head of Waterfall Creek—goes down Tindir Creek into the valley of the Nation River, and thence ascends that valley to the boundary. A branch trail, which is equally satisfactory, goes down Waterfall Creek for 5 or 6 miles, crosses thence through a low-timber-covered saddle into Tindir Creek, and joins the main trail.

Another trail used by the boundary commission, particularly at times of high water on the Tatonduk River, followed down the banks of the Yukon several miles from the mouth of the Tatonduk River and then crossed northeastward into the valley of Hard Luck Creek. Still another route into Hard Luck Valley was utilized by the Geological Survey party of 1930. Leaving the Tatonduk River halfway between the mouth and the boundary, this route ascends Pass Creek to its head and comes down into the valley of Hard Luck, just above the junction with Cathedral Creek. This is a shorter and less difficult route to Cathedral Creek than the boundary trail up Funnel Creek.

Considerable trapping is done in the valley of the Nation River and its tributaries, and trappers' trails were also noted on lower Hard Luck Creek and at other places. These, however, are for the most part poorly marked winter trails that follow through low country and are not very serviceable for travel by pack horses in summer.

## CLIMATE

This district is part of the great interior province of Alaska, and its climate is therefore characterized by long, cold winters and by short but often rather warm summers. For a 30-year period from 1900 to 1929, inclusive, the coldest recorded temperature at Eagle, according to the United States Weather Bureau,[14] is −75° F., and the highest temperature 95° F., thus showing a possible maximum range from winter to summer of 170° F. The mean annual temperature is 24.2° F. For nearly the same 30-year period, there are on the average 55 days during the year when the maximum temperature is 70° F. or above, 254 days when the minimum temperature is 32° F. or less, and 118 days when the minimum temperature is zero or less. The following tables give the available records for monthly and annual maximum, minimum, and mean temperatures at Eagle.

*Temperatures at Eagle, Alaska (° F.)*

**Highest**

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1900–1921 | 41 | 45 | 56 | 66 | 84 | 92 | 93 | 87 | 79 | 68 | 48 | 42 | 93 |
| 1922 | 29 | 17 | 36 | 60 | 85 | 82 | 78 | 81 | 60 | 53 | 36 | 18 | 85 |
| 1923 | 14 | 33 | 36 | 53 | 70 | 91 | 90 | 87 | 72 | 66 | 35 | 3 | 91 |
| 1924 | 16 | 43 | 47 | 68 | 72 | 82 | 84 | 83 | 60 | 48 | 43 | 14 | 84 |
| 1925 | 4 | 27 | 37 | 50 | 71 | 82 | 95 | 82 | 64 | 56 | 40 | 32 | 95 |
| 1926 | 38 | 21 | 52 | 61 | 69 | 85 | 80 | 83 | 62 | 56 | 45 | 35 | 85 |
| 1927 | 27 | 39 | 40 | 48 | 69 | 84 | 88 | 85 | 67 | 46 | 30 | 21 | 88 |
| 1928 | 23 | 38 | 30 | 58 | 62 | 80 | 78 | 76 | 61 | 42 | 42 | 38 | 80 |
| 1929 | 24 | 34 | 50 | 56 | 70 | 80 | 79 | 84 | 70 | 58 | 37 | 29 | 84 |

**Lowest**

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1900–1921 | −75 | −74 | −56 | −38 | 7 | 24 | 25 | 18 | 2 | −28 | −54 | −68 | −75 |
| 1922 | −51 | −54 | −42 | −11 | 10 | 30 | 30 | 16 | 14 | 4 | −38 | −44 | −54 |
| 1923 | −52 | −38 | −43 | 1 | 4 | 36 | 37 | 32 | 22 | 5 | −45 | −56 | −56 |
| 1924 | −65 | −51 | −30 | −33 | 24 | 32 | 32 | 23 | 10 | −3 | −19 | −66 | −66 |
| 1925 | −69 | −51 | −37 | −3 | 22 | 36 | 30 | 25 | 23 | −4 | −20 | −49 | −69 |
| 1926 | −12 | −46 | −16 | −5 | 23 | 33 | 31 | 30 | 21 | 6 | −30 | −53 | −53 |
| 1927 | −56 | −51 | −33 | −37 | 9 | 33 | 38 | 30 | 12 | −18 | −50 | −61 | −61 |
| 1928 | −26 | −21 | −45 | −34 | 21 | 36 | 33 | 30 | 13 | −2 | −29 | −39 | −45 |
| 1929 | −54 | −49 | −50 | −23 | 23 | 32 | 29 | 28 | 22 | 0 | −10 | −52 | −54 |

**Mean**

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1882 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 22.4 | 1.8 | −22.8 | ------ |
| 1883 | −4.8 | −5.8 | 14.0 | 29.0 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| 1884 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 41.0 | 9.0 | 7.6 | −7.6 | ------ |
| 1885 | −16.8 | −5.6 | 14.0 | 38.2 | ------ | ------ | ------ | ------ | 44.4 | 27.7 | 2.0 | −14.0 | ------ |
| 1886 | ------ | ------ | 5.8 | 25.8 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| 1899 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 50.0 | 41.1 | 20.5 | 1.3 | −18.9 | ------ |
| 1900 | −25.0 | −6.0 | 13.1 | 29.3 | 42.2 | 52.7 | 56.9 | 49.2 | 40.5 | 20.1 | −10.0 | −7.5 | 21.3 |
| 1901 | −17.8 | −15.3 | 5.0 | 19.0 | 39.1 | 52.8 | 57.6 | 49.0 | 42.0 | 23.6 | ------ | −7.0 | ------ |

[14] Summary of the climatological data for Alaska, by sections: U. S. Weather Bureau Bull. W, 2d ed., vol. 3, 1926.

*Temperatures at Eagle, Alaska (° F.)*—Continued

**Mean**—Continued

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1902 | 10.3 | 5.4 | −6.6 | 26.4 | 45.0 | 56.1 | 60.9 | 54.5 | 41.9 | 31.8 | −1.9 | −21.4 | 25.2 |
| 1903 | −19.3 | 3.0 | 8.8 | 20.9 | 40.1 | 64.1 | 65.4 | 52.6 | | | | | |
| 1905 | | | | | 47.4 | 56.8 | 64.8 | 60.6 | 42.6 | 29.6 | 14.4 | | |
| 1906 | | | 28.4 | 24.6 | 58.2 | | | | | | 0.0 | −16.2 | |
| 1907 | −9.8 | −20.0 | 4.6 | 30.4 | 49.8 | 57.2 | | | | | | | |
| 1908 | | | | | | | | 52.3 | 36.4 | 18.3 | 2.9 | −2.1 | |
| 1909 | −40.2 | −18.4 | 8.4 | 19.6 | 42.2 | 62.4 | 59.9 | 52.1 | 38.0 | 20.7 | −11.0 | −3.3 | 19.2 |
| 1910 | −13.1 | −15.8 | 6.6 | 23.4 | 44.4 | 55.8 | 59.0 | 50.6 | 43.6 | 26.2 | 1.2 | −19.6 | 21.9 |
| 1911 | −31.3 | 3.1 | 5.0 | 21.2 | 43.8 | 55.6 | 57.8 | 51.5 | 42.2 | 34.0 | 0.4 | −4.6 | 23.2 |
| 1912 | −5.0 | 8.8 | 18.4 | 32.2 | 47.7 | 51.2 | 54.7 | 50.6 | 42.9 | 28.2 | 9.0 | −7.6 | 27.6 |
| 1913 | −26.4 | 5.6 | 7.1 | 24.3 | 44.6 | 56.1 | 55.6 | 50.1 | 38.8 | 20.0 | 7.4 | −5.0 | 23.2 |
| 1914 | −13.4 | −2.4 | 8.6 | 26.2 | 45.5 | 55.4 | 54.4 | 52.8 | 38.8 | 31.8 | 10.2 | 7.8 | 26.3 |
| 1915 | .8 | 1.0 | 14.4 | 37.0 | 45.0 | 56.6 | 60.6 | 53.3 | 43.4 | 16.2 | 6.0 | −9.1 | 27.1 |
| 1916 | −16.6 | −9.6 | −7.2 | 35.9 | 46.6 | 59.0 | 59.6 | 53.2 | 43.4 | 30.8 | 8.7 | −14.4 | 24.1 |
| 1917 | −22.4 | −2.4 | 10.3 | 28.3 | 41.2 | 53.9 | 55.8 | 54.6 | 45.0 | 23.2 | −10.8 | −45.8 | 19.2 |
| 1918 | −10.8 | −10.1 | −4.2 | 25.2 | 43.7 | 52.6 | 61.9 | 53.0 | 48.2 | 20.5 | 0.1 | −7.0 | 22.8 |
| 1919 | −10.8 | 1.4 | 2.4 | 30.1 | 42.8 | 51.2 | 59.6 | 57.0 | 44.7 | 22.0 | −4.0 | −12.1 | 23.7 |
| 1920 | −19.2 | 15.8 | 5.2 | 21.8 | 41.4 | 56.3 | 61.0 | 53.8 | 40.9 | 22.1 | 2.8 | −8.6 | 24.4 |
| 1921 | −21.2 | −10.8 | 7.2 | 28.6 | 43.8 | 58.6 | 60.9 | 56.5 | 40.1 | 26.4 | −0.2 | 1.4 | 24.3 |
| 1922 | −1.6 | −5.6 | −0.7 | 31.0 | 40.4 | 55.0 | 55.0 | 52.6 | 38.0 | 31.0 | 6.0 | −12.5 | 24.5 |
| 1923 | −19.0 | 2.3 | 6.8 | 30.4 | 44.4 | 55.2 | 62.2 | 59.8 | 45.0 | 37.8 | 15.1 | −21.8 | 26.5 |
| 1924 | −9.8 | −7.6 | 19.0 | 16.0 | 46.0 | 56.0 | 57.6 | 52.9 | 40.4 | 19.4 | 10.0 | −15.0 | 23.7 |
| 1925 | −32.8 | −16.6 | 7.5 | 29.7 | 47.8 | 58.4 | 59.1 | 55.3 | 47.0 | 34.4 | 11.0 | −4.2 | 24.7 |
| 1926 | 12.2 | −3.7 | 22.9 | 31.0 | 47.2 | 57.0 | 58.8 | 55.6 | 45.2 | 32.0 | 15.4 | −9.6 | 30.3 |
| 1927 | −14.4 | 4.4 | 4.2 | 17.2 | 43.6 | 58.7 | 63.9 | 56.9 | 40.4 | 22.2 | −10.6 | −15.9 | 22.6 |
| 1928 | 2.0 | 11.4 | −4.0 | 22.0 | 42.1 | 55.8 | 58.0 | 50.9 | 37.9 | 23.2 | 18.2 | 5.6 | 26.9 |
| 1929 | −2.4 | 8.1 | 0.8 | 26.9 | 44.2 | 57.4 | 57.1 | 52.1 | 47.4 | 33.6 | 14.1 | −10.4 | 27.4 |
| Means | −13.5 | −0.3 | 7.5 | 26.7 | 44.6 | 56.2 | 59.2 | 53.3 | 42.1 | 25.3 | 0.4 | −11.0 | 24.2 |

The Weather Bureau has an uninterrupted record of the precipitation at Eagle since 1907 and partial records extending back as far as 1882. According to these records, the mean annual precipitation at Eagle is 10.78 inches, of which less than half falls as snow. The monthly and annual precipitation and snowfall records for Eagle are shown in the subjoined tables.

*Precipitation at Eagle, Alaska (inches)*

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1882 | | | | | | | | | | 0.58 | 0.38 | 0.69 | |
| 1883 | 0.74 | 0.45 | 1.01 | 0.44 | | | | | | | | | |
| 1884 | | | | | | | | | 1.65 | .27 | .87 | .40 | |
| 1885 | .28 | .70 | .41 | .92 | | | | | .96 | 1.32 | 1.27 | .22 | |
| 1886 | .19 | 1.23 | .36 | 1.19 | | | | | | | | | |
| 1899 | | | | | | | | 1.63 | .39 | .65 | .52 | .26 | |
| 1900 | .52 | .39 | .02 | .42 | 0.84 | 1.57 | 1.88 | 2.71 | 1.72 | 1.23 | .21 | .77 | 12.28 |
| 1901 | .42 | .55 | .55 | .56 | 1.63 | 1.22 | 1.47 | 4.73 | .84 | 1.06 | .24 | .19 | 13.46 |
| 1902 | | T. | .17 | .84 | .64 | 1.15 | 2.56 | 1.28 | .65 | .77 | .62 | .51 | |
| 1903 | .58 | .81 | .54 | .12 | 1.38 | .57 | 2.40 | 2.97 | 2.97 | | | | |
| 1905 | | | | | .33 | 1.95 | 1.52 | 2.72 | 3.38 | 2.96 | .93 | .68 | |
| 1906 | | .14 | 2.19 | .00 | .54 | .51 | 2.54 | 1.28 | .01 | 1.71 | .57 | .07 | |
| 1907 | 1.45 | .20 | .00 | .25 | .40 | 1.89 | 1.48 | 1.98 | 1.45 | 1.12 | .40 | .31 | 10.93 |
| 1908 | .12 | .02 | .75 | .10 | 1.02 | 2.16 | 2.47 | 1.02 | 1.48 | .18 | .82 | 1.09 | 11.23 |
| 1909 | .16 | .07 | .11 | .34 | .28 | 2.35 | 1.77 | .95 | .88 | .81 | .30 | .26 | 8.28 |
| 1910 | .83 | .01 | .53 | .25 | .28 | 1.05 | 2.28 | 2.63 | 2.98 | .69 | .25 | .30 | 12.08 |
| 1911 | .27 | .24 | .39 | .97 | 2.87 | 1.26 | 1.86 | 2.65 | 1.21 | .13 | .29 | .80 | 12.94 |
| 1912 | .06 | .29 | .11 | T. | .43 | 2.09 | 2.52 | 2.48 | .76 | 1.66 | .24 | 1.10 | 11.74 |
| 1913 | .62 | .41 | .65 | .04 | .39 | .37 | 1.06 | 2.74 | .56 | .78 | .26 | .46 | 8.34 |
| 1914 | .29 | .32 | .57 | .32 | 1.63 | .81 | 1.75 | 2.38 | 1.05 | .07 | .24 | .22 | 9.65 |
| 1915 | .47 | .09 | .51 | .53 | .34 | 3.30 | 1.55 | 2.30 | 1.41 | .47 | .33 | .70 | 12.00 |
| 1916 | 1.08 | .47 | .06 | .23 | 1.34 | .92 | 1.59 | 2.18 | 1.86 | .96 | .24 | .69 | 11.62 |
| 1917 | .28 | .62 | .34 | .09 | .50 | 2.26 | 1.71 | .74 | .75 | .69 | .65 | T. | 8.63 |
| 1918 | .72 | .42 | .51 | .96 | .18 | 1.33 | .80 | 1.33 | .54 | .88 | .93 | .33 | 8.93 |
| 1919 | .22 | .05 | .02 | .40 | 1.09 | 1.58 | 1.72 | 2.39 | 1.23 | .25 | .78 | .68 | 10.41 |

*Precipitation at Eagle, Alaska (inches)*—Continued

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1920 | 0.09 | 0.54 | 0.35 | 0.07 | 0.66 | 0.92 | 0.46 | 0.76 | 1.40 | 0.44 | 0.27 | 0.34 | 6.30 |
| 1921 | .27 | .28 | .45 | .69 | .43 | 1.13 | 1.88 | .61 | 1.02 | .52 | .07 | .51 | 7.86 |
| 1922 | .41 | .07 | .08 | .18 | .91 | 2.12 | 1.92 | .65 | .54 | .32 | .57 | .30 | 8.07 |
| 1923 | .19 | .87 | .44 | .22 | .54 | 2.67 | .66 | .75 | 1.25 | .10 | .74 | .36 | 8.79 |
| 1924 | .72 | .29 | .05 | .40 | .46 | 1.56 | 2.17 | 1.67 | .64 | 1.07 | .80 | .70 | 10.53 |
| 1925 | .26 | .21 | .17 | .12 | 1.15 | 1.64 | 1.06 | 1.57 | 2.78 | .94 | .45 | .51 | 10.86 |
| 1926 | .63 | .22 | .25 | .79 | 1.01 | 1.43 | 3.43 | 1.45 | 1.60 | .91 | .12 | .34 | 12.18 |
| 1927 | .32 | .17 | .27 | .49 | 1.03 | 1.42 | 1.07 | 2.45 | 1.71 | .56 | .10 | .81 | 10.40 |
| 1928 | .19 | .38 | .59 | 1.05 | .99 | 1.36 | 2.10 | 2.50 | .66 | .57 | .59 | .36 | 11.34 |
| 1929 | 1.26 | .39 | .28 | .23 | 1.45 | 1.53 | 2.89 | 1.43 | .48 | .97 | .57 | .14 | 11.62 |
| Means | .47 | .35 | .41 | .43 | .85 | 1.52 | 1.81 | 1.90 | 1.28 | .80 | .49 | .47 | 10.78 |

*Snowfall at Eagle, Alaska (inches)*

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1902 | ------ | T. | 2.4 | 10.1 | 0.2 | 0.0 | 0.0 | 0.0 | 3.2 | 8.5 | 14.5 | 7.3 | ------ |
| 1903 | 6.5 | 5.4 | 8.7 | 1.3 | .2 | .0 | .0 | .0 | ------ | ------ | ------ | ------ | ------ |
| 1905 | ------ | ------ | ------ | ------ | .0 | .0 | .0 | .5 | ------ | 30.0 | 7.0 | 10.0 | ------ |
| 1906 | ------ | 1.0 | 11.0 | .0 | .0 | .0 | .0 | .0 | .0 | 4.6 | 8.5 | 1.0 | ------ |
| 1907 | 20.0 | 2.0 | .0 | .8 | .6 | .0 | .0 | .0 | .0 | 13.0 | 4.0 | 7.0 | 47.4 |
| 1908 | 3.0 | .2 | .8 | 1.0 | ------ | .0 | .0 | ------ | 3.0 | 5.0 | 7.0 | 11.0 | ------ |
| 1909 | 2.0 | .1 | 1.0 | 2.0 | .2 | .0 | .0 | .0 | 6.1 | 11.7 | 3.0 | ------ | ------ |
| 1910 | 9.7 | .1 | 4.6 | 3.2 | T. | .0 | .0 | .0 | T. | 4.9 | 3.6 | 4.3 | 30.4 |
| 1911 | 5.3 | ------ | 7.1 | 14.7 | T. | .0 | ------ | .0 | T. | .0 | 9.8 | 20.4 | ------ |
| 1912 | 1.1 | 8.3 | 2.3 | T. | .0 | .0 | .0 | .0 | .0 | 9.6 | 6.0 | 16.9 | 44.2 |
| 1913 | 10.4 | 6.6 | 11.4 | .6 | T. | .0 | .0 | 4.2 | T. | 4.8 | 5.6 | 8.8 | 52.4 |
| 1914 | 4.6 | 5.4 | 9.1 | 5.2 | T. | .0 | .0 | .0 | .8 | 1.2 | 4.6 | 3.4 | 34.3 |
| 1915 | 9.3 | 1.3 | 5.5 | 2.8 | .3 | .0 | .0 | .0 | T. | 3.0 | 9.2 | 22.4 | 53.8 |
| 1916 | 18.1 | 7.1 | 2.0 | 1.5 | 1.2 | .0 | .0 | .0 | 1.0 | 3.1 | 3.5 | 9.2 | 46.7 |
| 1917 | 7.5 | 9.8 | 5.0 | .4 | .6 | .0 | .0 | .0 | 1.8 | 10.8 | 11.4 | T. | 47.3 |
| 1918 | 14.7 | 6.6 | 9.4 | 12.8 | .6 | .0 | .0 | .0 | .0 | 4.9 | 22.4 | 7.2 | 78.6 |
| 1919 | 5.9 | 1.0 | .5 | .3 | T. | .0 | .0 | .0 | T. | 4.8 | 16.1 | 12.9 | 41.5 |
| 1920 | 1.7 | 10.4 | 8.2 | .5 | 2.5 | .0 | .0 | .0 | 13.5 | 12.9 | 6.0 | 9.9 | 65.6 |
| 1921 | 6.1 | 6.8 | 7.0 | 4.0 | T. | .0 | .0 | .0 | .4 | 6.3 | 2.5 | 16.3 | 49.4 |
| 1922 | 8.6 | 1.9 | 1.9 | 3.6 | .0 | .0 | .0 | 2.0 | 2.5 | 5.3 | 12.7 | 7.0 | 45.5 |
| 1923 | 3.4 | 18.0 | 9.1 | 1.4 | 3.0 | .0 | .0 | .0 | .8 | .8 | 10.3 | 9.2 | 56.0 |
| 1924 | 15.2 | 6.8 | 1.5 | 4.8 | 3.2 | .0 | .0 | .0 | .5 | 14.2 | 18.2 | 14.8 | 79.2 |
| 1925 | 5.1 | 2.7 | 3.2 | 1.0 | .0 | .0 | .0 | .0 | T. | 9.1 | 9.5 | 16.0 | 46.6 |
| 1926 | 10.5 | 4.5 | 5.2 | 1.9 | .5 | .0 | .0 | .0 | T. | 6.6 | 2.9 | 10.5 | 42.6 |
| 1927 | 9.5 | 3.3 | 7.2 | 8.1 | T. | .0 | .0 | .0 | T. | 9.1 | 1.7 | 23.5 | 62.4 |
| 1928 | 5.2 | 9.2 | 9.8 | 7.9 | .0 | .0 | .0 | .0 | 7.0 | 8.5 | 12.2 | 8.3 | 68.1 |
| 1929 | 23.6 | 9.8 | 6.5 | 1.6 | .0 | .0 | .0 | .0 | .0 | 10.0 | 11.8 | 4.8 | 68.1 |
| Means | 8.6 | 5.1 | 5.4 | 3.5 | .5 | .0 | .0 | .3 | 1.6 | 7.8 | 8.6 | 10.5 | 51.9 |

The mean precipitation and mean temperature at Eagle have been plotted by months and connected as smooth curves, as shown in Figure 12. The maximum precipitation takes place in August, a month later than the time of warmest weather, and the precipitation curve rises more sharply to its maximum point than does the temperature curve. Nevertheless, the figure shows strikingly that summer is the rainy season and winter the dry season of this district.

## VEGETATION

Spruce, poplar, and white birch are the common trees of this district. White spruce (*Picea glauca*) is the most common tree of this genus and constitutes more than half of the forest growth, but the black spruce (*Picea mariana*) also grows as a small scrubby tree in boggy localities. Two varieties of poplar—the balsam poplar

(*Populus balsamifera*) and American aspen (*Populus tremuloides*)—and the white birch (*Betula neolaskana?*) constitute the three principal deciduous trees. Tamarack or larch (*Larix laricina*) is another deciduous tree that occurs sparingly in this region, but it was not observed in 1930. Willows and alders, though essentially shrubby plants, grow at favorable localities almost to the size of trees. Numerous species of willows are probably present, of which four are listed in the flora tabulated below. Only one species of alder is listed, but others may be present. Another shrubby plant is the

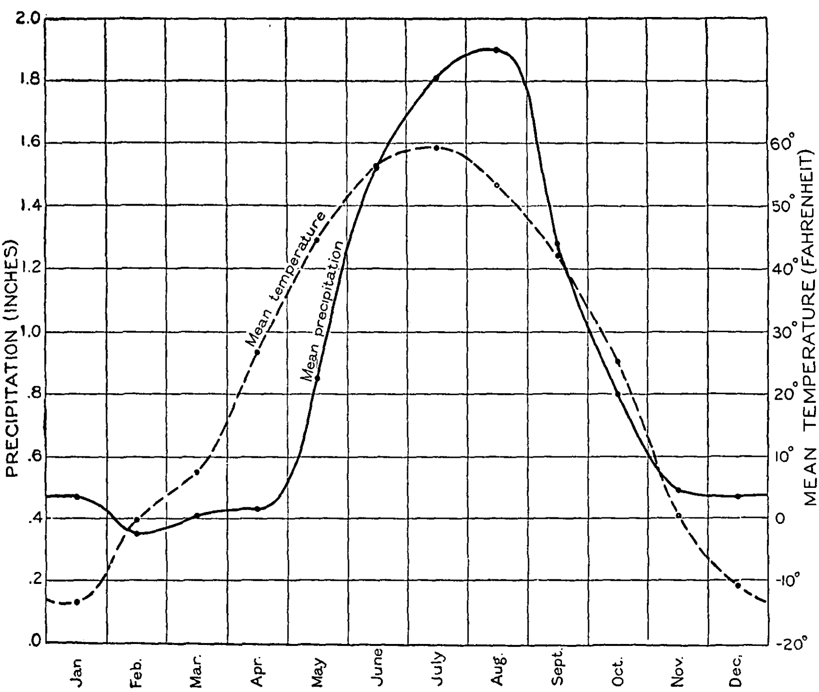


FIGURE 12.—Curves showing mean precipitation and mean temperature at Eagle

scrub birch (*Betula glandulosa*), which forms thickets, particularly on or near the tops of spurs and ridges.

Timber line in this district is about 2,500 feet above sea level, but in the larger valleys and on limestone ridges timber extends up to 3,000 feet. Spruce as much as 18 inches in diameter grows in the larger valleys, such as the Tatonduk Valley, and in the smaller limestone valleys, such as that of Funnel Creek, the spruce is noticeably larger than average size. Farther up on the spurs and ridges, however, the spruce gradually diminishes in height and girth and finally at timber line is little more than brush.

A number of different native wild grasses are found in this district, and some others perhaps have been imported as seed in hay.

In the lower valleys these grasses are usually available for horses by the first week in June, but in late seasons sufficient horse feed may not be available until the middle of June or later. In addition to the grasses horses soon learn to like some of the horsetails (*Equisetum* sp.), of which five are listed below, as well as certain other kinds of vegetation, particularly some of the genera of the pea family (Fabaceae). In general, work horses may subsist on the country in the highland areas from the first week in June to the first week in September.

A number of varieties of wild fruits grow in the country, of which the four most common and most useful are the blueberry (*Vaccinium uliginosum*), the low-bush cranberry (*Vaccinium vitis-idaea*), the red currant (*Ribes triste*), and several varieties of red raspberry (*Rubus* sp.). At Eagle and other places along the river gardens are planted, and all the hardy vegetables, including potatoes, turnips, cabbage, lettuce, beets, rhubarb, carrots, and radishes, are grown without difficulty.

During the season of 1930 a collection of plants was made from this district. This collection was determined mainly by C. V. Morton, of the United States National Museum. Another collection from the entire Yukon Valley was made by A. J. Collier in 1902, and the plants of this collection that were found at or near Eagle were used to supplement the writer's collection. The following composite list, which includes 109 genera and 164 species, is by no means a complete tabulation of the flora of this district but does indicate the plants more commonly found.

*Flora of Tatonduk-Nation district*

Polypodiaceæ (fern family):
- Cystopteris fragilis (Linnæus) Bernhardi. Brittle fern.
- Cystopteris montana Lamarck. Mountain cystopteris.
- Dryopteris fragrans (Linnæus) Schott. Wood fern.
- Dryopteris linnæana C. Christensen. Oak fern.
- Dryopteris robertiana (Hoffmann) C. Christensen.
- Polypodium vulgare Linnæus. Polypody.

Equisetaceæ (horsetail family):
- Equisetum arvense Linnæus. Field horsetail.
- Equisetum palustre Linnæus. Marsh horsetail.
- Equisetum prætense Ehrhart. Thicket horsetail.
- Equisetum scirpoides Michaux. Sedgelike equisetum.
- Equisetum sylvaticum Linnæus. Wood horsetail.

Lycopodiaceæ (club moss family):
- Lycopodium complanatum Linnæus. Ground cedar.

Pinaceæ (pine family):
- Juniperus sibirica Burgsd. Mountain juniper.
- Picea glauca (Moench) Voss. White spruce.
- Picea marianna (Miller) Britton, Stearns, Poggenberg, Black spruce.

Poaceæ (grass family):
- Agropyron repens (Linnæus) Beauvois. Quack grass.
- Bromus pacificus Shear.
- Calamagrostis canadensis (Michaux) Beauvois. Bluejoint grass.
- Calamagrostis purpurascens Robert Brown.
- Deschampsia alaskana L. and M.
- Elymus mollis Trinius. American dune grass.
- Poa prætensis Linnæus. Kentucky bluegrass.
- Trisetum subspicatum (Linnæus) Beauvois. Narrow false oat.

Cyperaceæ (sedge family):
- Eriophorum callitrix Chamisso. Cotton sedge.

Liliaceæ (lily family):
- Zygadenus elegans Pursh. Mountain death camas.

Orchidaceæ (orchid family):
- Cypripedium guttatum Swartz. Lady's slipper.
- Cypripedium passerinum Richardson.
- Habenaria obtusata Pursh. Small northern bog orchis.
- Ophrys borealis (Morong.) Rydberg.
- Orchis rotundifolia Pursh. Small roundleaf orchis.

Salicaceæ (willow family):
- Populus balsamifera Linnæus. Balsam poplar.
- Populus tremuloides Michaux. Quaking aspen.
- Salix arbusculoides Andersson.
- Salix bebbiana Sargent. Beak willow.
- Salix glauca Linnæus. Gray-leaf willow.
- Salix reticulata Linnæus. Net-leaf willow.

Betulaceæ (birch family):
- Alnus alnobetula (Ehrhart) Koch. Green alder.
- Betula glandulosa Michaux. Resin birch or buck brush.
- Betula neoalaskana (?).

Santalaceæ (sandalwood family):
- Comandra livida Richardson. Northern comandra.

Polygonaceæ (buckwheat family):
- Polygonum plumosum Small.
- Polygonum sp.
- Rumex crispus (Linnæus) (?). Curly dock.

Silenaceæ (pink family):
- Alsine longipes (Goldie) Coville. Starwort.
- Arenaria verna Linnæus. Tufted sandwort.
- Arenaria sp. A species not previously known from Alaska.
- Cerastium maximum Linnæus. Mouse-ear.
- Lychnis funstoni W. F. Wight, ined. Very rare.
- Lychnis sp.
- Merckia physodes Fischer.
- Moehringia laterifolia (Linnæus) Fenzl. Blunt-leaved sandwort.
- Silene acaulis Linnæus. Moss campion or carpet pink.
- Silene repens Patrin.

Ranunculaceæ (crowfoot family):
- Aconitum delphinifolium De Candolle. Monkshood.
- Actæa rubra (Aiton) Willdenow. Red baneberry.
- Anemone parviflora Michaux. Northern anemone.
- Anemone richardsonii Hooker. Richardson's anemone.
- Caltha arctica Robert Brown.

Ranunculaceæ—Continued
- Caltha palustris Linnæus. Marsh marigold.
- Delphinium blaisdelli Eastwood. Larkspur.
- Delphinium brownei Rydberg.
- Pulsatilla ludoviciana (Nuttall) Heller.
- Ranunculus lapponicus Linnæus. Lapland buttercup.
- Ranunculus nivalis Linnæus. Snow buttercup.
- Thalictrum sparsiflorum Turczaninow. Meadowrue.

Papaveraceæ (poppy family):
- Papaver nudicale Linnæus. Iceland poppy.
- Papaver sp. A white poppy not previously known from interior Alaska.

Fumariaceæ (fumitory family):
- Capnoides aureum (Willdenow) Kuntze. Golden corydalis.
- Capnoides pauciflorum (Stephan) Kuntze. Few-flowered corydalis.
- Capnoides sempervirens (Linnæus) Kuntze. Pink corydalis.

Brassicaceæ (mustard family):
- Cardamine pratensis Linnæus. Cuckoo flower.
- Cardamine purpurea Chamisso and Schlechtendal. Purple cress.
- Braya humilis (Ledebour) Robinson.
- Cheirinia cheiranthoides (Linnæus) Link. Blistercress or wild wallflower.
- Cheirinia sp. A species not known from Alaska.
- Draba fladnizensis (Linnæus) Regel. Whitlow grass.
- Parrya nudicalis (Linnæus) Regel.

Crassulaceæ (stonecrop family):
- Rhodiola integrifolia Rafinesque-Schmaltz. Roseroot.

Parnassiaceæ (parnassia family):
- Parnassia kotzebuei Chamisso. Kotzebue's grass of Parnassus.
- Parnassia palustris Linnæus. Northern grass of Parnassus.

Saxifragaceæ (saxifrage family):
- Saxifraga nelsoniana D. Don. Saxifrage.
- Saxifraga radiata Small.
- Saxifraga tricuspidata Rottboell. Three-toothed saxifrage.
- Therofon richardsonii (Hooker) Wheelock.

Grossulariaceæ (gooseberry family):
- Ribes hudsonianum Richardson. Hudson Bay or black currant.
- Ribes triste Pallas. Eardrop or red currant.

Rosaceæ (rose family):
- Dasiphora fruticosa (Linnæus) Rydberg. Shrubby cinquefoil.
- Dryas drummondii Hooker. Yellow dryad.
- Dryas integrifolia Vahl. Entire-leaved dryad.
- Geum oregonense (Scheutz) Rydberg. Oregon avens.
- Potentilla anserina Linnæus. Silver weed.
- Rosa acicularis Lindley. Prickly rose.
- Rubus arcticus Linnæus. Arctic raspberry.
- Rubus chamæmorus Linnæus. Bog apple or yellow berry.
- Rubus stellatus J. E. Smith.
- Rubus strigosus Michaux. Red raspberry.
- Spiræa stephenii (C. Schneider) Rydberg. Meadowsweet.

Fabaceæ (pea family):
- Astragalus arestis Douglas.
- Astragalus alpinus Linnæus. Alpine milk vetch or loco weed.
- Astragalus funstonii W. F. Wight, ined.
- Astragalus littoralis (Hooker) Coville and Standley, ined.

Fabaceæ—Continued
- Hedysarum americanum (Michaux) Britton. Sweet vetch.
- Lupinus arcticus Linnæus. Arctic lupine.
- Lupinus nootkatensis. D. Don.

Empetraceæ (crowberry family):
- Empetrum nigrum Linnæus. Black crowberry.

Violaceæ (violet family):
- Viola biflora Linnæus. Bicolor violet.
- Viola palustris Linnæus. Marsh violet.

Elæagnaceæ (oleaster family):
- Lepargyrea canadensis (Linnæus) Greene. Russet buffalo berry.

Onagraceæ (evening primrose family):
- Chamænerion angustifolium (Linnæus) Scopoli. Fireweed or blooming Sally.
- Chamænerion latifolium (Linnæus) Sweet. Broad-leaved willow herb.
- Epilobium sp.

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

Cornaceæ (dogwood family):
- Cornus canadensis Linnæus. Bunch berry.
- Cornus stolonifera Michaux. Red-osier dogwood.

Pyrolaceæ (shinleaf family):
- Moneses uniflora (Linnæus) A. Gray. Wood nymph.
- Pyrola grandiflora Radius. Wintergreen.

Ericaceæ (heath family):
- Andromeda polifolia Linnæus. Bog rosemary.
- Arctostaphylos uva-ursi (Linnæus) Sprengel. Kinnikinic or red bearberry.
- Arctous alpina (Linnæus) Niedenz. Ptarmigan berry.
- Cassiope tetragona (Linnæus) D. Don. Four-angled cassiope.
- Chamædaphne calyculata (Linnæus) Moench. Leatherleaf.
- Ledum groenlandicum Œder. Labrador tea.

Vacciniaceæ (blueberry family):
- Oxycoccus palustris Persoon. Small or European cranberry.
- Vaccinium uliginosum Linnæus. Bog blueberry.
- Vaccinium vitis-idaea Linnæus. Low-bush or mountain cranberry.

Primulaceæ (primrose family):
- Androsace chamæjasme Wulfen. Rock jasmine.
- Trientalis arctica Fischer. Starflower.

Gentianaceæ (gentian family):
- Gentiana propinqua Richardson. Four-parted gentian.
- Gentiana prostrata Hænke. Prostrate gentian.

Polemoniaceæ (phlox family):
- Phlox sibirica Linnæus. Siberian phlox.
- Polemonium acutiflorum Willdenow.

Boraginaceæ (borage family):
- Eritrichium aretioides Chamisso. Moss forget-me-not.
- Mertensia paniculata (Aiton) Don. Bluebell.
- Myosotis alpestris Schmidt. Alpine forget-me-not.

Scrophulariaceæ (figwort family):
- Castilleja pallida Kunth. Paintbrush.
- Castilleja tristis W. F. Wight, ined.
- Lagotis minor (Willdenow) Coville and Standley, ined.
- Pedicularis capitata Adams. Wood betony.

Scrophulariaceæ—Continued
- Pedicularis euphradioides Stephan. Eyebright pedicularis.
- Pedicularis langsdorfii Fischer.
- Pedicularis verticillata Linnæus.
- Penstemon gormani Greene. Beardtongue.

Pinguiculaceæ (bladderwort family):
- Pinguicula villosa Linnæus. Hairy butterwort.
- Pinguicula vulgaris Linnæus. Butterwort.

Rubiaceæ (madder family):
- Gallium boreale Linnæus. Northern bedstraw.

Caprifoliaceæ (honeysuckle family):
- Linnæa borealis Linnæus. Twinflower.
- Viburnum pauciflorum Pylaie. High-bush cranberry.

Valerianaceæ (valerian family):
- Valeriana bracteosa Britton. Valerian.
- Valeriana capitata Pallas.

Campanulaceæ (bellflower family):
- Campanula aurita Greene. Bellflower.
- Campanula lasiocarpa Chamisso. Harebell.

Asteraceæ (aster family):
- Achillea borealis Bongard. Yarrow.
- Arnica alpina (Linnæus) Olin. Arnica.
- Arnica sp.
- Aster sibiricus Linnæus. Siberian aster.
- Chrysanthemum integrifolium Richardson.
- Crepis elegans Hooker.
- Erigeron turneri Greene.
- Erigeron uniflorus Linnæus. Arctic erigeron.
- Saussurea alpina (Linnæus) De Candolle.
- Saussurea monticola Richardson.
- Senecio lugens Richardson. Groundsel.
- Solidago multiradiata Aiton. Goldenrod.
- Tanacetum huronense Nuttall. Huron tansy.

## ANIMAL LIFE

The larger animals native to this district are caribou, moose, bear, and sheep. Caribou as a rule are not plentiful in the early summer, but later in the season they migrate through the country in herds commonly numbering into the thousands and serve as a notable source of food for the white and native population. Moose are also plentiful, though, of course, they are not seen in large herds. Both the black bear and the grizzly live in this district, but the grizzly are less plentiful and more restricted to the mountainous regions. Sheep are rather scarce, but a number of them were seen by the writer in the Ogilvie Range during the summer of 1930.

The fur-bearing animals include fox, lynx, marten, muskrat, weasel, beaver, mink, land otter, wolf, and coyote. Other smaller animals, such as porcupines, rabbits, tree and ground squirrels, and mice are also found.

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The native game birds are ptarmigan and grouse, but during the season of 1930 very few of these were seen. These birds seem to be nomadic and more or less periodically appear in considerable numbers at different localities. In summer, ducks, geese, and other waterfowl are also found along the streams and lakes. Many other kinds of birds may also be seen.

Grayling are found in all the streams, and in some—for example, Hard Luck and Cathedral Creeks—trout were also noted. Salmon run up all the larger streams and are depended upon by the people of this district for dog feed, as well as for table use. Other fish, such as whitefish, pike, pickerel, and lake trout, are also present in the lakes and rivers.

## GEOLOGY

### GENERAL FEATURES

The Tatonduk-Nation district and the neighboring country are believed to present one of the most complete geologic sections of the Paleozoic rocks in Alaska, and in any event, because of the relatively small degree of metamorphism, they certainly yield a great volume of stratigraphic information regarding those rocks. On the accompanying geologic sketch map (pl. 7) 27 geologic units are shown, and it is likely that in more detailed work a number of additional formations might be discriminated.

The sedimentary rocks range in age from pre-Middle Cambrian to Recent, every system except the Jurassic being represented. The oldest pre-Cambrian rocks are a group of metamorphic rocks known as the Birch Creek schist, which lie south of the Yukon River. All the later formations of this district, including a thick sequence of pre-Middle Cambrian sediments and lavas, are little metamorphosed. Igneous rocks of several ages occur in this general region, including granitic rocks of at least three ages and basic rocks of many ages. The Tatonduk-Nation district, however, has relatively few igneous rocks, and the principal ones here discriminated are the lavas of the Tindir group, of pre-Middle Cambrian age.

### BIRCH CREEK SCHIST

The ancient rocks of this part of Alaska have been divided broadly into two units, known as the Birch Creek schist and the Tindir group. The Birch Creek schist, which crops out only in a small area in the valley of Mission Creek, south of the Yukon River, is considered to represent the basal part of the sedimentary sequence. This formation has been described in some detail by the writer[15] in an

[15] Mertie, J. B., jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 14–20, 1930.


GEOLOGIC RECONNAISSANCE MAP OF THE TATONDUK-NATION DISTRICT earlier publication, and a repetition of that description seems unnecessary here. It suffices to state that the Birch Creek schist is a group of highly metamorphosed sedimentary rocks of pre-Cambrian age that are typically developed in large areas between the Yukon and Tanana Rivers. Metamorphic igneous rocks, which may be only in part of pre-Cambrian age, have from necessity been mapped with the Birch Creek schist but are not considered to constitute an integral part of that formation. These metamorphic rocks consist mainly of quartzite, quartzite schist, quartz-mica schist, mica schist, granitic and dioritic gneisses, amphibolite, hornblende schist, and chlorite schist, and whatever their origin may have been, they are now for the most part recrystallized and have either schistose or gneissic structure.

## TINDIR GROUP

### DISTRIBUTION

The Tindir group, which is believed to overlie the Birch Creek schist, is found in an irregular-shaped area that extends from the south side of the Tatonduk Valley northward to the northern limits of the valley of Tindir Creek, and in its widest zone reaches from the international boundary westward into the lower valley of Hard Luck Creek. This group of rocks, therefore, forms the bedrock in an area of about 200 square miles in Alaska and extends eastward for an unknown distance into Yukon Territory.

The uppermost beds of the Tindir group are seen to best advantage along the banks of the Tatonduk River, from a point 5 miles above the mouth upstream for a distance of 4 miles. Here between 6,000 and 7,000 feet of sediments is exposed in nearly monoclinal structure, which permits close examination and fairly accurate measurement. On Hard Luck, Cathedral, Waterfall, and Tindir Creeks the lower beds of the Tindir group are visible, but the rocks are neither so simple in structure nor so continuously exposed as those on the Tatonduk River.

The Tindir group is also exposed along the southwest bank of the Yukon River from the mouth of Fourth of July Creek downstream for 3 or 4 miles, and a band of undifferentiated limestone that is exposed in the low hills to the southwest may also be a part of this group. These rocks are more likely to belong in the lower than in the upper part of the Tindir group.

### LITHOLOGY AND STRUCTURE

*General character of the rocks.*—The Tindir group consists of a great sequence of sedimentary rocks, with which are associated basic lavas of intrusive and extrusive character. The principal sediments are dolomite and limestone, shale, slate, and quartzite, and the igneous members are mainly diabases and basalts of greenstone and hematitic habit. The Tindir group, therefore, unlike the Birch Creek schist, is defined as an assemblage of both sedimentary and igneous rocks. Few of these rocks are recrystallized, and most of them are practically unmetamorphosed.

In the present mapping the Tindir group is divided into four lithologic units, as follows:

1. Massive limestone and dolomite.
2. Red beds.
3. Basic lava flows of greenstone habit.
4. All other rocks, including principally thin-bedded dolomite and limestone, shale, slate, quartzite, and undifferentiated greenstone.

All four of these lithologic units are repeated several times in the section, so that this cartographic classification by no means corresponds to the sequential or stratigraphic order in which these rocks have been deposited. The lithologic classification is here utilized, partly because no topographic base map was available for geologic mapping and partly because the data accumulated in a reconnaissance survey would not permit stratigraphic mapping to be followed consistently throughout this area. In subsequent mapping, on a more detailed scale, it should be possible to utilize a stratigraphic classification.

The general stratigraphic sequence, however, has been fairly well worked out, and in the following descriptions these rocks are discussed in their sequential order. In this area the upper part of the sequence is much better known than the basal part, and therefore it seems best to describe the Tindir group from the youngest to oldest, or in other words, from the best known to the least known. The stratigraphic units at present recognized, arranged from the youngest to the oldest, are as follows:

A. Principally thin-bedded limestone. Top of sequence.

B. Principally siliceous dolomite and shale, with beds of dolomitic conglomerate near the base.

C. Upper red beds, consisting of hematitic dolomite, shale, flint, tuff, and lava, with a red basal conglomerate.

D. Amygdaloidal and ellipsoidal lavas of greenstone habit.

E. Thin-bedded dolomite, shale, argillite, and quartzite, with local beds of more massive dolomite and quartzite. Also basic dikes and sills.

F. Massive magnesian limestone and dolomite. Lowest horizon thus far recognized in Tindir group.

G. Thin-bedded dolomites and argillaceous rocks not unlike those of unit E. Also contains a prominent horizon of lava flows and an equally prominent horizon of red beds.

*Unit A.*—The rocks composing unit A are rather soft and nonresistant to erosion and are nowhere completely exposed. They crop out principally at two localities—one in the valley of Thicket Creek and the other along the north side of the Tatonduk River, just above the mouth of Thicket Creek. In the upper valley of Thicket Creek these rocks consist for the most part of thin-bedded dark-gray limestone, in beds from half an inch to 6 inches thick. Thin-bedded argillite, interbedded with the limestone, constitutes a minor part of the sequence. At or near the bottom of the sequence beds of limestone breccia and limestone conglomerate were seen, both at the head of Thicket Creek and on the spur east of the mouth of the same stream. Also throughout the sequence, but particularly in the upper half of it, thin beds of coarsely crystalline black limestone were observed. This limestone contains black calcite crystals an inch or more in size, and the rock, when broken, always has a strongly fetid odor. Along the Tatonduk River most of these rocks are concealed, but a thickness of about 125 feet of them, in the lower part of the section, is visible in a bluff cut by the river just above the mouth of Thicket Creek. Here they consist of beds of limestone from one-eighth to 2 inches thick, interbedded with a more massive porous cream-colored limestone in beds from 2 to 18 inches thick. A partial analysis of a specimen of this more massive phase of this unit shows that the rock consists of 4.74 per cent of silica, 48.70 per cent of lime, 2.93 per cent of magnesia, with 41.21 per cent of the rock lost by ignition. If the ignition losses are regarded as carbon dioxide, the rock consists of 79.70 per cent of calcite, 13.48 per cent of dolomite, and 4.74 per cent of silica. This rock might be called a magnesian limestone but certainly not a dolomite, and this is one of the main points of difference between the rocks of unit A and unit B. The former are dominantly calcareous, whereas the latter are dominantly dolomitic.

Although the rocks of unit A are nowhere well exposed, they lie between more resistant formations whose limits can usually be recognized, so that the thickness of unit A can be fairly well measured. Three measurements were made—two in upper Thicket Creek and one on the Tatonduk River—from the base of the Middle Cambrian limestone to the top of the dolomites of unit B. The mean of these measurements indicates a thickness of about 1,700 feet.

In the upper valley of Thicket Creek the rocks of unit A strike a little north of west but veer gradually northward in going down Thicket Creek, so that at the Tatonduk River the strike is nearly north. The dip is southward in the zone that strikes east and westward in the zone that strikes north, and the magnitude of the dip ranges from 20° to 35°. The actual contacts between the rocks of unit A and the overlying and underlying formations were not visible, so that evidence of the structural relationship of unit A to the adjoining rocks is lacking. Away from the contact, however, these rocks appear to be concordant in strike and dip with the Middle Cambrian limestone, and all that may be stated with assurance is that they underlie that formation.

*Unit B.*—The rocks of unit B are seen to best advantage along both sides but particularly along the north side of the Tatonduk River, from the east end of unit A upstream for over a mile. Discontinuous exposures may also be seen on the spurs north and south of the Tatonduk River, and in the valleys of some of the tributary gulches, particularly the lower valley of Pass Creek. Along the Tatonduk River the following detailed stratigraphic section was measured by means of a tape traverse.

*Section of beds of unit B*

| | Feet |
|---|---|
| Covered. Computation of thickness made by means of strike and dip, averaged from rocks to east and west. Outcrops of this part of the formation occur along terrace scarps to the north, where the rocks are dolomite and shale | 987 |
| Yellow-weathering dolomite, in beds 1 to 6 inches thick. Specimen of dolomite analyzed (30AMt87) | 19 |
| Sandy shale, weathering yellowish gray, interbedded with very soft dark-gray nodular shale | 13 |
| Covered | 18 |
| Beds of dolomite, 1 to 6 inches thick. with local beds of sandy shale, some of which is so soft that it can not be collected. Specimen of dolomite analyzed (30AMt91). Another phase of the rock is a dolomite which weathers to a yellowish-ocher color and which contains curious nodules of black chert, especially numerous along bedding planes. Specimen of this rock analyzed (30AMt93) | 47 |
| Almost continuous exposures of thin-bedded dolomite (one bed as thick as 14 inches), interbedded with thin-bedded limestone and several varieties of shale, both sandy and argillaceous | 48 |
| Covered, except for one outcrop of yellow-weathering thin-bedded dolomite. One bed of dolomite, 18 inches thick at base of this sequence. Specimen of this bed analyzed (30AMt94) | 173 |
| Conglomerate, in beds 6 inches to 2 feet thick, resting on shale and sandstone and overlain by dolomite bed above noted. Conglomerate has two prominent joint planes, one striking north and dipping 80° E. and the other striking east and dipping vertically. Along the north-south joint plane a calcite seam has been offset 5 inches by slip faulting. Owing to the joints, the conglomerate weathers out in rhombohedra | 7 |
| Dolomite, in beds 4 to 24 inches thick, with very little interbedded shale | 130 |
| For the most part covered, but locally hard dolomite crops out in upper part | 205 |

| | Feet |
|---|---|
| Bed of crumpled nodular shaly sandstone near top, followed downward by a prominent bed of massive grit. Weathering is 1 inch deep in this grit, about five times the normal for these rocks | 18 |
| Dolomite and shale, the shale in part nodular. At base of section occurs a prominent bed of limestone conglomerate, 15 to 18 feet thick, composed of pebbles and cobbles of limestone and dolomite, from a fraction of an inch to 15 inches in size, set in a dolomite matrix. The pebbles and cobbles are mainly subangular, but both angular and well-rounded ones are also present | 29 |
| Nodular shale, alternating with beds of dolomite, probably 40 per cent dolomite. All the shale is nodular; some of the nodules are as large as 12 inches and flat kidney-shaped. The shale is greenish gray and very soft. At the base lies a 3-foot bed of a limestone-shale sedimentary breccia, composed of angular pieces of limestone and shale as much as 2 inches in size, in a shale matrix. A little slickensiding is visible on bedding planes | 117 |
| Alternating beds of dolomite and nodular shale, probably two-thirds shale | 122 |
| Mainly covered but locally outcrops occur. One massive dolomite, of which a specimen was analyzed (30AMt104) | 160 |
| Partly covered. Where exposed, dolomite and nodular shale alternate about half and half. Shaly calcidolomite at base. Specimen analyzed (30AMt105) | 193 |
| Nodular shale and argillite, with a 3-foot and a 2-foot bed of sedimentary grit near top of sequence and a bed of dolomite at base. The grits consist mainly of subangular to rounded grains of dolomite, a little quartz and chert, a few fragments of granite, and some pieces of slate, cemented by a light-brown argillaceous matrix. Nodular shale 15 feet thick overlies the grits, forming the top of this unit | 58 |
| Mainly hard argillite, the rock breaking with sharp angular edges | 42 |
| Conglomerate and grit in a little anticline. Only reversal in monoclinal dip noted in section | 20 |
| Covered. Base of section | 84 |

As shown by this section, many different kinds of rocks make up unit B. These rocks include dolomite, shale, argillite, sandstone, limestone, conglomerate, and grit, with many intergradations. Dolomite and shale, however, compose a large part of this sequence, and unit B is therefore referred to here and elsewhere in this paper as a dolomite-shale unit. The unity of this sequence is emphasized by the abrupt appearance of red beds at its base and by the lithologic differences in the thin-bedded limestone of unit A, which overlies unit B. To show the dolomitic character of the carbonate rocks of unit B, six samples, as noted in the section, were analyzed by J. G. Fairchild, of the United States Geological Survey. The partial analyses of these rocks and their mineral interpretation are given herewith:

*Partial analyses of carbonate rocks of unit B*

| No. of sample | $SiO_2$ | CaO | MgO | Ignition | Sum |
|---|---|---|---|---|---|
| 30AMt87 | 27.77 | 20.33 | 12.80 | 30.85 | 91.75 |
| 30AMt91 | 30.39 | 19.78 | 13.03 | 29.61 | 92.81 |
| 30AMt93 | 37.31 | 8.36 | 6.97 | 19.24 | 71.88 |
| 30AMt94 | 31.06 | 19.17 | 12.88 | 29.34 | 92.14 |
| 30AMt104 | 26.42 | 21.94 | 14.03 | 32.84 | 95.23 |
| 30AMt105 | 29.30 | 25.88 | 7.49 | 27.55 | 90.22 |

The ignition losses were regarded as $CO_2$; the CaO, MgO, and $CO_2$ were recomputed to molecular proportions; and then, by assigning equal parts of CaO to the proportions of MgO, the proportion of the mineral dolomite was obtained. The remaining CaO was computed as calcite. In one specimen insufficient CaO was available to match the MgO, so that a residual quantity of MgO remained to be computed as magnesite. The mineral interpretation of these analyses is given below:

*Mineral composition of carbonate rocks of unit B*

| No. of sample | Silica | Calcite | Dolomite | Magnesite | Sum |
|---|---|---|---|---|---|
| 30AMt87 | 27.77 | 4.30 | 58.88 | ---------- | 90.95 |
| 30AMt91 | 30.39 | 2.70 | 59.94 | ---------- | 93.03 |
| 30AMt93 | 37.31 | ---------- | 27.47 | 2.10 | 66.88 |
| 30AMt94 | 31.06 | 2.00 | 59.25 | ---------- | 92.31 |
| 30AMt104 | 26.42 | 4.00 | 64.54 | ---------- | 94.96 |
| 30AMt105 | 29.30 | 27.50 | 34.45 | ---------- | 91.25 |

Specimens 30AMt87, 30AMt91, 30AMt93, 30AMt94, and 30AMt104 may all be described as siliceous dolomites, as the proportion of calcite in all of them is small. Specimen 30AMt105 may better be described as a siliceous calcidolomite, as the proportions of calcite and dolomite are nearly equal. Doubtless a greater number of analyses would show still other variations, both in the direction of limestone and in the direction of pure magnesite. Exceptionally pure deposits of magnesite were in fact found by Cairnes [16] north of Orange Creek and elsewhere in these pre-Middle Cambrian rocks. It is believed, however, that the carbonate rocks of unit B are essentially dolomitic in character, as opposed to the essentially calcareous character of the carbonate rocks of unit A.

In addition to this chemical feature the analyses also show that the carbonate rocks of unit B are notably siliceous, the silica ranging from 26 to 37 per cent. This characteristic is particularly noticeable in the field, as most of these siliceous dolomites will scratch steel. Moreover, on the ridges, where long residual erosion has bared these

[16] Cairnes, D. D., The Yukon-Alaska international boundary, between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, pp. 112–113, 1914.

rocks, the carbonate minerals are commonly leached from the surface, with the result that such rocks may be mistaken, and in fact have been mistaken by the writer, for sandstones and quartzites.

The rocks of unit B, as shown in the above section, are not continuously exposed along the Tatonduk River but are sufficiently well exposed to give a fair idea of their structure. An average of eight observations in this section gives a mean strike of N. 5° E. and a mean dip of 30° W. Moreover, the variations from this mean dip are not large, and the dip is reversed in direction at only one place, and there for only a few feet along a beach, owing to a minor crumpling. It may therefore be stated with some assurance that the rocks of unit B constitute essentially a monoclinal sequence from top to bottom. A summation of the thicknesses of the members of unit B, as shown in the section above given, indicates a thickness of about 2,500 feet.

At their base, at their contact with the red beds (unit C), these rocks change abruptly in lithology but not at all in structure. At the top of unit B the contact with the overlying rocks of unit A is concealed, but the lowest recorded strike and dip in unit A is practically identical with the mean strike and dip of the rocks of unit B. No basis therefore exists for suspecting any discordance in structure between the rocks of units A and B, and none is postulated.

*Unit C*.—The rocks of unit C represent collectively the uppermost horizon of red beds in the pre-Middle Cambrian sequence. The best exposures are visible along the banks of the Tatonduk River, from the east end of unit B upstream for 2 miles or more. As with unit B, a tape traverse was made, and the following stratigraphic succession of beds was computed from it:

*Section of beds of unit C*

TOP OF SECTION

| | Feet |
|---|---|
| Brownish-red argillite, with gritty phases. One of the gritty beds is composed of angular grains, half an inch or less in diameter, cemented by a red matrix. Under the microscope the component grains are seen to consist of angular fragments of dolomite and siliceous dolomite, agatelike mixtures of dolomite and quartz, small grains of quartz, pieces of slate, and irregular areas of chlorite or serpentine, cemented together by a hematitic argillaceous matrix | 25 |
| Conglomerate composed of rounded to subangular pebbles, half an inch or less in diameter, in a reddish-brown matrix. Pebbles are principally dolomite | 7 |
| Red shale | 3 |
| Conglomerate | ½ |
| Red slate | ⅔ |

| | Feet |
|---|---|
| Conglomerate. Subangular to angular pebbles from a fraction of an inch to 2 inches in diameter, with here and there a cobble as large as 12 inches. Rock fractures across the pebbles. Pebbles appear to be about 75 per cent dolomite and occur in shades from light gray to brown. Next to dolomite chert is the most noticeable material and occurs in various shades of blue, green, red, yellow, and gray. Also a minor proportion of greenstone pebbles. Matrix appears to be mainly siliceous | 15 |
| Red shale with some jasper | 41 |
| Dolomite | 3 |
| Conglomerate, same as that described in detail | 30 |
| In part covered but believed to be mainly a soft red shale | 77 |
| Several varieties of brownish-red rocks, including shale, slate, argillite, and jasperoid material. One specimen of the red argillite is seen under the microscope to be composed mainly of angular grains of dolomite and less quartz, cemented by hematitic argillaceous material. This specimen also shows solution cavities filled by dolomite and replacements of the same material along lines of banding. Another specimen (30AMt115), which was analyzed, seemed to be almost massive hematite, with solution cavities now occupied by dolomite and quartz. The beds range from 1 inch to 1 foot in thickness, the thicker ones usually conglomeratic. Some beds of red shale, particularly in the lower part of this sequence, contain scattered boulders of dolomite as large as 2 feet in diameter, some of which are well rounded and others quite angular | 36 |
| Red beds of different types, including dolomitic, argillaceous and cherty varieties, and also altered lavas. Specimens 30AMt124 and 30AMt125, which were found on microscopic examination to be lavas replaced by hematite, were analyzed. Specimen 30AMt124, which may originally have been an andesite, is a hyalocrystalline rock composed of plagioclase laths in rock glass. The rock is exceedingly fine grained, the feldspars not exceeding 0.2 millimeter in length. The rock glass is now much altered to hematite, and the feldspars are altered to carbonates. Specimen 30AMt125 originally was probably a basalt but is somewhat coarser grained, and its feldspars are completely altered to calcite. It also contains a few grains of angular quartz and some nearly colorless chlorite. This rock may possibly be tuffaceous. One of the sedimentary specimens in this zone was seen under the microscope to consist of angular grains of dolomite, more or less silicified, and a few pieces of hematitic slate, cemented by an opaque hematitic matrix | 393 |
| Discontinuous exposures of red beds of same general character | 447 |
| Red beds, consisting of argillaceous, dolomitic, quartzitic, and cherty types | 223 |
| Conglomerate | 1 |

| | Feet |
|---|---|
| Red siliceous rock. Specimen analyzed (30AMt127). Found by microscopic examination to be fragmental and probably tuffaceous. Consists of angular to subangular as well as rounded grains of glassy igneous rock, probably originally black but now altered almost completely to hematite. The interstitial material is largely dolomite, with some grains of detrital quartz and some almost isotropic pale-green chlorite. The basaltic glass contains here and there laths of calcified plagioclase but more commonly irregular-shaped grains of chloritic and opaloid material | 16 |
| Mottled red and green conglomerate and grit. The gritty material is seen under the microscope to be probably tuffaceous, consisting of subangular to angular grains of several kinds of lavas, both andesitic and basaltic, cemented by a hematitic matrix. The mafic minerals are entirely chloritized, but the lath-shaped feldspars are little altered. The old amygdaloidal cavities, filled with calcite and chlorite, are well preserved. The hematitic matrix is filled with small, irregular-shaped grains of chlorite, calcite, and quartz, part of which probably represent original detrital grains. The matrix varies in opacity according to the amount of alteration to hematite | 2 |
| Red beds exposed on south side of the Tatonduk River and not examined at close range | 240 |
| Red beds. In the lower part of this sequence the beds are folded, and thickness was estimated | 300 |
| Basal red conglomerate. This member of the formation does not crop out on the Tatonduk River but appears on tributaries both to the north and south. On the south tributary this red basal conglomerate lies in a fault zone, and it is doubtful if more than 200 feet of it is exposed. On Funnel Creek, the north tributary, it crops out for about a mile but is so massive that the structure is hard to determine. At this locality the conglomerate was observed by Cairnes,[17] and Cairnes's estimate of 800 feet for its thickness is here used, although the true thickness may be only half that amount | 800± |

The section given above shows that many varieties of rocks compose the red beds. In general, from observations on the hillside exposures, the beds of the lower part of the sequence are inclined to be brownish red, whereas those in the upper part of the sequence are a somewhat brighter red. All these rocks are hematitic, however, and some thin beds of iron ore are present. Argillaceous, dolomitic, cherty, quartzitic, tuffaceous, and igneous varieties compose the sequence, but most of these, except the lavas, are mixed types of rocks. Thus the dolomitic rocks are dolomitic mainly because they are composed largely of detrital grains of dolomite, cemented by a

[17] Cairnes, D. D., op. cit., pp. 91–93.

hematitic matrix, and a similar statement applies to the siliceous and tuffaceous varieties. In general, the red matrix determines the appearance of the rock, and the characters thus observed under the microscope are believed to characterize equally well the coarser-grained conglomeratic members. The cause of the invariable presence of hematite is not known.

Four specimens of the igneous members of the red beds were partially analyzed by J. G. Fairchild, of the United States Geological Survey, with the following results:

*Partial analyses of igneous rocks of the red beds*

| No. of sample | $SiO_2$ | $Fe_2O_3$ | CaO | MgO | Ignition | Sum |
|---|---|---|---|---|---|---|
| 30AMt115 | 54.80 | 26.68 | 4.85 | 2.66 | 6.32 | 95.31 |
| 30AMt124 | 71.66 | 3.84 | 9.90 | 1.45 | 9.66 | 96.51 |
| 30AMt125 | 35.97 | 5.07 | 24.81 | 1.98 | 23.41 | 91.24 |
| 30AMt127 | 43.24 | 5.34 | 21.07 | 2.07 | 17.47 | 89.19 |

Of these specimens 30AMt115 may possibly have been originally of tuffaceous origin, 30AMt124 and 30AMt125 were probably respectively andesite and basalt, and 30AMt127 is a tuff composed of both andesitic and basaltic material. In these analyses $Al_2O_3$, FeO, $Na_2O$, and $K_2O$ were not determined, but the analyses above given account for all but 5 to 10 per cent of the rocks, whereas for basalts these four oxides should comprise from 25 to 30 per cent of the rock. This discrepancy of 20 per cent alone gives some idea of the chemical changes that have taken place. All these rocks have lost considerable MgO and have probably lost also most of their alkaline oxides. Specimen 30AMt115 has evidently been greatly enriched in $Fe_2O_3$, and specimens 30AMt125 and 30AMt127 have obviously acquired CaO in the form of carbonates.

The most interesting feature of these lavas and tuffs is that they are reddish fine-grained rocks that are quite indistinguishable in the hand specimens from the average type of red beds in this section. Only the examination of a large number of thin sections will demonstrate the proportion of igneous material contained in these red beds. However, out of 12 thin sections, picked at random, 2 have proved on examination to be lavas and 1 a tuff. It is possible, therefore, that such rocks constitute an appreciable part of the sequence.

The basal conglomerate is composed of a red to reddish-brown matrix in which is embedded subangular to angular detritus, ranging from the size of pebbles to boulders 2 or 3 feet in diameter. The matrix is hematitic and appears in general to be argillaceous, but, like that of the other red beds, it would probably be found on analysis to be in varying degrees siliceous and dolomitic and perhaps even tuffaceous in part. Most of the pebbles and cobbles are dolomite, but greenstone and chert in minor amounts were also observed. Other conglomeratic material, interbedded with quartzitic and dolomitic beds, is exposed on the spurs along the south wall of the Tatonduk Valley west of the fault zone. This material was previously described by the writer [18] as a part of the upper red beds but is now believed to belong in the basal part of unit B.

The type section of the upper red beds is on the Tatonduk River, although they must also be elsewhere exposed in the Ogilvie Range, farther east in Yukon Territory. At the west end of the section, which is in the upper part of the sequence, the structure is about as uniform as in the overlying rocks of unit B, and the red beds lie in a monoclinal sequence, dipping about 30° W., although upstream the strike veers to the northeast. In the eastern part of the section, at the lower horizons, the rocks depart from a monoclinal sequence, and numerous reversals in dip occur, so that the beds become progressively folded to the east. Also in this zone evidence of thrust faulting is visible, and at one locality a low-angle thrust fault plane, striking N. 20° W., and dipping 20° W., was noticed, with a displacement of 10 feet along the fault plane. For 100 yards east of the most easterly exposures of the red beds no exposures are visible, but the next outcrop to the east shows a tremendously fractured limestone filled with calcite veins, and a quarter of a mile farther up the Tatonduk River the massive Silurian limestone begins and continues upstream. The strike of this limestone is N. 20° E., and the dip 50° NW., so that the limestone appears to dip under the red beds. Without doubt a great fault exists here between the red beds and the Silurian limestone. The trace of this fault has also been observed at other localities in this district, and its sinuosity and other features indicate that it is probably a very old displacement, probably of Mesozoic age but possibly antedating even the Mesozoic diastrophism.

South of the Tatonduk River, on the spurs that form the valley wall, the red beds disappear in a short distance, giving place to the dolomites and associated rocks of unit B; farther south the rocks of unit B are succeeded by those of unit A, which in turn abut against the Middle Cambrian limestone. Thus, either westward down the Tatonduk River or southward across the hills the beds rise upward in the section, from the base of the upper red beds to the base of the Middle Cambrian limestone. Little doubt can therefore exist that the rocks of units A, B, and C, as well as the Middle Cambrian limestone, lie in a plunging anticline, the axis of which strikes in a general southwesterly direction toward the Yukon River. On the

[18] Mertie, J. B., jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 24–25, 1930.

east this anticlinal structure is interrupted by the fault above described.

A summation of the stratigraphic section along the Tatonduk River, not including the 800 feet of basal conglomerate postulated by Cairnes, gives a total thickness for the upper red beds—that is, the rocks of unit C—of 1,867 feet. The measurement, of course, should not be taken as correct to the last two digits, as the available data do not warrant such refinement. In round numbers, therefore, the thickness of the upper red beds is about 1,800 feet, to which should be added the estimated thickness of 800 feet for the underlying conglomerate. The thickness of this conglomerate may possibly not exceed 400 feet, but reliable data on this point are lacking. The total thickness of the upper red beds therefore lies between 2,200 and 2,600 feet.

A few outcrops of rocks that are believed to be the equivalent of the upper red beds of the Tatonduk River occur in the valley of Hard Luck Creek, at the northwest side of the Cambrian limestone. These exposures are rather insignificant in area and are exaggerated on the geologic map in order to be shown. These red beds are believed to lie in a fault zone similar to the one on the Tatonduk River and supply no additional lithologic or structural data. Their significance lies in the fact that they are interpreted as a connecting link between the rocks of unit C and those of unit D, which crop out downstream from this point on Hard Luck Creek.

Some scattered exposures and float of red beds, thought to belong to unit C, are also visible in the valley of Pass Creek, a tributary of the Tatonduk River, but no details are known as to their structure or extent.

*Unit D.*—The type locality of the rocks of unit D is a narrow belt that crosses Hard Luck Creek and the lower end of Pleasant Creek. Similar rocks that may lie at the same stratigraphic horizon were seen along the southwest side of the valley of Hard Luck Creek and also in a belt that crosses Pass Creek.

The rocks of unit D consist entirely of basic lavas and associated pyroclastics, the petrographic character of which is set forth in the description of the igneous rocks of this area. In the type locality, on Hard Luck and Pleasant Creeks, these rocks seem to consist at the top of volcanic conglomerate that grades downward into massive lava flows. The upper beds consist of subangular pebbles and cobbles of lava in a matrix of lava and tuff. The underlying flows are mainly amygdaloidal lavas of greenstone habit, and some of them are also ellipsoidal in character. In the hills north of this zone of lavas the older rocks of unit E are exposed, and these are cut by numerous basaltic dikes of greenstone habit that doubtless were the sources of supply for the lavas of Hard Luck Creek. These dikes weather to a yellowish-red color and give a pronounced yellowish discoloration to the upper beds of unit E.

Along the southwest side of Hard Luck Creek a group of hills lies between Hard Luck Creek and one of its tributaries that enters from the southwest. These hills appear to be composed entirely of igneous rock, ranging from a dense hard basaltic greenstone through amygdaloidal greenstone to a volcanic agglomerate. All these rocks weather reddish gray to brown and give a pronounced brownish color to these hills. The amygdaloidal material, as well as the agglomerate, appears to increase toward the top of these hills and at one point near the top well-marked pillow lavas were seen.

Lava flows that probably belong to unit D are particularly well exposed in Pass Creek for a distance of three-quarters of a mile or more. Here the individual flows appear in general to be from 3 to 6 feet thick, and many of them consist entirely of masses of ellipsoids, some as large as 3 feet in diameter. At one locality, near the southern limit of the lava in Pass Creek, a bed of lava 75 feet thick is visible, with ellipsoids as much as 12 feet in diameter. Although the bedding of these lava flows is easily recognizable, the observed presence of faulting serves to complicate any interpretation of the structure, and as these flows are not continuously exposed in Pass Creek, the presence of unobservable faults is possible. When due allowance is made for these features, the thickness of the lava flows on Pass Creek is believed to be about 1,000 feet, but this is only an estimate and is not comparable in accuracy with the measured thicknesses given for units B and C.

In a broad way, the lavas that form unit D are considered to inclose the end of the plunging anticline previously described. On Pleasant Creek these lavas strike N. 75° E. and dip south, thus plunging under the Upper Cambrian sequence and also under the small fragment of red beds exposed in Hard Luck Creek, just above the mouth of Pleasant Creek. A great fault has certainly removed from the surface all the rocks of units A, B, and most of C, which should here lie between the lavas and the Upper Cambrian sequence. But the fault, at this particular locality, is a strike fault and has not disturbed the relative attitude of the neighboring formations in any great measure. The similar attitude of the Cambrian and underlying rocks is therefore interpreted to indicate that the lavas do in fact underlie the pre-Middle Cambrian sequence, and the fragment of red beds on Hard Luck Creek, at the mouth of Pleasant Creek, with the same general attitude, is interpreted as furnishing evidence that the lavas of unit D also underlie the red beds of unit C, although the contact between units C and D is a part of this same zone of faulting. The presence of pebbles of greenstone in the conglomerate of the upper red beds also constitutes good evidence that these lavas are older than the upper red beds. None of this evidence, however, proves that the lavas of unit D directly underlie the upper red beds without the presence of intervening strata, and with the exposures available in the Tatonduk-Nation district the answer to this question seems indeterminate at the present time.

No additional structural evidence for the stratigraphic position of the lavas of unit D is available in the brownish hills along the southwest side of Hard Luck Creek. In the valley of Pass Creek the stratigraphic position of the lavas is quite enigmatical. These lavas dip westward and thus might be interpreted to overlie the upper red beds and to underlie the dolomites and shales of unit C. But the lavas of Pass Creek lie also in a zone of faulting, and their apparent stratigraphic position must to a large extent be discounted. Furthermore, on the Tatonduk River, where there is a regular monoclinal sequence of beds, no trace of a sheet of lava was seen between the rocks of units C and D, and no igneous material was observed in the basalt, grit, and conglomerate of unit C. Therefore the presence of the lavas in Pass Creek is explained as a phenomenon of faulting. The same faulting that produced this anomaly probably cut off the northward-trending Middle Cambrian limestone, which crosses the Tatonduk River just west of the mouth of Pass Creek but does not continue northward into the valley of Hard Luck Creek. In all probability, one or more ancient faults with sinuous traces are present in the valley of Pass Creek and result in the same abrupt terminations of formations as illustrated in the abuttal of the upper red beds against the Silurian limestone on the Tatonduk River.

*Unit E.*—The rocks of unit E occupy most of the area between Trail and Cathedral Creeks and extend thence southwestward in the direction of the Yukon until they are overlapped by the Nation River formation. The only place where anything approximating a continuous section may be observed is in the valley of Hard Luck Creek, from the west side of the lavas of unit D downstream for several miles. These rocks consist for the most part of thin-bedded dolomite, shale, argillite, and quartzite, with a few beds of more massive dolomite and quartzite, intruded by basic dikes and sills. No continuous section, comparable with that on the Tatonduk River, is exposed, but the general sequence and structure may be thus summarized: Beyond the lava beds, below the mouth of Pleasant Creek, there appears downstream a thin-bedded dolomite interbedded with black shale. This shale is very soft, apparently nonsiliceous, and in many places is covered by yellow stains produced by salts leached from within. Next appears a ledge of massive, crushed white dolomite, followed by black shale. The strike of all these rocks ranges from N. 60° E. to due east, and the dip ranges from 20° to 70° S., so that the older rocks appear progressively downstream. About a mile and a half below Pleasant Creek another ledge of light-gray dense, finely crystalline dolomite is exposed on the north bank, underlain by dolomite conglomerate. Below this ledge occurs more thin-bedded dolomite and shale, followed by much dolomite and dolomite conglomerate in thick beds. In the beds last mentioned, which occur about 3 miles below Pleasant Creek, the dip reverses to north, and black shale again is seen. Within the black shale the dip again changes to south and continues thus, so far as the intermittent exposures show, to the mouth of Cathedral Creek. In this area the outcrops consist mainly of shale, interbedded locally with dolomite and dolomite conglomerate. Much of the shale is black and carbonaceous and commonly coated with the sublimate above mentioned. This material, which varies from yellow to white, was tested by J. G. Fairchild, of the Geological Survey, and was found to consist of hydrous sulphates of ferrous and ferric iron, aluminum, and magnesium. Numerous dikes and sills also cut this part of unit E, and at one locality, on Hard Luck Creek, a sill about 20 feet thick has been faulted across the strike, resulting in a displacement of about 40 yards. The interbedded dolomite is hard and siliceous and grades into beds of true quartzite. The dolomite conglomerate has a dolomitic matrix, in which are set pebbles and cobbles of the same material, some as much as 8 inches in diameter. Many of these pebbles and cobbles are well rounded, and nearly all show some water action. One bed of dolomite conglomerate about 20 feet thick was noted.

No rocks from the valley of Hard Luck Creek were studied chemically, but one specimen from the same sequence of rocks taken on the divide west of Pleasant Creek was partially analyzed by J. G. Fairchild, of the United States Geological Survey. This analysis and its mineral interpretation are given below.

*Carbonate rock from unit E (Specimen 30AMt151)*

| | |
|---|---|
| Partial analysis: | |
| $SiO_2$ | 10.52 |
| CaO | 27.27 |
| MgO | 18.46 |
| Loss on ignition | 41.62 |
| | 97.87 |
| Mineral composition: | |
| Silica | 10.52 |
| Calcite | 2.60 |
| Dolomite | 84.91 |
| | 98.03 |

This rock is obviously a siliceous dolomite and is probably representative of many of the carbonate rocks of this sequence.

The only exposures of unit E in Cathedral Creek are found near its mouth, where the stream has cut a narrow gorge about half a mile long through hard, massive rocks. From the mouth of Cathedral Creek upstream the rocks are successively dolomite and dolomite conglomerate, quartzite, more dolomite conglomerate, quartzite, and finally, at the upper end of the canyon, dolomite conglomerate. The sequence up the canyon is from older to younger rocks. Some of the dolomite conglomerate beds are 20 feet or more thick, and boulders of the same material as much as 2 feet in diameter were noted. A system of joints that strike north and dip 55° W. is a prominent feature of these massive rocks.

Below the mouth of Cathedral Creek the valley of Hard Luck Creek is wider and exposures are less continuous. About 1½ miles below Cathedral Creek the valley of Hard Luck Creek becomes constricted as the stream cuts through a massive dolomite, which is probably the continuation of the massive rocks that make the lower canyon of Cathedral Creek, but downstream from this locality the bedrock appears from intermittent exposures to be graphitic shale interbedded with thin beds of dolomite. In this area the strike and dip become quite variable, and numerous reversals in dip probably occur.

Notwithstanding the irregularities in structure above noted, in a broad way the structure of the rocks of unit E on Hard Luck Creek is probably monoclinal, with older rocks appearing progressively downstream. Irregularities in strike and dip and lack of continuous exposures, however, make it difficult to arrive at any satisfactory estimate of the thickness. The minimum distance normal to the strike from the lavas of unit D to the massive carbonate rocks of unit G is 4½ miles; and if the average dip of these rocks is 45°, it follows that 16,800 feet is the maximum possible thickness. This figure, of course, is only approximate, as no account is taken of faulting, reversals in dip, and other factors which would tend to diminish the amount. The best estimate that can be made at the present time is that about 10,000 feet of sediments are represented by the rocks of unit E.

*Unit F.*—A part of the rocks of unit G is believed to intervene stratigraphically between units E and F, but as the rocks of unit F abut against those of unit E and are the next exposed downstream on Hard Luck Creek, they are described here before those of unit G. The rocks of unit F may be described as magnesian limestone and dolomite, without notable admixture of other types of sediments. These rocks crop out as a discontinuous belt, which extends from the head of Waterfall Creek, on the international boundary, southwestward along the north side of Cathedral Creek and cross Hard Luck Creek. At the boundary the repetition of beds by folding has widened this belt to 7 miles, but in general the width is about a mile.

These carbonate rocks are made up of both thick and thin beds, but the thin-bedded and laminated types are more characteristic than the massive beds, and even the more massive varieties cleave into thin slabs. The color is chiefly cream, buff, or light yellow, which gives a yellowish aspect to the hills of moderate height composed of these rocks, in contrast to the bluish-white color of the Paleozoic limestones, when viewed from a distance. The thin-bedded character also results in the development of less rugged crest lines and smoother slopes than those of the Paleozoic limestones. In the highest mountains of the Ogilvie Range, however, these carbonate rocks at a distance look quite like the Paleozoic limestones, and no distinction can be made except by actual examination of the rocks.

Although these rocks are believed to be mainly magnesian limestone and dolomite, variations occur. Some of them, for example, are much silicified, at some places forming siliceous beds, whereas at other places irregular blocks of siliceous limestone or even quartzite are found. Some of these more silicified varieties look very much like the Middle Cambrian limestone. Thus along the northwest side of Cathedral Creek, opposite the "bend," these limestones form a group of pinnacles along the ridge, called "Three Castle Mountain" by the writer. The limestone at and about "Three Castle Mountain" occurs largely in massive beds as much as 15 feet thick, which in places are much silicified and grade into white quartzite. These rocks resemble the basal part of the Middle Cambrian limestone more than the thin-bedded limestone of unit G and were in fact classified as part of the Tindir group more on account of their geographic position and apparent lack of fossils than for more cogent reasons.

Carbonate rocks that are believed to be a part of unit F also occur in an outlying area in the valley of Waterfall Creek. This area is about 2½ miles long and from a half to two-thirds of a mile in width and trends northeast. At its southwest end it includes the boundary topographic station known as "Nation," and it extends northeastward for an equal distance on the other side of Waterfall Creek. The rock exposed at "Nation" is a light-gray white-weathering magnesian limestone, in which the bedding is pronounced, ranging from a fraction of an inch to a foot in thickness. In places, however, the rock is much shattered and shows no bedding. Another phase of this limestone, which occurs farther down the southeast slope from "Nation," is a very dark, coarsely crystalline thin-bedded variety. In the valley of Waterfall Creek, where this belt of limestone crosses the creek, somewhat more massive limestone is exposed, but none of it appears to occur in very thick beds.

The structure of this massive limestone member of the Tindir group is only partly determined. Along the international boundary it is likely that these beds are much folded, to produce the considerable area of limestone there seen. Between this mass of limestone and the narrower belt that lies northwest of Cathedral Creek a belt of other rocks, probably a part of unit E previously described, is exposed. The dip of the limestone northwest of Cathedral Creek and also that of the outlying band in the valley of Waterfall Creek is northwestward and therefore in the opposite direction from that of most of the rocks of unit E, on Hard Luck Creek. The fact that this limestone belt is not in general duplicated to the northwest or southeast inhibits an interpretation of anticlinal or synclinal structure and leads more by elimination than otherwise to the idea that a zone of faulting may be present along the southeast side of unit F. This idea is further emphasized by the highly disturbed state of the rocks of unit E, on Hard Luck Creek, just southeast of the limestone belt. Also, Cairnes[19] has shown on his geologic map a major thrust fault between Cathedral and Tindir Creeks, by which one group of rocks has been thrust 6 miles over another group. The southwestward continuation of this fault may extend down the northwest side of Cathedral Creek. These considerations lead to the tentative conclusion that the rocks of unit F are not only older but probably considerably older than those of unit E, although their dip appears to place them stratigraphically above the rocks of unit E.

As the structure of unit F is only imperfectly understood, any estimate of the thickness of this unit is subject to a similar degree of uncertainty. The dip of this limestone along the northwest side of Cathedral Creek appears to be about 15° NW., so that with a width of about a mile for the limestone belt the thickness would be 1,370 feet. Such a measurement is probably accurate only to the thousands place, and the writer merely asserts that not less than 1,000 feet of sediments are represented in unit F.

*Unit G.*—The rocks of unit G are the least known of all those of the Tindir group thus far described, and in one sense this unit is a catchall for those rocks of the Tindir group that have not yet been described. Such rocks are best exposed on Hard Luck Creek and some of its westward-flowing tributaries and on Waterfall Creek, but the sections are not exactly comparable at the different localities. Unit G may be divided lithologically into three subunits, the

[19] Cairnes, D. D., op. cit., map 140-A.

stratigraphic relations of which to one another have not been completely discerned. These three subunits are as follows:

G–1. A group of thin-bedded dolomites and argillaceous rocks that are not essentially dissimilar to the rocks of unit E.
G–2. A notable horizon characterized by basic lava flows.
G–3. A horizon characterized by red beds.

As the exposures of subunit G–1 are not particularly good, and as these rocks resemble so closely those of unit E, no further description or discussion of them seems warranted. Similarly, the lavas of subunit G–2 appear to be identical petrographically with those of unit D. Subunit G–2, however, appears from the area covered by its rocks to represent an extensive area of ancient surficial volcanic action. The type locality is on lower Hard Luck Creek, 5 or 6 miles below the mouth of Cathedral Creek. Basic lava of greenstone habit is here found on both sides of Hard Luck Creek and covers a known area of about 8 square miles. The lavas at this horizon are amygdaloidal, at places ellipsoidal, and appear to strike about N. 75° E. Another area of basic volcanic rocks is found on Waterfall Creek and extends southwestward at least as far as a prominent hill called by the writer "Little Nation." Much of this lava is fine-grained and partly glassy and is assuredly surficial in character. It is in contact with the red beds of G–3, both on Waterfall Creek and around "Little Nation," and is believed to underlie these red beds.

Subunit G–3, which contains the red-bed horizon of unit G, seems worthy of particular description. These rocks are seen to best advantage in the gorge of Waterfall Creek, about 6 miles below the international boundary. The most easterly of these rocks on Waterfall Creek consist of thin beds of reddish-brown to almost black slate, interbedded with beds as much as 1 foot in thickness of more massive black rock. The slates are siliceous and hematitic, but the more massive rocks effervesce slightly when treated with hydrochloric acid and are therefore probably dolomitic as well as siliceous and hematitic. These rocks are generally similar to those of unit C, except that they are much more indurated. The strike of these rocks, at the east limit of unit G–3, is N. 75° E., and the dip is 75° S. Downstream from these rocks occurs more reddish-brown slate, interbedded with perhaps 10 per cent of blue and green slate. These rocks strike N. 60° E. and stand vertical, with a well-developed cleavage that strikes N. 15° E. and dips 15° W. Along these cleavage planes, the bedding lamellæ are intricately appressed into small recumbent folds, as illustrated in Figure 13. A distance of 50 yards farther downstream red and blue slate crop out in thin alternating bands. The blue slate is blue only on a fresh fracture; the weathered surfaces are a dirty green. The bedding here strikes N. 60° E. and dips 75°

SE. The banded slate then gives place to red slate, which continues on downstream for a quarter of a mile and then changes rather suddenly to a massive dark-green rock in beds 8 to 10 feet thick, which is followed downstream by a massive grit. The massive dark-green rock is the fine-grained lava above described. The grit may be a part of the Nation River formation, although it is unlike the grits usually found in that formation.

Below the lavas of subunit G–2, on Hard Luck Creek, different rocks of unit G are exposed in places downstream for about 1½ miles, at which point the whole formation is overlapped by the Nation River formation. Within this stretch, about half a mile downstream from the lava, red beds that strike N. 60° W. and stand vertical crop out on the northeast side of Hard Luck Creek in a prominent bluff. These red beds appear to be hematitic dolomites

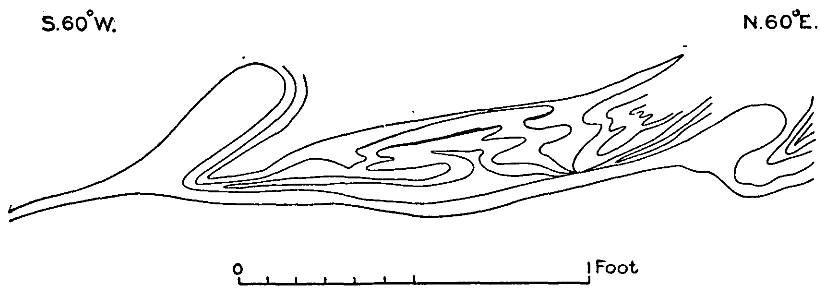


FIGURE 13.—Appressed folding in slates of Tindir group on Waterfall Creek

and shales. On lower Hard Luck Creek, however, just downstream from the Tahkandit limestone, the rocks of unit G again crop out in a bluff along the southwest side of the valley. These rocks consist of thin-bedded dolomite and calcareous shale, minutely laminated. These rocks are considerably disturbed, but one measurement indicated a strike of N. 45° E. and a dip to the southeast. Along the stream appears a limestone conglomerate, consisting of angular pieces of limestone several inches or less in diameter in a limestone matrix. The upper part of the bluff above referred to is formed of fine-grained basalt of greenstone habit. No amygdaloidal, ellipsoidal, or tuffaceous phases of this rock were seen, nor were any definite bedding planes identified, but the fine-grained character of such a large mass of basalt suggests that this rock may be a flow. Still farther downstream stand two more prominent bluffs, which are the last exposures on lower Hard Luck Creek. Both these bluffs consist of red beds that show much shearing and granulation, together with considerable fault breccia. Also in the creek opposite these bluffs the red beds that crop out strike N. 70° E. and dip 15° N., and both blue and red slates are there visible. Here, as on Waterfall

Creek, a sheet of lava appears to underlie a well-marked zone of red beds, and the writer is strongly inclined to correlate the two occurrences.

Rocks which may also be correlated with unit G crop out along the southwest bank of the Yukon River below the mouth of Fourth of July Creek. Just below the mouth of Fourth of July Creek a silicified oolitic dolomite appears and is succeeded downstream by a magnesian limestone conglomerate that consists of rounded pebbles of limestone in a limestone matrix. Still farther downstream thin-bedded, more or less silicified dolomite, in beds from half an inch to 5 inches thick, crops out along the river bank. This rock consists of alternating thin beds of black and white dolomite, and in places these beds show 50 laminæ to the inch. All these rocks are silicified to a greater or less degree, but no true cherts were seen. The general strike of these rocks is N. 55° W., with a variable dip to the southwest. These rocks were previously described by the writer [20] as undifferentiated Paleozoic rocks but are now believed to be a part of the Tindir group.

The structure of the rocks of unit G is the least understood among the units of the Tindir group. Some of these rocks are believed to lie above the horizon marked by the massive limestone of unit F. On the other hand, the rocks of unit E are also believed to overlie the rocks of unit G, and the problem of the proper correlation of units G and E immediately arises. No satisfactory answer to this problem has been obtained, but the following data have a bearing on the question.

1. Thin-bedded dolomites and shales occur both in units E and G and resemble one another so closely that no lithologic discrimination can be made.

2. Unit G is characterized by one or more horizons marked by lava flows, whereas unit E is not so characterized, unless the lava hills south of the mouth of Cathedral Creek be interpreted as a part of unit E.

3. Unit G is characterized by one prominent zone of red beds, with indications, both on Hard Luck and Waterfall Creeks, that less conspicuous beds of similar material may also be present at other horizons. No red beds, on the other hand, were observed among the rocks of unit E.

4. The lower red beds, both on Hard Luck and Waterfall Creek, are the farthest or nearly the farthest removed, among the rocks of unit G, from those of unit F.

Consideration of these data leads to the inference that the rocks of unit G are not in general correlative with those of unit E, but it

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[20] Mertie, J. B., Jr., op. cit., pp. 32–33.

by no means follows that these two units may not be in part correlative. The rocks of unit G, as shown on Plate 7, are in considerable measure overlapped by Carboniferous rocks, so that much of their structure is hidden. Also, the rocks of this group are the nearest of those studied to the Nation River flats, so that the rocks are more poorly exposed in these lower hills than those at the higher horizons of the Tindir group. Hence any estimate of thickness is subject to many uncertain factors that can not be properly evaluated. An estimate that the rocks of unit G are about as thick as those of unit E is as much and perhaps more than is really warranted.

In summary, it appears that the rocks of units A, B, C, D, E, and F together have an aggregate thickness of 18,600 feet, and to this amount must be added an unknown part of the thickness of unit G. The best estimate that can be made at present of the thickness of the Tindir group, as exposed in the valley of the Tatonduk River and in Hard Luck and Waterfall Creeks, is that between 20,000 and 25,000 feet of strata are there exposed.

### AGE AND CORRELATION

The rocks here designated as the Tindir group are believed to have a wide distribution in the Yukon-Porcupine region, and only a start has yet been made in the study of their lithology and structure. These rocks were first observed in 1888 by McConnell[21] along the upper ramparts of the Porcupine River, both above and below the international boundary. McConnell described these rocks on the American side of the boundary as alternating bands of shale, slate, limestone, dolomite, and quartzite but was unable to make any suggestion regarding their possible age.

These rocks were next studied in 1907 by Kindle, in connection with a geologic exploration of the Porcupine River. Kindle[22] estimated that a minimum thickness of 50,000 feet of these rocks was present in the vicinity of the international boundary but thought it probable that a much greater thickness might be present. Kindle also recognized a Middle Ordovician (Mohawkian) limestone in the Porcupine section, and by a process of elimination rather than by the study of structural data he placed the rocks now designated as Tindir under the Ordovician limestone. The term pre-Ordovician was used to describe these older rocks, but the data at hand showed only that they were not younger than Middle Ordovician.

[21] McConnell, R. H., Report on an exploration in the Yukon and Mackenzie Basins, Northwest Territories: Canada Geol. and Nat. Hist. Survey Ann. Rept., vol. 4, pt. D, pp. 129–132, 1891.

[22] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, pp. 320–322, 1908.

During the summer of 1911 Maddren [23] continued the study of these pre-Middle Ordovician rocks along the international boundary north of the Porcupine River. He also recognized a group composed of quartzite, phyllite, and slaty shale, which he considered to be of pre-Ordovician age.

The section south of the Porcupine was studied by Cairnes [24] in 1911 and 1912, and it was Cairnes who proposed and used the designation Tindir group, by which these older rocks are now known. Cairnes found the rocks of the Tindir group widely distributed along the boundary between latitude 66° 5′ and 66° 45′, and also in the area here described as the Tatonduk-Nation district. His description of the lithology of this group of rocks is excellent, but the exigencies of the work in which he was engaged made it impossible for him to obtain adequate structural data on which to base an estimate of the total thickness of the group. Cairnes estimated in the Porcupine section a minimum thickness of 5,000 feet and farther south, along the boundary, a minimum thickness of 6,000 feet, but at both places he believed that the thickness might be considerably greater than these amounts. His best evidence for the age of the Tindir group was obtained in the area north of Jones Ridge, where he believed that the Tindir group underlay unconformably the Cambrian limestone of Jones Ridge. The fossils collected by Cairnes from Jones Ridge were determined as Upper Cambrian in age, but one of his other collections, which was made 10 miles south of Jones Ridge, was stated by L. D. Burling [25] to be possibly as old as the upper part of the Middle Cambrian. On the basis of these paleontologic data and other data that he deduced from the geologic structure at Jones Ridge, Cairnes designated the Tindir group as pre-Middle Cambrian in age. Collections made by the writer in 1930 show that the limestone composing Jones Ridge is of Ordovician and Upper Cambrian age, and it is now believed that no Middle Cambrian limestone is present on or about Jones Ridge. Hence, on the basis of the biologic evidence available at Jones Ridge, the Tindir group can not be designated as older than pre-Upper Cambrian.

On the Tatonduk River, however, a different condition prevails. There Middle Cambrian rocks that are believed to underlie the limestone of Jones Ridge have been identified. The Tindir group, as shown in the preceding discussion and sections, definitely underlies these Middle Cambrian rocks and can not therefore be younger than Middle Cambrian in age. No unconformity was observed,

[23] Maddren, A. G., Geologic investigations along the Canada-Alaska boundary: U. S. Geol. Survey Bull. 520, pp. 300–309, 1912.

[24] Cairnes, D. D., op. cit., pp. 44–58.

[25] Idem, p. 63.

however, between the Middle Cambrian rocks and the underlying rocks of the Tindir group. On the contrary, the trend of these two groups of rocks appears in general to be parallel, so that the structural evidence does not suggest the designation of pre-Cambrian for the Tindir group. There is a marked change in lithology, however, and the rocks of the Tindir group appear to be entirely unfossiliferous. Well-preserved and diagnostic fossils are far from plentiful in the Middle Cambrian limestone, but in almost all places where this limestone is exposed some remains of organisms, commonly imperfect but nevertheless recognizable, may usually be found. This condition is in marked contrast to the universal absence of organic remains in the underlying Tindir group and leads to the conclusion that a marked stratigraphic hiatus exists between the Middle Cambrian limestone and the Tindir. Although this evidence is too weak to justify the definite appellation pre-Cambrian for the Tindir group, it does justify the designation pre-Middle Cambrian, and the writer is inclined to the opinion that these rocks are probably of Algonkian age.

## CAMBRIAN SYSTEM

### DISTRIBUTION

Both Middle and Upper Cambrian rocks are present in the Tatonduk-Nation district. The Middle Cambrian rocks crop out about a mile north of the boundary topographic station "Chief" and from this place extend in a narrow belt westward to "Crow," and thence northward to the Tatonduk River. The Upper Cambrian rocks lie in a large mass to the northeast, east, and southeast of "Chief," and continue thence southeastward into Yukon Territory. The Upper Cambrian rocks also crop out in a crescentic arc, which starts at Jones Ridge, veers southwestward and southward, and thence extends southeastward to include topographic stations "Hiyu," "Skook," and "Squaw."

### LITHOLOGY AND STRUCTURE

The Cambrian may be divided tentatively into the following sequence:

1. Upper Cambrian limestone, which grades upward without any noticeable stratigraphic or lithologic break into Ordovician limestone.
2. Upper plate of Middle Cambrian limestone.
3. A thin formation of slate and quartzite, also of Middle Cambrian age.
4. Lower plate of Middle Cambrian limestone.

The Middle Cambrian sequence was recognized by the writer in 1925 in the high bluffs along the north side of the Yukon River about 4 miles downstream from Calico Bluff and was described in part in an earlier publication.[26] Perhaps the best exposures of the lower plate of the Middle Cambrian limestone are along the eastward-striking ridge that forms the divide between the Tatonduk River on the north and Shade Creek and the Yukon on the south. For some distance along this ridge, particularly at the head of Thicket Creek, the lower Middle Cambrian limestone forms a southward-dipping hogback that exposes the base of the limestone. The top of the limestone continues on down the slopes to the south and is concealed in timber. In this vicinity the lower Middle Cambrian limestone is for the most part a massive white finely crystalline rock. Some of it appears to be a purely carbonate rock, but most of it is silicified to a greater or less degree. The silica occurs at some places in the form of chert but more commonly in the form of quartz, and some of the rock is so greatly silicified that it resembles a granular white quartzite more than a limestone. Oolitic limestone also forms a part of the lower Middle Cambrian limestone, but this type of rock is more prevalent in the upper plate of the Middle Cambrian limestone. Still another variety is the limestone conglomerate, composed of subangular to rounded pebbles of limestone in a limestone matrix. Both the oolitic limestone and the limestone conglomerate are also partly silicified, and this infiltration of chert and quartz lends further diversity to the lower Middle Cambrian limestone.

Where the lower Middle Cambrian limestone crosses the Tatonduk River this formation has been faulted and materially altered, so that its appearance here is somewhat different from that seen at the head of Thicket Creek. On the Tatonduk River this limestone outcrop forms a prominent bluff along the north bank, where it is a white to light cream-colored, massive and medium to coarsely crystalline rock. In addition, it is greatly fractured and silicified and in places is thoroughly permeated with secondary quartz. Similarly, on the south wall of the Tatonduk Valley, west of Thicket Creek, the lower Middle Cambrian limestone shows the same fractured character, although the varieties above mentioned may on close examination be easily identified. The thickness of the lower Middle Cambrian limestone, as exposed in this district, is believed to be between 600 and 800 feet.

Above the lower Middle Cambrian limestone lies a thin formation composed mainly of slate and quartzite. These rocks appear to present little resistance to erosion and therefore tend to occur in saddles

[26] Mertie, J. B., jr., op. cit., pp. 64–66.

and timbered slopes, where their character and sequence can not be readily ascertained. North of the triangulation station "Chief" the top of this formation appears to be mainly a fine-grained dark-gray quartzite and the lower part is a mixture of quartzite and slate. Somewhat above the middle of the formation is a thin band of limestone, which appears to be an integral part of the formation. A similar band of limestone appears to be present in this formation in the prominent bluffs along the north side of the Tatonduk River. At this locality, this thin band of limestone contains organic remains, but the rocks are here so much shattered that the stratigraphic sequence can not be made out with certainty. The thickness of this formation is estimated to be about 300 feet.

The upper plate of the Middle Cambrian limestone is partly exposed along the north bank of the Yukon about 4 miles downstream from Calico Bluff. At this point it crops out at the water's edge and continues northwestward, forming a steep dip slope on the hillside. To the east it continues to a point north of "Chief," where the entire Middle Cambrian sequence ends against a fault. In an earlier publication [27] this plate of limestone was classified as Upper Cambrian in age, but a reexamination of its fossils, in comparison with other material subsequently collected, indicates that it is a part of the Middle Cambrian sequence. This change in assignment of age from Upper to Middle Cambrian does not apply to the great mass of Upper Cambrian limestone that extends southeastward from "Chief."

This upper limestone of the Middle Cambrian sequence, as seen along the banks of the Yukon, is a massive light-gray crystalline rock, not greatly unlike the lower Middle Cambrian limestone, except that it is not so much silicified. This lack of silicification is probably due more to the fortuitous chances of later silicification than to any inherent qualities of the limestone. It has conglomeratic and oolitic phases, the former consisting of small pebbles of gray limestone and a few well-rounded pebbles of black shiny chert in a limestone matrix. Organic remains were found near the water's edge.

This upper Middle Cambrian limestone has not been traced from the Yukon northward down the timber-covered slopes to the Tatonduk River, though it may well be continuous in this stretch. At the prominent bluff on the north side of the Tatonduk River, however, an upper plate of limestone that crops out is interpreted as the upper Middle Cambrian limestone. Here this limestone ranges from an almost lithographic finely crystalline brownish-gray variety to a cream-colored coarsely crystalline variety, as well as containing

[27] Mertie, J. B., jr., op. cit., pp. 66–67.

beds of the oolitic type. It is greatly fractured and in places appears to be a limestone breccia or conglomerate, the fragments being slightly rounded. Some organic remains were also found at this horizon.

This thin plate of upper Middle Cambrian limestone, which crops out between "Chief" and the Yukon and again on the Tatonduk River, is not more than 300 feet thick and is overlain by late Paleozoic rocks, the overlying Cambrian and Ordovician limestone having in all probability been removed by erosion.

On and near Hard Luck Creek beds of Upper Cambrian and Ordovician limestone are exposed. This group of beds represents a continuous deposit of limestone, so that no lithologic boundary line may be drawn between the Upper Cambrian and the Ordovician, although a discontinuity of sedimentation may possibly exist. On Jones Ridge this limestone ranges from a massive white to cream-colored coarse-grained rock to a dense, fine-textured brownish-gray rock with prominent bedding planes. The limestone, particularly the coarser-grained variety, appears to be lower in the section and is in places much fractured and silicified. The gray lithographic limestone is higher in the section. The total thickness of the Upper Cambrian and Ordovician sequence is believed to be about 3,000 feet. The line between the Upper Cambrian and Ordovician, in the Jones Ridge and Hard Luck Creek sector, must be drawn entirely on paleontologic grounds, as the massive limestone of these two ages has not been discriminated on the basis of lithology. As fossils are not found continuously throughout the section, the proportion of the limestone that should be assigned to the Upper Cambrian is doubtful, but a rough approximation is that two-thirds of the sequence is Cambrian and one-third Ordovician.

The structure of the Cambrian rocks is not simple but is nevertheless fairly well understood in a broad way. In the Yukon-Tatonduk section all three of the Middle Cambrian formations lie in the form of an anticline that plunges southwestward toward the Yukon River. This structure is essentially similar to that of the underlying rocks of the Tindir group. At the east end of this section, north of "Chief," the Middle Cambrian beds may be terminated by the old fault that forms the eastern boundary of the Tindir rocks on the Tatonduk River, but the details of this structure have not been worked out. The Upper Cambrian limestone, however, is known to be present southwest of this fault, for it crops out continuously around the head of Shade Creek.

The northwest end of this anticline is also known to be terminated by faulting, but here again the exact locus of the fault zone has not been determined. Again, in the southwest, where the anticline plunges toward the Yukon, another zone of faulting has been recognized in the younger rocks that lie southwest of the nose of the Cambrian anticline. Thus it appears that the Middle Cambrian rocks and units A, B, and C of the Tindir group constitute an island of relatively undisturbed rocks, considered structurally bounded on at least three sides by zones of faulting. In this respect these rocks suggest the condition of Calico Bluff, which likewise is an isolated occurrence of little deformed rocks, surrounded by much more highly deformed strata.

The Upper Cambrian and Ordovician limestone of Jones Ridge presents a somewhat similar and probably related structure. Along Jones Ridge the rocks strike approximately east and dip 50° to 90° S. West of Hard Luck Creek, however, the trend of the limestone changes to south and then to southeast, continuing to a point about 2 miles southeast of "Squaw," where the limestone probably ends against the same curved fault that terminates the Middle Cambrian rocks south of the Tatonduk River. Thus there appears to be in the valley of Hard Luck Creek a syncline comparable in size with the Middle Cambrian anticline on the Yukon, which plunges eastward. As a result the older rocks of the Tindir group lie north, west, and south of the Cambrian and Ordovician limestone, whereas in the east-central part of the syncline, near the international boundary, later Paleozoic rocks crop out. The north, west, and south boundaries of the Cambrian and Ordovician limestone are believed to be mainly fault boundaries, so that the lower part of the Cambrian sequence is faulted out. A close analogy exists in that the Cambrian and Ordovician syncline of Hard Luck Creek is another relatively little disturbed structural island, bounded at least on three sides by great fault displacements.

The structure of the Cambrian rocks would not be complete without a reference to the eastward continuation of these rocks. From the top of "Squaw," at an altitude of 4,720 feet, an unimpeded view to the east shows a great anticline which strikes about N. 80° E. and extends for a number of miles into Yukon Territory. The center of this structural feature is marked by a flat valley, perhaps 5 miles wide, which may be the upper valley of the Tatonduk River. The north and south sides of the anticline are marked by prominent limestone hogbacks, which dip away from the axis of the anticline to the north and south. These two hogbacks are believed by the writer to represent Cambrian limestone. On the north side of the north hogback several other limestone strike ridges stand out prominently, indicating that a rather complete lower Paleozoic section is there present. South of the south hogback other limestone ridges are either scarce or nonapparent, and the impression gained is that much of the lower Paleozoic section on this side has been removed by erosion, its place being taken by the beds of the Nation River formation. The structure on the south side of the anticline also appears to be less regular, and at one place there is a prominent offset in the Cambrian limestone, so that the limestone east of the fault is displaced southward about a mile with reference to its westward continuation.

The features above described constitute a magnificent exposure of the geologic structure involving the Cambrian and pre-Cambrian sequence of this region. Broadly, the section exposed in the valleys of Hard Luck Creek and the Tatonduk River constitutes the western termination of this great structural feature, and in so far as the rocks are there found in plunging anticlines and synclines this district should afford a splendid insight into the section. But at the same time this western termination of the structure also approaches closely to the region of intense metamorphism that exists south of the Yukon, so that the end of the structure has been considerably modified by faulting, which tends to obscure the true stratigraphic sequence. A close study of this great exposure of the structure east of the international boundary should therefore yield many additional facts regarding this early geology.

### AGE AND CORRELATION

The Upper Cambrian sequence in this district was first discovered by Cairnes [28] and his assistants in 1912, during which season eight collections of fossils from this horizon were made. In the following year Burling, also representing the Geological Survey of Canada, visited this district and collected additional material from the Upper Cambrian. Burling's material was never described, but five of his Cambrian collections are now in the United States National Museum, where they have been partly studied by C. E. Resser, of that organization.

The Middle Cambrian sequence was first recognized by the writer in 1925, and since that time 10 collections have been made by the United States Geological Survey from these beds and 5 from the Upper Cambrian. Thus 28 collections of Cambrian fossils have so far been made in the Tatonduk-Nation district.

The Cairnes collections were determined by Burling; the Burling collections and collection 25AMt146 were determined by Resser; and the remaining 14 collections have been determined by Edwin Kirk, of the United States Geological Survey.

[28] Cairnes, D. D., op. cit., pp. 61–65.

The localities and fauna of the 10 Middle Cambrian collections are given below.

25AMt148 (2062). Northeast side of Yukon River, at an altitude of about 1,400 feet above the river and 3.1 miles N. 2½° E. of Eagle.

Nisusia or Jamesella sp.
Dorypyge 2 sp.
Albertella mertieii (MSS.).
Stenotheca rugosa.
"Ptychoparia" 2 sp.
Ogygopsis sp.

28AMt263. Limestone bluff along northeast bank of Yukon River, north of the north end of Calico Bluff.

Archæocyathus (?) sp.

30AMt47. Limestone bluff on north side of Tatonduk River, about 5¾ miles above mouth.

Archæocyathus sp.

30AMt77. About 1 mile N. 63° W. from "Chief," a triangulation station on the international boundary.

Archæocyathus sp.
"Cocinoptycha" sp.
Ethmophyllum sp.

30AMt136. One mile above mouth of creek that enters Tatonduk River 1¼ miles below international boundary.

Archæocyathus sp.

30AMt214. Float from gulch, about 1½ miles S. 60° W. from "Hiyu," a triangulation station on the international boundary.

Archæocyathus sp.

30AW13 (2537). Northeast side of Yukon River, altitude 1,400 feet above river and 3.1 miles N. 2½° E. of Eagle. Same locality as 25AMt148; collected in 1925.

Eoorthis? sp.
Archæocyathus sp.

30AW58–59. Ridge just west of "Hiyu," a triangulation station on the international boundary.

"Archæocyathus."

30AW60. Limestone bluff on north side of Tatonduk River, about 5¾ miles above mouth, altitude 1,080 feet above river.

Archæocyathus sp.
"Archæocyathus" sp. (same as in 30AW58–59).

30AW62. Same general locality as 30AW60, except 75 feet above river.

Archæocyathus sp.
Ethmophyllum sp.
Doropyge? sp.

This lot carries the same *Archæocyathus* as that determined from locality 28AMt263.

With regard to this Middle Cambrian fauna, Kirk makes the following statement:

The problematic corals in the lists above are of very great interest. Their closest relationships are with forms hitherto known only in the lower Cambrian and of wide distribution. Their presence in rocks of Middle Cambrian age, as determined by other invertebrates, is therefore notable. The forms have been assigned to those described genera with which they are most closely allied. There are certainly two or more undescribed genera, however. *Ethmophyllum* and *Archæocyathus* seem definitely to be present.

Eighteen Upper Cambrian collections are listed below, beginning with the Cairnes collections. All the fossils collected by Cairnes in 1912 were given Roman and ordinary numbers and small letters, which referred to a gridwork that he used in the field. This gridwork was described by the writer in an earlier publication.[29]

It has recently been discovered that the original key to this gridwork was incorrect, as the letter a should be at the east side of the gridwork, and t should be at the west side, instead of the reverse order, as published. This discovery has cleared up many baffling discrepancies in the locations of the Cairnes fossils and makes it possible now to utilize almost all of them in stratigraphic interpretation. The Upper Cambrian collections of Cairnes, arranged in order from south to north, are given herewith:

XXc29. About 2¼ miles northeast of boundary triangulation station "Hug" (McCann Hill).

| | |
|---|---|
| Obolus sp. | Ptychoparia sp. |
| Acrotreta sp. | Anomocare sp. |
| Agraulos sp. | Solenopleura sp. |

XXi34. About 2 miles east of boundary triangulation station "Chief."

| | |
|---|---|
| Foraminifera. | Agnostus 3 sp. |
| Hyolithellus (?) sp. | Agraulos 3 sp. |
| Stenotheca 2 sp. | Ptychoparia 2 or 3 sp. |
| Conularia sp. | Anomocare sp. |
| Micromitra (Iphidella) pannula (White). | Dorypyge (?) sp. |
| Acrotreta 4 sp. | Neolenus (?) sp. |
| Ostracodes 4 sp. | Solenopleura 3 sp. |

XXe39. Southwest bank of Tatonduk River, about 2 miles in an air line upstream from international boundary.

| | |
|---|---|
| Curticia (?) sp. | Agnostus sp. |
| Acrotreta sp. | Dicellocephalus (?) sp. |

XIXj9. Just east of boundary monument 103.

| | |
|---|---|
| Obolus sp. | Ptychoparia sp. |
| Lingulella sp. | Anomocare sp. |
| Acrothele cf. A. coriacea Linnarsson. | Liostracus sp. |
| Acrotreta 2 sp. | Levisia sp. |
| Agnostus 2 sp. | |

XIXj17, 18. Northeast of boundary triangulation station "Squaw."

| | |
|---|---|
| Obolus (Westonia) cf. O. stoneanus (Whitfield). | Acrothele cf. A. coriacea Linnarsson. |
| Lingulella sp. | Schizambon cf. S. typicalis Walcott. |
| | Undetermined trilobite. |

XIXp20. About 2 miles southwest of boundary monument 102.

| | |
|---|---|
| Obolus 2 sp. | Acrotreta 2 sp. |
| Lingula sp. | Asaphus (?) sp. |

[29] Mertie, J. B., jr., Geology of the Eagle-Circle district: U. S. Geol. Survey Bull. 816, p. 47, 1930.

XIXj31. Jones Ridge, just east of international boundary.

Foraminifera? undetermined.
Obolus 2 sp.
Obolus (Westonia) cf. O. stoneanus (Whitfield).
Lingulella 2 sp.
Dicellomus? sp.
Curticia? sp.
Acrothele cf. A. coriacea Linnarsson.
Acrotreta sp.
Orthoid.
Coral?
Ostracode.
Agnostus sp.
Eurycare? sp.
Three undetermined trilobites.

XIXj32, Jones Ridge, just east of international boundary.

Micromitra (Iphidella) pannula (White)?
Obolus 2 sp.
Obolella? sp.
Acrothele cf. A. coriacea Linnarsson.
Acrotreta 2 sp.
Ostracode.
Illænus? sp.

The five available collections of the Burling suite were made in 1913 at Squaw Mountain and Jones Ridge and evidently represent a reexamination by Burling of these localities of Cairnes. The localities of these collections and their fauna are given herewith:

4730, 4731, 4732, and 4733. Squaw Mountain (triangulation station "Squaw"), north of Tatonduk River, along international boundary. 4734. Jones Ridge, exact locality unknown.

Eoorthis sp.
Westonia sp.
Acrothele sp.
Parobolus sp.
Trilobites of several genera and species.

The Upper Cambrian collections made by the United States Geological Survey are as follows:

28AMt262. North Fork of Shade Creek, 1.15 miles N. 29½° W. of "Hug" boundary triangulation station (McCann Hill).

Acrothele sp.

30AMt146. Northeast side of Hard Luck Creek 1.6 miles N. 55° W. from international boundary monument 102. Underlying 30AMt145.

Obolus sp.
Acrothele sp.
Dicellomus? sp.

30AMt147. Northeast side of Hard Luck Creek 1.7 miles N. 54° W. from international boundary monument 102. Underlying 30AMt146.

Eoorthis sp.
Briscoia 2 sp.
Trilobite, probably new genus.
Hyolithes sp.

30AW22. Jones Ridge, northeast of Hard Luck Creek and half a mile west of international boundary. Altitude 3,500 feet above sea level.

Dicellomus sp.
Acrothele sp.
Acrotreta sp.
Eurekia sp.

30AW61. Same general locality as 30AW60, except 1,100 feet above river.

Fragmentary brachiopods, probably referable to *Eoorthis* and *Obolus*.

If the stratigraphic interpretations of the writer are correct collection 30AW61 should properly belong with the Middle Cambrian collections, but it occurs in a zone where faulting is prevalent, so that some Upper Cambrian limestone may be present at this locality.

The oldest Cambrian horizon so far recognized appears to be represented by collection 25AMt148. The species identified in this collection are quite similar to or possibly identical with forms found in the Langston limestone and the Ross Lake shale of Walcott, and therefore, according to Resser, belong well down in the Middle Cambrian. The remarks of Kirk, previously quoted, regarding the presence of *Ethmophyllum* and *Archæocyathus*, serve further to stress the fact that the basal limestone of this sequence belongs not far above the Lower Cambrian.

Insufficient work has yet been done on the Upper Cambrian collections to correlate the formations with Upper Cambrian formations elsewhere described. Resser has stated, however, that the Burling collections from Jones Ridge and from the vicinity of "Squaw" belong to the Upper Cambrian of Ulrich, which in the nomenclature of the United States Geological Survey is the lower part of the Upper Cambrian. Higher horizons in the Upper Cambrian are nevertheless doubtless represented, for one of the Burling collections—No. 4689, from Jones Ridge—is of Lower Ordovician age. Lower and Middle Ordovician fossils were also collected by the writer at Jones Ridge, so that it is likely that all horizons from the lower part of the Upper Cambrian to the Trenton may be present in the limestone mass that forms Jones Ridge.

## ORDOVICIAN SYSTEM

### DISTRIBUTION

Two types of Ordovician rocks are known in the Tatonduk-Nation district. One of these types, which is essentially limestone, forms the top of the limestone sequence at Jones Ridge and probably at other localities where it has not been eroded. The other type, which is noncalcareous, has been identified as a band overlying the Upper Cambrian limestone at the head of Shade Creek.

### LITHOLOGY AND STRUCTURE

The older Ordovician rocks are limestone, essentially similar in character to the Upper Cambrian limestone. In fact, these two limestones have not been separated at Jones Ridge and are shown on Plate 7 as a single pattern. If a line must subsequently be drawn between them it will have to be done on the basis of paleontologic rather than lithologic differences. As indicated in the discussion of the Upper Cambrian rocks, the thickness of the Ordovician part of the Upper Cambrian and Ordovician sequence is probably about 1,000 feet.

The rocks overlying the Upper Cambrian limestone at the head of Shade Creek are dark-gray to black thin-bedded siliceous slates and cherts. Here the Ordovician limestones appear to be absent, but this can not be attributed entirely to erosion, for the age of these siliceous rocks, as revealed by fossil Bryozoa, ranges from high Lower to low Middle Ordovician. These rocks must therefore be essentially contemporaneous with the Ordovician limestones of Jones Ridge, and conditions of sedimentation at the head of Shade Creek must have been different from those at Jones Ridge, 10 miles to the north. These siliceous beds appear to be entirely conformable upon the Upper Cambrian rocks, but the data are insufficient to deny the possibility at least of a discontinuity in sedimentation between the two formations.

Directly overlying the slate-chert formation, in the Shade Creek area, is another formation lithologically so similar to the Ordovician rocks that it would probably not have been differentiated as a distinct formation if no fossils had been found. This formation is of high Middle Devonian or possibly Upper Devonian age, and as the boundary line between the two formations has not been recognized, the thickness of neither can be given. In all probability, however, some of the Ordovician slate-chert formation at the head of Shade Creek has been removed by erosion, so that the complete sequence is not there present. The writer estimates that only 200 to 300 feet of this formation is present at this locality.

In the Jones Ridge area the Ordovician limestones are equally involved with the Upper Cambrian limestone in the plunging synclinal structure, previously described. Eastward from the ridge north of "Hiyu" this structure is singularly clear and unmistakable. The Upper Cambrian limestone, which occurs at "Squaw" and at Jones Ridge, is joined between those two localities in an arc of limestone that includes "Skook" and "Hiyu." The inner side of this arc is formed by the Ordovician limestone, inside of which are two Devonian formations.

## AGE AND CORRELATION

One collection of fossils was made by the writer from the Ordovician limestone that overlies the Upper Cambrian limestone of Jones Ridge. This collection has been examined by Edwin Kirk, of the United States Geological Survey, by whom it is stated to represent two faunal horizons, one of Lower and one of Middle Ordovician age. As these fossils were collected from slabs of rock at the base of a steep cliff, such an intermingling of material may well have occurred, and in fact the discovery of a Lower Ordovician as well as a Middle Ordovician horizon in the limestone of Jones Ridge justifies the interpretation that limestone sedimentation was properly continuous at this locality from Upper Cambrian to Middle Ordovician time. These two faunas are listed below:

30AMt145. Northeast side of Hard Luck Creek, 1.5 miles N. 56° W. of international boundary monument 102.

Dalmanella sp.
Syntrophia sp.

This fauna is of Lower Ordovician age.

| | |
|---|---|
| Streptelasma sp. | Catazyga sp. |
| Halysites sp. | Platystrophia sp. |
| Strophomena sp. | Lingula sp. |
| Dinorthis sp. | Rhynchotrema sp. |
| Dalmanella sp. | Sowerbyella sp. |
| Leptelloides sp. | Illaenus sp. |
| Zygospira sp. | Bumastus sp. |
| Christiania sp. | Eoharpes sp. |

This fauna is of Middle Ordovician age.

One of the collections made by Burling from Jones Ridge, has also been determined by Resser to belong in the upper part of the so-called "Canadian system," or, in the nomenclature of the United States Geological Survey, to the Beekmantown group of the Lower Ordovician series. This collection is listed below.

Collection 4689.

Symphysurina sp.
Eoorthis sp.

The Ordovician limestone has not been found in place on the Squaw Mountain side of the Upper Cambrian and Lower Ordovician beds, but its presence there is indicated by the presence of *Columnaria alveolata* Goldfuss, found in the gravels of Funnel Creek, about 2 miles west of boundary station 103, by G. L. Harrington.

Kirk further states that the Middle Ordovician fauna of collection 30AMt145 is approximately Trenton or upper Mohawkian in age but that it does not appear to be equivalent to the Mohawkian fauna collected by Kindle[30] from the Porcupine River nor in fact to any other Ordovician fauna hitherto known in Alaska or northern North America. The Ordovician collections made at the base of the massive limestone in the White Mountains, northeast of Fairbanks, which have been collected by Prindle, Stone, Blackwelder, and the writer, were first determined to be of Richmond age but subsequently were placed somewhat lower in the geologic column by Kirk. In a late report Kirk states that the Middle Ordovician fauna of collection 30AMt145 is probably older than the Ordovician of the White Mountains.

From the siliceous formation that overlies the Upper Cambrian limestone at the head of Shade Creek two collections of fossils have

[30] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., vol. 19, pp. 323–324, 1908.

been made. The earliest and best of these collections was made by F. J. Barlow, one of Cairnes's assistants in 1912, and contained both graptolites and other invertebrates. The graptolites were examined by R. Ruedemann and the other invertebrates by L. D. Burling. The locality and determination of these fossils follow.

XXi25. About half a mile northeast of boundary triangulation station "Hug" (McCann Hill).

Dicranograptus cf. D. ramosus Hall.
Retiograptus geinitzianus Hall.
Diplograptus foliaceus incisus Lapworth.
Obolus sp.
Ostracode.
Ptychoparia sp.
Isotelus? sp.
Harpes? sp.

Another collection of graptolites was made at the head of Shade Creek in 1928 by Philip S. Smith and subsequently identified by Kirk. This collection was as follows:

28AMt261. A mile N. 17½° W. from "Hug" boundary triangulation station (McCann Hill).

Diplograptus sp.

In 1913 L. D. Burling made several additional collections from localities whose exact positions are not known to the writer. Probably some or all of these collections were from Barlow's type locality. These forms were likewise determined by R. Ruedemann, and it was in fact through Doctor Ruedemann that the writer learned of the existence of this material. These collections are given below:

Collection 4636.

Cactograptus n. sp.
Callograptus cf. C. diffusus Hall.

Collection 4662.

Lingula n. sp.
Obolus n. sp. Strongly ribbed.
Paterula n. sp.
Caryocaris n. sp. Large form with fringed posterior extremity.
Sponge spicules.
Tetragraptus similis (Hall).
Didymograptus patulus Hall.
Didymograptus cf. D. extensus Hall.

Collection 4680.

Caryocaris n. sp.
Tetragraptus similis (Hall). Young specimen.
Didymograptus nitidus Hall.
Didymograptus extensus Hall.

Collection 4683.

Lingula n. sp.
Caryocaris n. sp.
Sponge spicules.
Tetragraptus similis (Hall).
Didymograptus nitidus Hall.

## SILURIAN SYSTEM

### DISTRIBUTION

The exact limits of the Silurian rocks in this district are not yet precisely known. One locality is in the upper Tatonduk Valley, just west of the international boundary, where an area of about 5 square miles is occupied by Silurian limestone. The other locality is on the Canadian side of the boundary southeast of Jones Ridge. The shape and size of this occurrence are unknown.

### LITHOLOGY AND STRUCTURE

The Silurian limestone in the upper part of the Tatonduk River Valley does not look essentially different from the Cambrian and Ordovician limestones. It is a massive white to cream-colored rock and is silicified in different places to different degrees. Oolitic phases were also seen. On the north slopes of the spur of Silurian limestone that faces the Tatonduk River crinoids and corals are plentiful, but along the banks of the river fossils were not found On the north side of the Tatonduk River, just west of the boundary, the Silurian limestone was also identified by fossils found by Cairnes and his assistants. Hence the Silurian limestone in the Tatonduk Valley crops out in a crescentic arc, similar to but somewhat smaller than the Upper Cambrian arc, and in the center of this arclike band are Devonian rocks. This area, therefore, contains another eastward-plunging syncline that is very similar to the Upper Cambrian and Lower Ordovician syncline of the Hard Luck Creek area.

The geologic map prepared by Cairnes shows that about a mile east of the boundary the trend of Jones Ridge changes from east-northeast to northeast. At the point of this flexure a fault striking about N. 30° W. probably cuts across the ridge. Just east of this supposed fault line two collections of Silurian fossils were made by Cairnes and his assistants. These fossil localities lie east of the fault above postulated and indicate that another cross fault, similar to the one at the northwest side of Jones Ridge, has ruptured and modified this synclinal structure, incidentally bringing to the surface the Silurian rocks.

Another supposed Silurian fossil locality found by Cairnes is on the mountain southwest of Hard Luck Creek, which might be considered the continuation of Jones Ridge in that direction. Two collections at this locality were made at a point where Ordovician rocks would be expected to occur, but a slight error in the plotting may have shifted this locality to the south side of the Ordovician limestone, where some Silurian rocks may conceivably be present.

### AGE AND CORRELATION

The six Silurian collections so far made in this district are given below, together with their approximate positions. The first five of these collections were made by Cairnes and his assistants and identified by E. M. Kindle, of the Canadian Geological Survey. The last was made by the writer and identified by Edwin Kirk, of the United States Geological Survey.

XIXm6. About 1 mile southwest of boundary monument 103.

Cladopora sp.
Favosites sp.
Zaphrentis sp.
Camarotœchia? cf. C. acinus Hall.
Camarotœchia? cf. C. indianensis (Hall).
Atrypa sp.
Atrypina sp.
Nucleospira cf. N. pisiformis Hall.
Trematospira cf. T. camura Hall.
Sieberella n. sp.
Mytilarca? cf. M. sigilla Hall.
Platyceras sp.
Orthoceras sp.
Dalmanites sp.

XIXf31. About 1¼ miles east of highest point of Jones Ridge.

Stropheodonta sp.
Rhipidomella n. sp.
Gypidula? sp.
Clorinda cf. C. fornicata (Hall).
Sphærexochus sp.
Illænus cf. I. imperator Hall.

XIXh31. About three-fourths of a mile east of highest point of Jones Ridge.

Stropheodonta sp.
Orthis flabellites Fœrste.
Dalmanella cf. D. elegantula (Dalman
Meristina sp.
Spirifer radiatus Sowerby.
Spirifer sp.
Sphærexochus romingeri Hall.
Illænus cf. I. imperator Hall.
Brontiopsis sp.

XIXs28. About 2¼ miles N. 67° E. of boundary monument 102.

Pholidops cf. P. squamiformis Hall
Atrypa sp.
Atrypa cf. A. marginalis Dalman.
Orthis flabellites Foerste.
Dalmanella cf. D. elegantula (Dalman).
Whitfieldella cf. W. nitida Hall.
Anoplotheca sp.
Illænus cf. I. armatus Hall.

XIXt27. About 2½ miles N. 75° E. of boundary monument 102.

Whitfieldella sp.
Atrypa reticularis Linn.

25AMt168 (2064). South side of Tatonduk River, 1.3 miles N. 70½° W. of boundary monument 104 and about 800 feet above river.

Diphyphyllum sp.
Alveolites sp.
Crinoid columnals.

The first four of these collections were determined by Kindle to be of middle Silurian age, but collection XIXt27 was referred to a late horizon in the Silurian. Collection 25AMt168 was determined by Kirk as questionably of Silurian age, the possible alternative assignment being Devonian. There can be little doubt of the middle Silurian age of collection XIXm6, and it seems rather likely that collection 25AMt168 may be of the same age. It is well established, however, that a Middle Devonian horizon of massive limestone also exists in this district, so that the age of collection 25AMt168 can not be regarded as proved.

Collections XIXm6, XIXf31, and XIXh31 were made in areas of massive limestone, and it therefore seems evident that the massive limestone of middle Silurian age so well known elsewhere in Alaska, is also present in this district. In northern Alaska, the limestone at this horizon is known as the Skajit limestone, which is believed to be of late middle and early upper Silurian age; in interior Alaska, northeast of Fairbanks, the heavy limestone of the White Mountains is also of middle Silurian age; and along the Porcupine River the middle Silurian horizon is marked by a massive magnesian limestone. In the upper Kuskokwim region, Upper Ordovician, late Silurian, and Middle Devonian rocks are known to exist, and considering the small amount of work so far done in that region it is a fair guess that the middle Silurian is also represented there. Hence, by connecting the discontinuous areas of middle Silurian limestone in Alaska there appears a great arc of limestone, roughly parabolic in outline, which starts from Cape Krusenstern on the Arctic coast, continues eastward to longitude 146°, thence veers southeastward to the Porcupine, southward to the Yukon, westward to the White Mountains, and finally extends southwestward into the Kuskokwim Valley. The structural and stratigraphic significance of this major geologic feature remains a problem for future study.

## DEVONIAN SYSTEM

### DISTRIBUTION

Middle Devonian rocks representing three different horizons are known at several localities within the Tatonduk-Nation district. Beds at the lowest horizon occur in an area on the south side of Hard Luck Creek, north of boundary triangulation station "Squaw"; and also in another area between Ettrain and Tindir Creek, just south of boundary monument 96, which probably continues southwestward to boundary triangulation station "Casca." The next higher horizon is represented along the Tatonduk River, just west of the international boundary. The highest Middle Devonian rocks are those that overlie the Ordovician graptolite horizon at the head of Shade Creek. Beds at this same horizon are known also to occur on the Tatonduk River and on Eagle Creek. This horizon is believed also to be represented on Last Chance Creek and in the valley of Hard Luck Creek, where these rocks lie upon the lowest Middle Devonian rocks.

### LITHOLOGY AND STRUCTURE

The Middle Devonian limestone resembles very much the older Paleozoic limestones previously described, except that no oolitic variety was observed. The two most common types observed are a dense light-gray lithographic limestone and a dark-gray, coarsely crystalline limestone. The former type occurs in the upper part of the Devonian limestone exposed north of "Squaw" and the latter at a somewhat lower horizon. Still lower in the sections quartzose varieties were noted, but it is likely that some of these may be a part of the Upper Cambrian and Ordovician sequence. The crystallinity of some of the Middle Devonian limestone is due to some inherent character of the rock rather than to excessive metamorphism, for it is bordered above and below in the section by noncrystalline limestone and moreover yields perfect fossils. Perhaps the most significant difference between the Middle Devonian and the older Paleozoic limestones is the paucity of secondary silica.

North of "Squaw" this limestone lies in a synclinal basin upon the Upper Cambrian and Lower Ordovician limestone. At the localities where collections 30AMt137 and 30AMt138 were made, the limestone is locally nearly horizontal, but in the direction of Hard Luck Creek it gradually dips northward. This Middle Devonian limestone is easy to recognize because of the abundance of fossils, but where it abuts against other limestones that are scantily fossiliferous or nonfossiliferous the absence of fossils in these beds does not constitute adequate data for the placement of a boundary line, so that boundaries between the Middle Devonian and other limestones are likely to be more or less in error.

Another Devonian formation considerably younger than the Middle Devonian limestone rests upon that bed north of "Squaw," and between these two formations there is believed to be a discontinuity of sedimentation. Therefore, as erosive processes are believed to have acted upon the Middle Devonian limestone before the deposition of the higher Devonian beds, some of the limestone has probably been unmoved by erosion, and the entire sequence is not here represented. The thickness exposed at this locality is estimated not to exceed 600 feet.

A second occurrence of Middle Devonian limestone is along the international boundary, between Tindir and Ettrain Creeks and south and southeast of boundary monument 96. This locality was not visited by the writer but is known from a group of fossil collections made by Cairnes. Another collection by Cairnes from boundary station "Casca" indicates that the area near boundary monument 96 extends 3 or 4 miles south-southwest to this point.

The next Devonian horizon above the Middle Devonian limestone is represented by the rocks in the Tatonduk Valley, just west and probably also east of the boundary. The lower part of this sequence consists of alternating thin beds of dark-gray limestone and shale, with more or less chert at some horizons. Some of these thin-bedded limestones are black crystalline rocks that have a strongly fetid odor when broken. Both the limestone and shale seem to have acted as a medium for taking up the stresses generated in the regional deformation and are much bent into folds of small amplitude but are not recrystallized. At the west end of these limestone and shale beds, both on the Tatonduk River and in the lower part of Funnel Creek, the limestone and shale is overlain by contorted beds of black chert and siliceous slate. These beds are from 1 to 4 inches thick, and in places thin films of graphitic material have developed along the bedding planes. The complete sequence of this intermediate formation of the Middle Devonian is not yet known, but it is likely that other lithologic varieties than those here mentioned will be found, both in this district and elsewhere, to correlate with the beds at this horizon. As the sequence is incomplete, no trustworthy estimate of the total thickness can be made, and the beds in the Tatonduk Valley are too crumpled to permit the measurement of a reliable section. It is estimated that about 500 feet of strata lie at this horizon in the Tatonduk Valley.

The highest of the three Middle Devonian horizons is best represented at Shade Creek and on Eagle Creek, both of which localities have yielded fossils that give a reliable basis for determining the place of the rocks in the geologic column. The rocks of this horizon consist essentially of argillite, slate, chert, and cherty grit. The argillaceous varieties are dark gray and usually siliceous, so much so in fact that these rocks may better be called siliceous slate and siliceous argillite. Chert seems to be more characteristic of the upper part of the sequence. One particularly distinctive type of rock in the upper part of this formation is a cherty grit that contains peculiar involute fossil forms. This rock is really a sedimentary chert breccia, composed of angular to subangular fragments of cherty material in a chalcedonic matrix. The grains of chert range in size from a quarter of an inch down to microscopic dimensions. On the hills north of Eagle Creek the upper part of this sequence of rocks includes chert, siliceous argillite, siliceous slate, quartzitic graywacke, fine-grained sandstone, fine-grained quartzite, probably derived from chert, and the grit above described. The lower part of the sequence, as exposed in the valley of Eagle Creek, consists mainly of a number of varieties of shale, including black shale with numerous concretions, soft thin-bedded nodular sandy shale, bluish-gray argillite ranging into limestone, siliceous slate, and some chert.

The rocks at this highest Middle Devonian horizon, as exposed in Eagle Creek, are highly disturbed, and only a very general idea of their structure can be obtained. The beds, being incompetent, are closely folded and appear to have taken up a good deal of the movement attendant on the metamorphism of the other Paleozoic rocks south of the Yukon. The average strike is N. 75° W., but the dip is too variable to allow satisfactory measurements of a stratigraphic section. The writer, however, estimates that not less than 1,000 feet of these sediments is present in the valley of Eagle Creek.

In the valley of Hard Luck Creek the rocks of this formation are dark gray to black thin-bedded siliceous shales and slates. The more argillaceous varieties, such as those seen near the bottom of the sequence, along the south side of Jones Ridge, have a well-developed slaty cleavage. The beds at the upper horizons appear to approximate more closely to cherty rocks. These rocks weather to lighter shades of gray, but on bare hillsides the weathered débris appears reddish from a distance. Good exposures of this formation are available at intervals in the cut banks of Hard Luck Creek, but their discontinuity and the intricate folding of the strata precludes any measurement of thickness. The estimated thickness of strata present in the valley of Hard Luck Creek is only about half that exposed in the valley of Eagle Creek.

### AGE AND CORRELATION

The lowest of the three Middle Devonian horizons was first recognized on the Porcupine River in 1907 by Kindle,[31] who applied the designation Salmontrout limestone. A comparative study of the fossils from the Salmontrout limestone and those from the basal Middle Devonian limestone in the Tatonduk-Nation district has recently been made by Edwin Kirk, of the United States Geological Survey, with the result that the two formations are now considered to be identical. The designation Salmontrout limestone is therefore applied to this formation.

Fifteen collections of fossils have so far been made from the Salmontrout limestone of this district. Twelve of these collections were made by Cairnes and determined by Kindle. Three others were made by the writer during the season of 1930 and determined by Edwin Kirk. The collections from the area just south of Hard Luck Creek are first considered. The Cairnes collections from this area were made at five localities, of which four were on the Canadian side of the boundary line and one on the Alaska side. Another Cairnes collection, XIXp10, which is also given, appears to have been made on the spur east of lower Funnel Creek, in an area where the Salmontrout limestone was not recognized by the writer. The three collections by the writer were made from the same belt of limestone as the five collected by Cairnes but were determined by Edwin Kirk. These faunas are given herewith:

[31] Kindle, E. M., op. cit., pp. 327–329.

XIXh19. About a mile northeast of "Squaw."

Zaphrentis sp.
Atrypa reticularis (Linnæus).
Stropheodonta sp.
Camarotœchia sp.
Meristella? sp.
Meristella cf. M. lævis (Vanuxem).
Pugnax pugnus (Martin) var.
Gypidula sp.

XIXi20. About 1 mile N. 30° E. of "Squaw."

Productella cf. P. spinulicosta Hall.
Stropheodonta sp. (same species as in collection XIXh19).
Atrypa reticularis (Linnæus).
Schizophoria striatula (Schlotheim).
Gypidula sp.

XIXp10. About 2 miles S. 35° W. of "Squaw."

Cyathophyllum? sp.
Atrypa reticularis.
Leptæna rhomboidalis (Wilckens).
Spirifer sp.

XIXq23. About 2⅛ miles N. 40° W. of "Squaw."

Fenestella sp.
Atrypa reticularis (Linnæus).
Atrypa cf. A. flabellata Goldfuss.
Stropheodonta cf. S. arcuata Hall.
Conocardium cf. C. cuneus Conrad.

XIXh, i, j, 22, 23. Small area centering about a point 2 miles N. 20° E. of "Squaw."

Atrypa reticularis.
Stropheodonta sp.
Schizophoria striatula (Schlotheim).
Cryphæus ? sp.

XIXd22. About 2¼ miles N. 50° E. of "Squaw."

Cyathophyllum cf. C. quadrigeminum Goldfuss.
Crinoid stems.
Atrypa reticularis (Linnæus).
Camarotœchia sp.
Gypidula sp.
Conocardium cf. C. cuneus Conrad.
Platychisma? sp.

30AMt137. West side of creek, about three-fourths of a mile north of "Squaw."

Acervularia sp.
Favosites sp.
Heliolites sp.
Atrypa reticularis Linnæus.
Rhipidomella sp.
Camarotœchia sp.
Spirifer sp.
Pentamerella sp.
Naticopsis sp.
Cyclonema sp.
Conocardium sp.

30AMt138. East side of creek, about three-fourths of a mile north of "Squaw."

Atrypa reticularis Linnæus.
Atrypa n. sp.
Camarotœchia 2 sp.
Platyceras 2 sp.
Large crinoid columnals, seven-eighths of an inch in diameter.

30AMt141. About 1¾ miles N. 32° W. of "Squaw."

Atrypa reticularis Linnæus.
Atrypa n. sp.
Stropheodonta sp.
Camarotœchia sp.
Reticularia sp.
Cyrtina sp.
Fragment of fish spine?

The Cairnes collections from the belt between Tindir and Ettrain Creeks are as follows:

XVIIp4, 5. Vicinity of boundary station "Casca."

Favosites sp.
Camarotœchia sp.
Pugnax cf. P. pugnus (Martin).
Atrypa reticularis Linnæus var.
Leptæna rhomboidalis (Wilckens).
Schizophoria striatula (Schlotheim).
Reticularia sp.
Anoplotheca cf. A. acutiplicata (Conrad).
Platyceras sp.
Cytherella sp.
Cyphaspis cf. C. bellula.

XVIIj16, j17, i15, i16. About 1 mile south of boundary monument 96.

Atrypa reticularis (Linnæus).
Atrypa spinosa (Hall).
Schizophoria striatula (Schlotheim).
Reticularia? cf. R. subundifera (Meek and Worthen).
Reticularia sp.
Athyris? n. sp.

XVIIj, k, 16. About 1 mile south of boundary monument 96.

Zaphrentis sp.
Favosites sp.
Stropheodonta sp.
Atrypa reticularis (Linnæus).
Schizophoria striatula (Schlotheim).
Gypidula sp.

XVIIh19, i19. About half a mile east of boundary monument 96.

Crinoid stems.
Productella sp.
Atrypa reticularis (Linnæus).
Reticularia cf. R. lævis (Hall).
Reticularia cf. R. subundifera (Meek and Worthen).
Nucleospira sp.
Fish bone.

XVIIi13, i14. About 1½ miles south and a little east of boundary monument 96.

Cyathophyllum sp.
Atrypa reticularis (Linnæus).
Camarotœchia contracta (Hall)?
Strophoedonta arcuata (Hall).
Reticularia sp.
Nucleospira n. sp.
Proëtus sp.

XVIIh, i, 18, 19.

Favosites cf. F. basaltica (Goldfuss).
Favosites cf. F. canadensis (Billings).
Alveolites sp.
Schizophoria striatula (Schlotheim).
Chonetes sp.
Atrypa reticularis (Linnæus).
Martinia cf. M. maia (Billings).
Nucleospira sp.
Proëtus sp.

This Salmontrout fauna is rather distinct from the higher faunas of the Middle Devonian. According to Kirk, its aspect is early Middle Devonian, not later than Onondaga. From all available Salmontrout collections, including those made by Kindle on the Porcupine River, 53 genera are now known, of which 19 have been found only on the Porcupine and 17 have been found only in the Tatonduk-Nation district. Seventeen other genera are common to both areas. Thus the collections from this horizon in the Tatonduk-Nation district have expanded by 47 per cent the available paleontologic data regarding the Salmontrout limestone. The tabulation of the complete fauna remains a task for a more detailed paper.

The intermediate Middle Devonian horizon is represented by seven collections of invertebrates, of which six were collected by G. L. Harrington, formerly of the United States Geological Survey, and one by the writer. All were determined by Edwin Kirk. These seven collections are as follows:

736. Triangulation station "Barney," latitude 65° 5′ 51″ and longitude 140° 52′ 43″.

Fenestella.

738. South bank of Hard Luck Creek 0.4 mile southwest of boundary monument 102.

| | |
|---|---|
| Fenestella sp. | Pugnax sp. |
| Atrypa reticularis (Linnæus). | Eatonia? sp. |
| Martinia cf. M. maia (Billings). | |

739. Crest of ridge about 1¼ miles N. 52° E. of boundary monument 102.

| | |
|---|---|
| Cyathophyllum sp. | Leptæna rhomboidalis (Wilckens). |
| Atrypa reticularis (Linnæus). | |

740. Stream gravels 0.45 mile southwest of boundary monument 102.
Fenestella.

741. South side of Hard Luck Creek, 0.4 mile from boundary monument 102.
Chonetes sp.

742. Tatonduk River, float in stream bed on island about 2 miles west of boundary.
Stropheodonta sp.

25AMt161 (2063). North bank of Tatonduk River, 0.38 mile N. 41½° W. of boundary monument 104.

| | |
|---|---|
| Alveolites sp. | Gypidula comis Owen. |
| Striatopora sp. | Atrypa reticularis (Linnæus). |
| Acervularia cf. A. arctica (Meek). | Atrypa near A. hystrix Hall. |
| Heliophyllum sp. | Chonetes cf. C. pusilla Hall. |
| Favosites cf. F. polymorpha Goldfuss. | Camarotœchia sp. |

The fauna of the intermediate Middle Devonian horizon may not be materially different from the Salmontrout fauna, for the stratigraphy indicates that the Salmontrout limestone merges lithologically upward into the thin-bedded limestone and shale of the intermediate formation.

The highest of the three Middle Devonian horizons is represented by two collections of invertebrates made by the writer and by a collection of plants made by Cairnes. The invertebrates were determined by Edwin Kirk and the plants by David White, both of the United States Geological Survey. The invertebrate collections are as follows:

28AMt260. North fork of Shade Creek, 0.72 of a mile N. 13° W. from "Hug" boundary triangulation station (McCann Hill).

| | |
|---|---|
| Favosites sp. | Spirifer sp. |
| Acervularia? sp. | Stropheodonta sp. |
| Zaphrentis sp. | Bactrites? sp. |
| Leiorhynchus sp. | Orthoceras sp. |
| Pteropod (?) | |

25AMt85 (2061). About three-eighths of a mile S. 23° E. of boundary monument 108 on south fork of ridge north of Eagle Creek.
Pteropod (?).

The main value of the pteropod (?) of collection 25AMt85 is that it also occurs with the other invertebrates in collection 28AMt260, thus making it possible to correlate the rocks of Eagle and Shade

Creeks. The zoologic character and affinities of this fossil have been noted in a previous publication[32] and will not here be repeated. Collection 29AMt260 is the real horizon marker, and this fauna, according to Kirk, represents a high horizon in the Middle Devonian, verging close to the Upper Devonian.

From this same formation, along the north bank of Hard Luck Creek near the boundary, Cairnes collected some fragments of a fossil plant, which were subsequently examined by David White, of the United States Geological Survey. According to White, these fragments probably represent the basal portion of a small stem of *Archæosigillaria* and are either of Upper Devonian or Mississippian age. The determination of highest Middle Devonian for the invertebrates and possible Upper Devonian for the plant remains is as close an agreement as might be expected, considering the differences in character of material examined.

The stratigraphic studies of 1930 have shed considerable additional light on the Devonian sequence in the Tatonduk-Nation district and indirectly have suggested problems of correlation with the Devonian in other parts of Alaska. In the past the designation Salmontrout fauna has been applied rather loosely to the general run of Middle Devonian faunas from interior and northern Alaska. Now, by means of a comparative study of the Salmontrout fauna from the Porcupine with its counterpart in the Tatonduk-Nation district, Kirk has recognized that this horizon is distinctly lower than that of the usual Middle Devonian collections previously made. For Alaska in general, therefore, the Devonian sequence may be stated as follows:

1. Upper Devonian, characterized by *Spirifer disjunctus* and other Upper Devonian invertebrates. This horizon is typically developed in the Brooks Range of Arctic Alaska and on Prince of Wales and Chichagof Islands in southeastern Alaska.

2. High Middle Devonian, typified by the siliceous and slaty beds of Eagle, Shade, and Hard Luck Creeks and probably also by the limestones interbedded with the Woodchopper volcanics farther down the Yukon.

3. Middle Devonian proper, exemplified by the thinner beds of limestone and shale that overlie the Salmontrout limestone in the Tatonduk-Nation district and by many other beds containing Middle Devonian faunas in interior and northern Alaska.

4. Salmontrout limestone or lowest Middle Devonian. This horizon is represented by the Salmontrout limestone, on the Porcupine

[32] Mertie, J. B., jr., Geology of the Eagle Circle district, Alaska: U. S. Geol. Survey Bull. 816, p. 83, 1930.

River, as described by Kindle,[33] and by the lowest Middle Devonian limestone, also called Salmontrout, in the Tatonduk-Nation district. In the past a number of Middle Devonian collections from various districts have been rather loosely correlated with the Salmontrout limestone of the Porcupine River. Examples of this treatment are contained in a paper by Brooks,[34] where the Woodchopper volcanic rocks are correlated with the Salmontrout limestone, and in another paper by the writer,[35] where certain Middle Devonian rocks of northern Alaska, consisting largely of slate and sandstone, were also stated to be correlative with the Salmontrout limestone. It is entirely possible that the Devonian formations that differ lithologically from the Salmontrout limestone may indeed be correlative with that limestone chronologically, but unless more paleontologic evidence is available than is presented in the two papers cited it will be better in the future to correlate such rocks with the Middle Devonian rocks that immediately overlie the Salmontrout limestone.

No Lower Devonian rocks have yet been found in Alaska, and the Tatonduk-Nation district affords no exception to this generalization. On the Porcupine River the Salmontrout limestone rests upon black graptolitic shales of Silurian age, and south of Hard Luck Creek it appears to rest upon Ordovician limestone. At neither of these localities was a structural unconformity observed, but parts of the geologic column are missing, probably through an interruption to sedimentation, accompanied by regional erosion. This interval is believed to be represented chronologically by Lower Devonian time.

## CARBONIFEROUS SYSTEM

### GENERAL FEATURES

Carboniferous rocks are known along the Yukon River at a number of localities from the international boundary downstream to Circle, and these rocks, together with their faunas, interrelations, and correlations have previously been described in some detail by the writer.[36] It seems unnecessary at this time to repeat, or even to summarize comprehensively, all these data. As this bulletin is intended to be a report of progress, the writer aims to present only the additional studies of the Carboniferous rocks that were made during the season of 1930 and to indicate wherein these additional

[33] Kindle, E. M., op. cit., pp. 327-329.

[34] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the Upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, p. 283, 1908.

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

[36] Mertie, J. B., jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 84-130, 1930.

data serve to supplement or alter prior ideas of the Carboniferous sequence.

The earlier studies have indicated that the Carboniferous along the upper Yukon may be divided into the following units:

1. Tahkandit limestone, of lower Permian age.
2. Nation River formation, probably of Pennsylvanian age.
3. An intermediate formation, lying between the Nation River and the Calico Bluff formations.
4. Calico Bluff formation, of upper Mississippian age.
5. A formation underlying the Calico Bluff formation and of supposed lower Mississippian age, which was correlated with a chert formation of the Yukon-Tanana region.
6. Volcanic rocks, exemplified by the Circle volcanics, which may be in part contemporaneous with the formation that underlies the Calico Bluff formation.

Two problems that are mutually related have arisen as a result of the work of 1930. First, certain of the rocks that formerly were considered to be a part of the so-called intermediate or transitional formation appear on the basis of paleobotanic evidence to underlie rather than to overlie the Calico Bluff formation. This possible interpretation makes further work on this intermediate formation desirable at localities north of the Yukon, where the geologic structure is less complex, in order to determine its real nature and thickness. For reasons set forth below, this reallocation of these rocks is tentatively accepted by the writer. But if the paleobotanic evidence is subsequently supplemented by favorable paleozoologic and structural evidence and the reallocation is finally confirmed, then another problem of Devonian sequence and correlation will be raised that will require still further investigation.

## LOWER (?) MISSISSIPPIAN ROCKS

### DISTRIBUTION

The rocks that underlie the Calico Bluff formation are exposed at several localities, of which the best is directly down the river bank from Calico Bluff. They are also exposed opposite to this locality, on the north bank of the Yukon below the mouth of Shade Creek and above the mouth of the Seventymile River, as well as on the west bank of the Yukon, opposite the mouth of Tatonduk River. According to the paleobotanic evidence these rocks also occur northeast of the mouth of the Tatonduk River and underlie the Calico Bluff formation at that locality.

### LITHOLOGY AND STRUCTURE

Along the beach below Calico Bluff, these rocks consist of carbonaceous and siliceous shale and argillite, together with dark-gray to black chert, the latter occurring near the base of the measured section. Most of this section appears to form a simple monoclinal sequence, but at the north end of the section, where chert becomes dominant, the rocks are compressed into numerous sharp folds. On the whole, however, the structure is simple and subject to but one interpretation—that the lower (?) Mississippian rocks above described lie conformably below the Calico Bluff formation.

The lower (?) Mississippian rocks just below the mouth of Shade Creek are essentially similar in lithologic character to those north of Calico Bluff, but as they form an isolated occurrence, they can contribute no evidence of value in the placement of these rocks in the geologic sequence. The rocks themselves consist essentially of siliceous slates, most of them hard as flint, and perhaps are better described as silica slates. The beds are from a fraction of an inch to 2 feet thick and include also some conchoidally fracturing chert, a little exceedingly fine quartzite (probably recrystallized chert), and one 2-foot bed of dark-gray oolitic limestone.

North and northeast of the Tatonduk River, however, lie a group of shales, which on the basis of their contained flora must also be included in the sequence that underlies the Calico Bluff formation. A belt of Calico Bluff formation at this locality is described below (p. 421). Both to the east and west of this belt occur very thin-bedded dark-gray to brown shales that weather in shades of white, cream, yellow, and brownish red. On bare spurs and hill slopes these rocks on weathering develop films, perhaps 0.1 millimeter thick, of white material on bedding and joint planes, thus giving to these hills a creamy yellow appearance when viewed from a distance.

These shaly beds range from almost paper thinness up to 2 inches thick and are commonly either crumpled from folding or slumped from weathering, so that good structural data are difficult to obtain. The white and cream-colored coating on the weathered bedding planes of many of these rocks led to the belief in the field that some of them were calcareous shales. On testing these rocks in the laboratory, however, no evidence of carbonates was found. The white coating on the bedding planes, moreover, is not a sulphate but is believed to represent only a leaching of the shale by the action of the weather, the iron and perhaps other elements having thus been removed. In some places this leaching has been accompanied or followed by oxidation of the iron, to give the colored surfaces above mentioned. Finally these rocks are not markedly siliceous, as nearly all of them can be scratched readily with steel.

At the top of this sequence, along the west side of the Calico Bluff formation, siliceous shale and cherty rocks appear, but these are considered to be the basal part of the Calico Bluff formation. These beds dip east and therefore appear to underlie the Calico

Bluff beds. At the base of this group of rocks, near the valley floor of the Yukon, occur sandy beds that contain comminuted plant remains. The base of the sequence is not exposed, but about 1,000 feet of these shales lies between the valley floor and the base of the Calico Bluff formation to the east.

The same beds crop out on the next ridge east of the Calico Bluff formation, but there they dip west, so that a strong presumption exists that these rocks lie in a syncline, in the west limb of which they are overlain by the Calico Bluff formation. The structural and paleobotanic evidence may therefore be said to agree in placing these rocks under the Calico Bluff formation, but the differences in lithology between these nonsiliceous shales and the siliceous shales and cherts below the Calico Bluff formation at its type locality leave much yet to be explained.

### AGE AND CORRELATION

The lower (?) Mississippian rocks just below the mouth of Shade Creek have yielded the only invertebrate fossils so far collected from this sequence of rocks in this particular district. This collection, No. 844, made by E. M. Kindle in 1906, contains the following forms:

Enchostoma sp.
Lingula cf. L. spatulata.

These fossils are regarded by G. H. Girty, of the United States Geological Survey, as possibly of Devonian but more probably of Mississippian age.

The sequence of rocks at the type locality, along the beach north of Calico Bluff, has yielded no fossils. Certain fossils which were collected at this locality by Brooks and Kindle[37] in 1906 and which were considered by them to be a part of the sequence below the Calico Bluff formation are now included in the basal part of the Calico Bluff formation.

The possibility that these rocks are Mississippian and their apparent upward gradation into the upper Mississippian rocks of the Calico Bluff formation make it more logical to label them Mississippian than Devonian. The designation lower (?) Mississippian as here applied is not meant necessarily to signify a correlation with the Madison of the western Cordillera, but merely to show clearly that they underlie definitely the Calico Bluff formation, of upper Mississippian age.

No invertebrates have yet been collected from the rocks north and northeast of the mouth of the Tatonduk River, but during the season of 1930 three plant collections were made from the lower part of

[37] Brooks, A. H., and Kindle, E. M., op. cit., p. 291.

this sequence of rocks. The location of these and their determinations by David White, of the United States Geological Survey, are given herewith:

30AW72. Three miles down the Yukon from mouth of Tatonduk River, and half a mile east of the Yukon, on yellow hill, about 300 feet above valley floor.

"This collection consists of a few waterworn and torn fragments of fernlike stems. They are not even generically identifiable. One of the small pieces of stem appears to be provided with thornlike appendages suggesting *Psilophyton*."

30AW75. Same locality as 30AW72, but 400 feet above valley floor.

"This, the largest of the three lots submitted, embraces a number of fragments of impressions of stems marked by transverse fractures suggesting shrinkage. The stems branch sparingly, the branches tapering relatively rapidly near the base. In several specimens portions of the thin carbonized residue are marked by more or less faint though sometimes distinctly longitudinal ribs suggesting calamarian relations. Close examination shows, however, that these ribs are not in close association with the outer zone or cortex of the stem. They evidently represent the vascular strands or steles or possibly the ends of radiating divisions of the stele, as in *Asteroxylon* or some of its associated genera. This is indicated by their disappearance and irregularity of trend, by which they are seen in one specimen to have been free to move independently of the outer covering of the plant.

"These stems apparently represent the same generic type as that which occurs in the Devonian of Ohio and New York and which I have tentatively referred to the genus *Pseudobornia*. Leaves of the *Pseudobornia* type have not been found, however, in the American deposits.

"The collection also includes a number of spore cases suggestive of *Lepidocystis*."

30AW78. South slope of spur leading up to "Windfall Mountain" and about 2¾ miles south of the limestone summit composed of Tahkandit limestone.

"This lot consists of one fragment of transversely cracked stems similar to those in collection 30AMt75."

With regard to the age of these collections White further states:

The age evidence of the scanty material presented in these collections is insufficient, on account of the nature and state of preservation of the stems and sporangium fragments. In its general aspect it is strikingly similar to the Devonian material mentioned above, and though it may be specifically different, it is probably of the same generic type. From the rather meager collection as it stands, extraneous stratigraphic and paleontologic data being disregarded, the material would be immediately regarded as Devonian in age, or possibly earliest Mississippian. In fact, on taking the collateral data into account, the aspect of the material argues for the correlation of the flora with early Mississippian only at the latest.

If the fragmental nature of both the invertebrate and plant collections is considered there is little difference in the determinations of age. So far as this particular district is concerned, it is of little moment whether the rocks next below the Calico Bluff formation are lower Mississippian or Upper Devonian. With reference to the geologic column farther down the Yukon and farther west in the Yukon-Tanana region, however, serious difficulties of correlation arise if these rocks are assigned to the Upper Devonian, and on the whole, in the light of present knowledge, their assignment to the lower Mississippian seems much more logical.

This assignment, however, does not obviate the difficulty, previously mentioned, of the lack of lithologic similarity between these rocks north of Calico Bluff and their apparent counterpart northeast of the mouth of the Tatonduk River. The writer has been constrained on the evidence of the fossil plants to discuss the argillaceous series north of the Tatonduk River as a part of the lower Mississippian sequence. If the evidence of the plants were disregarded entirely this series of rocks might be interpreted in a number of ways, some of which might involve a radical departure from the Carboniferous sequence accepted at the present time. It seems useless, however, to outline hypothetic alternatives of correlation, with inadequate evidence to prove or disprove any of them. A revision of the Carboniferous section can be attempted only when considerably more evidence of a very positive type has been accumulated.

## UPPER MISSISSIPPIAN ROCKS

### CALICO BLUFF FORMATION

#### DISTRIBUTION

The type locality of the Calico Bluff formation is at Calico Bluff, on the west bank of the Yukon River, about 8 miles due north of Eagle. Faulted parts of the Calico Bluff formation are exposed on the north bank of the Yukon, about 3 miles north of Calico Bluff; on the west bank of the Yukon, just below the mouth of the Seventymile River; and also opposite the mouth of the Tatonduk River. The work of 1930 has definitely identified another occurrence of the Calico Bluff formation, which lies 2 to 3 miles northeast of the mouth of the Tatonduk River.

#### LITHOLOGY AND STRUCTURE

The Calico Bluff formation consists of alternating beds of limestone and shale that range downward into siliceous argillite and cherty beds and upward into calcareous shale and sandy beds. The lithology at the type locality has been described by the writer in considerable detail in an earlier publication [38] and need not be here repeated.

The section of these rocks northeast of the mouth of the Tatonduk River is incomplete and adds nothing to what was previously known of the sequence. The basal cherty bed is present at this locality, and a part of the upper group of alternating beds of limestone and shale,

[38] Mertie, J. B., jr., op. cit., pp. 96–98.

but most of the upper part of the formation has been removed, either by erosion or by faulting, and upon this truncated surface rests a block of the Tahkandit (Permian) limestone.

This piece of the Calico Bluff formation, together with the Permian rocks above it and the lower Mississippian(?) shales below it, all strike from N. 10° E. to N. 10° W., and dip about 25° E. As the underlying shales also crop out on the next ridge to the east, westward with a dip, a synclinal structure has been postulated, so that the so-called lower Mississippian(?) rocks pass below the Calico Bluff formation.

### AGE AND CORRELATION

The Calico Bluff formation contains a large fauna based upon 35 collections made by numerous collectors at intervals since 1896. One hundred and seventeen genera have been identified and probably more than 250 species are represented in the material so far collected. This fauna is Asiatic in aspect and is more closely related to the marine faunas described by Tschernyschew than to the Mississippian faunas of our western Cordillera. According to G. H. Girty, of the United States Geological Survey, who has studied most of the fossils, this formation is upper Mississippian in age and corresponds roughly with the Chester group of the United States.

Additional fossils were collected during the season of 1930 from this formation north of the Tatonduk River. These eight collections add no new genera to the complete list previously published by the writer but do include some new species. For this reason, as well as for the sake of completeness, these faunas are here listed. As heretofore, all the determinative work has been done by Doctor Girty.

30AMt3 (6840). Limestone point on north side of Tatonduk River, about 2½ miles from mouth.

| | |
|---|---|
| Triplophyllum sp. | Pugnoides? sp. |
| Batostomella sp. | Spirifer cf. S. logani. |
| Fenestella sp. | Brachythyris cf. B. subcardiiformis. |
| Rhombopora sp. | Leda sp. |
| Cystodictya cf. C. pustulosa. | Caneyella? sp. |
| Productus cf. P. inflatus. | Pleurotomaria sp. |
| Productus sp. | Pleurotomaria? sp. |
| Pustula n. sp. | Euomphalus sp. |
| Pustula? sp. | Naticopsis sp. |
| Camarophoria sp. | |

30AMt4 (6841). Shale bluff a quarter of a mile west of locality 30AMt3.

| | |
|---|---|
| Productus cf. P. ovatus var. latior. | Caneyella cf. C. wapanuckensis. |
| Pustula cf. P. subsulcata. | Aviculipecten cf. A. rectilaterarius. |
| Leiorhynchus carboniferum. | Gastrioceras? sp. |

30AMt12 (6842). Crest of ridge N. 50° E. of mouth of Tatonduk River, Altitude about 2,100 feet above sea level.

Leiorhynchus carboniferum var. polypleurum.

30AMt28 (6843). Shale bed just below the base of Tahkandit limestone that forms the mountain 4½ miles N. 45° E. of mouth of Tatonduk River. West flank of mountain. This collection represents the highest horizon in the remnant of Calico Bluff formation at this locality.

Leiorhynchus carboniferum var. polypleurum.
Caneyella cf. C. nasuta.
Caneyella cf. C. wapanuckensis.

30AW79. Calcareous shale in bench 2 miles northeast of Miller's cabin at mouth of Tatonduk River. This collection is probably the northwestward extension of the horizon represented by 30AMt4.

Caneyella cf. C. nasuta.

30AW80 (6846a). Argillaceous limestone overlying shale that furnished collection 30AW79.

Fenestella, several sp.
Rhombopora sp.
Cystodictya cf. C. lineata.
Orthotetes? sp.
Rhipidomella cf. R. burlingtonensis.
Chonetes sp.
Productus cf. P. inflatus.
Productus ovatus?
Productus cf. P. parvus.
Productus sp.
Pustula cf. P. vittata.
Pustula cf. P. wallaciana.
Pustula cf. P. wallaciana var.
Pustula cf. P. biseriata.
Pustula? sp.
Spirifer sp.
Brachythyris cf. B. subcardiiformis.
Cleiothyridina cf. C. sublamellosa.
Composita sp.
Hustedia sp.
Edmondia sp.
Parallelodon? sp.
Cypricardinia sp.
Bucanopsis? sp.
Pleurotomaria sp.
Euomphalus sp.
Goniatites cf. G. choctawensis.
Paraparchites? sp.

30AW81 (6846-b). Shale overlying limestone that furnished collection 30AW80.

Caneyella cf. C. nasuta (?).
Gastrioceras cf. G. caneyanum.

30AW83 (6841-a). Thin limestone bed at the locality and same general horizon as the shale that furnished collection 30AMt4.

Productus sp.
Pustula cf. P. biseriata.
Pustula sp.

In addition to the invertebrates above listed, some plant remains were also found in collection 30AMt12. After the invertebrate material of this collection had been studied, with the results above given, the plants of the collection were referred to David White, who contributed the following determinative data:

Collection 30AMt12 consists of a few fragments of rock on which are scattered portions of waterworn and generally very badly triturated plant débris. The largest and best specimens are referable to *Asterocalamites* and may not be specifically different from that found in collection 30AW12. [The species referred to is *Asterocalamites scrobiculatus*.]

With the frayed débris of calamarian stems are small fragments of other parts of plants, some of which may have been from roots and fern stems. One small fragment closely resembles the middle portion of a long leaf of a lepidophyte.

Lots 30AMt12 and 30AW12 are rather clearly Mississippian.

Collection 30AMt12, which contains Mississippian invertebrates, is also determinable as Mississippian on the basis of paleobotanic evidence. But the plants of collection 30AW12, which contains Permian invertebrates, represent the lower part of the upper Mississippian. The report of David White, in regard to collection 30AW12, is given in connection with the description of the Permian rocks.

Farther north along the international boundary Cairnes and his assistants in 1912 made 15 collections of Mississippian invertebrates, of which 10 were made in the belt between the Yukon and the Nation Rivers. Most of these 10 localities lie east of the boundary, and none of them have been visited by the writer. Broadly, however, these 10 collections are known to come from two general areas—one about 2 miles east of the boundary and from 1½ to 3 miles north of Hard Luck Creek and the other in the belt between Ettrain and Jungle Creeks, about 2 miles east of the boundary. Although some species different from those found along the Yukon are present in these collections, the general aspect of the fauna, according to Girty, is Mississippian, comparable with that of the Calico Bluff formation. Further data about the lithology of the rocks from which these collections were made are expected to be obtained as the geologic surveys of the Yukon-Porcupine region are extended.

### INTERMEDIATE FORMATION

Between the Calico Bluff formation and the Nation River formation a group of intermediate or transitional rocks is believed by the writer [39] to occur. Such rocks have been observed on the north and south sides of the Seventymile River west and southwest of Calico Bluff, and along the northeast side of the Yukon River, north of Nation. The so-called lower Mississippian (?) rocks northeast of the mouth of the Tatonduk River were also considered originally to belong to this intermediate formation but have now been assigned tentatively to the lower (?) Mississippian.

As originally defined, this formation was said to consist of several types of shale, including argillaceous, arenaceous, calcareous, and siliceous varieties, siliceous limestone and slate, and beds of chert and cherty grit. Not all these rocks were exposed at any one locality, and the different localities were supposed to represent different horizons in the formation. These rocks are usually characterized by a peculiar type of weathering, giving rise to films of limonitic or hematitic material on bedding and joint planes, so that, when viewed from a distance, the hill slopes composed of such rocks show a bright reddish color.

[39] Mertie, J. B., jr., op. cit., pp. 109–113.

These rocks are relatively nonresistant to erosion and therefore crop out on low inconspicuous ridges or in valleys, so that complete stratigraphic sections and good structural data are difficult to obtain. As a result of these conditions, the complete sequence of these rocks has nowhere been observed, nor have their upper or lower contacts been observed in any locality free from faulting. These rocks were finally regarded as belonging above the Calico Bluff formation and below the Nation River formation but as being more closely related stratigraphically to the former than to the latter. The thickness was estimated to be somewhere between 1,000 and 2,000 feet.

No new work was done on this series of rocks during the season of 1930, but the rocks north and northeast of the mouth of the Tatonduk River, which formerly were supposed to be a part of this formation, have been tentatively reassigned to the lower (?) Mississippian. This new assignment is rendered necessary by the determinations of fossil plants collected at this locality and by the simplest possible interpretation of the structure. These rocks, however, occur in a zone of faulting, and the most apparent structural interpretation is perhaps not the true one; also, a determination of geologic age based upon very fragmental fossil material is not necessarily dependable. The study of this obscure formation, because of the difficulties above mentioned, is one of the baffling problems of this district, and one which is not likely to be solved completely until a detailed study of the geology of the district is made.

### NATION RIVER FORMATION (PENNSYLVANIAN?)

#### DISTRIBUTION

The Nation River formation crops out along the Yukon below Eagle and extends westward to the Seventymile River and northward in a widening band parallel to the Yukon into the valley of "Hug" (McCann Hill). It also crops out as a thin wedge northwest of boundary station "Crow" and extends thence northwestward in a widening band parallel to the Yukon into the valley of the Nation River and northeastward up the southeast side of the valley of the Nation River to the international boundary.

#### LITHOLOGY AND STRUCTURE

Much of the area above outlined represents an extension of this formation not previously known, and the work of 1930 has also added some new ideas regarding the stratigraphy and structure. This formation consists of gray clay shale, sandstone, and conglomerate, and except for the fact that it is more indurated it resembles the Tertiary rocks southwest of the Yukon on the Alaska side of the boundary.

Below Eagle, along the Yukon, the Nation River formation consists of dark-gray sandstone in beds from a few inches to 20 feet thick, interbedded with beds of drab clay shale. The sandstone is composed of grains of chert, decomposed feldspar, quartz, and more or less carbonaceous material. Ripple marks are common, as are various kinds of mud lumps and concretions, but cross-bedding is less common. Beds of dark conglomerate, 10 feet or more thick, composed mainly of chert pebbles set in a sandy matrix, are interstratified with the sequence. Below Boulder Creek, the proportion of sandstone to shale is greater, and comminuted and carbonized plant remains are present in and between the beds of sandstone and shale.

To the north and east, in the vicinity of stations "Chief" and "Hug," the base of the Nation River formation is seen to best advantage. At "Chief" no stratigraphic section was actually measured, but the writer estimated that the basal conglomerate there present was about 80 feet thick, and about 250 feet above it another conglomerate about 50 feet thick was present. At this point the Nation River formation lies upon cherty rocks, probably correlative with the highest Middle Devonian formation, and as the geologic structure at this locality is rather simple, it seems evident that the base of the Nation River formation is marked by two or more massive plates of coarse conglomerate. This generalization implies that where the Nation River formation lies upon older rocks and the basal conglomerate members are absent, as at certain localities along the Yukon, the contact is probably a fault rather than a bedding plane.

From Trout Creek down the west bank of the Yukon to the vicinity of the Nation River the Nation River formation shows much the same assemblage of rocks. On the Nation River this formation contains a bed of bituminous coal, but this and the other details of lithology and structure on the Nation River have previously been described by the writer and need not be repeated here. Certain features of the stratigraphy of this formation on the Nation River, however, require repetition because of their general interest and utilization in correlation. First is the apparent gradation downward of the Tahkandit limestone into the underlying Nation River formation. Below the massive Permian limestone itself lies about 300 feet of conglomerate and sandstone, with one thin bed of massive limestone, all of which contains Permian fossils and below which begins the drab shale and sandstone so characteristic of the Nation River formation. Were it not for the contained fossils, this 300 feet of conglomeratic strata would certainly be considered a part of the Nation River formation. This relationship is the strongest argument for the placement of the Nation River formation just below the Permian limestone in the geologic column but can not be considered absolute proof of the relative age of the Nation River formation, as a disconformity might exist between the two formations, and the 300 feet of conglomeratic material might be interpreted as reworked material from the Nation River formation, derived from an old land surface that bordered the Permian sea. Within these 300 feet of strata, about 50 feet above the top of the true Nation River formation, occurs a bed of sandstone that shows curious irregular imprints from 4 to 12 inches long that resemble a ropy lava that was cooling while being agitated. These imprints are probably of inorganic origin, but the interesting feature is that a similar bed of sandstone with identical markings was found during the season of 1930 on Hard Luck Creek in the lower part of the Nation River formation as there exposed. There may, of course, be several such horizons characterized by these inorganic markings, but if only one exists it seems probable that a disconformity is present between the Permian and Nation River formations. A corollary of this conclusion would be that the contact between the Nation River formation and the Tindir group on Hard Luck Creek is not a normal depositional contact. This horizon, characterized by inorganic markings, with its possible interpretations, leads to no definite conclusions at the present time but may subsequently be of value in connection with further study of the Nation River formation.

So far as general lithologic and structural data are concerned, the section of the Nation River formation on Hard Luck Creek yields little information of value, as only a few intermittent exposures along the banks of the creek are available. At the northwest end of the sequence, a sandstone of the type characteristic of this formation crops out in the creek bed and dips conformably northeast under the Tahkandit limestone, but the actual contact is not visible. Upstream from this point for 2½ miles conglomerate crops out at intervals in bluffs along the northeast bank. These conglomerates are believed to be intraformational. At the last exposure of these rocks upstream a bed of massive conglomerate crops out on a high spur on the northeast bank and dips downstream or northwest. Stratigraphically below this conglomerate lie beds of massive sandstone from 2 to 6 feet thick, succeeded below by thinner beds of sandstone interbedded half and half with soft brown friable shale. The very lowest exposures consist of nearly pure shale. The base of the formation is not exposed, so that it is impossible to state whether the basal conglomerate is present or not.

On Waterfall Creek, the Nation River formation is also exposed, but only a small part of the formation is present. The contact between it and the underlying lavas and tuffs of the Tindir group is a fault contact, and all the lower beds of the Nation River formation are faulted out. At the top of the formation it appears to grade upward into the Tahkandit limestone in much the same way as at the mouth of the Nation River.

No complete section of the Nation River formation has yet been observed, but a series of estimates of its thickness have been made by the men who have studied it. Brooks [40] in 1906 estimated the thickness at 3,700 feet; Cairnes [41] in 1911 and 1912 estimated it at 4,000 feet; Blackwelder [42] suggested a possible thickness of 5,000 to 6,000 feet; and the writer,[43] without suggesting any definite figure, has been inclined to favor the higher estimate made by Blackwelder.

### AGE AND CORRELATION

The Nation River formation, so far as known at present, is a group of nonmarine sediments. The ripple marks, cross-bedding, and muddy concretionary forms that characterize these rocks suggest that they are of fluviatile origin. No invertebrate fossils have yet been found in this formation, but a number of collections of fossil plants have been made by several geologists, including Collier, Hollick, Kindle, Martin, Blackwelder, and the writer. David White, of the Geological Survey, who has determined some of this material, is of the opinion that the plants are of lower Mississippian or Upper Devonian age. The stratigraphy, so far as it is known at present, indicates that this formation directly underlies the Tahkandit limestone, and as the next lower stratigraphic horizon in this district that is determined by fossils is upper Mississippian in age, it has been concluded that the Nation River formation is probably of Pennsylvanian age.

The weakness of the conclusion mentioned above is the fact that the Nation River formation has not yet been observed resting directly upon Mississippian rocks nor in fact in contact with them where there is no possibility of faulting. Only at "Chief" has the undisturbed basal conglomerate of the Nation River formation been observed, and there it rests upon the highest Middle Devonian rocks. Brooks, Cairnes, Blackwelder, and the writer have interpreted the Nation River formation as directly underlying the Tahkandit lime-

[40] Brooks, A. H., and Kindle, E. M., op. cit., p. 294.
[41] Cairnes, D. D., The Yukon-Alaska international boundary between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, p. 90, 1914.
[42] Blackwelder, Eliot, unpublished notes.
[43] Mertie, J. B., jr., op. cit., p. 199.

stone and overlying the Calico Bluff formation, but Martin[44] has always been of the opinion that the Nation River formation lies stratigraphically below the Calico Bluff formation, and in this opinion he is upheld by David White's determinations of the fossil plants. Until more critical stratigraphic data have been obtained this question will have to remain unsolved.

No fresh-water formation of Pennsylvanian age is known elsewhere in Alaska. On the Porcupine River, Kindle[45] found Mississippian plants at a horizon in black shale that directly underlies the marine Mississippian sequence, and during the season of 1930 the writer, with reservations previously noted, found a similar horizon north of the mouth of the Tatonduk River. Neither of these two occurrences can be correlated lithologically with the Nation River formation.

Near Cape Lisburne, on the Arctic coast, a coal-bearing freshwater bed has been described by Collier[46] and by Smith[47] at the base of the marine Mississippian sequence. The rocks at this horizon consist of slate, shale, and limestone, and therefore they also do not correspond lithologically with the rocks of the Nation River formation.

Therefore, although Mississippian floras are known elsewhere in interior and northern Alaska, no other rocks that are lithologically similar to the Nation River formation have yet been discovered north of the Alaska Range. The area occupied by the Nation River formation, however, can not yet be regarded as definitely circumscribed, for it may extend for miles eastward into Yukon Territory. It is a unique geological unit that merits much further investigation.

## PERMIAN ROCKS

### TAHKANDIT LIMESTONE

#### DISTRIBUTION

The Tahkandit limestone occurs in a folded sequence of rocks at the mouth of the Nation River, where it was originally identified and studied. It is now known to extend from this locality in a northeasterly direction up the southeast side of the Nation River to and beyond the international boundary. From the mouth of the Nation River it also continues southwestward for a number of miles until it is overlapped by later rocks, but farther south it emerges again

[44] Martin, G. C., informal communication, based on field work in 1914.

[45] Kindle, E. M., Geologic reconnaissance of the Porcupine Valley, Alaska: Geol. Soc. America Bull., col. 19, pp. 332–336, 1908.

[46] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: U. S. Geol. Survey Bull. 278, pp. 18–19, 1906.

[47] Smith, P. S., and Mertie, J. B., jr., Geology and mineral resources of northwestern Alaska: U. S. Geol. Survey Bull. 815, pp. 151–185, 1930.

from beneath these younger rocks and returns eastward nearly to the Yukon. The termination of this eastward-trending band of the limestone is represented by an isolated block that forms the top of a mountain about 4 miles northeast of the mouth of the Tatonduk River.

#### LITHOLOGY AND STRUCTURE

The lithology and structure of the Tahkandit limestone formation at the mouth of the Nation River has previously been described by the writer.[48] It suffices to state here that it consists at that place of 373 feet of limestone and 154 feet of conglomerate and sandstone, more or less interbedded but with conglomeratic beds forming the basal part of the section. This 527 feet of strata probably does not represent all of the Permian section of this district.

During the season of 1930 the Tahkandit limestone was observed where it crosses Hard Luck and Waterfall Creeks; it was also identified on the mountain northeast of the mouth of the Tatonduk River; it was observed along the valley wall of the Yukon, about a mile northeast of the mouth of the Tatonduk River; and a somewhat better idea of its distribution along the southwest side of the Yukon River was obtained.

On Hard Luck Creek the massive beds of soft buff limestone were observed on both walls of the lower valley, striking N. 35° E. and dipping 35° SE., thus overlying as usual the adjoining Nation River formation. No section was measured here, and although the limestone was highly fossiliferous no collections were made, as they were not required for identification of this horizon. On Waterfall Creek part of the fossiliferous basal conglomerate of the Tahkandit limestone was observed, above which lay the Permian limestone. This conglomerate crops out in beds from 6 inches to 4 feet thick, but it is probable that even thicker beds are present. The basal limestone beds are much crushed and have a greenish cast, similar to the green of the cherty fragments in the underlying conglomeratic beds. The higher beds in general are more massive and of a cream color. All these rocks are fossiliferous, and a collection was made from the lower limestone beds. These rocks crop out for a distance of 1,500 feet in Waterfall Creek, but the top of the sequence can not be seen, as the valley opens up to the northwest into the flats of the Nation River and the valley walls become gentle wooded slopes, under which all hard rocks are concealed. The strike here is N. 10° W., but the dip ranges from 10° to 60°. The thickness of beds here exposed can not be accurately computed but is believed to be about 600 feet.

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[48] Mertie, J. B., jr., op. cit., pp. 122-123.

On the mountain 4 miles northeast of the mouth of the Tatonduk River, the Tahkandit limestone consists for the most part of dense, finely crystalline limestone, in beds from 6 inches to 3 feet thick, separated by partings of nodular limestone in beds from 1 to 6 inches thick. The thinner beds seem to be lighter in color than the more massive beds. The Tahkandit limestone here directly overlies the Calico Bluff formation, and the fossiliferous conglomeratic beds that elsewhere characterize the basal part of this formation are absent. The limestone is fossiliferous, and collections were made both from its upper and lower horizons. The Tahkandit limestone at this locality strikes about north and dips 10°–25° E. After making due allowance for strata concealed by talus on the west side of this mountain, it is estimated that 400 feet of limestone is present. Neither the whole of the Permian nor the whole of the underlying Calico Bluff formation are here represented, and it is altogether likely that both formations have been faulted into their present position; indeed, the shattered character of some of the limestone beds bear out this interpretation. Unfortunately, absolute evidence of faulting with consequent dislocation of the geologic section was not obtained, with the result that the shale formation that underlies both the Calico Bluff formation and the Tahkandit limestone at this locality has been interpreted as older than upper Mississippian.

About 1½ miles southwest of the base of the Permian limestone above described, along the west edge of a 400-foot rock terrace that forms the northeast wall of the Yukon Valley, the lower fossiliferous conglomeratic bed of the Tahkandit limestone occurs above a thin fringe of the Nation River formation. This represents the horizon that is missing on the mountain to the northeast and suggests a great thrust fault, by which the Permian limestone has been dislocated and moved transversely and upward for a distance of 1½ miles. The evidence of faulting in the basal Permian and in the underlying Nation River beds is unmistakable, several fault planes with deep striæ being noted along the face of this terrace. Evidently this locality is part of the same zone of faulting, in which several formations have been sliced into thin bands, along the north bank of the Yukon, northwest of Calico Bluff. The true Carboniferous sequence will be very difficult to unravel in this area, and it is to be hoped that less complex structure will be found farther north, in the Yukon-Porcupine region.

## AGE AND CORRELATION

A complete tabulation of the fauna of the Tahkandit limestone has previously been published by the writer,[49] based upon the paleontologic determinations of G. H. Girty, of the United States Geological Sur-

[49] Mertie, J. B., jr., op. cit., pp. 123–130.

vey. At that time 54 genera were known, and at least 123 species had been recognized. The age was determined to be early Permian.

During the summer of 1930 four additional collections were made from the Tahkandit limestone, which are recorded below. The determinative paleontologic work, as before, was done by Mr. Girty. These collections are as follows:

30AMt29 (6843 a). Base of Permian limestone that forms the mountain 4½ miles N. 45° E. of mouth of Tatonduk River. West flank of mountain.

Productus cf. P. cancriniformis.
Productus cf. P. aagardi.
Pustula cf. P. punctata.
Pustula sp.
Spiriferella arctica var.
Martinia? sp.
Cleiothyridina cf. C. incrassata.
Pleurotomaria? sp.
Bulimorpha? sp.

30AMt30 (6843 b). Upper part of Permian limestone that forms the mountain 4½ miles N. 45° E. of mouth of Tatonduk River. Cliffs near top of ridge on west flank.

Chonetes cf. C. ostiolatus var. impressus.
Productus cf. P. phosphaticus var.
Pustula cf. P. humboldti.
Pustula sp.
Rhynchopora cf. R. nikitini.
Spiriferella arctica var.
Spiriferella cf. S. saranæ.
Squamularia cf. S. perplexa.
Aviculipecten sp.
Ostracoda.

30AMt200 (6844). Southwest side of Waterfall Creek, about 3½ miles N. 40° W. from "Nation," a station of the international boundary survey.

Leioclema? sp.
Rhipidomella? sp.
Chonetes cf. C. ostiolatus.
Chonetes cf. C. ostiolatus var. impressus.
Productus cf. P. aagardi.
Productus cf. P. geniculatus.
Productus cf. P. phosphaticus.
Productus cf. P. phosphaticus var.
Pustula cf. P. humboldti.
Pustula cf. P. humboldti var.
Rhynchopora cf. R. nikitini.
Squamularia cf. S. perplexa.
Aviculipecten sp.
Streblopteria sp.
Paraparchites? sp.

30AW12 (6845). From conglomeratic beds at base of Permian sequence. Outcrop about 2 miles east-northeast of mouth of Tatonduk River, along bluffs bordering valley floor of Yukon River.

Acervularia? sp.
Cœloconus? sp.
Chonetes sp.
Productus cf. P. cora Tschernyschew, not D'Orbigny.
Pustula cf. P. punctata.
Pustula cf. P. irginae.
Modiola sp.
Aviculipecten cf. A. magnus.
Ostracoda.

Cairnes in 1912 also made three collections of fossils from the beds now called the Tahkandit limestone. The localities of the collections and their fauna, as listed by Girty, are given below:

XVIk15. About 2¾ miles north of Nation River and a quarter of a mile or less west of the international boundary. This collection was obtained a short distance north of the area here designated the Tatonduk-Nation district.

Chonetes cf. C. variolatus.
Productus cf. P. aagardi.
Rhynchopora cf. R. nikitini.
Spiriferina sp.
Aviculipecten? sp.

XVIIf42. Along Jungle Creek, about 1¼ miles in an air line east of the international boundary line.

Polypora sp.
Chonetes sp.
Productus cf. P. aagardi.
Productus n. sp.
Rhynchopora cf. R. nikitini.

XVIIn34. About 1 mile west of the international boundary and about three-fourths of a mile north of Ettrain Creek.

Chonetes cf. C. ostiolatus.
Productus cf. P. aagardi.
Productus n. sp.
Rhynchopora cf. R. nikitini.

The tabulation of the Tahkandit fauna previously published by the writer, together with the three collections made by Cairnes in 1912 and the four collections made by the writer in 1930, constitute all the invertebrate material at present available from this horizon. The four recent collections have added 7 genera and 8 species hitherto unknown from the Tahkandit limestone, so that now 61 genera and about 131 species are recognized.

Many of the species from this horizon are more closely related to Asiatic than to North American forms, and Girty correlates this fauna with the Artinskian of Tschernyschew or places it at a low horizon in the Permian. The same horizon is widely known elsewhere in Alaska, but at many places the lithology is quite different from that of the Tahkandit limestone.

The tabulation of fossil data regarding the Tahkandit limestone would be incomplete without a reference to the single collection of plants that has been made from this formation. These plants are included in collection 30AW12, the locality and invertebrate fauna of which have been given above. The plant remains were referred to David White, of the United States Geological Survey, with the following results:

30AW12 (6845). From conglomerate beds at base of Permian sequence. Outcrop about 2 miles east-northeast of mouth of Tatonduk River, along bluffs bordering valley floor of Yukon River.

Lot 30AW12 consists of the slightly worn impressions of a calamarian stem. The impression shows the narrow transverse nodal crease and the uninterrupted ribs characteristic of *Asterocalamites* (*Bornia*). The species is included in *Asterocalamites scrobiculatus* and is characteristic of the Mississippian. From the size of the ribs and the nodal characters I should be inclined to refer this specimen to the lower part, perhaps, of the upper Mississippian.

Thus, from the same pieces of rock, Permian invertebrates and early Mississippian plants have been recognized. In the opinion of the writer the quantity of the zoologic evidence in this case so outweighs the quantity of the botanic evidence that the zoologic evidence has been regarded as more convincing.

## MESOZOIC AND TERTIARY ROCKS

Mesozoic rocks occur in the Tatonduk-Nation district, but no work supplemental to that of 1925 was done during the season of 1930. In fact, these rocks were not even examined or visited, so that no new data are available. Therefore, for the purpose of this bulletin, it suffices to refer to the previously published description of the Mesozoic rocks[50] and to enumerate them, stating in summary their general characteristics.

Triassic, Lower Cretaceous, Upper Cretaceous, and Tertiary rocks have all been recognized, and maps showing their distribution given in the publication cited above. In the work so far done, the Upper Cretaceous and Tertiary rocks have not been separated, but their differences are fairly well known, and the separation can easily be made in the course of more detailed work. The general distribution of these rocks is shown on the accompanying geologic map.

The Triassic system is represented here as elsewhere in Alaska only by rocks of the Upper Triassic series. They consist essentially of thin-bedded limestone and shale and are highly fossiliferous. At one or more horizons in the series lie beds of oil shale, and one sample from the valley of Trout Creek carried 28 gallons of shale oil to the ton.[51] Neither the thickness of the Upper Triassic series nor its relations to overlying and underlying rocks are known, but from the best evidence available no structural unconformity exists between it and the underlying Tahkandit limestone. T. W. Stanton, of the United States Geological Survey, has recognized 28 genera and about 35 species of invertebrates in the rocks of this series. Its age is definitely determined as Upper Triassic.

The Lower Cretaceous rocks of this region have received the formal designation of Kandik formation. This formation consists of black slate and fairly thin beds of dark-gray to dull-brown sandstone. Some thicker beds of quartzitic sandstone serve at some localities as horizon markers in the sequence. The upper part of the sequence appears to be composed mainly of sandstone and conglomerate. Neither the top nor the bottom of the series has been definitely recognized, but at least 2,400 feet of strata is known to be present. Twelve collections of invertebrates have been made from this formation by Collier, Kindle, Cairnes, Blackwelder, and the writer, and in these collections 9 genera and about as many species of invertebrates have been recognized. The type fossil is *Aucella crassicollis* Keyserling. The age is definitely determined as Lower Cretaceous.

[50] Mertie, J. B., jr., op. cit., pp. 130–146.
[51] Idem, pp. 131–132.

The Upper Cretaceous and Eocene rocks consist mainly of impure greenish-gray to almost black sandstone, graywacke, sandy shale, and beds ranging from grit to coarse conglomerate. These rocks are of nonmarine and probably of fluviatile origin and contain fossil plants at different horizons. Along the southwest side of the Yukon they have an economic significance, in that they are the proximate source of some of the placer gold found on the creeks that drain from them. These rocks are much more indurated and deformed than might be expected from their age, but this condition has been produced by their proximity to a great granitic batholith southwest of them. The thickness has not been definitely determined, but 4,000 feet is believed to represent the minimum. From 20 or more collections of fossil plants, both Upper Cretaceous and Eocene floras have been identified. Obviously two distinct series of rocks are present, but they have not yet been mapped as separate formations.

### QUATERNARY SYSTEM

Unconsolidated deposits of Pleistocene and Recent age are present in all the stream valleys of this district, but no special study has been made of them, and all types and ages of alluvium have been mapped collectively as a single unit. In general the volume of alluvial deposits in this district bears a close relation to the size of the valley that contains them, and therefore the Yukon Valley has the most extensive deposits of such material. The Nation River is next to the Yukon in the extent of its alluvial deposits and the other streams all have smaller tracts of these deposits.

The unconsolidated deposits of this district may be classified broadly as follows:

- Recent deposits:
  - Fluviatile deposits.
  - Residual and hillside deposits.
- Pleistocene fluviatile and lacustrine deposits.

The terms "Pleistocene epoch" and "ice age" are not synonymous in Alaska, for the ice age in Alaska may have begun sooner and certainly persisted longer than in the northern United States. In fact, some parts of Alaska are still covered by glacial ice and may therefore be said to be still in the ice age. Interior Alaska, however, with the exception of some local alpine glaciers, remained free from glaciation throughout the Quaternary period. Yet the Alaska Range in the south, the Brooks Range in the north, and the upper Yukon Valley in Canada were all glaciated during the Pleistocene, with the result that interior Alaska was girdled on three sides by ice. Only in western and southwestern Alaska was an ice barrier lacking. This girdle of ice naturally had marked effects on the climate, erosional processes, and sedimentation of interior Alaska, not only during the Pleistocene but also during a part of Recent time.

One of the effects of the surrounding ice fields during the Pleistocene epoch must have been an appreciable lowering of the mean annual temperature, without regard to any general lowering of temperature in North America as a whole. The present climate of interior Alaska is so close to a glacial climate that glaciation could be brought about at the present time by slight changes in the mean annual temperature or in precipitation, or by numerous combinations of changes in both of these features. But if the mean annual temperature during the glacial epochs of the Pleistocene was less than at present, three explanations of the absence of glaciation in interior Alaska during the Pleistocene suggest themselves:

1. The precipitation may have been essentially the same as at the present time, but the lowering of the mean annual temperature may have been insufficient to produce glaciation.
2. The precipitation may have been somewhat greater but the mean annual temperature only slightly less than at the present time.
3. The precipitation may have been less and the mean annual temperature considerably lower than at the present time.

As climatologic data for the Pleistocene are lacking, the prevalence or absence of these alternative conditions can not be proved. It should be observed, however, that for any particular Pleistocene climate the third of these hypotheses permits a greater lowering of the mean annual temperature without the production of glaciation. If the total decrement in the mean annual temperature of interior Alaska during the Pleistocene was of considerable magnitude, it is probable that precipitation was less during the Pleistocene than at the present time.

As the interior of Alaska was not glaciated, no true glacial deposits are found. In the upper Yukon Valley, however, ice fields existed during the Pleistocene epoch, and these produced a great volume of morainal and glaciofluviatile deposits that were eventually transported downstream by the Yukon River. The glacial sources of such material, however, were a considerable distance upstream from the Tatonduk-Nation district, and by the time this glacial outwash was transported into Alaska it had been reworked and mixed with nonglacial alluvium to such an extent that it was nearly normal stream detritus. Most of the fluviatile deposits of this district were derived in this manner from glacial débris in the upper Yukon Valley of Canada.

These Pleistocene fluviatile deposits consisted of silt, sand, and gravel. Much of the very finest silt, or rock flour, was probably transported all the way to the mouth of the Yukon, and little of this now occurs in the upper Yukon Valley. In the present valley floor of the Yukon such deposits of the ice age have been largely reworked by later erosion, and if preserved at all are buried under a mantle of later sediments. Along the river terraces, however, such deposits are still preserved in some places as thick alluvial banks and in others as thin veneers upon the old bedrock surface of the river. In the vicinity of the Tatonduk River the oldest well-marked river terrace lies at an altitude of about 400 feet above the present valley floor of the Yukon. It is covered with a thin mantle of detritus, and along the upper edge of the escarpment, where the detritus slumps down the hill slopes, it consists of a varied assortment of pebbles and small cobbles. Finer material is also probably present but not visible under present conditions. This terrace is particularly well developed along the east side of the Yukon below the mouth of the Tatonduk River but is also visible farther upstream. It also follows up the Tatonduk River itself and may be recognized for 4 or 5 miles up that stream, principally along the north valley wall. This 400-foot terrace along the Yukon probably correlates with a 500-foot terrace in the upper part of the Seventymile River, previously described by the writer,[52] and probably represents a late Pliocene or early Pleistocene valley floor of the Yukon, developed by a constant base level that persisted over a long period of time. A similar well-developed terrace about 50 miles farther down the Yukon stands at an altitude of 700 feet above the present river level, so that still older valley floors of the Yukon are preserved at favorable localities.

A lower but more persistent terrace is visible along the west side of the Yukon, opposite the mouth of the Tatonduk River. This terrace is 75 to 100 feet above the river, is timber-covered, and extends downstream, first on one side of the river and then on the other, to a point beyond the Nation River. It is not a flat terrace but is somewhat undulating and rises gradually from the river toward the hills. This terrace also is an old valley floor and is correlated with the equally persistent bench observed by the writer[52] along the south side of the Seventymile River. When the Yukon controlled the Seventymile River at this level, the latter probably emptied into the former at the south end of Calico Bluff, instead of at the present junction.

Other lower terraces are also present in this district. In the valley of the Tatonduk River, about 3 miles above its mouth, a well-developed little timber-covered bench 20 feet above the level of the Tatonduk River was observed. Similar benches were seen in the

[52] Mertie, J. B., jr., op. cit., p. 8.

upper Seventymile River, and on Hard Luck Creek, below the mouth of Pleasant Creek, this stream has incised itself in a well-developed old valley floor, from 20 to 50 feet above the present level of Hard Luck Creek.

The second type of ancient fluviatile or perhaps lacustrine deposits of this region consists of the thick deposits of so-called muck, or silt charged with black peaty material, which at places overlie the normal type of fluviatile material. In some places lenses of sand or gravel are interbedded with this black mucky material, but as a whole the muck can hardly be considered to have originated by normal stream action. Such sediments are characteristic of the valleys of the streams tributary to the Yukon, which, unlike that river, headed in nonglaciated areas. The exact origin of the black mucks has not been explained, but their present position in old stream channels, commonly in bench channels well above the level of present streams, shows that they were deposited in large part at the time when interior Alaska was girdled with ice. Vegetation existed, streams flowed, and animals such as the bison and mammoth lived at the time of their formation, so that such deposits can not be regarded as eolian deposits of an Arctic desert. The idea that they are of lacustrine origin has much in its favor but is beset with certain difficulties that make its acceptance at present somewhat questionable.

After the retreat of the glaciers both master and tributary streams began to approach one another in the character of their erosional processes and transported sediments, and at the present time the transportation and sedimentation of stream detritus in interior Alaska during the open season is not essentially different from that observed in the northern United States. Alluvial deposits of silt, sand, and gravel have been and continue to be deposited in Recent time. The low benches and terraces above mentioned indicate that at intervals the level of erosion for the Yukon has been lowered in Recent time, and the fact that the river cuts bedrock at numerous places between the international boundary and Circle corroborates this conclusion.

The residual and hillside deposits, however, serve to emphasize certain conditions of weathering and transportation of sediments that are peculiar to this sub-Arctic region. At the present time as well as during the Pleistocene, much of the alluvium and upper bedrock, except near running streams, has a temperature below the freezing point of water. This condition is due partly to the low mean annual temperature and partly to the presence of a heavy layer of moss and peaty vegetation that acts as an insulator against the heat of the sun's rays. Hence, except at favorable localities, a water table is not present. Moreover, the moss and other vegetal material, which acts as a sponge, retains much of the precipitation at the surface of the ground, thus diminishing the supply of water available for circulation in the zone of weathering, above the water table. Therefore the solvent and depositional effects of circulating water, both in the zone of weathering and below the water table, are sharply restricted. But water also carries in solution oxygen and carbon dioxide, and the chemical effects of these reagents are likewise diminished. Hence, chemical weathering in the frozen ground of interior Alaska is accomplished mainly by the action of oxygen and carbon dioxide in the gaseous state, and as the effects of these reagents without the aid of water are relatively small, it follows that chemical weathering is not nearly so effective as in regions farther south.

Although chemical weathering is thus restricted, the frozen condition of the ground gives rise to other processes that compensate in some measure for this deficiency. Near the surface, where the rays of the sun are effective, a continual process of thawing and freezing goes on in summer and results in frost heaving and related phenomena. The rocks are fractured and loosened by the formation of ice in their crevices, and in this manner peculiar types of angular rubble, showing little oxidation, tend to form above the surface of bedrock, giving rise to the so-called residual deposits. This method of rock comminution is very effective but is seasonal rather than continuous, so that less residual material in the aggregate is doubtless produced than by the more familiar processes that operate in temperate climates.

The same thrusting forces that tend to fracture the rocks are also effective in their subsequent transportation. By alternate thawing and freezing, the loose débris is thrust upward and laterally away from its place of origin. On flat or nearly flat surfaces circular or irregular boils of angular rock and mud, resembling landslide débris, are commonly visible at the surface. Eventually this material begins to move slowly downhill toward the stream channels and in so doing produces on the hill slopes characteristic flow lines that resemble successive wave crests on a shallow body of water. Such mantles of rock rubble, on their way to the lower valleys, constitute the hillside or eluvial deposits of this region.

The depth of the residual deposits that have not moved appreciably from their site of origin is dependent not only on their rate of accumulation but also on their rate of dissipation. It has been suggested that the rate of accumulation is slow, as compared with the accumulation of residual material in temperate climates. Yet these deposits in sub-Arctic Alaska are shallow, and the natural inference is that the movement down the hill slopes by soil flowage, aided by the effects of freezing and thawing, is equally effective as an agent of transportation. This inference is further indicated by the commonplace observation, in upper valleys, of soil-flow material crowding laterally into the stream channels at a rate so great that the stream is unable to handle the material. At such localities the stream develops a deep, narrow channel, flowing in and upon alluvium, and aggradation proceeds apace at the very headwaters of a valley.

This cursory sketch of the formation and transportation of residual and hillside deposits is intended as a summary rather than a complete description or exposition of the peculiar processes of weathering and alluviation that characterize sub-Arctic climates. The formation of high rock terraces by such processes is another characteristic sub-Arctic phenomenon that is very prevalent. These and other features of sub-Arctic weathering constitute special phases of physiography which have been more intensively studied in the Scandinavian countries than in Alaska.

## IGNEOUS ROCKS

### GENERAL FEATURES

The igneous rocks of the Tatonduk-Nation district may be divided, on the basis of relative ages, into two groups, both of which, however, are petrographically similar. The older of the two groups is composed of lavas and intrusive rocks of pre-Middle Cambrian age. The younger group is made up of undifferentiated lavas and intrusive rocks of several ages, ranging from the Devonian or perhaps earlier up to the end of the Paleozoic.

### IGNEOUS ROCKS OF TINDIR GROUP

#### DISTRIBUTION

The older group of lavas and intrusive rocks occurs in a number of small areas, in association with the rocks of the Tindir group. Five principal areas of lavas and associated pyroclastic rocks are shown on Plate 7, together with some smaller areas, which may or may not be of surficial origin. The five areas of lavas are located (1) in the valley of Pass Creek; (2) in the upper valley of Hard Luck Creek, at the mouth of Pleasant Creek; (3) in the hills south of the mouth of Cathedral Creek; (4) in the lower valley of Hard Luck Creek, about 5 miles below the mouth of Cathedral Creek; (5) in a zone extending from Waterfall Creek to "Little Nation" (the intrusive rocks occur in the form of dikes and sills and in general are too small to be shown on the geologic map).

#### PETROGRAPHIC CHARACTER

The general lithology of these rocks has been considered under the heading of the rocks of the Tindir group. (See pp. 380–382.) In petrographic character, megascopically, these rocks are medium gray to very dark gray when little altered, but many of them are greenish gray through subsequent chloritization. All of them are fine grained and even glassy. A considerable proportion of the lavas are amygdaloidal, with vesicles filled with later minerals. The agglomeratic types have suffered the greatest subsequent alteration and generally are mottled in tones of dark green and dark brownish red. The dikes and sills are in general not quite so fine-grained as the flows and appear to be somewhat less altered.

Under the microscope these rocks are seen to range in crystallinity from holocrystalline to hyalocrystalline, or from wholly crystalline to half glassy. None of the dike rocks were observed to be appreciably glassy, but a considerable proportion of the lavas are glassy in varying degrees. Neither the extrusive nor intrusive types of these rocks are noticeably porphyritic, the component minerals being either nearly equigranular or else ranging gradually from smaller to larger crystals.

The common constituents of these rocks are plagioclase feldspar, pyroxene, iron oxides, and rock glass, with accessory apatite. The plagioclase, where determinable, generally has the composition of acidic labradorite, but much of it is altered to paragonite and chloritic material and is practically indeterminate. A little albitization of the plagioclase feldspar was also observed, but this is not typical of much of the alteration. The pyroxene, in its unaltered condition, is more commonly colorless and diopsidic than colored and augitic. On the whole, the pyroxene is less altered than the plagioclase feldspar, but where it is altered the secondary products are chiefly chloritic minerals. A few of these rocks, particularly the intrusive types, also contain small amounts of orthoclase and quartz, and in one rather coarse-grained specimen graphic intergrowths of these two minerals were observed. Green and brown hornblende and biotite were also observed in small amounts in the dikes and sills but not in the lava flows. The iron oxides include both magnetite and ilmenite, both of which are to some extent oxidized. Titanite is also a common alteration product of the titaniferous iron ores. The rock glass of the lavas, where unaltered, is dusty brown, but for the most part it has subsequently been altered to chloritic minerals. Calcite, quartz, and chalcedony are also present as secondary minerals and are particularly prevalent as vesicular fillings. In the lavas of Pass Creek some striking seams of white and rose quartz were also observed.

In the holocrystalline and slightly glassy types of these rocks the plagioclase feldspar occurs as euhedral to subhedral laths, either partly surrounded by pyroxene or as smaller crystals interstitially located between the crystals of pyroxene. Seldom is a true poikilitic fabric visible, where numbers of feldspar laths are included in a single large crystal of pyroxene, and therefore the typical ophitic fabric is not really developed. Nevertheless, the feldspar has so characteristically crystallized in advance of the pyroxene that the crystal boundaries of the pyroxene are more commonly determined by feldspar outlines than by the natural boundaries of the pyroxene. In the highly glassy varieties plagioclase feldspar has crystallized in slender laths with feathered ends where no pyroxene at all has crystallized. These textural features, together with the minerals above described, therefore show that many of these rocks, particularly the dikes, sills, and coarser-grained lavas, are better described as diabases. The finer-grained lavas are for the most part glassy or partly glassy basalts. The presence of orthoclase and primary quartz shows that some of these rocks have a tendency to belong at the acidic end of the diabase-basalt family and warrants the designations quartz diabase and quartz basalt for some of them.

The alteration of the plagioclase feldspar, pyroxene, and iron oxides has already been described. The degree of this alteration is of such an order that some of these rocks may properly be described as diabases and basalts of greenstone habit, but this type of alteration has scarcely progressed far enough to classify all these rocks as greenstones. In view of the ages of these lavas and their associated intrusive rocks, this relatively small degree of alteration is particularly noteworthy, especially when it is remembered that much later rocks of similar character in the Yukon-Tanana region are so much more altered. In the absence of any essential chemical differences between these rocks and the later Paleozoic greenstones, this anomalous condition may best be explained as due to lack of regional metamorphism in the region north of the Yukon, and this generalization fits very well with the relatively unaltered condition of the rocks of the Tindir group, as compared with the more greatly deformed and altered lower Paleozoic rocks south of the Yukon.

### AGE AND CORRELATION

The data upon which may be based the determination of the age of these basic rocks have already been outlined in the description of the rocks of the Tindir group. (See pp. 390–392.) All these rocks are believed to be older than the Middle Cambrian limestone because, so far as observed, they are not interbedded with and do not invade either the Middle or Upper Cambrian rocks. This, of course, is negative evidence and is therefore not conclusive, but to anyone who has observed the labyrinth of dikes in rocks of unit E in the upper valley of Pleasant Creek and the scarcity of igneous material a short distance southeast, on Jones Ridge, the pre-Upper Cambrian age, at least, of these lavas is rather certain, and the similar absence of these intrusive rocks in the Middle Cambrian limestone of the Yukon-Tatonduk area is likewise impressive, although at this place no labyrinth of intrusive rocks is visible near at hand.

As shown on page 381, these lavas and their associated intrusive rocks are confined, as far as known, to the lower horizons of the Tindir group. In the rather regular and continuous section along the banks of the Tatonduk River, such igneous rocks were not observed, either in units A or B of the Tindir group. Some exceedingly fine-grained lavas and associated tuffs, now altered to hematitic beds, have been found to constitute a part of unit C, but little is known of the original character or extent of these igneous members of the red beds. It seems probable that the lavas of unit D, which underlie the red beds, represent the latest of the major periods of pre-Cambrian volcanic activity. One or more periods of volcanic activity that preceded the period represented by unit D indicate that the lavas as a whole are of several ages, but all of them are considered to be an integral part of the Tindir group, and none of these volcanic epochs are believed to have occurred subsequent to the time when the upper red beds, or unit C, were laid down. Moreover, each of the more notable zones of red beds so far recognized in the Tindir group is either interbedded with or directly underlain by lava flows.

### UNDIFFERENTIATED GREENSTONE

#### DISTRIBUTION

Greenstones of several types and ages are known throughout interior Alaska. In the Tatonduk-Nation district, however, the age of most of the greenstone is known, and the only occurrence that might be called undifferentiated is a mass of greenstone that forms the river bluff at Eagle and extends west-northwestward up the north side of Mission Creek. The eastward continuation of this greenstone is visible along the north bank of the Yukon River, about 4 miles upstream from Eagle.

#### PETROGRAPHIC CHARACTER

The greenstone at Eagle Bluff is essentially a basaltic greenstone with which are interbedded flow breccia and tuff, also of greenstone habit, as well as some sedimentary beds. Much of the lava appears to be very fine grained and to some extent glassy. These lavas and associated pyroclastic rocks have not been studied under the microscope but are believed to be mainly typical basaltic rocks that have been altered in large measure to chloritic minerals and serpentine. Some ultrabasic greenstone is also believed to be present. Owing to the fact that these greenstones lie along a fault zone that trends up Mission Creek, they are probably more than ordinarily altered by secondary processes.

Above Eagle, along the north river bank, the same greenstone is closely infolded with slate and quartzite, and owing to the deformation to which it has been subjected, much of it is entirely recrystallized into types of rock that resemble but little the original lava flows.

#### AGE AND CORRELATION

The age of the greenstone that forms Eagle Bluff is not definitely known. It is associated with crystalline limestone or dolomite, the age of which is likewise indeterminate. Farther up the Yukon, however, about a mile above the international boundary, similar greenstone is associated with similar crystalline limestone in which Silurian or Devonian corals were found. On this rather weak basis of correlation the writer has been inclined to regard the greenstone at Eagle Bluff as Lower Devonian in age, thus placing its origin in what is believed to have been a period of regional volcanism of that age which affected much of interior Alaska.

# INDEX

# SELECTED LIST OF GEOLOGICAL SURVEY PUBLICATIONS ON ALASKA

[Arranged geographically]

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

1. The reports are sold, at the prices indicated, by the Superintendent of Documents, Washington, D. C., to whom remittances should be sent by money order. No copies are available of those marked with an asterisk (*); they may be consulted at many public libraries.

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

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

## GENERAL

### REPORTS

* The geography and geology of Alaska, by A. H. Brooks. Professional Paper 45, 1906, 327 pp.

The Alaskan mining industry in 1930 by Philip S. Smith. In Bulletin 836, 1932, — cents. The preceding volumes in this series and years covered are Bulletins 259, 1904, 15 cents; 284, 1905, 25 cents; 314, 1906, 30 cents; 345, 1907, 45 cents; 379, 1908, 50 cents; 442, 1909, 40 cents; 480, 1910, 40 cents; 520, 1911, 50 cents; 542, 1912, 25 cents; * 592, 1913 (592–A, 15 cents); 622, 1914, 30 cents; 642, 1915, 35 cents; 662, 1916, 75 cents; * 692, 1917 (692–A, 5 cents); * 712, 1918; * 714, 1919 (714–A, 25 cents); 722, 1920, 25 cents; 739, 1921, 25 cents; 755, 1922, 40 cents; 773, 1923, 40 cents; 783, 1924, 40 cents; 792, 1925, 25 cents; 797, 1926, 80 cents; 810, 1927, 50 cents; 813, 1928, 40 cents; 824, 1929, — cents.

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

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

Alaska coal and its utilization, by A. H. Brooks. Bulletin 442–J, reprinted 1914, pp. 47–100. 10 cents.

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

* Methods and costs of gravel and placer mining in Alaska, by C. W. Purington. Bulletin 263, 1905, 273 pp.

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

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

Antimony deposits of Alaska, by A. H. Brooks. Bulletin 649, 1916, 67 pp. 15 cents.

The use of the panoramic camera in topographic surveying, by J. W. Bagley. Bulletin 657, 1917, 88 pp. 25 cents.

Mineral springs of Alaska, by G. A. Waring. Water-Supply Paper 418, 1917, 114 pp. 25 cents.

The future of Alaska mining, by A. H. Brooks. Bulletin 714–A, 1921, pp. 5–57. 25 cents.

Preliminary report on petroleum in Alaska by G. C. Martin. Bulletin 719, 1921, 83 pp. 50 cents.

The Mesozoic stratigraphy of Alaska, by G. C. Martin. Bulletin 776, 1926, 493 pp. 75 cents.

The Upper Cretaceous flora of Alaska, by Arthur Hollick, with a description of the Upper Cretaceous plant-bearing beds, by G. C. Martin. Professional Paper 159, 1930, 123 pp., 87 pls. 80 cents.

Glaciation in Alaska, by S. R. Capps. In Professional Paper 170, 1932, pp. 1–8. 35 cents.

*In preparation*

Tertiary flora of Alaska, by Arthur Hollick.

Igneous geology of Alaska, by J. B. Mertie, jr.

### TOPOGRAPHIC MAPS

Map of Alaska (A); scale, 1:5,000,000; 1931. 10 cents retail or 6 cents wholesale.

Map of Alaska (C); scale, 1:12,000,000; 1929. 1 cent retail or five for 3 cents wholesale.

Map of Alaska, showing distribution of mineral deposits; scale, 1:5,000,000; 1925. 20 cents retail or 12 cents wholesale.

Index map of Alaska, including list of publications; scale, 1:5,000,000; 1929. Free on application.

Relief map of Alaska (D); scale, 1:2,500,000; 1923. 50 cents retail or 30 cents wholesale.

Map of Alaska (E); scale, 1:2,500,000; 1931. 25 cents retail or 15 cents wholesale.

## SOUTHEASTERN ALASKA

### REPORTS

The Juneau gold belt, by A. C. Spencer, pp. 1–137, and A reconnaissance of Admiralty Island, by C. W. Wright, pp. 138–154. Bulletin 287, 1906, 161 pp. 75 cents.

Reconnaissance on the Pacific Coast from Yakutat to Alsek River, by Eliot Blackwelder. In Bulletin 314, 1907, pp. 82–88. 30 cents.

The Ketchikan and Wrangell mining districts, by F. E. and C. W. Wright. Bulletin 347, 1908, 210 pp. 60 cents.

The Yakutat Bay region, Alaska, by R. S. Tarr and B. S. Butler. Professional Paper 64, 1909, 183 pp. 50 cents.

Occurrence of iron ore near Haines, by Adolph Knopf. In Bulletin 442, 1910, pp. 144–146. 40 cents.

Geology of the Berners Bay region, by Adolph Knopf. Bulletin 446, 1911, 58 pp. 20 cents.

The Eagle River region, southeastern Alaska, by Adolph Knopf. Bulletin 502, 1912, 61 pp. 25 cents.

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

The earthquakes at Yakutat Bay, in September, 1899, by R. S. Tarr and Lawrence Martin. Professional Paper 69, 1912, 135 pp. 60 cents.

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

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

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

*Geology and mineral resources of the west coast of Chicagof Island, by R. M. Overbeck. In Bulletin 692, 1919, pp. 91–136.

The Porcupine district, by H. M. Eakin. Bulletin 699, 1919, 29 pp. 20 cents.

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

Marble resources of southeastern Alaska, by E. F. Burchard. Bulletin 682, 1920, 118 pp. 30 cents.

Water-power investigations in southeastern Alaska, by G. H. Canfield. In Bulletin 722, 1922. 25 cents. Similar previous reports in Bulletins 642, 1916, 35 cents; 662, 1917, 75 cents; *692, 1919; *712, 1920; 714–B, 1921, 10 cents.

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

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

Mineral investigations in southeastern Alaska in 1924, by A. F. Buddington. In Bulletin 783, 1927, pp. 41–62. 40 cents. Similar report for 1923 in Bulletin 773, 1925, pp. 71–139. 40 cents.

Aerial photographic surveys in southeastern Alaska, by F. H. Moffit and R. H. Sargent. In Bulletin 797, 1929, pp. 143–160. 80 cents.

Geology of Hyder and vicinity with a reconnaissance of Chickamin River, southeastern Alaska, by A. F. Buddington. Bulletin 807, 1929, 124 pp. 35 cents.

Geology and mineral deposits of southeastern Alaska, by A. F. Buddington and Theodore Chapin. Bulletin 800, 1929, 398 pp. 85 cents.

The occurrence of gypsum at Iyoukeen Cove, Chichagof Island, by B. D. Stewart. In Bulletin 824, 1931, pp. 173–177. 20 cents.

Notes on the geography and geology of Lituya Bay, by J. B. Mertie, jr. In Bulletin 836, 1931, pp. 117–135. 5 cents.

Surface water supply of southeastern Alaska, by F. F. Henshaw. In Bulletin 836, 1932, pp. 137–218. 10 cents.

*In preparation*

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

TOPOGRAPHIC MAPS

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

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

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

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

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

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

Juneau and vicinity (No. 581D); scale, 1:24,000; 1918, by D. C. Witherspoon. 20 cents retail or 12 cents wholesale.

Hyder and vicinity (No. 540C); scale, 1:62,500; 1927, by R. M. Wilson. 10 cents retail or 6 cents wholesale. Also published in Bulletin 807, 1929, 35 cents.

Revillagigedo Island; scale, 1:250,000; 1931, by R. H. Sargent (preliminary edition). Free on application.

*In preparation*

Wrangell district; scale, 1:250,000, by R. H. Sargent.

## CONTROLLER BAY, PRINCE WILLIAM SOUND, AND COPPER RIVER REGIONS

### REPORTS

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

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

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

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

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

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

Headwater regions of Gulkana and Susitna Rivers, with accounts of the Valdez Creek and Chistochina placer districts, by F. H. Moffit. Bulletin 498, 1912, 82 pp. 35 cents.

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

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

Geology of the Hanagita-Bremner region, Alaska, by F. H. Moffit. Bulletin 576, 1914, 56 pp. 30 cents.

* Mineral deposits of the Yakataga district, by A. G. Maddren. In Bulletin 592, 1914, pp. 119–153.

* The Port Wells gold-lode district, by B. L. Johnson. In Bulletin 592, 1914, pp. 195–236.

* Geology and mineral resources of Kenai Peninsula, by G. C. Martin, B. L. Johnson, and U. S. Grant. Bulletin 587, 1915, 243 pp.

The gold and copper deposits of the Port Valdez district, by B. L. Johnson. In Bulletin 622, 1915, pp. 140–188. 30 cents.

The Ellamar district, by S. R. Capps and B. L. Johnson. Bulletin 605, 1915, 125 pp. 25 cents.

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

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

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

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

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

* Mining on Prince William Sound, by B. L. Johnson. In Bulletin 692, 1919. Similar previous reports in Bulletins * 592, 1914; 622, 1915, 30 cents; 642, 1916, 35 cents; 662, 1918, 75 cents.

* Mineral resources of Jack Bay district and vicinity, by B. L. Johnson. In Bulletin 692, 1919, pp. 153–173.

* Nickel deposits in the lower Copper River Valley, by R. M. Overbeck. In Bulletin 712, 1919, pp. 91–98.

The Kotsina-Kuskulana district, by F. H. Moffit and J. B. Mertie, jr. Bulletin 745, 1923, 149 pp. 40 cents.

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

The occurrence of copper on Prince William Sound, by F. H. Moffit. In Bulletin 773, 1925, pp. 141–158. 40 cents.

Notes on the geology of the upper Nizina River, by F. H. Moffit. In Bulletin 813, 1930, pp. 143–163. 40 cents.

The Slana district, upper Copper River region, by F. H. Moffit. In Bulletin 824, 1931, pp. 111–124. 20 cents.

*In preparation*

Geology of the Chitina quadrangle, by F. H. Moffit.

TOPOGRAPHIC MAPS

Central Copper River region; scale, 1:250,000; by T. G. Gerdine. In Professional Paper 41, 1905, 50 cents. Not issued separately. Reprint in Bulletin 498, 1912, 35 cents.

Headwater regions of Copper, Nabesna, and Chisana Rivers; scale, 1:250,000; by D. C. Witherspoon, T. G. Gerdine, and W. J. Peters. In Professional Paper 41, 1905, 50 cents. Not issued separately.

Controller Bay region (No. 601A); scale, 1:62,500; 1907, by E. G. Hamilton and W. R. Hill. 35 cents retail or 21 cents wholesale. Also published in Bulletin 335, 1908, 70 cents.

Headwater regions of Nabesna and White Rivers; scale, 1:250,000, by D. C. Witherspoon, T. G. Gerdine, and S. R. Capps. In Bulletin 417, 1910, 25 cents. Not issued separately.

Latouche Island, part of; scale, 1:21,120; by D. F. Higgins. In Bulletin 443, 1910, 45 cents. Not issued separately.

Chitina quadrangle (No. 601); scale, 1:250,000; 1914, by T. G. Gerdine, D. C. Witherspoon and others. Sale edition exhausted. Also published in Bulletin 576, 1914, 30 cents.

Nizina district (No. 601B); scale, 1:62,500, by D. C. Witherspoon and R. M. La Follette. In Bulletin 448, 1911, 40 cents. Not issued separately.

Headwater regions of Gulkana and Susitna Rivers; scale, 1:250,000; by D. C. Witherspoon, J. W. Bagley, and C. E. Giffin. In Bulletin 498, 1912, 35 cents. Not issued separately.

Prince William Sound; scale, 1:500,000; compiled. In Bulletin 526, 1913, 30 cents. Not issued separately.

The Bering River coal field; scale, 1:62,500; 1915, by G. C. Martin. 25 cents retail or 15 cents wholesale.

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

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

* Geology and mineral resources of Kenai Peninsula, by G. C. Martin, B. L. Johnson, and U. S. Grant. Bulletin 587, 1915, 243 pp.

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

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* Mining developments in the Matanuska coal fields, by Theodore Chapin. In Bulletin 714, 1921. (See also Bulletin 692–D, 1919, 15 cents; and Bulletin *712, 1920.)

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Geology of the vicinity of Tuxedni Bay, Cook Inlet, by F. H. Moffit. In Bulletin 722, 1922, pp. 141–147. 25 cents.

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

Chromite of Kenai Peninsula, by A. C. Gill. Bulletin 742, 1922, 52 pp. 15 cents.

Geology and mineral resources of the region traversed by the Alaska Railroad, by S. R. Capps. In Bulletin 755, 1924, pp. 73–150. 40 cents.

An early Tertiary placer deposit in the Yentna district, by S. R. Capps. In Bulletin 773, 1925, pp. 53–61. 40 cents.

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The Iniskin-Chinitna Peninsula and the Snug Harbor district, Alaska, by F. H. Moffit. Bulletin 789, 1927, 71 pp. 50 cents.

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Geology of the Knik-Matanuska district, Alaska, by K. K. Landes. In Bulletin 792, 1927, pp. 51–72. 25 cents.

The Skwentna region, by S. R. Capps. In Bulletin 797, 1929, pp. 67–98, 80 cents.

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The Lake Clark-Mulchatna region, by S. R. Capps. In Bulletin 824, 1931, pp. 125–154. 20 cents.

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The Cold Bay-Chignik district, by W. R. Smith and A. A. Baker. In Bulletin 755, 1924, pp. 151–218. 40 cents.

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* Aniakchak Crater, Alaska Peninsula, by W. R. Smith. In Professional Paper 132, 1925, pp. 139–149.

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

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

The Bonnifield region, by S. R. Capps. Bulletin 501, 1912, 64 pp. 20 cents.

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

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

A geologic reconnaissance of the Circle quadrangle, by L. M. Prindle. Bulletin 538, 1913, 82 pp. 30 cents.

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

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Quicksilver deposits of the Kuskokwim region, by P. S. Smith and A. G. Maddren. In Bulletin 622, 1915, pp. 272–291. 30 cents.
The Chisana-White River district, by S. R. Capps. Bulletin 630, 1916, 130 pp. 20 cents.
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Lode mining in the Fairbanks district, by J. B. Mertie, jr. In Bulletin 662, 1918, pp. 403–424. 75 cents.
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The Lake Clark-central Kuskokwim region, by P. S. Smith. Bulletin 655, 1918, 162 pp. 30 cents.
The Cosna-Nowitna region, by H. M. Eakin. Bulletin 667, 1918, 54 pp. 25 cents.
The Anvik-Andreafski region, by G. L. Harrington. Bulletin 683, 1918, 70 pp. 30 cents.
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* The gold and platinum placers of the Tolstoi district, by G. L. Harrington. In Bulletin 692, 1919, pp. 339–351.
* Mineral resources of the Goodnews Bay region, by G. L. Harrington. In Bulletin 714, 1921, pp. 207–228.
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The Ruby-Kuskokwim region, by J. B. Mertie, jr., and G. L. Harrington. Bulletin 754, 1924, 129 pp. 50 cents.
Geology and gold placers of the Chandalar district, by J. B. Mertie, jr. In Bulletin 773, 1925, pp. 215–263. 40 cents.
The Nixon Fork country, by J. S. Brown. In Bulletin 783, 1927, pp. 97–144. 40 cents.
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Koyukuk and Chandalar region, reconnaissance map; scale, 1:500,000; by T. G. Gerdine, D. L. Reaburn, D. C. Witherspoon, and A. G. Maddren. In Bulletin 532, 1913, 25 cents. Not issued separately.

Fairbanks quadrangle (No. 642); scale, 1:250,000; 1911, by T. G. Gerdine, D. C. Witherspoon, R. B. Oliver, and J. W. Bagley. 50 cents retail or 30 cents wholesale. Also in Bulletin 337, 1908, 25 cents, and Bulletin 525, 1913, 55 cents.

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

Rampart quadrangle (No. 643); scale, 1:250,000; 1913, by D. C. Witherspoon and R. B. Oliver. 20 cents retail or 12 cents wholesale. Also in Bulletin 337, 1908, 25 cents, and part in Bulletin 535, 1913, 20 cents.

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

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

Chandalar-Sheenjek district; scale, 1:500,000; by Gerald FitzGerald and J. O. Kilmartin. In Bulletin 810, 1930, 50 cents. Not issued separately.

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Geology of the Seward Peninsula tin deposits, by Adolph Knopf. Bulletin 358, 1908, 71 pp. 15 cents.

Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula, by P. S. Smith. Bulletin 433, 1910, 234 pp. 40 cents.

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

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

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

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

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

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A reconnaissance in northern Alaska in 1901, by F. C. Schrader, with notes by W. J. Peters. Professional Paper 20, 1904, 139 pp. 40 cents.

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

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The Noatak-Kobuk region, by P. S. Smith. Bulletin 536, 1913, 160 pp. 40 cents.

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

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

Summary of recent surveys in northern Alaska, by P. S. Smith, J. B. Mertie, jr., and W. T. Foran. In Bulletin 783, 1926, pp. 151–168. 40 cents.

Geologic investigations in northern Alaska, 1925, by Philip S. Smith. In Bulletin 792, 1927, pp. 111–122. 25 cents.

Surveys in northwestern Alaska in 1926, by Philip S. Smith. In Bulletin 797, 1928, pp. 125–142. 80 cents.

Preliminary report on the Sheenjek River district, Alaska, by J. B. Mertie, jr. In Bulletin 797, 1928, pp. 99–123. 80 cents.

The Chandalar-Sheenjek district, by J. B. Mertie, jr. In Bulletin 810, 1930, pp. 87–139. 50 cents.

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

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Chandalar-Sheenjek district; scale, 1:500,000; by Gerald FitzGerald and J. O. Kilmartin. In Bulletin 810, 50 cents. Not issued separately.

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