GEOLOGIC INVESTIGATIONS ALONG THE CANADA-ALASKA BOUNDARY.

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WORK OF THE BOUNDARY COMMISSION.

During the summer of 1911 the joint commission appointed and authorized by the Governments of Canada and the United States to locate and mark the boundary line separating British territory from Alaska advanced field operations northward along that part of the one hundred and forty-first meridian which extends from Porcupine River to the Arctic Ocean. This work was a direct continuation of the boundary survey that was carried northward from Yukon River to Porcupine River during the summers of 1909 and 1910. The commission expects to complete this part of the survey in 1912.

The 320 miles through which the one hundred and forty-first meridian extends between Yukon River and the Arctic Ocean is crossed about midway by Porcupine River, which thus separates the region into north and south subdivisions that form convenient units for geographic and geologic description. The southern subdivision, about 175 miles in length, may be designated the Yukon-Porcupine section, and the northern one, about 145 miles in length, the Porcupine-Arctic section.

Porcupine River is easily navigated by shallow-draft steamboats to New Rampart, an Indian trading settlement on the north bank of the river just east of the boundary line, or about 225 miles above its confluence with the Yukon near Fort Yukon. It thus affords a natural route for the transportation of supplies and makes it practicable to maintain a very convenient base of operations for both sections of the boundary at this point.

At the close of the field season of 1910 there still remained in the northern half of the Yukon-Porcupine section a stretch of about 80 miles south from the Porcupine, the final work of permanently placing the intermediate monuments at intervals of 3 to 5 miles and of clearing a strip 40 feet wide through the timbered portions along the line. There also remained the topographic mapping of a strip 2 miles wide on each side of the line for about 45 miles

south from the Porcupine. Of this work the mapping was completed to Porcupine River in July, 1911, but, owing to unforeseen delays, the setting of the monuments and clearing through timber lacked 30 miles of reaching the Porcupine. This work will be completed in 1912.

In the meantime field work was commenced on the Porcupine-Arctic section at New Rampart in June, 1911, and continued northward until the middle of August. The one hundred and forty-first meridian was located to a point within 7 miles of the Arctic Ocean. The topographic mapping of the 4-mile strip along the line was completed for about 115 miles, or within about 30 miles of the Arctic coast. The boundary was marked with permanent bronze monuments at intervals of 4 or 5 miles over approximately 70 miles, or about half the length of the section north from the Porcupine, and the strip 40 feet wide was cleared through such timbered portions as occurred in this distance.

GEOLOGIC WORK.

Realizing that its well-equipped field organization afforded unusual facilities in this remote and rather inaccessible region for gathering much information not directly connected with the particular work of locating and marking the boundary line, the joint commission extended an invitation, which was readily accepted, to the geological surveys of Canada and the United States to send geologists to accompany the field parties during 1911 and 1912 and to examine the geology along the boundary from the Yukon to the Arctic.

The most satisfactory arrangement for making such a geologic examination in the two summers available appeared to be to assign one of the two sections of the line to each Government. The alternative plan, by which each Government should make observations side by side on Canadian and Alaskan territory, would not only have caused more or less duplication, but would also have compelled all the observers to traverse the whole length of both sections. Accordingly the Canadian geologists undertook to examine the southern, or Yukon-Porcupine, section and the United States geologists the northern, or Porcupine-Arctic, section.

During the field season of 1911 two Canadian geologists examined the part of the Yukon-Porcupine section extending from Orange Fork, the southernmost branch of Black River, northward to the headwaters of Salmontrout River, or approximately between 66° and 67° north latitude. They concluded their field work for the summer about 30 miles south of New Rampart and plan to continue it in 1912. The boundary-survey topographic map of the 4-mile strip, drawn on a field scale of 1 to 45,000, was used as a base on which the

geologic data were platted. Reports on the geology along this section of the meridian will be published by the Canadian Geological Survey.

Two geologic observers from the United States Geological Survey commenced a field examination of the Porcupine-Arctic section at New Rampart in the second week of June, 1911, and carried their work northward approximately 100 miles, to the headwaters of Firth River, which flows into the Arctic Ocean. The observations were carried along simultaneously with the topographic mapping of the 4-mile strip on a field scale of 1 to 45,000, with contour lines at intervals of 100 feet. The geologic data observed over the surveyed area were platted upon tracings from the plane-table sheets which were furnished by the topographers at frequent intervals as the field work advanced.

It is planned to continue the geologic field work to the Arctic coast in 1912 and then to publish a report fully describing the geologic section along the boundary line from Porcupine River to the Arctic Ocean. From the character of the area examined so far it appears that the results will be primarily of stratigraphic rather than of mineralogic importance and will be interesting chiefly as a contribution to the study of the general geologic history of this northern region. Although some search for placer gold has been made about the headwaters of Old Crow River during the last few years by several prospectors, no mineral resources have been discovered in this region, and the existence of deposits of value within the immediate area examined does not appear probable.

GEOLOGY.

ROCK FORMATIONS.

A preliminary outline of the geologic results obtained during 1911 over the part of the section between Porcupine River and the upper basin of the Firth is herewith presented.

Four groups of sedimentary formations have been distinguished, and two types of igneous rocks are associated with what is apparently the oldest of these groups. Considered in what is thought, at present, to be the order of age from older to younger, these sedimentary groups are:

1. A group of quartzites, phyllites, and slaty shales of pre-Ordovician age, some of which are schistose, which have been intruded by masses of granitic rocks that locally cover considerable areas and also by some diabasic igneous rocks of much smaller extent.

2. A group of Carboniferous age, which is for the most part made up of heavily bedded limestones but which also comprises some shaly, sandy, and cherty members.

3. At least one formation of Upper Triassic age, composed of beds of sandy and limy shales containing marine fossils.

4. Another group of quartzites and shale slates, with some beds of conglomerate, which may be of Mesozoic age.

From this it seems that the varied and well-developed Paleozoic section that occurs along Porcupine River west of the one hundred and forty-first meridian is not represented along the 115 miles of the boundary extending northward from Porcupine River except by the pre-Ordovician quartzite and slate series and the Carboniferous limestones. Along the Porcupine Kindle[1] has found a quartzite and slate series which he considers, on stratigraphic grounds, to comprise the oldest rocks exposed in the Porcupine River section and to be of pre-Ordovician age. These are followed by Ordovician limestones; Silurian dolomites and shales; Devonian limestones, shales, and lavas; and Carboniferous shales and limestones, most of which are represented by formations of considerable thickness, containing fossils at many horizons. In fact, all these Paleozoic formations, except the pre-Ordovician quartzite and slate series and the supposedly Devonian igneous flows, contain enough fossil-bearing beds to establish their stratigraphic identity and relative position.

PRE-ORDOVICIAN ROCKS.

PORCUPINE RIVER.

Kindle's description of these rocks as they occur along Porcupine River[2] is as follows:

> The oldest rocks exposed in the Porcupine River section are found in the vicinity of the international boundary. This series is well exposed in the steep slopes and cliffs facing the river at New Rampart House and outcropping continuously for 6 or 7 miles below there. It is composed largely of thin-bedded and very fine grained quartzites, which are bedded usually in thin strata 1 to 6 inches thick. Interbedded with the quartzites are considerable beds of black shale and limestone and thin beds of dolomites. The nearly universal color of the quartzites (as exposed along the river) is light gray or white, which gives them a strong resemblance to limestones. Occasional beds occur, however, which are specked with brown, and one 30-foot bed of dark-brown sandstone was observed in the river bank at New Rampart. Sulphide of iron is present in some of the beds, as is indicated by the accumulation of films of sulphur on protected rock faces. Where exposed to weathering the quartzite beds disintegrate to a fine white or cream-colored powder. This powder covers all the steep slopes where vegetation is absent, giving the appearance of great marl or clay beds at a little distance.
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> The black shales and slates occur usually as thin films alternating with limestone bands one-half inch to 3 inches thick. The presence of the limestone, although it comprises the bulk of these beds, is not evident in the weathered

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

[2] Kindle, E. M., op. cit., pp. 320–322.

exposures of steep slopes, where the intensely black shale or slate fragments are apt to conceal the light-colored thin limestone strata, giving the whole the appearance of a shale or slate formation. Below New Rampart House 1 mile a set of these black beds 500 or 600 feet thick is interbedded in the quartzite series. The quartzites are well exposed in the gorge of the small stream [Sunaghun Creek] entering the Porcupine at New Rampart House. The creek section exposes here 1,000 feet or more of the quartzite series, which is uninterrupted by other beds. The sharp contrast of the exposures of the intensely black slate-limestone beds and the white quartzites is one of the most striking scenic features of the Upper Rampart gorge near the boundary. Some dolomites also occur in the quartzites, but they play a subordinate rôle as regards their importance in making up the total mass of the series.

Metamorphism is not pronounced in this series [as exposed along the Porcupine], but the argillaceous sediments are noticeably more altered than those of the higher [Paleozoic] horizons. In the latter the shaly phase is found, as a rule, while in the former [pre-Ordovician series] the shales have been altered to slates or slatylike slickensided films where they are in very thin sheets interleaved with limestones, as generally happens.

It is difficult to make any estimate of the thickness of these beds without detailed work. The prevailing westerly dip, which continues for about 6 miles below New Rampart House, points to a great thickness for the series, but the possibility of faulting and of close folding in a part of the series leaves some uncertainty in regard to the actual thickness. Five thousand feet would seem to be a conservative estimate, and it is probable that a much greater thickness is represented.

No fossils have been found in these rocks, consequently their age can only be stated with reference to that of the oldest paleontologically determined beds of the section—the Ordovician. That they antedate the Ordovician in age is indicated by the fact that no series corresponding to them in lithologic features occurs in the portion of the geologic section lying above the Ordovician. The several main divisions of the Paleozoic section from the Ordovician to the Carboniferous have been recognized on the Porcupine by their fossils.

This series of rocks continues along the Porcupine east of the boundary for 10 or 12 miles. As exposed in the Upper Rampart bluffs along this part of the river it presents much the same lithologic character as is shown by the exposures along the river bluffs west of the boundary. The whitish and in places somewhat varicolored quartzites form an important part of the strata, as to the west, and individual members of the series appear to be more heavily bedded. The exposures of black shale slate for at least 5 or 6 miles immediately east of the boundary appear to be thicker and more numerous and to contain less limestone than those west of it. The greater number of thick exposures of these slates may be due to repetitions of some of the members by faulting, or there may really be a greater number of such members along this part of the river. That this sedimentary series has suffered more or less disruption in at least this part of the region is indicated by the fact that it has been intruded, both across and along the bedding, by dikes and sheets of diabase, several of which, 20 to 40 feet thick, are well exposed along the north-side river bluffs

a short distance above New Rampart. Slaty cleavage is common and some schistose structure has been developed locally.

Along the eastern border of the section exposed in the Upper Ramparts limestones again become more abundant. One very highly contorted black shale and limestone member several hundred feet thick is well exposed in the river bluffs about 10 miles above New Rampart, where it shows alternating limestone and shale beds from 1 to 2 feet thick, about equal both in number and total thickness. Above this locality the limestone outcrops along the river become discontinuous, then less and less close, and in a short distance they disappear beneath an extensive terrane of partly consolidated clays and sands of probable Tertiary age, which fill a large basin-like expanse of the Porcupine Valley east of the Upper Ramparts. The disconnected outcrops along the upper 2 or 3 miles of this part of the river are different in character from those below. They are made up mostly of more or less massive limestone and granular to fine-textured dolomites which may prove on detailed examination not to be closely related to the pre-Ordovician series of rocks, but rather to one or more of the Paleozoic formations which occur southwest of this series on the Alaskan side of the boundary.

Northward from the Porcupine there are noticeable color variations, apparently due to differences in weathering, between the outcrops of the quartzites and the shale slates along the river and their exposures on the higher ridges and mountains away from the river. In the bluffs of the Porcupine the quartzites are prevailingly whitish with a small percentage of varicolored pinkish, purplish, and brownish beds; whereas away from the river the same rocks are mostly dull white and light to dark gray and contain some iron-stained brown beds. The shale slates along the Porcupine are for the most part black, some of them intensely so, but away from the river bluffs these rocks, although in some beds predominantly black and dark gray, show in others banded bright reds and purples, dark to pale greens, and light drabs or grays.

SOUTH OF PORCUPINE RIVER.

The same pre-Ordovician quartzite and slate rocks which occur along Porcupine River in the vicinity of the one hundred and forty-first meridian are reported by the Canadian geologists to extend southward from the river along the boundary for 25 to 30 miles.

Farther south along the meridian, between 66° and 67° north latitude, the same observers examined in more detail a group of quartzites and shale slates of very similar lithologic character, which on this indefinite basis they tentatively correlated with the pre-Ordovician series of rocks along Porcupine River. This group

appears to overlie unconformably formations of Ordovician, Silurian, and Carboniferous age similar to those exposed along Porcupine River below or southwest from New Rampart. The unconformity appears to be marked both by discordance of bedding and by a more or less well-developed basal conglomerate. This discordance with the underlying Carboniferous and the meager evidence afforded by a few unsatisfactory fossils of indefinite character indicate that this group of quartzite, slate, and conglomeratic sediments may be of Mesozoic age.

A group of rocks of this same general character, whose stratigraphic relations to some Carboniferous limestones near by may be close but are not very apparent, occupy an area just west of the one hundred and forty-first meridian 37 to 52 miles north of Porcupine River. (See p. 313.) It seems very probable that there are in this region two groups of quartzite and shale slate rocks of very similar lithologic character but of entirely different geologic ages; but, if so, the fact can be proved only by further field study of the area as a whole.

NORTH OF PORCUPINE RIVER.

Porcupine River to Old Crow Mountains.—Northward from Porcupine River the pre-Ordovician series of interbedded quartzites and shale slates extends for about 6 miles to the headwaters of Sunaghun Creek, which discharges into the river at New Rampart. On the upper part of Sunaghun Creek the sedimentary series is interrupted by massive granites which are known to have an uninterrupted north-south extent of about 23 miles along the one hundred and forty-first meridian. No information is at hand regarding the occurrence or distribution of the granites or the quartzite and slate series for more than 4 or 5 miles westward from the boundary. It is supposed, however, that the granites at least may extend westward or northwestward for a number of miles. The quartzite and slate series extends only about 7 miles below the boundary on Porcupine River. Whether it extends farther west north of the Porcupine is not known.

Eastward from the one hundred and forty-first meridian these granites are known to extend for at least 10 or 12 miles as the backbone of the Old Crow Mountains, a short range whose bare summits rise about 2,000 feet above Porcupine River and form the southwestern rim of the basin of Old Crow River, separating the drainage of the latter stream from that of the Porcupine to the south. Granitic intrusive rocks are known to extend across lower Old Crow River 40 miles east of the boundary, about 12 miles above its mouth, or 6 miles north from the Porcupine in a direct line. It seems probable that this occurrence may be an eastward continuation of the granite belt of the Old Crow Mountains. How far east of Old Crow River these

granites may extend and what their relation may be to the Cretaceous sedimentary formation on the Porcupine 8 miles above the mouth of Old Crow River are not known. Further examination may prove that these granites are not only a continuous belt of intrusion, but that they may cut the Cretaceous sedimentary rocks just mentioned and are therefore younger. The granite is more or less porphyritic, a fact which may indicate that it is of deep-seated origin.

So far as known the disruption of the country rocks which accompanied the intrusion of this wide belt of granite has not brought to view, along either its southern or its northern borders in the vicinity of the one hundred and forty-first meridian, the base of the pre-Ordovician quartzite and slate series or any older formations that may underlie them. This seems to add weight to the opinion that the quartzite and slate series of this part of the area may be the oldest known sedimentary series in this region. However, the Canadian geologists who examined the section along the one hundred and forty-first meridian between 66° and 67° north latitude, and also hastily traversed the remaining 30 miles northward to Porcupine River, have been led by their observations to suggest tentatively that all the quartzite, shale, and slate rocks which occur along the boundary for 100 miles south from the Porcupine are of the same age and are Mesozoic rather than Paleozoic or older. They base their opinion on the facts (1) that over the southern half of this 100 miles they found a group of quartzites and shale slates, including some beds of conglomerate (one of which seems to be basal), unconformably overlying Ordovician, Silurian, and Carboniferous formations, and (2) that the quartzite and slate series along the Porcupine appears to be lithologically similar to the rocks farther south. The quartzite and shale slate series that extends some 20 miles along, about 30 miles south from, and 6 miles north from Porcupine River, appears, however, to be distinguished from the supposedly Mesozoic quartzite and shale slate group that occurs from 30 to 100 miles south of this river, by the fact that the former contains some intrusive diabase in the form of dikes and sheets, whereas the latter contains what appears to be a basal and perhaps several other beds of conglomerate. If the series along Porcupine River is the same as the group to the south it does not seem unreasonable to expect that the former would contain at least some of the conglomerate members or some of the underlying Ordovician, Silurian, or Carboniferous formations characteristic of the southern area, and that, if it does contain them, they would be exposed by displacement along the borders of so extensive a break in the sedimentary formations as that which must have accompanied the intrusion of the granite that extends from 6 to 29 miles north of the Porcupine. No such conglomerates or other beds, however, are known to occur.

The pre-Ordovician rocks between Porcupine River and the granite belt 6 miles to the north are not severely metamorphosed, either regionally or by contact alteration along the border of the intrusive rock. The quartzites are, for the most part, very thoroughly and compactly cemented; locally, however, they are somewhat schistose. Most of the shale beds have developed more or less slaty cleavage, and some of them have become typical slates. Contact metamorphism along the immediate southern border of the granite mass is not intensely developed, and the effects of the intrusive rock do not seem to have extended out into the sedimentary rocks for more than a few hundred yards.

Old Crow basin.—North of the granites which extend along the one hundred and forty-first meridian for 23 miles is a belt of intimately associated quartzite schists, intensely plicated micaceous phyllites, and foliated slates, which extends from south to north for about 8 miles. This group of highly metamorphosed sedimentary rocks appears to be lithologically equivalent to the pre-Ordovician series of quartzites and shale slates that occur along Porcupine River south of the granite belt. Although the presence of subordinate amounts of limestone and intrusive diabase has not yet been recognized in these schists, they apparently differ from the rocks along the Porcupine only in the amount of metamorphic alteration they have undergone. In general this metamorphism appears to be of the regional type in that the rocks in a belt of considerable width have been more or less altered. Yet there seems to be a gradual transition from a thoroughly schistose condition of the sedimentary rocks near the granite contact to a less altered condition several miles away from the granite and a fading out of the schistose aspect in the rocks of the same kind a few miles farther north, so that the strata along the northern part of the belt, 7 or 8 miles from the granite contact, are very similar in texture and general appearance to the semimetamorphosed pre-Ordovician series along Porcupine River south of the granite belt. This difference in the degree of metamorphic alteration, shown by what appear to be rocks of the same sedimentary series exposed along opposite sides of this massive granitic intrusion, may have resulted simply from the position of the break through which the granites were intruded. If this break was just south of an old axis of deformation along which regional metamorphism had already been developed for a width of several miles, it would have separated a highly altered belt on the north from a semimetamorphosed zone on the south, and little contact-metamorphic alteration might have been produced by the granite along either border. On the other hand, however, the massive deep-seated intrusion may have caused strong and widespread contact metamorphism in the country rocks now exposed along the

northern border and for some reason may have failed to affect the rocks on the southern margin to any marked degree. Perhaps faulting and crumpling, some evidence of which seems to be shown in the repeated occurrence of what may be the same quartzite and shale slate beds along Porcupine River, modified the intrusive effects along the southern border.

Ammerman Mountain.—More or less altered sedimentary rocks, comprising quartzites, phyllites, slates, and a small amount of highly crystalline limestone, intruded by a mass of granite, make up Ammerman Mountain. These rocks are similar to and appear to be the same as the pre-Ordovician rocks that flank the north and south sides of the wide belt of granite forming the Old Crow Mountains to the south. The granite of Ammerman Mountain, although not extensive, is of a massive character. Whether it is connected in any way with the wide granite belt to the south is not known. However, there is a strong general resemblance in the intrusives themselves, in the country rocks intruded, and in the contact-alteration effects produced. There may be a deep-seated underlying connection between these two granite masses.

The Ammerman Mountain mass extends across the boundary in an east-west direction about 67 miles north of Porcupine River, or 12 miles north of Old Crow River. Although its highest summits rise only about 3,400 feet above sea level, they stand out somewhat prominently by contrast with the widespread lowlands of the upper Old Crow basin, whose level surface, over which are scattered many large and small lakes, extends for a considerable distance from its southern and western flanks at an elevation of 1,200 to 1,500 feet. The main headwaters of Old Crow River flow from the north and northwest around the western flanks of Ammerman Mountain and then southeastward through the Old Crow basin and cross the one hundred and forty-first meridian about 55 miles north of Porcupine River. The meridian crosses the Ammerman Mountain group through a saddle 2,600 feet in elevation between two of the highest summits, each of which is about 3,400 feet above the sea.

From the divide of this saddle a semicircular basin about 2 miles wide opens out southward. The bedrock over the bottom and lower slopes of this basin for 1½ miles is granite. To the north, east, and south the granite seems to be confined within the basin, but to the west it extends along the south flank of the mountain for several miles. The upper slopes on either side, the higher summits to the east and west, and the saddle connecting these summits around the northern margin of this basin are composed of the sedimentary country rocks, for the most part quartzites and quartzite schists, with some thin beds of phyllites or slates and one or more narrow disconnected bands of crystalline limestone. All these sedimentary

rocks are locally very schistose for some distance from the borders of the granite mass, but seem to be less intensely altered a mile or so away from the contact. They are, however, strongly metamorphosed along the southeastern rim of the basin.

About the summit half a mile northeast of the granite contact in this basin considerable vein quartz is present in a network of stringers. These vary from a few inches to several feet in thickness and are deposited along some irregular fractures in the blocky schistose quartzite country rock. For the most part they are made up of clear crystalline quartz, but some of them contain a little pyrite and some of the weathered fragments are stained with iron oxide. No other mineralization seems to have occurred. A little prospecting for placer gold done several years ago along the bed of the stream that drains the basin to the south and in the valley of Thomas Creek, a larger stream, which also flows southward and empties into the Old Crow about 6 miles east of the boundary, is said to have yielded a few colors of gold. No mining, however, has resulted from the reported discoveries.

North of Ammerman Mountain the gray quartzites give way to coarse-textured black and gray slates which extend 2 miles or more immediately east of the boundary for about 4 miles north and apparently disappear beneath a heavy series of Carboniferous limestones. West of the boundary the northern flanks of Ammerman Mountain are made up of a phyllite slate bedrock similar to that on the east, but with possibly more quartzite members; 3 miles west of the boundary, however, the gray quartzite phase gradually changes to phyllites and slates with only a few beds of quartzite, and bedrock of this character extends to the west end of the mountain, where it descends to Old Crow River 6 miles west of the boundary. One dikelike body of granite, observed on the south side of a saddle about 3 miles west of the boundary, is probably an offshoot from the mass that forms the lower slopes of the southern flank of the mountain.

All the sedimentary rocks of Ammerman Mountain are provisionally considered to belong to the pre-Ordovician quartzite, phyllite, and slate series which occurs along Porcupine River in the vicinity of the one hundred and forty-first meridian and extends northward from that river for about 37 miles.

The granites of Ammerman Mountain are likewise considered to belong to the same general mass of intrusives as those associated with the similar altered sedimentary rocks in the wide belt to the south.

North of Ammerman Mountain.—About 40 miles north of Ammerman Mountain, along the west side of Firth River, the one hundred and forty-first meridian crosses another area of considerable width that is apparently occupied by a series of more or less metamorphosed quartzites, phyllites, and slates, which bear a striking resemblance to

some phases of the rocks of the Ammerman Mountain and Porcupine River areas. Only about 2 miles of the southern part of this northern belt, lying on the southern slopes of Tub Mountain, was hastily observed in 1911. The rocks of this mountain are gray quartzite schists, gray phyllites and slates, some layers of which contain pyrite, reddish-purple slates, pale-green and gray slates, and a considerable thickness of black shale slates which weather into shingle and flaky fragments. These rocks occupy a belt about 2 miles wide down the southern slope of Tub Mountain in the order named above. The black shale slate member shows the widest surface outcrop, being about a mile in width, and the varicolored members occupy the upper slopes of the mountain almost to its summit, where the phyllites and schistose quartzites occur.

The southern border of this series seems to be in fault contact with the northern margin of a widespread series of massive Carboniferous limestones (see p. 310), which extend south for nearly 40 miles, or within a few miles of Ammerman Mountain. The limestones show much contorted folding along this part of their northern border and the black shale slates with which they are in contact are much crumpled and disturbed. The structure of the contact seems to be that of either an overturned fold or an overthrust fault.

Southwest of Old Crow basin.—The southwest side of the Old Crow basin opposite the west end of Ammerman Mountain is occupied by an upland area about 10 miles square made up, for the most part, of a number of broad, round-topped, gentle-sloped ridges of irregular arrangement with intervening wide saddles and basins. The northeastern flank of this upland is named Yankee Ridge. The general trend of this ridge, which is about 5 miles long and 1 mile broad, is northwest and southeast, and its highest parts stand about 1,000 feet above the Old Crow Valley, whose gravel-covered floor is here about 2 miles broad. The Old Crow flats between Yankee Ridge and Ammerman Mountain are markedly contracted compared to their wide expanse above and below this place. The wide, flat valley area above or northwest of Yankee Ridge and Ammerman Mountain may well be termed the headwater basin of the Old Crow, in distinction to the much more extensive main Old Crow basin below, to the southeast. This headwater basin bounds the upland area on the north and is bounded by the flats of the main Old Crow basin on the west. The upland area is separated from the mountains to the south by the wide, flat valley of Casey Fork, a large west-side tributary of the Old Crow which rises 15 or 20 miles west of the boundary and joins the main river about 3 miles below the boundary. From 10 to 15 miles west of Old Crow River this upland appears to connect by several gradually rising ridges with the foothills of a low range of mountains, which forms the watershed between the west-side drainage of this part of

the Old Crow basin and the east-side drainage of the upper part of Coleen River. In fact, this upland area may be considered an eastward extension of the foothills which lie between Casey Fork and the northwestern headwaters of Old Crow River.

The eastern half of this upland is rather thickly covered, except over the higher hilltops, by a growth of spruce timber, most of which is scrubby and stunted, and a thick undergrowth of willow and alder brush and moss, which obscures most of the bedrock. Within 5 or 6 miles of Old Crow River the only outcrops of bedrock are on the highest parts of the ridges. So far as known rocks of Carboniferous age form the bedrock of all this upland area except Yankee Ridge, the bedrock of which may be of Devonian age.

DEVONIAN (?) ROCKS.

All the exposed bedrock of Yankee Ridge seems to be a greenish semischistose rock, apparently chloritic, which contains considerable magnetite distributed throughout its mass in the form of small crystals. In the weathered outcrops these rocks part into more or less flaggy slabs along what may be closely set structural planes, which strongly resemble bedding in their parallelism and uniform direction of strike and dip. Their strike averages about N. 50° W. and they dip 50°–65° SW. In massive unweathered exposures, however, these parting planes are not so apparent. In places there is between the stronger planes of separation a secondary wavy crinkling such as occurs in many phyllites and fine-grained quartzite schists.

The relations of the rocks exposed in Yankee Ridge are obscure. Their condition suggests that they have been subjected to the same metamorphic changes as the sedimentary rocks of Ammerman Mountain, but their actual contact with these rocks has not been observed, for bedrock is not exposed across the Old Crow Valley. Nor can their contact with an extensive area of Carboniferous limestone outcropping on several low ridges 3 to 6 miles to the south and west be observed, for there is a wide basin-like depression between, across which all the bedrock is covered by a heavy growth of moss and brush.

It is probable, however, that the greenstone rocks are older than the Carboniferous limestones. They may be a more schistose phase of somewhat similar rocks which occur on Porcupine River at the lower end of the Upper Ramparts, about 45 miles below the boundary, and which are considered to be of Devonian age. Their southwest dip may be an indication that they pass beneath the Carboniferous limestones which occupy the western part of the Old Crow basin just south of them.

CARBONIFEROUS ROCKS.

There are two areas of Carboniferous rocks along the one hundred and forty-first meridian within the 110-mile stretch north from Porcupine River that has been examined. The southern area lies west of upper Old Crow River, about 60 miles north of Porcupine River; the other extends for about 40 miles, from a point several miles north of Ammerman Mountain, or about 70 miles north of the Porcupine, within 2 miles of Tub Mountain.

West of Old Crow River.—As has been already briefly stated, the Carboniferous rocks west of upper Old Crow River appear to make up all the bedrock of at least the eastern half of the timbered upland previously described with the exception of Yankee Ridge. The several low ridges that extend for about 5 miles southward from Yankee Ridge to Casey Fork show practically no definite exposures of bedrock except on their highest parts, and even there the rocks have been considerably disrupted by weathering and are more or less covered by vegetation; consequently wide intervals, about which no information can be gathered and only inferences can be made, occur between outcrops. The few exposures observed on these hilltops are of a bluish-gray semicrystalline limestone that contains fossil corals and brachiopods of Carboniferous age.

About 6 miles west of Old Crow River and 4½ miles southwest of Yankee Ridge stands the highest point on this upland, a bare cone named Horse Hill, whose elevation is several hundred feet greater than that of all the other hills within 6 or 7 miles. Horse Hill is made up of rocks which contain fossils of Carboniferous age, but which differ somewhat lithologically from the limestones of the low ridges to the east and northeast. It may be that there are two formations of Carboniferous age in this area. The rocks of Horse Hill consist of sandy and limy shales and impure limestones, most of which are very thinly bedded. The beds along its lower eastern slopes are of a yellowish-buff sandy rock with conspicuous reddish banding and some layers or streaks of pyrite, usually altered to hematite. The coloration is no doubt due to the iron content of some of the beds. Above the buff, sandy beds is a considerable thickness of more massive tough dark-gray beds alternating with softer layers.

This formation seems to extend southeast and northwest. Rocks of similar lithologic appearance were seen along the base of the mountains that lie south of Casey Fork just west of the boundary, or about 12 miles southeast of Horse Hill; but as they have not yet been shown to contain fossils and as continuity with the rocks of Horse Hill can not be traced across the alluvium-filled valley of Casey Fork they are not known to be the same.

North of Ammerman Mountain.—The Carboniferous rocks that extend northward along the one hundred and forty-first meridian for

nearly 40 miles north of Ammerman Mountain appear to make up, with the exception of two known occurrences of Triassic rocks, practically all of the country rock in this distance. They are known to extend 5 or 6 miles east and west from the meridian in a number of places, and they appear to be very widely distributed in this region. In general the rocks of this belt are lithologically similar throughout, being composed for the most part of massive gray, drab, blue, and black limestones, some members of which contain a large proportion of chert. In texture they vary from fine and close grained to coarsely crystalline. The series no doubt is made up of several formations, but these have not yet been distinguished. Apparently enough fossiliferous members have been found to justify at least the provisional grouping of all these rocks in one series. So far no depositional breaks have been recognized, but severe folding and probably faulting seem to be indicated. Some of the folding, especially in the northern part of the belt, appears to be of the overturned type. It is not improbable that overthrust faulting has also occurred. It is tentatively suggested that to such faulting are due the involved positions of the Upper Triassic rocks with relation to the normally underlying Carboniferous rocks of this belt.

The southernmost outlier of this Carboniferous series caps a broad-topped ridge, about 2 miles west of the boundary, that extends northward about 3 miles from Ammerman Mountain. About a mile of the phyllite and slate bedrock that flanks the north side of Ammerman Mountain intervenes between these limestones and the quartzites of the mountain. East of the boundary about 4 miles of the phyllite and slate bedrock lies between the quartzites of Ammerman Mountain and the Carboniferous limestones. The contact of the limestones with the slates and phyllites along their southern border is not visible in this vicinity, because of a heavy mantle of rock débris and moss. It appears, however, that the limestones overlie and are structurally unconformable with the more metamorphosed, supposedly pre-Ordovician quartzite, phyllite, and slate series of Ammerman Mountain. From their southern border northward for 12 miles to the southern slopes of the wide valley of upper Firth River the limestones make up the bedrock of a broad, moderately mountainous highland that forms the watershed between the headwater basin of the Old Crow on the west and that of Thomas Creek, a long northern headwater tributary of the Old Crow, on the east. Both streams have sources that rise within a few miles of upper Firth River, which flows from west to east across the boundary 17 miles north of Ammerman Mountain. The summits on this broad north-south divide are 2,500 to 2,700 feet in elevation and the saddles connecting them 2,000 to 2,400 feet. In general this highland belt may be said to have an average height of about 2,500 feet.

No very good fossiliferous beds have been found in the limestones between Firth River and Ammerman Mountain, but fragmentary remains indicate the Carboniferous age of the rocks.

Firth River basin.—About 18 miles north of Ammerman Mountain the boundary crosses the gravel-filled valley basin of upper Firth River a few miles east of the junction of the three large valleys of its chief headwaters, which rise in a group of high mountains 30 to 40 miles to the west and northwest. This basin has been named on the maps the Valley of Three Rivers. It is 3 to 4 miles wide from north to south and about 8 miles from east to west. Its elevation above sea level is about 1,700 feet. Firth River flows from this high interior valley basin in a general direction a little east of north for 75 miles and discharges into the Arctic Ocean about 25 miles east of the one hundred and forty-first meridian. Its descent to the coastal plain is said to occur mostly through a series of canyons 50 or 60 miles above its mouth.

The larger part of the Firth River basin west of the main river and north of its upper valley is occupied by moderately rugged mountains. The one hundred and forty-first meridian passes over a number of irregular ridges, most of which are more than 3,000 feet high, with high peaks rising to elevations of 4,000 to 5,000 feet. Practically all these mountains, so far as examined, for 25 miles north from the boundary at the Valley of Three Rivers, are made up of limestones of various kinds. Some of these limestones contain Carboniferous fossils and, so far as has been distinguished, all except an Upper Triassic formation (described below) belong to a single Carboniferous series. This Carboniferous limestone series seems to terminate along its northern border in unconformable contact with a series of semimetamorphosed quartzites, phyllites, and slates which closely resemble the similar rocks of Ammerman Mountain and are supposed to be of pre-Ordovician age.

TRIASSIC ROCKS.

Several miles south of the northern border of the Carboniferous rocks just described and about 8 miles west of the one hundred and forty-first meridian marine fossils of Upper Triassic age occur in a formation that is made up largely of black shales and impure thin-bedded shaly limestones, but possibly contains some massive limestones. This formation appears to be involved by profound folding and possibly faulting with the intimately associated Carboniferous limestones in such a manner that its position is now apparently beneath the older formations. At least, this is the tentative view now held as a result of the preliminary examination made in 1911.

Similar Upper Triassic rocks are situated approximately 1 mile west of the one hundred and forty-first meridian about 5 miles south

of the upper Firth River basin or Valley of Three Rivers. These are likewise associated with the massive Carboniferous limestone series and in the field examination of 1911 were considered possibly to underlie them. The outcrops from which the Triassic fossils were obtained are poorly exposed. Beds of impure flaggy limestone interbedded with sandy shales, which have not been observed in contact with the older series. They lie in the wide valley head of one of the extreme northern headwaters of Old Crow River. These rocks were not recognized elsewhere in this basin by fossils, but some black limy shales of somewhat similar appearance occur along the foot of the eastern slopes of the basin several miles to the southwest.

MESOZOIC (?) ROCKS.

Between the belt of schists whose northern border is 37 miles north of Porcupine River and the valley of Casey Fork, about 15 miles farther north, extends a group of mountains whose summits are about 3,000 feet above sea level and are 2 to 5 miles west of the boundary, which passes across their eastern flanks. These mountains are made up almost entirely of massively bedded quartzites with a small amount of interbedded shale slates and several beds of conglomerate, one of which seems to occupy a position at or near the base. The quartzites are for the most part fine grained, hard, and dense, and have a sugar-like fracture. They are predominantly white or light gray in color, but also show varicolored shades of pink, red, and brown. The shale beds are darker colored and are somewhat metamorphosed, showing slaty cleavage. The conglomerates, so far as observed, are made up of hard pebbles of white quartzite and white vein quartz in a coarse gritty matrix. The pebbles of quartz may well have been derived from veins which occur in the schists to the south, but no pebbles of schist were noted; neither were there seen any granite pebbles which might have come from the granites farther south, nor limestone pebbles that might have been derived from the Carboniferous formations north of Casey Fork. More extended examination, however, may disclose pebbles derived from these presumably older rocks. Only a few small and poorly exposed outcrops of conglomerate have been observed, and no statement of their thickness, extent, or development as a whole can be given. In some places the conglomerate contains a large percentage of matrix material in which the pebbles are somewhat separated or scattered, but in other outcrops it is composed of a more compact mass of pebbles with only a small percentage of finer matrix.

If it were not for the beds of conglomerate, the much smaller development of the beds of shale slate, and the more massive bedding of the quartzites, this series would differ little from the pre-Ordovician series along Porcupine River to the south, or from the less meta-

morphosed phases of the schists farther south, which are now considered to be altered equivalents of the quartzite, phyllite, and slate series of Porcupine River.

Because of the conglomerate member at or near the base of these rocks, their apparently unconformable position upon the supposedly schistose equivalents of the pre-Ordovician quartzite, phyllite, and slate series along their southern border, their marked dissimilarity to any of the known Paleozoic series which are well developed to the southwest, and the fact that the uppermost Paleozoic rocks (the Carboniferous) lie just north of Casey Fork, these rocks between Casey Fork and the Porcupine are considered to be possibly of Mesozoic age and to represent the apparently somewhat similar series that has been observed by the Canadian geologists to occupy considerable areas from 30 to 100 miles south of Porcupine River, where rocks of this general character, with a conglomerate member at their base, unconformably overlie formations of Ordovician, Silurian, and Carboniferous age.

As already suggested (p. 303) it seems very probable that two somewhat similar series, of widely different geologic age, the predominant rocks of which are white quartzites, may occur in this general region, the older being pre-Ordovician and the younger Mesozoic, and that under some of the conditions of their occurrence in proximity to each other they may be more or less confused.