CANADA
DEPARTMENT OF MINES
HON. T. A. CRERAR, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

BUREAU OF ECONOMIC GEOLOGY
GEOLOGICAL SURVEY

R. L. Christie

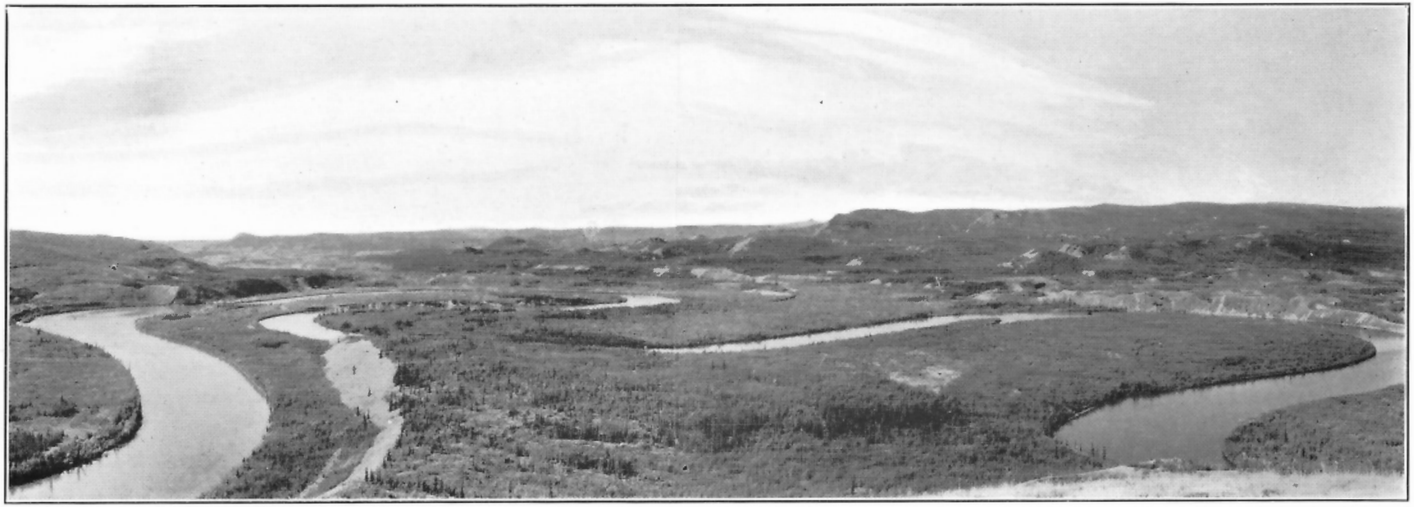
MEMOIR 189

Carmacks District, Yukon

By
H. S. Bostock

OTTAWA
J. O. PATENAUDE, I.S.O.
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1936

Price, 25 cents No. 2413



Looking southwest from Tantalus butte; on the left, beyond Carmacks, is Nordenskiöld River valley; note the even skyline typical of the Yukon plateau.

CANADA
DEPARTMENT OF MINES
HON. T. A. CRERAR, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

BUREAU OF ECONOMIC GEOLOGY
GEOLOGICAL SURVEY

MEMOIR 189

Carmacks District, Yukon

By
H. S. Bostock

OTTAWA
J. O. PATENAUDE, I.S.O.
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1936

Price, 25 cents No. 2413

CONTENTS

Illustrations

Carmacks District, Yukon

CHAPTER I

INTRODUCTION

The area here referred to as Carmacks district lies between latitudes 62 and 63 degrees north and longitudes 136 and 138 degrees west. It is approximately 65 miles from east to west, 69 miles from north to south, and 4,500 square miles in area.

Since 1898 placer gold has been found in several localities in the district, but not in important amounts. These discoveries served, however, to keep a few prospectors interested in the district and as a result a lode gold strike was made in 1930 on the ridge now known as Freegold mountain, some 30 miles northwest of Carmacks. It attracted considerable attention and a large number of claims were staked in the vicinity.

Prior to the present undertaking by the Geological Survey very little surveying of any kind had been done in the district, though the main route of travel of the territory passes through it. Robert Campbell of the Hudson's Bay Company and his small party of explorers were the first white men to leave any record of visiting the district. The party descended Pelly river in 1843 and returned up it the same year.[1] In 1848 Campbell established a trading post at the confluence of Pelly and Lewes rivers and named it Fort Selkirk (Plate II B). At first it was situated on the extreme point of land between the two rivers, but this site being subject to floods during the breakup of the ice, the post was moved in 1852 to the present site of Selkirk. The outline of the original fort and parts of some of the buildings can still be seen as low ridges, though they are now overgrown. The second (?) post was burnt in 1852[2] by a party of hostile coast Indians and it was not re-established.

The first mapping of any part of the district was a route map of Yukon river made in 1883 by Frederick Schwatka of the United States army, and his party.[3] In 1887 Wm. Ogilvie surveyed the course of Lewes-Yukon rivers from lake Lindeman to the 141st meridian.[4] In the same year G. M. Dawson reached Selkirk by descending Pelly river. He met Ogilvie there and then proceeded up Lewes river leaving the territory by the route by which Ogilvie had entered it. Dawson's maps and reports give the first geological information of the district.[5] The following year R. G. McConnell passed through the district as he ascended Yukon river and his report gives the first geological information on the district below Selkirk.[6]

---

1 Campbell, Robert: "Discovery and Exploration of the Pelly (Yukon) River, 1843".

2 Dawson, G. M.: "Report on an Exploration in the Yukon District, N.W.T., and Adjacent Northern Portion of British Columbia, 1887"; Geol. Surv., Canada, Ann. Rept. 1887-88, pt. B.

3 Schwatka, Frederick: "Report of a Military Reconnaissance in Alaska made in 1883"; U.S. Senate.

4 Ogilvie, William: "Exploratory Survey of Part of Lewes, Tatondue, Porcupine, Bell, Trout, Peel, and Mackenzie Rivers"; Ann. Rept. Dept. of Interior, Canada, 1889, pt. VIII.

5 Dawson, G. M.: "Report on an Exploration in the Yukon District, N.W.T., and Adjacent Northern Portion of British Columbia, 1887"; Geol. Surv., Canada, Ann. Rept. 1887-88, pt. B.

6 McConnell, R. G.: "Report on an Exploration in the Yukon and Mackenzie Basins, N.W.T."; Geol. Surv., Canada, Ann. Rept. 1888-89, vol. IV, pt. D.

In 1891 C. W. Hayes travelled down Teslin and Lewes rivers as far as Selkirk, from where he started overland to the head of White river. His report is the first to describe the country southwest of Selkirk.[1] After the Klondike gold strike in 1896 the district, with the whole Yukon territory, received much more attention in the way of mapping and exploration. In 1897 J. J. McArthur made a topographical map of a route known as the Dalton trail, which enters the district from the south, passes up Schist creek and over the Dawson range to Selkirk.[2] The following year McArthur continued his survey northward across Yukon river to Stewart river.[3] In the same year J. B. Tyrrell travelled the trail down Nordenskiöld river to Carmacks, thence up Rowlinson creek and down Nisling river. His accounts give notes on the geology of these portions of the district.[4] In 1902 McConnell and Joseph Keele working together amplified the work done by Dawson along Pelly river up to the mouth of Macmillan river.[5] In 1906 D. D. Cairnes paid a visit to the Tantalus, Tantalus Butte, and Five-finger coal mines.[6] The following year Cairnes returned and commenced mapping the coal-bearing areas in the neighbourhood of Carmacks and visited the lode prospects in the vicinity of Williams and Merrice (Merritt) creeks.[7] In 1908 he continued this work.[8] The results obtained during these three seasons were assembled in a short memoir and maps published in 1910.[9] In 1909 he again visited the prospects at Williams and Merrice creeks and reported more fully on them.[10] In the Yukon section of the geological guide book written for the International Congress in 1913, Cairnes adds a number of additional notes on this district.[11] In 1914 he examined the gold placers on Nansen and Victoria creeks.[12] After this, to the writer's knowledge, no geological work was done in the district until that of his own visits in 1931 and the three subsequent years.[13] Further topographical information was, however, provided by traverses and a line of precise levels carried along the Whitehorse-Dawson road by the Department of the Interior.[14]

The topographical mapping of the district has been under the direction of W. H. Miller of the Topographical Division of the Geological Survey and was done in 1932, 1933, and two weeks of the 1934 season. The geo-

---

1 Hayes, C. W.: "Exploration Through the Yukon District"; Nat. Geog. Mag., Washington, May 15, 1892.

2 Yukon Map, Sheet No. 7, Surveyor General's Office, Department of Interior, Canada, 1898.

3 Map of the Exploratory Survey of the Stewart River in the Yukon Territory; Topographical Surveys Branch, Dept. of Interior, Canada, 1898.

4 Tyrrell, J. B.: Geol. Surv., Canada, Sum. Rept. 1898. "The Basin of Yukon River in Canada"; Scottish Geog. Mag., June, 1900.

5 McConnell, R. G.: Geol. Surv., Canada, Sum. Rept. 1902.

6 Cairnes, D. D.: Geol. Surv., Canada, Sum. Rept. 1906.

7 Cairnes, D. D.: "Report on Portions of Yukon Territory, Chiefly between Whitehorse and Tantalus"; Geol. Surv., Canada, Sum. Rept. 1907.

8 Cairnes, D. D.: "Preliminary Report on a Portion of the Yukon Territory, West of the Lewes River and Between the Latitudes of Whitehorse and Tantalus"; Geol. Surv., Canada, Sum. Rept. 1908.

9 Cairnes, D. D.: "Preliminary Memoir on the Lewes and Nordenskiöld Rivers Coal District"; Geol. Surv., Canada, Mem. 5 (1910).

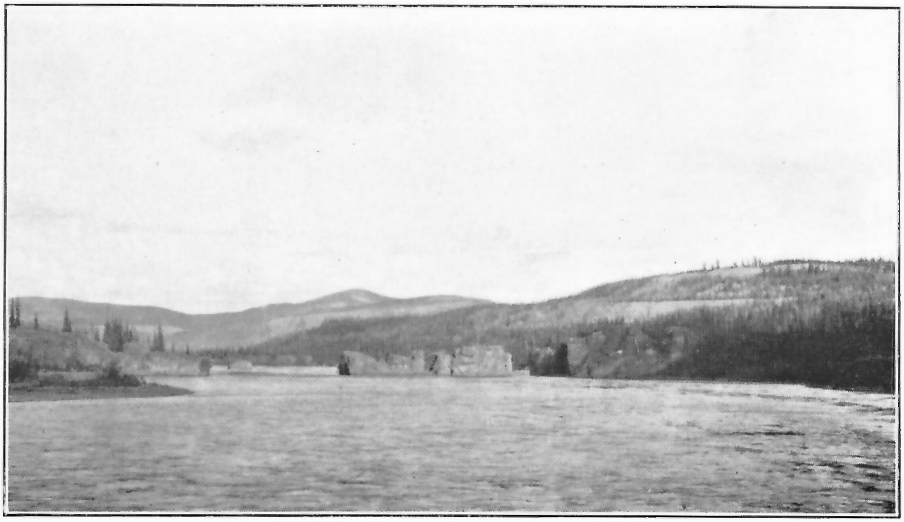
10 Cairnes, D. D.: "Williams and Merritt Creeks"; Geol. Surv., Canada, Sum. Rept. 1909.

11 Cairnes, D. D.: "The Skagway-Whitehorse-Dawson Section"; Geol. Surv., Canada, Guide Book No. 10 (1914).

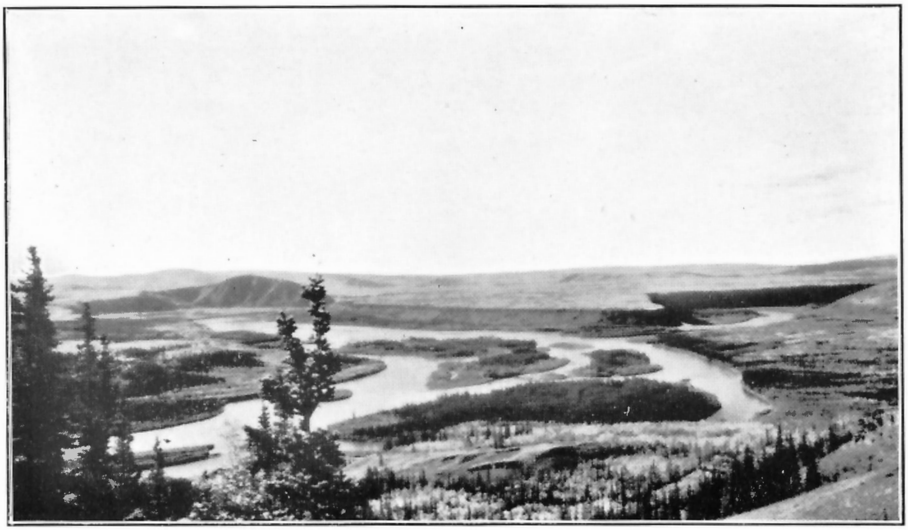
12 Cairnes, D. D.: "South Western Yukon"; Geol. Surv., Canada, Sum. Rept. 1914.

13 Bostock, H. S.: "Mining Industry of Yukon"; Geol. Surv., Canada, Sum. Rept. 1931, pt. A; 1932, pt. A II; 1933, pt. A: and Mem. 178 (1934).

14 Reports and Maps by the Department of the Interior, Ottawa.



68717
A. Five-finger rapid, looking down stream; fossil locality is on extreme right.



75748
B. Looking down Lewes river to its junction with Pelly river; on the right is the mouth of Pelly river and on the left is Yukon river, formed by the confluence of Lewes and Pelly rivers.

logical work, under the direction of the writer, was performed in 1932, 1933, and 1934.

The field seasons extended from the end of the first week of June to the third week of September. The district being large it was essential to move camp every day or second day in order to cover it in reasonable time and much energy and time were thus spent in travelling. The geological traverses were necessarily widely spaced and very long, affording few opportunities for making detailed examinations. Added to this, the unglaciated areas have but few good exposures in spite of the great areas in which the rock is close to the surface and readily determinable by float. The work, however, was in keeping with the 4-mile scale of the map, but in many sections where more exact knowledge is desirable, as for instance those containing the Mesozoic sediments, more detailed mapping will be required to clear up existing problems.

The writer was ably assisted in the field in 1932 and 1933 by J. R. Johnston and in 1934 by J. E. Armstrong.

Lewes-Yukon river traverses the district diagonally and forms the main route of transportation. From late in May to mid-October the stern-wheel steamers of the White Pass and Yukon Route run on the river, and Pelly river is frequently navigated by smaller steamers and boats. Much of the travelling on these two rivers is done in small power boats in summer. The rivers are very swift, but no rapids obstruct navigation for suitable craft of good power. Five-finger and Rink rapids can be run in any buoyant craft. It is advisable for a stranger descending them for the first time in a small boat to use the channels on the east side (*See* Plate II A). In ascending them the same east channel is preferable for Rink rapids, but a channel known as " canoe pass " on the west side is usually better for Five-finger rapid.

Some of the lakes in the east part of the district, including Merrice lake, are suitable for planes to land, and planes can also land on Yukon, Lewes, and Pelly rivers. Few good trails exist, but in summer pack-horses can be used in any part of the district, though the character of the country in many parts makes this mode of transport slow and arduous. The main road of the territory from Whitehorse to Dawson and Mayo passes through Carmacks and on northward across the district. In winter the mail, passenger, and freight service is maintained on the road by means of tractors. The local inhabitants use dogs in winter and to some extent in summer.

The climate of south-central Yukon is by no means as severe and unattractive as is generally believed. The winters on account of the northern latitude and interior situation, are rigorous, but though extremely low temperatures occur they do not as a rule continue for long periods of time. On no day in the winter does the sun fail to appear above the horizon. The summers are particularly delightful, as on account of the northern latitude practically continuous daylight prevails from the latter part of May well into July. The interior situation results in a relatively dry and sunny summer, though inclined to be more showery than in more southern latitudes. The rivers open in May and remain open until well on into October or even November. In the spring ice may remain on the larger lakes until the first week of June. Normally lake Laberge is open about the last week in May and from then until the first week of October the steamers are operating on Lewes-Yukon river. Slack water freezes any time after the middle of October.

Generally speaking the district is forested, but particularly in the southwest part there are large areas above timber line. This is at approximately 4,000 feet, though in a few favourable localities in the Dawson range trees occur up to 4,500 feet. Below timber line in the glaciated parts of the district trees grow everywhere except on the south faces of hills and terraces. These are usually covered by grasses and plants characteristic of rather arid, northern interior climates, and have groves of aspens and spruces in hollows in the slopes. On the north slopes, in poorly drained flats, and in hollows, the ground is usually frozen a foot or so below the surface for the whole year. It is carpeted by moss in which stunted trees, largely black spruce and shrubs, grow. Groves of good timber, mainly white spruce, grow in parts of the valley bottoms and other localities where the ground thaws to some depth. These trees are commonly 15 inches in diameter 2 feet above the ground, straight and tall. The same features are characteristic of the vegetation in the unglaciated parts of the district, but there the stretches of frozen ground are more persistent and the vegetation is inferior to that in glaciated parts. In the unglaciated areas, too, flat valley bottoms, such as that of Lonely creek, are bare and treeless over considerable areas. Pack-horses were used in all parts of the district and no feed or grain was ever carried as little difficulty was experienced in finding feed close to any campsite.

The most important tree economically is the white spruce, the chief source of timber and firewood. The other trees noted are black spruce, black pine, balsam fir, white birch, aspen poplar, and balsam poplar. The spruces and poplars are common in their own environments in all parts of the district. The birch and pine are rare in the southwest parts of the district, but common in the north and east. Balsam fir was noticed only on Ptarmigan mountain near the timber line.

The most important game animals are moose and barren ground caribou, and the inhabitants very largely depend upon these two species for their meat supply. Moose are relatively abundant in most of the less accessible areas north and east of Yukon and Lewes rivers. Southwest of the rivers they are rarer and seem confined to a few localities. The small barren ground or migratory caribou (*Rangifer articus*) wander in winter over the country, particularly the southwestern part of the district. Some years they appear in large numbers along Lewes river from Selkirk to Carmacks, and as far east as Willow creek on Pelly river, but usually they do not frequent the eastern parts of the district in large numbers. The caribou migrate northwest in the spring, return in great herds of many thousands for a short period in July, and then turn back north to reappear for the winter in October. The sight of these vast herds in July is an experience never to be forgotten. On Ptarmigan mountain a few caribou were seen that were said to be the woodland caribou (*Rangifer Osborni*) which frequent that neighbourhood throughout the year. A small band of ewes and lambs seen on the slopes of Prospector mountain and some sheep whose tracks were seen on the ridge west of it are apparently the only mountain sheep that regularly range in the district, though wandering sheep may be seen from time to time at other points along the Dawson range and elsewhere. The sheep in the Dawson range appear to be wholly white, but occasionally some are observed which show faint saddle-back markings. An occasional grizzly may be met with anywhere, but they are more common on the southwest side of Lewes river. Brown and black bears are found in all parts of the district and are plentiful in the northern parts. Wolves likewise occur in all parts of the district, but were seen more often back from the main rivers, and are particularly common in the country frequented most by the caribou. They vary considerably in colour, some practically black, some grey, and some of a tawny grey shade. Coyotes occur in the main valleys. Fox, wolverine, lynx, martin, mink, weasel, rabbit, squirrel, ground squirrel, muskrat, beaver, etc., are among the other animals of the district.

The game birds that remain throughout the year include spruce partridge, willow grouse, sharp-tailed grouse, and ptarmigan. The spruce partridge and willow grouse are found wherever the environment is suitable. The sharp-tailed grouse frequent the drier sections along the main valleys of Lewes and Pelly rivers and the country between them. Ptarmigan were seen in great numbers in the Dawson range.

CHAPTER II

SUMMARY AND CONCLUSIONS

The rocks of Carmacks district include a basement of old metamorphic rocks, the Yukon group, and early intrusives. This basement is overlain by areas of Mesozoic sediments, the Lewes River, Laberge series, Tantalus formation, and Mount Nansen volcanic group. These Mesozoic strata and older rocks are cut into and separated by great and small bodies of intrusive rocks, largely of granitic composition and mainly of Mesozoic age. Large areas of the Mesozoic intrusives and older rocks are covered by volcanics and sediments of Tertiary to Recent age. In the Pleistocene rather more than half the district was covered by the last glaciation which encroached upon it from the east and southeast leaving large areas covered by glacial drift. There is some record of earlier glacial advances which were locally more extensive than the last.

The district contains gold placer deposits and lode deposits carrying gold, silver, copper, lead, zinc, antimony, and other metals, as well as large reserves of bituminous coal.

All of the lode deposits and placers, except those of the bars of Pelly river, have been found southwest of Lewes river, and the more important of these are along the Dawson range where there is the greatest variety of differentiates of intrusives. Gold placers have been found along the range in places in the district and to the northwest where it extends beyond the district. The range has not been subjected to glaciation except at its southeast end and any placers that have formed lie undisturbed. The lode deposits found to date in the range are those of Freegold mountain, and the assemblage of rocks associated with them occur elsewhere along the range and may be expected to produce similar mineralization elsewhere in it.

The development of the Laforma group of mineral claims shows that gold-bearing veins of a persistent character occur there and the underground work demonstrates that the values continue with depth and are not a local concentration at the surface. That mineral deposits occur outside the belt is evidenced by the copper and gold placer deposits of Williams creek, and their position suggests that some importance may be attached to the northeast contact of the granitic body with which they are associated.

The coal resources of the district are of importance. The areas of the Tantalus formation offer the best coal prospecting ground, but the upper horizons of the Laberge series immediately east of the areas of Tantalus formation at Carmacks and near the old Five-finger mine also probably carry seams of good and readily accessible coal. With the probability of metal mining in the district requiring a considerable quantity of power the value of the coal for generating power by burning it at the coal mine is apparent.

Though the district is traversed by the main routes of Yukon and is one of the most accessible parts of the territory, it has received very little prospecting, particularly lode prospecting, and the whole district may be regarded as practically virgin ground.

CHAPTER III

PHYSIOGRAPHY AND GLACIATION

Yukon territory includes parts of three major physiographic provinces, namely, the Coast Range province on the southwest, the Yukon Plateau province in the south-central part, and the Mackenzie Mountain province to the north and east of the plateau. Carmacks district lies in the central part and wholly within the Yukon Plateau province.

The area included in the plateau is by no means flat, but exhibits a relief of 2,000 feet and more. However, in every part of the plateau, including Carmacks district, the skyline seen from any prominent point is markedly even and interrupted only here and there by small mountain ranges, mountain groups, or individual peaks (Plate III A). The skyline owes it evenness to the existence of a gently rolling upland surface which extends over most of the higher ground of the plateau province. This upland surface is dissected by valleys and by larger areas cut well below it, as in the vicinities of Five-finger rapid and Pelly crossing. Along the divides the general elevation rises and many high points, such as the mountains of the Dawson range, have not been reduced to the level of the upland and still stand well above it.

The upland surface is best seen on the southwest side of the Dawson range about the headwaters of the streams, where it has been least modified. Here its elevation is between 4,000 and 5,000 feet and streams such as Klaza river and its main tributaries have cut their valleys 1,000 to 1,500 feet below the general level. On the northeast side of the range the upland surface slopes from elevations of 4,000 to 5,000 feet along the edge of the range to elevations 2,500 to 3,500 feet along Lewes river, but along the north and east borders of the district it rises again to 3,000 and 4,000 feet.

The remnants of the upland surface are of a hilly though rolling character and exhibit a relief of 500 feet and more. The valleys that have not yet been cut down are broad and mature. From this it seems correct to regard the upland as a physiographically mature surface rather than an old age surface or peneplain.

This upland surface has truncated the structures of all the older formations, including the Carmacks volcanics and Tertiary intrusives. The Selkirk volcanics are definitely younger than it as they have been poured out on to its surface.

This upland surface is that described by Cockfield[1] in Sixtymile and Ladue Rivers area and by Cockfield and Bell in Whitehorse district.[2] This surface in Sixtymile and Ladue Rivers area is believed to have been completed and uplifted before the close of the Miocene.

[1] Cockfield, W. E.: "Sixtymile and Ladue Rivers Area, Yukon"; Geol. Surv., Canada, Mem. 123, pp. 7, 8 (1921).

[2] Cockfield, W. E., and Bell, A. H.: "Whitehorse District, Yukon, 1926"; Geol. Surv., Canada, Mem. 150, pp. 3, 4 (1926).

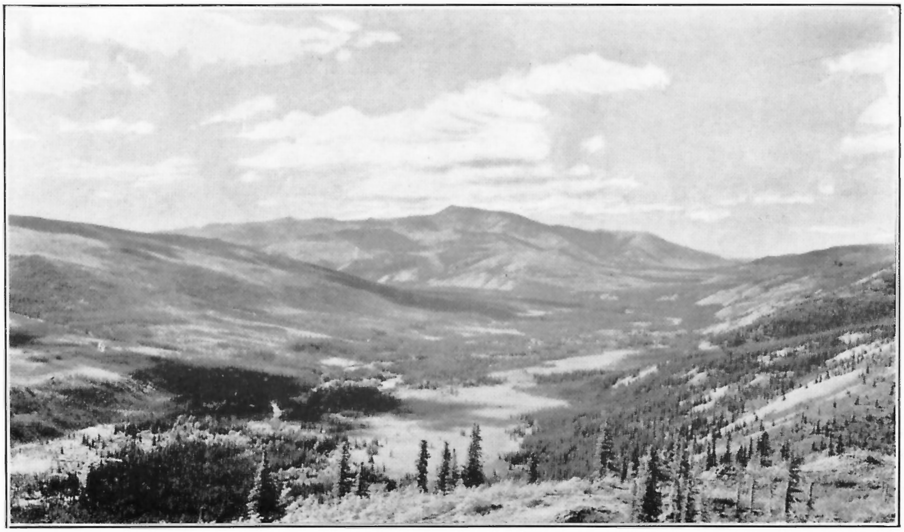
The break between the upland surface and the sides of the larger valleys is marked by abrupt changes in slope. This is particularly apparent along the main valleys where the valley floors have been widened at the expense of the projecting spurs. Below this break, which marks the initial major change in level of the district and rejuvenation of its drainage, other changes of level are indicated.

Along Yukon river below Selkirk remnants of a rock terrace occur approximately 600 feet above the present river and on some of the truncated spurs there are two facets, a steep lower one and above it and the level of the terrace a more gently sloping one. Above Selkirk, terraces cut in bedrock are more in evidence. Starting about Williams creek and extending down stream for a few miles is a marked terrace cut in rock about 500 feet above the river. Below Minto the terrace is still marked in places and is probably the same as that seen below Selkirk. Along this part of the valley, and at Five-finger and Rink rapids, remnants of former bedrock levels of the valley bottom occur at various lower levels from 10 feet to 70 feet above the present high-water level. Along Pelly River valley at and below Bradens canyon, for 3 miles, remnants of a terrace occur at about 400 to 500 feet above river level and perhaps correspond to that in Lewes River valley.

Along the valley of Big creek four features of interest are recorded. Near the head the valley is broad and close to the level of the surrounding upland surface. Down stream it becomes steep walled and narrow as it crosses the line of the ridge between Prospector and Klaza mountains, below which it widens as the creek continues to the river and grows in volume. Along this latter part two rock terraces mark former levels of the valley bottom. Remnants of the upper of these occur along the south side of the valley from opposite Prospector mountain (*See* Plate III A) to the mouth of Stoddart creek where it is approximately 500 feet above the present valley floor. Remnants of this same terrace level occur on the tributaries, Bow and Seymour creeks, and old rounded stream gravels still remain on it in many places. The lower occurs on both sides of Big creek for 5 or 6 miles above the mouth of Dark creek, and to a less marked extent in Dark Creek valley. Big creek has cut a canyon approximately 200 feet deep at the lower end in its former valley bottom marked by this terrace.

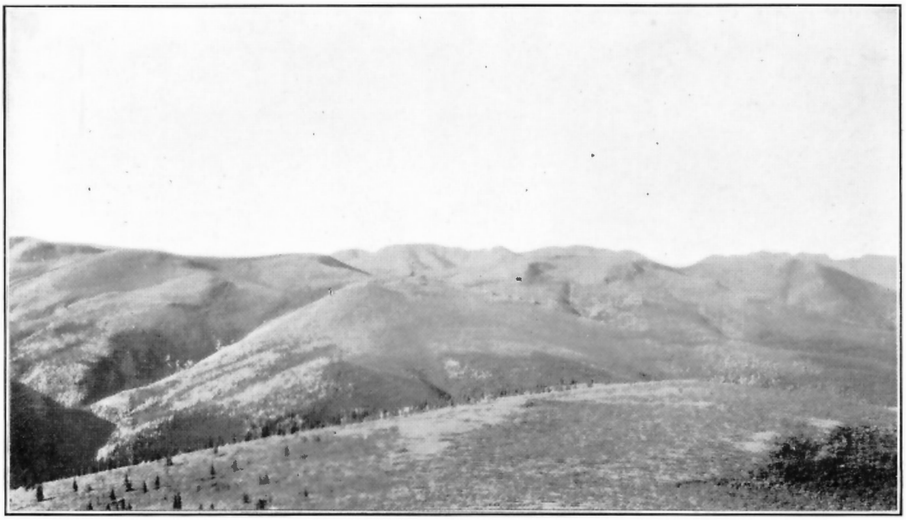
Below its junction with Dark creek, Big creek turns abruptly north through a deep canyon instead of following the much broader gap that leads eastward to Lewes river opposite McCabe creek. Big creek has already widened the floors in both of these canyons sufficiently to meander to a limited extent, which suggests that this diversion was established well before the last glaciation though there is a conspicuous similarity between this diversion and that of Merrice creek which suggests that it may be of earlier glacial origin. On the southeast fork of Hayes creek remnants of a terrace occur that correspond to the higher terrace on Big creek.

On the southwest side of the Dawson range a terrace cut in rock lies along the lower part of Magpie creek and the valley of Klaza river below this creek. This terrace, like the higher terrace of Big creek, gradually increases its height above the present stream as it follows down the valley.



68716

A. Prospector mountain from the north side of Big creek; note the terrace on the south side of Big Creek valley.



75670

B. Part of Dawson range, looking southwest from Freegold mountain; typical of Dawson range and unglaciated, mountainous parts of the district; note slopes of debris and occasional bedrock outcrops on summits.

In many places streams occupy valleys out of proportion to the size of the streams, and large valleys occur through which no streams run. The most notable of the latter is the large valley between Wolverine creek and a stream running west out of the district into Selwyn river. Looking eastward along this valley it appears to continue eastward across Lewes river to Von Wilczek lakes where a large depression extends through to Pelly River valley. Here it is joined by the valley of Tatlmain lake and Mica creek and extends northward up the course of Willow creek to the great valley occupied by Crooked creek, beyond the district. The general level of this valley is approximately 2,000 feet, or 500 feet above that of the present Lewes and Pelly valleys.

It is believed that the higher of the two terraces in Big Creek valley is the same as that occurring in Lewes valley below Williams creek and those of approximately the same level on Yukon and Pelly rivers. It is also thought that there is a significance in the close correspondence in level between these terraces and the level of the unoccupied valley mentioned. Together they mark an extensive change in the drainage system and a renewal of active stream cutting which subsequently, from time to time, has been renewed to a less extent, as evidenced by the lower rock terrace remnants along Big creek and Lewes river. At the present time the streams have cut their valleys to more or less uniform gradients and are occupied in broadening these valleys.

The drainage of the district is of the trellis type. This is distinct in almost every part of the district, but particularly in the unglaciated area. Two directions, northwest and northeast, are predominant. In the eastern half of the district a few north-trending canyons have been developed. An interesting feature is the converging, fan-like drainage arrangement along the southern border of the district in the vicinity of Nansen creek.

The western boundary of the area occupied by the last extensive Pleistocene ice-sheet passes through Carmacks district (*See* Plate III B). The position of the edge of the glaciated area as shown on the accompanying map of the district (No. 340 A) could be accurately determined in a few places, as on the ridge west of Carmacks, but, for the most part, its position is largely a matter of conjecture. It approximately marks the boundary of the country in which glacial phenomena due to the last main glaciation are fresh and widespread. To the west of this boundary, and in parts of the district close to it, other features have been found that indicate an earlier glaciation.

The phenomena that most definitely seem to belong to an earlier glaciation are those found in the vicinity of Nansen creek. A boulder clay described in a later chapter occurs in this area and is covered by deposits of normal erosion. The surrounding country shows no other sign of glaciation except some changes in drainage. The slopes are typical of the normal process of erosion. The drainage changes relate to Klaza river and Lonely creek.

The divide between the head of Lonely creek and Klaza river is in a large open valley which extends down Lonely creek and is now becoming filled by alluvium brought into it from the steep tributary valleys, as Lonely creek, a small stream with a gentle gradient, is unable to keep so large a valley clear. The divide is practically flat. From the divide Klaza river flows northwest to Magpie creek. Its valley is at first wide with sloping sides and in this part a terrace occurs which slopes against the stream, i.e., towards Lonely creek. Again, whereas tributaries normally enter a main stream at an acute angle, two large tributaries of this part of Klaza river make an obtuse angle with the river so that their waters turn more than 90 degrees upon entering the main stream. These features indicate that the head of Klaza river formerly flowed southeast and must have passed down Lonely Creek valley. Although the relationships suggest stream piracy, it is believed that this is not the correct explanation of the diversion and that a temporary blocking of Lonely Creek valley by the front of an ice-sheet advancing from the south caused the change. The diversion of the drainage, and the presence in this recently unglaciated district of a boulder clay so old that the pebbles in it have decayed and placers have formed on top of it, are believed to indicate that this part of Carmacks district was encroached upon by an ice-sheet advancing northerly in the earlier part of the Pleistocene.

In the vicinity of Selkirk and in the country bordering Pelly river the determination of the western limit of the later glaciation is difficult. The glacial features die away across a broad area. On ridges whose general features seem to indicate that they have escaped glaciation the presence of occasional large erratics is perplexing. Directly northwest of Selkirk on a hill composed of the Mount Nansen group and granitic intrusives, boulders of Selkirk lavas occur up to heights of 2,200 feet, more than 400 feet higher than the lavas directly across the river. South of Selkirk, near meridian 137° 45′, north of Wolverine creek, boulders of the Selkirk volcanics were found up to elevations of 3,300 feet. These places are the farthest west at which erratics were found. They are considered to be products of a glaciation earlier than the last because they occur in an area characterized by the general adjustment of the drainage, lack of lakes, unglaciated appearance of the topography, and presence of outcrops of castellated form on some of the lower hills. That the earlier glaciation of Selkirk area and that of the vicinity of Nansen creek were contemporaneous is doubtful. The writer believes that the glaciation of Nansen Creek area was the earlier.

Evidences of the last glaciation in the districts east of the limit shown on the map are numerous. Not many striæ were found. The few discovered occur in and near the valley of Lewes river and show that the ice moved northwesterly parallel to the general course of the river. Striæ found east of Legar lake show that there the ice moved somewhat south of west through this gap. Striæ found in Pelly River valley north of Selkirk also indicate a direction of movement south of west.

In Lewes valley from Minto upstream the river has cut its course through a thick deposit of glacial gravels, etc., and although the river is continuously changing its course and meanders extensively, as for instance at Carmacks, no meander has yet been cut off. Glacial features such as the edges of kettle-holes are sharp and have been scarcely modified by erosion. The materials in the gravels, boulder clay, etc., and the surfaces of rock outcrops show hardly any sign of decay. Features such as these seem to indicate that the ice retreated from Lewes River valley at a relatively recent date. This conclusion seems also to be supported by features exhibited by Lewes river for several miles above and below Five-finger rapid. Here since the retreat of the ice the river has been held in a course that cuts across low rock spurs on the east side of its former valley. The rocks of these spurs are relatively soft and although the river has cut its channel down to such an extent as to eliminate any formidable rapid, it has not widened its bed beyond its present needs nor removed the small rock islands of Five-finger rapid.

In Pelly River valley the glacial features appear to be relatively more modified. The river below Bradens canyon has developed flats on either side and removed all but a few remnants of high gravel terraces. Above the canyon it has also developed wide flats, though the valley appears to have been as deeply filled with gravel, etc., as that of Lewes river, and a few miles above the canyon the river has already cut off a meander. Pelly river is a smaller stream than Lewes river and the rocks of Bradens canyon appear to be tougher than those along the stretch of Five-finger rapid, yet Pelly river has cut away all sign of a rapid in Bradens canyon which appears to be post-Glacial as the former course of the river lay in the drift-covered area north of the canyon. The same conditions obtain at Granite canyon, but proceeding up river the glacial features become less modified in appearance. These features, compared with those to be seen along Lewes River valley, suggest that the ice withdrew from the lower part of Pelly River valley earlier than it did from Lewes River valley.

A number of smaller features and changes in drainage were produced by glaciation. Seymour Creek valley formed a spillway for a considerable volume of water which it received from the ice lying at its head and in Crossing Creek valley. This explanation also accounts for the quantity of gravel that covers the floor of Seymour Creek valley. Other similar spillways probably operated on the north side of Granite mountain and in the pass between Hoochekoo creek and Big creek.

The forming of the two lakes between Merrice and Crossing creeks and the diversion of Merrice creek through its steep-walled narrow canyon are typical effects of the last glaciation. Besides this a large number of small canyons have been cut during the disappearance of the last ice-sheet in the granite slopes south of Tatlmain lake.

The last glaciation of the district is regarded as late Pleistocene and is tentatively correlated with that in Alaska which has been called Late Wisconsin by Capps.[1]

The tracing of the limit of the last glaciation has furnished some information regarding the slope of the surface of the ice at a stage believed to be the maximum of the last glaciation. Supposing the front of the ice reached to a point between the lower end of Ingersoll islands and Selkirk, then from this point to the mountain west of Minto, a distance of 10 to 13 miles, the surface of the ice rose from an elevation of 1,450 feet to 2,750 feet or at a rate of between 130 and 100 feet a mile. In the next 20 miles to the southwest it rose to an elevation of 3,550 feet or at a rate of 40 feet a mile, and in the next 20 miles farther southeast it rose to an elevation of 4,200 feet at a rate of 32·5 feet a mile. Farther southeast

[1] Capps, Stephen R.: "Glaciation in Alaska"; U.S. Geol. Surv., Prof. Paper 170-A, pp. 1-8.

the hills are lower until at a distance of 80 miles the mountains east of Big Salmon river are reached. There evidence was found by the writer in 1934 showing that the ice on the north side of Big Salmon river moved over ridges rising to 5,500 feet if not higher. This indicates that in the 80 miles the ice surface rose at a rate of approximately 16 feet to the mile. As the direction of movement of the ice was probably much influenced by the rather mountainous character of the country, the course followed was probably not that along which the gradients have been calculated. The gradients as here given are subject to a further correction because no allowance has been made for any post-glacial tilting of the region. These figures are only approximate and undoubtedly will be revised if a more detailed study is made.

Distinct cirques do not occur in the part of the Dawson range within Carmacks district. The streams running into Hayes and Big creeks from the northerly slopes of Prospector mountain rise in deeply cut, straight valleys having relatively steady gradients. Though these valley heads show no positive evidence of glaciation, their general form somewhat resembles that of a cirque and it is possible that they are cirques produced during an early Pleistocene glaciation and subsequently modified by normal processes of erosion. A few miles west of the border of the district, between the heads of Hayes and Big creeks on the north side of the highest point (6,635 feet) in the Dawson range, there is a small but typical cirque containing a small lake held in by morainal debris and solid rock. The alpine glacier that formed this cirque was probably not over a mile long. The fresh appearance of the cirque and the presence of the lake indicate that the cirque is of recent age. It is believed to have developed during the last glaciation.

CHAPTER IV

GENERAL GEOLOGY

The physiographic provinces referred to in Chapter III are in a broad way geological units. The Coast Range province is largely made up of granitic intrusives with remnants of older sedimentary and volcanic rocks. The Mackenzie Mountain province is mainly composed of folded sediments. The intervening Plateau province is one of old metamorphic rocks, folded sedimentary rocks, volcanics, and intrusives.

Carmacks district lies well within the Plateau province and the basal rocks are metamorphosed sediments and possibly volcanics invaded, in places, by granite-gneiss and diorite-gneiss. It has been customary to include all of them in the Yukon group, but it is now proposed to exclude the granitic gneisses which are probably deformed intrusives. The Yukon strata and the deformed granitic rocks invading them are presumably of Precambrian and early Palæozoic age.

The next rocks in point of age are those of the Lewes River series, and are mainly limestones of Triassic age. They are overlain by the Laberge series of Jurassic age, mainly coarse clastics. The Laberge series is in places overlain by the Tantalus formation, a clastic assemblage of Jurassic or early Cretaceous age. These Mesozoic sediments are confined to Lewes River valley and occur mainly in the southeast corner of the district. They were folded, faulted, and eroded before the extrusion of a later volcanic assemblage. This group of volcanic rocks corresponds to what, in other parts of Yukon, has been termed the Older Volcanic group, but it is proposed to refer to them in this report as the Mount Nansen group. Their age is presumably late Jurassic or early Cretaceous. They are largely developed along Lewes River valley and also occur to the southwest in the Dawson range. The Mount Nansen volcanics and the older Mesozoic sediments suffered folding and have been invaded by a succession of igneous rocks apparently contemporaneous with the Coast Range intrusives. These include a wide range of types varying from basic to acid, but granodiorite and granitic types prevail.

The period of igneous invasion was followed by one of erosion which exposed the intrusives. Erosion was interrupted in the early part of the Tertiary by the accumulation of clastic sediments and the extrusion of the Carmacks volcanics. In part contemporaneously with these volcanics, but probably in the main at a somewhat later date, numerous dykes and small intrusive bodies invaded the southwest part of the district. The clastics and volcanics have been faulted and warped and they have been removed to a great extent by erosion. From the late Tertiary or Pleistocene to quite recent time extrusion of the Selkirk volcanics has gone on. In the Pleistocene a large part of the district was subject to glaciation by ice moving into it from the southeast and east.

The main trend of the Mesozoic and older surficial rocks is northwest-southeast, although parts of the Yukon group in the southwest and to a limited extent in the northeastern parts of the district have northeast trends. Injection of great bodies of intrusives has, however, broken the belts of older sediments; and, further, large areas are now covered by more or less flat-lying Tertiary sediments and volcanics, so that the older structure is not now easily determined.

Table of Formations

Late Tertiary or early Pleistocene to Recent		Alluvium, glacial drift; volcanic ash
	Selkirk volcanics	Basalt, andesite, breccia, tuff
Later Tertiary		Quartz porphyry, granite porphyry, granophyre, rhyolite
Miocene or older	Carmacks volcanics	Basalt, andesite, trachyte, dacite, breccia, tuff; some intercalated conglomerate and sandstone
Eocene (?)		Conglomerate, tuff, tuffaceous sanstone, shale
Upper Jurassic or later		Granite, granodiorite, and allied types
		Syenite, monzonite, and allied types
		Diorite, gabbro, and allied types
Late Jurassic or early Cretaceous	Mount Nansen group	Andesite, basalt, dacite, breccia, tuff; some intercalated tuffaceous argillite, quartzite; small bodies of intrusive diorite
Jurassic or Cretaceous	Tantalus formation	Conglomerate, sandstone, shale, coal
Jurassic	Laberge series	Conglomerate, sandstone, arkose, greywacke, shale, coal
Triassic	Lewes River series	Limestone; some tuffaceous clastics
Probably Palæozoic		Granite-gneiss, diorite-gneiss
Probably mainly Palæozoic	Yukon group	Northeast section: limestone, mica-quartz-chlorite schist, quartzite; green schist, gneiss, mica schist, quartzite, limestone
Possibly mainly Precambrian		Southwest section: quartz-mica schist, hornblende schist, quartzite, gneiss, limestone

YUKON GROUP

Metamorphic rocks of the Yukon group occur in all parts of the district except the southeast and they underlie the greatest area occupied by any one formation in the district. They consist of crystalline rocks of sedimentary and volcanic origins. The great majority of them are schistose and gneissic. They include rocks that are probably Precambrian and others that are almost certainly of later age, but no evidence has been found that permits their separation into divisions of definitely different ages.

The strata probably have a great thickness, totalling some thousands of feet, but their thickness is not even approximately known. Their structure shows a prevailing dip to the northeast in all the areas north of Klaza river and Rowlinson creek and from this it appears that the base of these strata occurs in the areas south of these streams where the strikes trend northeast.

Lithology

The following sequence is thought to be approximately correct for the schists south of Klaza river. Near the west border of the district, at the base, some 300 feet of limestone occurs. This is light grey to white, crystalline, and forms beds 1 to 3 feet thick with thinner beds at the base. In places lime silicates have been developed in limestone and adjacent schists. The limestones are interbedded with light-coloured mica schists and thinly bedded quartzites. The schists form most of the adjacent strata. To the south of the limestone a southeast dipping section is exposed which is representative and appears to overlie the limestone. At the base, slightly above the limestone, quartz-mica schists are interbedded with micaceous quartzites in beds 1 to 2 inches thick. These are followed by several hundred feet of soft mica schists which seldom outcrop. They are capped by more resistant strata composed of light-coloured gneisses of quartz and feldspar with small amounts of biotite and hornblende. The gneisses form bands up to 3 feet thick separated by thinner bands of biotite-quartz-hornblende schist and in places by fine-grained hornblende-feldspar gneiss. In a few places lenses of crystalline limestone 2 to 3 feet thick also occur. These strata are overlain by quartzose schists, micaceous quartzites, and mica schists, with a minor quantity of amphibolite, all of which are commonly in layers a few inches thick. In the vicinity of Schist creek several of the prominent hills are composed of resistant, white and grey, micaceous quartzite in beds up to 3 feet thick interbedded with mica schists. These seem to overlie the thinner bedded rocks just mentioned. Small veins of white quartz are a notable feature in the rocks of this section. The whole section from the limestones up appears to be at least 2,500 feet thick and probably is considerably thicker.

On the northeast side of Lonely creek the rocks are more coarsely crystalline and massive, containing among them banded gneiss of hornblende and feldspar. These features are also true of the areas adjacent to Nansen and Victoria creeks where granitic rocks have intruded them. Along the contacts here much of the schist appears to have been partly assimilated by the intrusive, with marked introduction of pink feldspar and coarsening of grain size in the schists along the contact.

Along the Dawson range west of mount Pitt, in the belt stretching from Freegold mountain across Big creek, and in the basin of McCabe creek, the schists are much like those to the south. Quartz-mica schists, quartzites, and banded gneisses, the alternating bands of which hold different proportions of feldspar, quartz, hornblende, and mica, are the chief types and occur interbedded with one another. The quartzites are commonly white or blue-grey, fine grained, and thinly bedded, the beds separated by seams of brown biotite schist. In several widely separated localities thinly bedded graphitic quartzites and schists were noted. Some massive, white quartzites, in beds up to 3 feet thick, occur northwest of mount Pitt in the thinner bedded schist. In a few places some bodies of limestones are present and some chloritic schists also occur.

In the northeast parts of the district the general sequence from southwest to northeast appears to be as follows. At the base, near the mouth of Pelly river, some grey mica schists, quartzite, and hornblende-feldspar gneiss occur. With them occur belts of limestone lenses forming some of the high points of the ridge southwest of Bradens canyon. The limestone lenses represented on the map as occurring between Von Wilczek and Legar lakes and along the northeast side of Towhata and Tatlmain lakes are thought to be of the same horizon. The individual limestone bodies are as thick as 300 feet in some instances, but pinch and swell rapidly along their strike. In some places the limestone is light grey and finely crystalline, in others it has been rendered schistose. Where beds can be seen they are a few inches thick as a rule, but in one place massive beds 2 and 3 feet thick were noted. The lower part of the limestone in some localities is interbedded with thin beds of white quartzite. In places the limestone is silicified and lime silicates have developed. Brecciation is also a feature of some bodies. Objects thought to be fragments of fossils were found in a limestone lens southeast of Bradens canyon. Above the limestone lenses the rocks become dominantly green in colour and some of them are typical greenstone schists. They are, to a great extent, schists and gneisses in which hornblende and chlorite are the important constituents, with feldspar, mica, and quartz in smaller quantities than in other horizons. In the vicinity of where the 137th meridian crosses Pelly river areas of massive, green gneiss containing a large percentage of serpentine occur. The green schists commonly contain red garnets, a feature not often noted in other gneisses and schists. In places they exhibit the remnants of structures resembling volcanic flow breccias. Some quartz-mica and graphitic schists are intermingled with the greenstones and towards the upper part one or more horizons of limestone lenses 1 to 20 feet thick occur interbedded with them. The rocks to the northeast, which apparently overlie the greenstones, consist mainly of schists of quartz and mica interbedded with quartzite and banded gneisses of feldspar, quartz, mica, and hornblende. On the northeast side of Ptarmigan mountain a belt of limestone occurs in these horizons. It appears to occur in a closely pinched syncline, as the adjacent schists dip steeply inward on either side. The limestone is probably 500 feet or more thick and appears to increase to the east beyond the border of the district. To the northeast similar rocks occur, but at the border of the district they are mainly light grey schists composed of mica and quartz, but also include some composed of sericite and chlorite.

Structural Features

The rocks of the Yukon group are everywhere intensely recrystallized and, except in the case of the limestones and quartzites, schistose or gneissoid. Their original characters have been completely masked and only the limestones and quartzites show distinctly the original bedding planes. Schistosity has been developed in many places along more than one plane so that the rocks break into splintery fragments rather than plates.

Though local irregularities are common, yet in general two main trends of folding are exhibited, one northwest and the other approximately north 60 degrees east. The northeast trend is predominant south of Klaza river and Rowlinson creek and the dips are seldom over 30 degrees, though steep dips were noted in a few localities. The northwest trend prevails in other areas of these rocks except north of Legar lake where a large syncline plunges northeast. Where the trend is to the northwest the dip is prevailingly northeast and commonly over 45 degrees.

In the southwest part of the district, except on the northeast side of Lonely creek, most of the Yukon group strata strike between north 30 degrees and 70 degrees east. In this southwest part of the district several nearly parallel anticlinal folds in the Yukon group trend north 55 degrees east. The axes of the folds are 1½ to 3 miles apart. Dips are, as a rule, between 20 and 40 degrees, but in places the dip is steeper. Contacts with granite in this part of the district mainly trend northeast, parallel to the strata, whereas elsewhere they predominatingly trend northwest. The reason for the northeasterly trends in the southwest are not clearly understood, but may be due to a folding older than that which predominates over the rest of the district. The strata of the disconnected areas of the Yukon group in the Dawson range and between it and Yukon river mainly strike northwest and dip northeast. In the vicinity of the upper part of Wolverine creek, and the creeks draining into Selwyn river, the Yukon group form an irregular anticline trending north and northeast and plunging in that direction. Here the angles of dip are prevailingly 35 degrees or higher. On the northeast side of Lewes river the Yukon strata strike northwest except in a belt of country from near Bradens canyon to the granite southeast of Legar lake, where a syncline occurs whose axis lies between Von Wilczek and Legar lakes and plunges northeast. The strata in this fold dip at angles of 30 degrees and higher. This fold does not appear to extend beyond Mica creek, where the strata appear to turn north and then west around the nose of the succeeding anticline. The areas of the Yukon group north of Yukon river exhibit a number of folds, in which the prevailing strike is north 65 degrees west, and the dips range from 45 degrees to more than 70 degrees in many places.

Relationships

The strata of the Yukon group do not occur in areas adjacent to areas occupied by the Lewes River or Laberge series. The Mount Nansen group is the next oldest formation found in contact with it. The Mount Nansen volcanics in several places cap the tops of hills whose lower parts are formed of strata of the Yukon group lying in structures unrelated to those of the Mount Nansen group and from this, though no exposed contact has been found, it is concluded that the Mount Nansen group rests unconformably on the Yukon group. The group is intruded by granite-gneisses and all the later intrusives.

Origin

The presence of quartzites and limestones at many horizons and intermittently distributed among the schists strongly suggests a sedimentary origin for the greater part of them. The presence of graphite in quartzite and schist in a number of horizons is also suggestive of sedimentary origin. In places the thinly bedded quartzites alternating with seams of brown schist are very fine grained and have a cherty appearance. These features suggest that these strata were originally alternating beds of chert and argillaceous material. In the Dawson range and to the southwest it is thought that the schists were mainly siliceous, argillaceous, and arenaceous sediments. In the greenstones near Bradens canyon the remnants of structures resembling those of lava flows suggest that some of these rocks were probably originally basic lavas, but some may have been small basic intrusives.

Age and Correlation

Fossil fragments were found in only one locality. Though these were indeterminable, their presence shows that some of the limestones in the supposedly higher horizons in the northeast part of the district are younger than Precambrian. A part or all of the supposedly lower horizons to the southwest may be Precambrian, but the areas are so disconnected that no relationships can be established between them and the fossiliferous limestones. The next oldest formation whose age is known with any degree of certainty is the Triassic Lewes River series. Though its relationships to the Yukon group were not directly established, the unmetamorphosed condition of the Lewes River series shows it to be younger and, therefore, the Yukon group in the district is pre-Triassic. The name Yukon group was proposed by D. D. Cairnes[1] to designate the complex of metamorphic sediments and igneous rocks widely distributed in Yukon. He considered the group to be of Precambrian age as he correlated it with rocks on the 141st meridian north of Yukon river which he believed to be overlain by rocks of the Tindir group which in turn, he thought, are overlain by strata containing Middle Cambrian fossils. J. B. Mertie, jun.,[2] has since found fossils and structural features in that locality which lead him to believe that the rocks that Cairnes considered pre-Tindir and pre-Middle Cambrian in age are more probably Palæozoic. Elsewhere, however, Mertie[3] found evidence leading him to believe that the Birch Creek schists are definitely older than Middle Cambrian and as two other formations "that are not a part of the Birch Creek schist appear to lie between it and the Middle Cambrian beds, assignment of the Birch Creek schist to the Precambrian

[1] Cairnes, D. D.: "Yukon-Alaska International Boundary"; Geol. Surv., Canada, Mem. 67, pp. 40-44 (1914).
[2] Mertie, J. B., jun.: U.S. Geol. Surv., Bull. 816, p. 20.
[3] Mertie, J. B., jun.: Ibid., pp. 17-20.

seems now to be fully justified." He also points out that the term Yukon group as defined by Cairnes would include the Birch Creek schist.

It is believed that some of the Yukon group of Carmacks district, particularly the part south of Klaza river, is of pre-Middle Cambrian age, but the fossil fragments in strata in the northeastern part of the district indicate that at least a part of the group is Palæozoic. The fact that the strata south of Klaza river and Rowlinson creek appear to be the lowest and show a general northeast structural trend such as is almost lacking in the case of the strata of the other areas of the Yukon group and of the younger formations suggests that these rocks are the oldest part of the Yukon group and may be Precambrian.

GRANITE-GNEISS, DIORITE-GNEISS

Several areas of gneisses occur in the central and northeastern parts of the district. The gneisses vary greatly in texture, composition, and general appearance, including fine-grained material difficult to distinguish from schists of the Yukon group, and coarse-grained gneiss. They are in the main granite-gneiss in most of the areas, but in the vicinity of Legar lake they are closer to diorite-gneiss in composition. The granite-gneiss is a grey rock of rather uniform coarse grain, but it contains bodies composed of augen gneiss alternating with gneiss having a streaky appearance. This latter gneiss consists of lenses and irregular laminæ of quartz and feldspar bordered by darker material that contains abundant biotite and hornblende as well as quartz and feldspar. Augen gneiss is seldom coarsely developed and is not a conspicuous feature of the rock as a whole. Aplite and pegmatite dykes are commonly associated with the gneisses.

On Wolverine creek the typical rock is a coarse granite-gneiss composed of quartz, orthoclase, acid plagioclase, and biotite. In this locality the gneiss shows less alteration than elsewhere and the gneissoid structure is only slightly developed in some places. It contains many areas of Yukon schists into which sheets of the gneiss extend, apparently as intrusive dykes. White pegmatite and aplite dykes traverse the gneiss and schist along the planes of schistosity. These are all cut by pegmatites, containing pink feldspar, which cut across the schistosity. The white pegmatites have not been noted cutting the Mesozoic granites. These two factors are regarded as pointing to the gneiss being older than the granite. Areas of the same gneiss in the northwest part of the district are surrounded by Mesozoic granite. The gneiss of the area northwest of Freegold mountain and at the head of Hoochekoo creek is much like that on Wolverine creek, but the gneissoid structure is more developed. The first of these two areas contains bodies of Yukon schists and this is regarded as evidence of the intrusive character of the gneiss. The gneiss is cut by dykes of aplite, pegmatite, and granite. On the northeast side of Lewes river some large areas of gneisses occur. Those on the north ridge of Ptarmigan mountain, and in the lower ridge on the southwest side of the mountain, are coarse, grey granite-gneisses and form belts a mile or more wide and apparently parallel to the strikes of the adjacent Yukon schists. Like that northwest of Freegold mountain, bodies of schists occur in them but beyond this no evidence of relationships to the other formations was found. The belt south of Legar lake is mainly composed of granite-gneiss, but in places the rock is rich in hornblende and appears to have the composition of a quartz diorite. East of Towhata lake bodies of schists were found in the gneiss. The contacts between these and the gneiss were clearly exposed and showed the gneiss to be intrusive into the schists. The belt between Legar lake and Mica creek may be broadly described as consisting of diorite-gneiss that normally is dark grey and uniform. Hornblende and biotite are the dark minerals and make up a considerable percentage of the rock. They lie in a white or slightly greenish groundmass of quartz and what was thought to be in some cases feldspar. In some of the rock the groundmass has the yellow-green colour of epidote and no sign of feldspar is apparent. A thin section of what was thought to be a relatively unaltered phase showed it to be made up of hornblende, quartz, white mica, and epidote without even a remnant of feldspar. This rock is believed to have been a quartz diorite. No evidence of the relationships of this body to the other formations was found.

On the evidence given above the gneisses are believed to intrude the neighbouring Yukon group strata and from this to be younger than this group. The Mesozoic granites are believed to intrude the gneisses, as west of Selkirk areas of the gneiss are surrounded by the granite, and in places on Big creek dykes that are apparently apophyses of the granite traverse the gneiss near the granite-gneiss contact though the actual contact was not observed. In the areas northeast of Lewes river the relationships are not known. It must be added that difficulty was found in deciding in some localities whether the rock, a foliated granite containing areas of schist, should be classed as granite-gneiss or as a foliated phase of the Mesozoic granites. However, on account of the development of the gneissoid structure in these gneisses and the intrusive relationships of the Mesozoic granites towards some of them, the gneisses are considered to be older than the Mesozoic intrusives.

The relative ages of the gneisses and the Mesozoic strata of the district are nowhere directly determinable. The gneisses are believed to be older than the Mesozoic strata of the district on account of the greater metamorphism exhibited in the gneisses by their gneissoid structures. The granite-gneisses associated with what appear to be the youngest members of the Yukon group intrude these strata and, therefore, are of Palæozoic or a younger age. The granite-gneisses occurring southwest of Lewes river and intruding what are thought to be older members of the Yukon group may be of Precambrian age. The gneisses are tentatively considered together to be Palæozoic.

LEWES RIVER SERIES

Limestones with some underlying, tuffaceous, clastic beds occupying an area south of Tatchun lake are considered to belong to the Lewes River series.[1] They form a belt extending southeastward beyond the border of the district. To the northwest, north, and northeast they dip under the overlying Laberge series and to the southwest they are in contact, along

[1] Lees, E. J.: "Geology of the Laberge Area, Yukon"; Trans. Roy. Can. Inst., vol. XX, pt. 1, 1934.

a fault, with the Laberge series. The following is a section of the Lewes River series south of Tatchun lake.

	Thickness Feet
Concealed	
Limestone	100
Concealed	300
Limestone	200
Concealed	400
Limestone	50
Concealed	150
Tuffaceous sandstone, breccia	50
Concealed	

The lowest exposed beds consist of approximately 50 feet of greenish grey, brown weathering sandstone and breccia, sandstones predominating. The sandstones contain some tuffaceous material, andesitic in composition, with conspicuous feldspar phenocrysts. Some 150 feet above these strata 50 feet of impure grey limestone, in beds 2 to 8 inches thick, outcrops. An exposureless area, perhaps representing 400 feet of strata, separates these beds from 200 feet or more of massive limestone with only a vague trace of bedding in a few places. The surface of the limestone is rough, with ridges and points of less soluble material standing in relief. The rock has a mottled appearance and is traversed by a network of veinlets of calcite. The still higher strata are very poorly exposed, but an outcrop of limestone was found which is thought to belong some 100 feet above that just described. In view of the lack of an exact knowledge of the structure it is difficult to give even an approximation of the thickness, but it is thought that at least 1,200 feet of strata are present. The total thickness of the series may be much greater.

The beds strike northwest and dip approximately 30 degrees northeast. They appear to lie in the upthrown northeast limb of a broken anticline that extends northwest (*See* Figure 1). Along the axis of the anticline they are faulted against the Laberge series. Down the dip they appear to be conformably overlain by the Laberge beds, but outcrops of the two series were not found closer than 100 feet apart.

No fossils were found in these rocks in this district. From their relationship to the Laberge series and their lithology they are judged to belong to the Lewes River series,[1] which has been dated as Triassic.

LABERGE SERIES

Distribution

A considerable area in the southeast corner of the district is underlain by clastics of the Laberge series, but elsewhere only two very small areas of rocks thought to belong to this series were found. One of these is on the west side of Lewes river 4 miles above Selkirk and the other is on the southwest side of Seymour creek. The presence of these two areas suggests that the Laberge series formerly covered a much greater part of the district than it now does.

[1] Lees, E. J.: "Geology of the Laberge Area, Yukon"; Trans. Roy. Can. Inst., No. XX, pt. I, Toronto.

Lithology and Thickness

Though apparently nearly every horizon in the series occurs in the district no complete section has been found (*See* Figure 1). The basal part occurs south of Tatchun lake overlying the Lewes River limestone. The few outcrops are of brown, tuffaceous sandstone and arkose. These outcrops are separated by a considerable width of drift from exposures of higher strata which consist of grey-green tuff and coarse arkose containing sub-angular grains of quartz and feldspar, and fragments of plants. Brown, impure sandstone and greywacke displayed along Lewes river between the mouth of Tatchun river and Rink rapid also belong to the lowermost part of the series, estimated to be between 2,000 feet and 3,000 feet thick.

In the vicinity of Tatchun lake no outcrop of the next higher strata was found. These presumably underlie the depression in which lies Tatchun lake. This depression extends northwest, along the strike of the strata, to Rink rapid where the soft strata outcrop, to whose presence the depression is thought to owe its position. These strata as exposed at Rink rapid are shales and sandstones. The shales are dark grey to black and form beds $\frac{1}{10}$ to 3 inches thick. At intervals of 3 to 6 feet, beds of grey sandstone 2 to 12 inches thick are interbedded with them. A few beds of buff sandstone 20 to 40 feet thick occur at wider intervals. These massive sandstones show no sign of bedding, and contain numerous, small, white quartz pebbles, mostly rounded and one-tenth to one-fifth inch long. Fragments of plants are abundant in both sandstones and shales and the latter carry a considerable percentage of carbonaceous matter. The shales with interbeds of sandstone, as exposed, are 200 feet or more thick. They outcrop on the southwest side of the depression and it is thought that they may be only the lower beds of a much thicker shaly member. North of the west end of Tatchun lake, at a considerably higher horizon than the shales, some coarse arkose outcrops and dips under the Mount Nansen volcanics.

In the river banks in the vicinity of Five-finger rapid a considerable thickness of strata is exposed. The lowest beds are on the east side some hundreds of yards above the rapid and dip steeply southwest. Exposures continue down the river in an almost continuous succession, the dip becoming vertical, then steep to the northeast, and finally the northeast dip sinks to 35 degrees or less at the rapids. The structure does not appear to repeat the lower beds, but this is uncertain. The lowest strata exposed are light grey to buff sandstones. To the northeast, and presumably overlying them, are some 300 feet of black shale correlated with the dark shales exposed at Rink rapid. The black shales are succeeded by some 500 feet of light grey to buff sandstones in which the grains are chiefly of quartz and only minor quantities are of feldspar. The beds are a few inches to a few feet thick and are interbedded here and there with seams of coaly shale and fine-grained sandstone beds 3 inches to 3 feet thick. Overlying the sandstones and dipping northeast is a conglomerate bed 50 feet thick. It is composed of fairly well-rounded pebbles or boulders which are as large as 1 foot in the basal part of the bed. The pebbles are mainly porphyritic, andesitic, and basaltic lavas, a minor proportion are granitic rocks, and some are quartzite. Overlying the conglomerate are some 200 feet of black shales. These are in friable beds one-half to one inch thick. Two beds, 2 and 4 feet thick, consist of closely packed concretions of dark cherty material through which the bedding planes can be traced. The concretions are 2 to 4 inches thick and 6 to 10 inches long. A collection of fossils was made from the shales and from the material surrounding the concretions which in one bed is full of shell fragments. Fragmental plant remains also occur in these beds. Some 50 feet of massive, buff sandstone overlies the fossiliferous shales and is overlain in turn by the conglomerate and sandstone beds that form the Five-finger rapid. These beds are about 500 feet thick. The sandstone occurs in lenses forming perhaps 15 per cent of the 500-foot zone. The pebbles and boulders in the conglomerate vary much in size. The largest noted was 1½ feet long. They are mainly of granite, diorite, basic dyke rocks, and basic volcanics, but some are of aplite, black cherty shale, and conglomerate. They are well rounded, particularly those of granite, and show no sign of weathering or decomposition produced prior to their inclusion in the conglomerate.

The conglomerate zone forming Five-finger rapid is overlain by brown shales, sandstones, and grits in which white quartz and feldspar form large, conspicuous grains. The beds are thick and show but little signs of stratification. Small folds occur in them but do not bring the conglomerate to the surface again. Brown greywacke, sandstone, softer shaly sandstones, dark sandy shales, and conglomerate, dipping northeast, continue to outcrop intermittently along the river to a point three-quarters mile above the mouth of Tatchun river where the dip changes to southwest. Some outcrops back from the river to the east are composed of conglomerate and grit in massive beds. They overlie the strata along the river and with them form the ridge extending southeast towards where Lewes river enters the district. The thickness of all these strata, from the top of the Five-finger conglomerate upwards to those exposed near Tatchun river, is estimated to be 500 feet or more.

On the north side of Lewes river, near the east border of the district, strata higher in the series outcrop. The lower members here are mainly light-coloured sandstones and grits composed of quartz grains with some feldspar. The strata above them are of the same general type, but are reddish. In these beds the grains are markedly angular. Overlying beds are coarser and are mainly conglomerates in which most of the fragments are angular, though a few, 3 to 4 inches long, are well rounded. The resistant sandstone, grit, and conglomerate form ridges. The intervening ravines are lacking in exposures and probably are underlain by shales and other soft beds. The sandstones, grits, conglomerates, etc., prevail to an horizon probably some 1,500 feet above the conglomerate at Five-finger rapid. At this horizon the rocks change from the light-coloured types described to darker coloured materials derived from basic and intermediate igneous rocks, particularly basic volcanics. Some greenish, tuffaceous greywackes and fine-grained, andesitic and acid tuffs are present, and also some sills of dioritic composition. The areas of the Laberge series on the west side of Lewes river southwest of Five-finger rapid are considered to belong to this horizon, because they also contain some volcanic materials. The thickness of the darker coloured strata with the associated volcanic materials is estimated to be about 500 feet.

The general dip of the Laberge strata along the south side of Lewes river from the east border of the district to the overlying Tantalus formation is southwest, and apparently an unbroken section of the upper part of the series is present. Some of the lower beds of this section are thought to represent strata north of the river and described in the preceding paragraph, but no beds found in one section could be definitely correlated with beds in the other section.

In a creek canyon 5 miles northeast of the corner of the district beds outcrop that are considered younger than any yet described. They are about 600 feet thick and consist of dark grey shales with a few beds of light-coloured sandstone 1 to 3 feet thick. Only a few outcrops of the beds immediately above the shales were found. They are sandstones and conglomerates from a few inches to several feet thick, composed of material derived from quartz veins, from pegmatite, from granitic and more basic intrusive types, from andesite porphyry lava, and from green metamorphic rocks. The largest pebbles are 6 inches long. Of the still higher beds to the southwest few outcrops were seen, but they also appear to be largely sandstones and conglomerates. The sandstones that form much the greater part of the section are composed almost wholly of quartz and feldspar and are light coloured. Fragments of plants are to be seen here and there in them. The total thickness of these sandstones and conglomerates is estimated to be 2,000 feet.

Similar sandstones and conglomerates were found along their strike to the northwest close to the river 4 miles east of Carmacks. The beds directly above them occur beneath drift-covered depressions on both sides of the river and only one small outcrop of shale and sandstone was found. To the southeast, beyond the district, Cairnes[1] found several coal seams in the horizons of the Laberge series close beneath the Tantalus formation. No coal outcrops in this locality, but coal seams occur at the Five-finger mine (*See* Figure 1) in the Laberge rocks which the structure suggests belong to these horizons. The beds at the Five-finger mine dip to the east and form part of the west limb of a syncline whose east limb is the southwest-dipping strata east of Carmacks. The lowest beds exposed near the mine are massive, greenish yellow conglomerates and sandstones. They are overlain by fine-grained sandstone and light and dark shale beds containing the coal seams. Few exposures occur east of the mine, but a mile or more south white tuffs outcrop which, from their position, should lie almost directly on top of the beds just described. The tuffs form cliffs. At the base of the exposure the tuff is fine grained and well stratified, but higher up a coarser bed some 40 feet thick exhibits no stratification. The tuff is composed of fragments of quartz and a few of feldspar in a matrix of fragments of devitrified glass which has been kaolinized to a great extent. The tuff contains fragments of carbonaceous shale and plants that have been turned to flakes of graphitic material. At the top of this bed of tuff some beds of shaly sandstone are exposed. The whole exposure exhibits about 100 feet of strata.

---

[1] Cairnes, D. D.: "Lewes and Nordenskiöld Rivers Coal District, Yukon Territory"; Geol. Surv., Canada, Mem. 5, pp. 48-50 (1910).

Two miles northeast of Tantalus butte beds of coarse conglomerates with well-rounded pebbles and boulders up to 1 foot long occur. In some beds the pebbles are largely of volcanic rocks and in others of granitic rocks. The matrix in some of these beds is in part tuffaceous and some beds of tuff occur among them. These beds form the top of the Laberge series or are very close to it as outcrops of Tantalus conglomerates, apparently directly overlying them, occur a short distance to the west.

On top of the ridge some 3 miles southeast of Carmacks conglomerates outcrop containing many pebbles derived from granitic rocks. It is thought that these conglomerates form the top of the Laberge series lying in an anticline that comes out at Lewes river just west of the old Tantalus mine.

The area of the Laberge series near Selkirk consists of some black carbonaceous shale and light-coloured sandstone with plant fragments outcropping at the edge of the overlying Selkirk lavas. Cairnes[1] reports coal as occurring here but the workings have collapsed; the dump on the river bank has been washed away and no sign of coal remains. The Laberge series on the south side of Seymour creek is a small area of black, slaty shale containing impressions of fragments of plants. It is surrounded by intrusive rocks.

The following is a composite section of the Laberge series as described in some detail in preceding paragraphs.

		Thickness Feet
Tantalus conglomerate		
Laberge series:	Conglomerate; locality, 2 miles northeast of Tantalus butte. Tuffs; locality, 1 mile south of Five-finger mine. Sandstone, conglomerate, shale, coal; locality, Five-finger mine	1,000
	Sandstone and conglomerate; locality, south of Lewes river	2,000
	Dark shale; locality, canyon 5 miles northeast of the corner of the district	600
	Conglomerate and sandstone; locality, south of Lewes river and east of Carmacks..	(?)
	Dark conglomerate, greywacke, tuff, breccia; locality, north side of Lewes river near east border of district	500
	Sandstone, shale, conglomerate; locality, same as above..	1,000
	Brown sandstone, shale, grit, and conglomerate; locality below Five-finger rapid	500
	Conglomerate; locality, Five-finger rapid	500
	Sandstone; locality, just above Five-finger rapid	50
	Black shale, fossiliferous; locality, just above Five-finger rapid	200
	Conglomerate; locality, just above Five-finger rapid	50
	Sandstone; locality, above Five-finger rapid ..	500
	Dark shale, sandstone; locality above Five-finger rapid and at Rink rapid	300
	Sandstone; above Five-finger rapid	(?)
	Tuffaceous sandstone, arkose; locality, south of Tatchun lake..	1,800

[1] Cairnes, D. D.: "Excursions in Northern British Columbia and Yukon Territory and along the Northern Pacific Coast"; Geol. Surv., Canada, Guide Book No. 10, 1913.

The thickness of the Laberge series is thus perhaps about 9,000 feet. Cairnes[1] stated that the thickness was at least 3,800 feet. Recently E. J. Lees[2] in his account of the Laberge district wrote "The thickness of the Laberge series, based on composite sections, may be conservatively placed at 2,800 to 4,400 feet, and undoubtedly the series attains a greater thickness." Cairnes[3] in his report on Wheaton district considered the series to be between 5,000 and 6,000 feet thick. Cockfield and Bell[4] writing about Whitehorse district state that "A section where the dips are fairly constant for about 2 miles in a direction at right angles to the strike, gives a thickness of approximately 10,000 feet, but this result is based on the assumption that the dip and strike remain constant across an intermediate drift-covered area half a mile wide, and that there is no repetition due to folding or faulting or both. On the other hand there is the possibility that not all of the Laberge series strata have been included." In Carmacks district there are the same possibilities of error, but in the composite section they have been minimized as far as possible, and the writer believes that unless some drastic error has been made in interpreting the structure and correlating the various parts the series is probably as thick as 9,000 feet.

Relationships

The Laberge series in this district seems to overlie the Lewes River series conformably, but in neighbouring districts, as stated by Cairnes, Cockfield and Bell, and Lees[5], the evidence suggests that erosional and angular unconformities separate the two series.

The contact between the Laberge series and the Mount Nansen group has not been found in this district. North of the west end of Tatchun lake the Laberge series and the volcanics outcrop close to one another and the Laberge beds, which here belong to a lower part of the series, dip under the volcanics. But the upper part of the series and the Tantalus formation are absent, so that the volcanics appear to overlie the Laberge strata unconformably in this locality and all along the ridge to the northwest and southeast.

The Laberge series was not found in contact with any intrusive igneous rocks other than some small bodies of diorite which in the form of sills intrude the series near the east border of the district on the north side of Lewes river. The small area of Laberge series near Seymour creek appears to be surrounded by intrusives.

The Carmacks volcanics unconformably overlie the Laberge series, but in a few places, as east of Five-finger mine, the contact is probably along a fault zone.

[1] Cairnes, D. D.: "Lewes and Nordenskiöld Rivers Coal District, Yukon Territory"; Geol. Surv., Canada, Mem. 5, p. 30 (1910).

[2] Lees, E. J.: "Geology of the Laberge Area, Yukon"; Trans. Roy. Can. Inst., vol. XX, pt. 1, 1934.

[3] Cairnes, D. D.: "Wheaton District"; Geol. Surv., Canada, Mem. 31, pp. 54-56 (1912).

[4] Cockfield, W. E., and Bell, A. H.: "Whitehorse District, Yukon"; Geol. Surv., Canada, Mem. 150, pp. 14-16 (1926).

[5] Cairnes, D. D.: Lewes and Nordenskiöld Rivers Coal District, Yukon Territory"; Geol. Surv., Canada, Mem. 5 (1910).

Cockfield, W. E., and Bell, A. H.: "Whitehorse District, Southern Yukon"; Geol. Surv., Canada, Mem. 150.

Lees, E. J.: "Geology of the Laberge Area, Yukon"; Trans. Roy. Can. Inst., vol. XX, pt 1.

Age and Correlation

A collection of fossils was made from the shale beds under the sandstone and conglomerate at Five-finger rapid. This horizon is placed approximately at 2,800 feet above the base of the series. The fossiliferous locality is just above the rapid and on the east side of the river. The collection was examined by F. H. McLearn who reports the presence of Hildoceratids, Belemnites, Cucullaca, and other pelecypods, and states that they indicate the age to be late Lower, or early Middle, Jurassic.

McLearn has directed the writer's attention to the following points with regard to these fossils, those described by E. J. Lees,[1] from the Laberge district, and other collections from Yukon. The collections of Lees are said to have come from just below the base of a massive conglomerate which was correlated by Cairnes[2] with the conglomerate and sandstone directly overlying the fossil horizon at Five-finger rapid. They include specimens of Lower Liassic age. Crickmay[3] dates an ammonite from Rink rapid, collected by Dawson[4], as early Middle Jurassic. Dawson's collection was from the same horizons under the conglomerate at Five-finger rapid as that made by the writer, though Dawson refers to that rapid as Rink rapid. It is unfortunate that it is not known from what horizons A. H. Bell's[5] collection came. They were dated by S. S. Buckman as Middle Lias to Lower Inferior Oolite. It is doubtful if Whiteaves' identification of the Upper Cretaceous "*P. woolgari*" from this series is correct.

Thus there is fair evidence that the part of the series immediately underlying the massive conglomerate is of middle Lower Jurassic to perhaps early Middle Jurassic age. The age of the upper part of the series is unknown, but may be Jurassic. Lees[1] remarks that in the Laberge district " occasionally a massive conglomerate belonging higher up in the Laberge series is near if not actually upon the massive limestone " of the Lewes River series. This and the fact that all the fossils so far collected have been from beds beneath the conglomerate suggest that the conglomerate marks a break above which, because of changes in conditions of deposition, marine fossils are absent or much scarcer.

TANTALUS FORMATION

Distribution

This formation outcrops on both sides of Lewes river just east of Carmacks where exposures extend a few miles from the river, both to the north and south. It directly underlies an area of approximately 14 square miles and probably extends beneath the Carmacks volcanics. The formation also outcrops about 4 miles south of Minto, where only a few low outcrops of the conglomerate are surrounded by a large drift area. It is probable the formation underlies a considerably larger area than indicated on the map.

---

1 Lees, E. J.: "Geology of the Laberge Area, Yukon"; Trans. Roy. Can. Inst., vol. XX, pt. 1.

2 Cairnes, D. D.: "Lewes and Nordenskiöld Rivers Coal District, Yukon Territory"; Geol. Surv., Canada, Mem. 5 (1910).

3 Crickmay, C. H.: "Jurassic History of North America; Its Bearing on the Development of Continental Structure"; Proc. Am. Phil. Soc., vol. 70, No. 1, 1931, pp. 15-102.

4 Dawson, G. M.: "Report on an Exploration in the Yukon District, N.W.T., and Adjacent Northern Portion of British Columbia"; Geol. Surv., Canada, Ann. Rept. 1887, pt. B, p. 145.

5 Cockfield, W. E., and Bell, A. H.: " Whitehorse District"; Geol. Surv., Canada, Mem. 150 (1926).

Lithology

The Tantalus formation consists largely of conglomerate, with some sandstone, shale, and a few coal seams. The conglomerate is composed of pebbles of black, greenish grey, and white, cherty slate and quartzite in a matrix of finer particles of the same materials. The pebbles are well rounded and in most beds the largest are about 1 inch in diameter, though in a few beds they attain 3 inches. The cement is siliceous in some localities and calcareous in others. In many places joints traverse the pebbles, but in other places do not. The conglomerate beds are 3 to 6 feet thick and are separated by beds of sandstone 3 to 12 inches thick. The sandstones resemble the matrix of the conglomerate. The shales comprise only a very small percentage of the formation and the coal seams are associated with them.

Thickness

On the south side of Lewes river the thickness of Tantalus formation is difficult to determine because of the presence of minor folds. On the north side, on Tantalus butte, it is estimated at 700 feet or more. Other writers have stated that the formation is more than 1,000 feet thick. The greatest thickness reported, according to Cairnes[1], is 1,700 to 1,800 feet in Wheaton River district.

Relationships

The Tantalus formation overlies, apparently conformably, the Laberge series along their contacts on both sides of Lewes river. It was not found in contact with any intrusives or the Mount Nansen group, but in the Laberge district Lees[2] found rocks presumably of the Tantalus formation apparently overlain unconformably by the Hutshi-Schwatka group, considered as the equivalent of the Mount Nansen group. Northwest of Tantalus butte and south of Carmacks the Tantalus beds are unconformably overlain by the Carmacks volcanics.

Age and Correlation

Collections of fossil plants from the Tantalus formation at the Tantalus mine and in other areas to the south were formerly considered to indicate that the strata are Cretaceous. Later a collection of fossil plants from the Tantalus formation in Wheaton district[3] was thought to indicate a Jurassic age, and the Tantalus was correlated with the Kootenay formation. The various collections contain few species and some doubt exists as to their correlation value. For these reasons the age of the Tantalus formation is here considered to be either Jurassic or Cretaceous.

STRUCTURE OF LEWES RIVER, LABERGE, AND TANTALUS FORMATIONS

The area of the Lewes River, Laberge, and Tantalus strata in the southeast corner of the district forms the northwest end of a broad belt

[1] Cairnes, D. D.: "Wheaton District, Yukon Territory"; Geol. Surv., Canada, Mem. 31, p. 57 (1912).
[2] Lees, E. J.: " Geology of the Laberge Area, Yukon"; Trans. Roy. Can. Inst., vol. XX, pt. 1, p. 24 (1934).
[3] Cairnes, D. D.: "Wheaton District, Yukon Territory"; Geol. Surv., Canada, Mem. 31, p. 58 (1912).

that extends southeast across Laberge district, where it lies between areas containing metamorphic rocks probably of the Yukon group. In Carmacks district the structure is complicated by folds and faults, and is probably much more complex than is indicated on Figure 1 (in pocket). On either border of the belt these rocks are overlain by the Mount Nansen group and the Carmacks volcanics. The two faults represented in the figure are depicted with the upthrow on the northeast sides, and as occurring along or near anticlinal axes. The fault planes are represented as being vertical, but no direct evidence of the attitudes of these planes was found. Some of the small folds are overturned to the southwest and this suggests that the strata of the larger folds have been thrust in that direction and that the fault planes may incline to the northeast. The angles of dip of the massive members of the Laberge series are commonly 45 degrees or less, but the less competent shale beds have been so squeezed that for the most part they dip at angles of 60 to 80 degrees.

MOUNT NANSEN GROUP

An almost continuous belt of volcanic rocks assigned to the Mount Nansen group stretches from the north side of Tatchun lake northwest diagonally across the district. Besides lava flows, breccias, and tuffs, it includes small areas of sediments and small intrusive bodies of types allied to and intimately associated with the lavas. In the south and west parts of the district isolated areas of similar rocks occur. The rocks of the Mount Nansen group are typically dark green or greenish grey and andesitic to basaltic in composition, but in a few localities they are grey, red or purple. On the surface the rocks commonly weather brown. A marked feature of these rocks is their resistance to erosion, so that they form high hills with long, steep slopes leading down to the floors of the bordering valleys.

The volcanic rocks include many varieties of andesite and basalt. Typically they are porphyritic with pale greenish feldspar phenocrysts approximately one-twentieth inch long. Black or dark green phenocrysts of hornblende or pyroxene are also commonly present, and in some cases the hornblendes are large. The groundmass is very fine grained and normally has a uniform pale green colour. Excellent exposures occur on Yukon river 12 miles below Selkirk of green (brown-weathering) lavas composed of dark green hornblende in a greenish white groundmass largely composed of feldspar. In places the hornblende phenocrysts are one-quarter to one-half inch long and chunky in form. Elsewhere, and as a rule, the hornblende phenocrysts are smaller and less conspicuous. The rock usually shows flow structures and in some places there are flow breccias in which the fragments either are closely packed or are widely separated in a matrix of lava. In places the lavas are vesicular, the vesicles being filled with carbonate and zeolites. Small veins of carbonate and numerous veinlets of epidote are common features. Bodies of medium- and coarse-grained hornblende diorite occur here and there in the volcanics as dykes and sills belonging to two or more sets that cut one another.

The base of the group is present in the ridge north of Tatchun lake and Rink rapid where the volcanics directly overlie the Laberge series. The rocks are the typical lavas of the group and are associated with dykes and sills. The rocks along the main river to McCabe creek and in the vicinity of Selkirk are similar and are also thought to belong to the basal part of the group.

A thin section of typical lava from the ridge north of Rink rapid is composed of feldspar and pyroxene phenocrysts in a fine-grained groundmass. The feldspar phenocrysts are almost completely altered. The groundmass consists of basic andesine feldspar, pyroxene, and fine-grained material which is apparently devitrified glass, together with thickly scattered, small crystals of black iron ore, probably magnetite, and some pyrite and quartz. The thin section contains an abundance of alteration products that appear to be mainly chlorite and epidote.

The dykes and sills show all gradations from rocks resembling the porphyritic lavas to diorite porphyry and to non-porphyritic, medium-textured diorite.

At Hoochekoo bluff, a mile above the creek of that name, Dawson[1] reported the presence of some fine-grained, nearly black argillite and agglomerate, apparently interbedded with rocks of the Mount Nansen group. In a few other exposures in the same neighbourhood argillite and quartzite beds were found with the andesites. On the ridge west of Black creek some fine-grained, tuffaceous argillite beds 4 to 12 inches thick are interbanded with distinctly bedded, grey tuffs. The tuffs and argillites exhibit a slaty cleavage. The sedimentary beds are overlain by andesite lavas.

In the vicinity of Minto, particularly in the mountain northwest of it, the lava flows are accompanied by considerable amounts of tuff, agglomerate, and breccia. The tuffs are fine to moderately coarse grained and in places exhibit very thin and even bedding. The tuffs, agglomerates, and breccias have the same general green colour and the same composition as the lavas already described. At the upper end of the lower canyon of Big creek, in the vicinity of the mouth of Dark creek, dark green andesite or basalt lava flows are associated with coarse volcanic breccia and conglomerate. The pebbles in the conglomerate are of dark green lava, well rounded, and up to 6 inches long.

The thickness of the rocks forming the northwesterly trending belt of the Mount Nansen group is not known. In the ridge north of Rink rapid, unless the structure is much more complicated than believed, at least 1,800 feet of strata probably occur. The thickness at several other localities may be about as great and that northwest of Selkirk may be considerably more, but too little is known of the structure to make an estimate.

The areas of the volcanic group in the Dawson range form a second somewhat broken and irregular belt. They constitute most of the highest peaks, thus illustrating their resistance to erosion. Though the rocks have the same main features as in the Lewes River belt there are some differences. Their prevailing colour is greenish grey to black rather than the dark, decided green of the Lewes River belt. They have a speckled appearance, due to the presence of light-coloured individuals of feldspar thickly scat-

[1] Dawson, G. M.: "Report on an Exploration in the Yukon District, N.W.T., and Adjacent Northern Portion of British Columbia, 1887"; Geol. Surv., Canada, Ann. Rept. 1887-88, pt. B, p. 144.

tered through a dark groundmass. They weather to shades of grey or greenish grey, lighter than those of fresh surfaces. They break into angular fragments with sharp edges and relatively smooth faces, and produce a talus of fragments 6 inches to 1 foot long. Peaks composed of these rocks, such as Klaza mountain, have relatively flat tops and uniformly steep slopes. In many instances they form small conical points projecting above talus slopes exhibiting terrace-like forms.

One of the best exposures is furnished by the highest peak of Dawson range, 3 or 4 miles west of the district at the head of the west forks of Hayes creek. Here a section of more than 2,000 feet occurs. At the base are lavas and breccias much like those of the Lewes River belt. Overlying them with a gentle dip in a southerly direction are some 1,000 feet or more of grey, speckled, bedded tuffs and breccias of which the top of the mountain is formed. The tuffs are distinctly, and in many instances very thinly, bedded. They vary in grain from almost cherty fineness to very coarse. The majority of the rocks are composed of andesitic material, but some dacites occur. Much of Prospector mountain is formed of similar rocks.

A thin section of a lava from Klaza mountain is very like that of the lava near Rink rapid, but the groundmass is more feldspathic and the whole section is less altered. In the vicinity of Klaza mountain fine tuffs are scarce and the rocks are mainly agglomerates and lavas. Some fragments in the agglomerates are of rocks of the Yukon group. Generally the fragments weather more slowly than the groundmass and stand out in relief. South and east of this mountain a large proportion of dacite accompanies the andesite. The dacites are dark grey to black and contain phenocrysts of feldspar, quartz, hornblende, and biotite lying in a nearly black, fine-grained groundmass. The same rock type occurs in the vicinity of mount Nansen, but here in addition occur dacite breccias and agglomerates of purplish colour and having fragments up to 12 inches long. Veinlets of epidote and of carbonate are common features. Intrusive bodies are less numerous in the southwestern occurrences than in the Lewes River belt.

In the Dawson range and to the southwest the rocks are prevailingly fresh in appearance and show no sign of regional metamorphism. In a number of places, where intruded by the granitic rocks, they have recrystallized to hornblende-rich material along the contacts. In a few places, as along Klaza river, contact metamorphism with production of epidote and sulphides was noted. Near contacts with granitic rocks in either of these belts, and notably on Merrice, Williams, and McGregor creeks, the rocks of the Mount Nansen group have been sheared and recrystallized to green hornblende and chlorite schists.

The flows and breccias of this group in most localities afford only indefinite evidence of their attitudes. The tuffaceous beds along Lewes river have steep dips, indicating relatively close folding. In the Dawson range the dips are relatively low. The absence of distinguishable horizon markers makes the determination of faulting uncertain, but fractures with slickensiding, gouge, and veinlets are common features and show that the rocks have been subjected to a considerable amount of fracturing, though the magnitude of the movements is unknown.

The strata of the Mount Nansen group unconformably overlie the Laberge series and the belt of these rocks along Lewes river apparently forms an anticlinal structure superimposed on the more complicated structure of the underlying formations. On both sides of the river below Yukon crossing dips and strikes were observed evidencing this structure. To the northwest very little evidence was discovered, though the presence of an anticlinal structure is indicated by the outcrops of the Tantalus formation along the centre of the belt southwest of Minto and those of Laberge series on the west side of Lewes river 4 miles above Selkirk.

In the Lewes River belt the contact between the Mount Nansen group and the Yukon group was not observed. In the Dawson range although the contact was not seen, yet in many places the position of the plane of contact could be closely determined and there remains no doubt that the comparatively flat-lying Mount Nansen group lies unconformably on upturned and eroded strata of the Yukon group.

In the southeast corner of the district the rocks of the Mount Nansen group appear to overlie the eroded surface of the Laberge series, but no exposures of them were seen close together. North of Tatchun lake outcrops of both formations were observed close together, the Mount Nansen group apparently lying unconformably over the folded and eroded Laberge strata. The relationships to the Tantalus formation were not observed, but the absence of the Tantalus formation between the Mount Nansen group and the Laberge series and the conformable relationship of the Laberge and Tantalus evidence that the relationship to the Tantalus formation is the same as that to the Laberge series.

At various places the rocks of the Mount Nansen group are intruded by the Mesozoic intrusive rocks. In the Dawson range several areas of the Mount Nansen group form tops of hills whose bases are largely or wholly composed of Mesozoic granitic rocks, and in nearly all cases the granitic rocks were observed to intrude the volcanics, to send apophyses into them, and in several places to have induced considerable metamorphism in them. The areas of volcanics are roof pendants, and their preservation is due to their ability, particularly in unglaciated areas, to resist erosion.

The Mount Nansen group is unconformably overlain by the Carmacks volcanics.

No fossils have been found in the rocks of the Mount Nansen group. There seems little doubt that they rest on the eroded edges of the upper part of the Laberge series and in all probability have the same relationship to the Tantalus formation. Since these older formations are not older than middle Lower Jurassic and probably include Middle Jurassic or even younger strata, the Mount Nansen group is presumably no older than Upper Jurassic. The volcanic group has been intruded by all phases of the Mesozoic intrusives. The Mount Nansen group is in all probability the equivalent of the Hutshi-Schwatka groups described by D. D. Cairnes[1] and E. J. Lees[2] in the adjoining districts to the southeast. Cairnes intro-

[1] Cairnes, D. D.: "Lewes and Nordenskiöld Rivers Coal District"; Geol. Surv., Canada, Mem. 5, p. 38 (1910).

[2] Lees, E. J.: "Geology of the Laberge Area, Yukon"; Trans. Roy. Can. Inst., vol. XX, pt. I, p. 28 (1934).

duced the name Older Volcanics for those volcanics in White River district that are older than the granitic intrusives corresponding to the Coast Range intrusives. He found evidence that some of the volcanics were younger than Cretaceous sediments, but he believed that the group included some volcanics that are equivalents of the Upper Carboniferous volcanics in Alaska.[1] It is possible, but not probable, that some part of the group in Carmacks district is older than the Laberge series. It has been suggested by Cockfield and Bell[2] that in Whitehorse district the Older Volcanic group may be in part contemporaneous with the Laberge series, though the weight of the evidence points to them being later. The Mount Nansen group in Carmacks district is, therefore, considered to have formed in late Jurassic or early Cretaceous time.

MESOZOIC INTRUSIVES

A large part of the district is underlain by intrusives which by reason of their relationships and lithology may be correlated with the Coast Range intrusives. The great majority are thought to have been intruded at intervals during a single period of batholithic invasion. For purposes of mapping and description these intrusives have been classed as diorites, syenites, and granites. Each class includes a great variety of types.

DIORITES

The diorites form small stocks and bosses, the largest of which is less than 4 square miles in area. The majority of these bodies occur along the belt of Mount Nansen group that follows the course of Lewes river from north of Rink rapid to near Selkirk; others occur along Dawson range and near Bradens canyon. Only the larger areas have been separately mapped and they, with smaller bodies, for the most part occur with the Mount Nansen group.

At the mouth of Wolverine creek outcrops of a small stock of diorite occur on both sides of Lewes river. The rock is dark green and varies in grain considerably, but for the most part is coarse. It appears to the unaided eye to be composed mainly of hornblende and pyroxene with minor quantities of feldspar. In places small masses of magnetite occur and specks of magnetite are disseminated thickly through it. The rock varies in composition from hornblende diorite or gabbro to pyroxenite. The feldspars and much of the older mineral constituents are entirely altered to chlorite in the sections examined. The rocks are cut in places by veinlets of a brittle fibrous serpentine and also by small veins of carbonate.

Other bodies along Lewes river are mainly dark green, hornblende-rich diorites. Scattered crystals of biotite are also commonly present. A body about 3½ miles northwest of the mouth of Seymour creek appears to be mainly a coarse, hornblende-rich rock like that found at the mouth of Wolverine creek.

---

[1] Cairnes, D. D.: "Upper White River District, Yukon"; Geol. Surv., Canada, Mem. 50, p. 93 (1915).
[2] Cockfield, W. E., and Bell, A. H.: "Whitehorse District, Yukon"; Geol. Surv., Canada, Mem. 150, p. 29 (1926).

The diorite in Pelly River valley near the mouth of Grayling creek is like those along Lewes river, but is foliated. It clearly intrudes the Yukon group and dykes extend from it into them.

The body of dioritic rocks at the east foot of Prospector mountain intrudes both the Yukon group and the Mount Nansen group, as do other bodies along Lewes river. In a number of places in the Dawson range bodies of diorite are intruded by syenites and other phases of the Mesozoic intrusives. The body at the mouth of Wolverine creek is cut by dykes of granite that probably extend from the areas of that rock to the southwest. The diorite body southeast of Victoria mountain is unconformably overlain by the Carmacks volcanics. The diorite body at the mouth of Wolverine creek is unconformably overlain by the Selkirk volcanics.

SYENITES

Intrusives of intermediate and moderately alkaline composition form a number of small stocks and one large irregular stock in the Dawson range. They also occur in a narrow belt southeast of Ingersoll islands. They display a wide range of types including coarse alkaline porphyritic granite, porphyritic syenite, hornblende syenite, monzonite, hornblendite, and quartz monzonite and intermediate phases.

The different syenitic phases are believed to grade into one another, but it is certain that this is not the case everywhere as in several places boulders were noted showing a sharp contact between two phases, though no such contact was found in place.

The prevailing type south of Big creek is a porphyritic syenite. It is coarse grained, and grey with a distinct characteristic pink tinge. It has a mottled appearance caused by large pink phenocrysts of feldspar that are conspicuous against a background of dark green hornblendes surrounded by smaller grains of white feldspar. Small grains of quartz occur here and there. Titanite, apatite, and magnetite are present as accessory minerals and are commonly visible to the unaided eye. The rock is estimated to be composed of 25 per cent microcline phenocrysts, 25 per cent hornblende, 25 per cent orthoclase, 15 per cent oligoclase, 6 per cent quartz, and 4 per cent apatite, titanite, and magnetite, all in unusually large crystals. In some specimens the phenocrysts appear to be orthoclase. The rock is coarsely jointed and forms coarse talus.

In several places in the larger bodies, notably in that southeast of Freegold mountain, the average grain size increases, and the phenocrysts attain lengths in places of 2½ inches and also increase in number so as to make up the greater part of the rock. In this phase quartz forms a considerably larger part of the rock, the hornblende content decreases, and the rock becomes a porphyritic alkaline granite. In other places the average grain size and number of phenocrysts decrease and hornblende increases until the rock is composed predominantly of hornblende, with a little pyroxene and accessory constituents and practically no feldspar. This hornblendite phase occurs in only a few localities, but intermediate phases such as hornblende syenite and hornblende monzonite were noted in a number of places. The alkaline rocks exhibit various structures. In places they are massive, but more commonly they are gneissoid, or vaguely banded, the bands exhibiting different proportions of feldspar and hornblende. The porphyritic syenite makes up the greater part of the areas south of Big creek. The darker, less feldspathic, hornblende-rich phases occur more commonly along the northeast sides of the stocks, but north of Klaza mountain they are well within the large syenitic area that appears to contain northwesterly trending zones of the different phases. In many places the syenitic intrusives are traversed by veinlets of epidote, and in others the rock is greatly crushed and consists of large, cracked remnants of phenocrysts, embedded in a meshwork of fine chloritic material, the whole traversed by numerous small veinlets of epidote.

The large area of syenite near Victoria mountain is mainly composed of syenite types like those already described. They are traversed by bodies of dyke rocks, many of which are acid intrusives of Tertiary age. On Victoria mountain the syenite rocks are in contact with a large irregular body, or bodies, of quartz diorite and hornblende porphyry, but the relationships between them are obscure and doubt remains as to which is the older, though the syenite is believed to be. The quartz diorite and hornblende porphyry are medium-grained, grey rocks in which hornblende and feldspar, and in some instances quartz, form the chief constituents visible to the unaided eye. The groundmass is fine or medium grained and is mainly composed of oligoclase with small quantities of hornblende, quartz, and orthoclase.

The syenitic rocks southeast of Ingersoll islands are somewhat like those already described. Their general appearance and pink colour are the same as those of the porphyritic syenite, but the rocks where observed contain much less hornblende and instead a considerable quantity of biotite. They are also much altered, so that in places chlorite and epidote replace the biotite and hornblende. The rocks of the east side of the area are fine grained, and less markedly porphyritic than those on the west side which grade into porphyritic granite.

On the upper slopes of Prospector mountain, and to the west, the syenitic rock is somewhat different. It is still a pinkish grey rock in which pink feldspars are the most prominent constituents, but its grain size is more uniform and the texture is more like that of a normal granite. It is composed of orthoclase and plagioclase in approximately equal amounts, and quartz is present as a main constituent but in widely varying quantities. Biotite is the main dark mineral, but hornblende and pyroxene are present in some specimens. Scattered specks of magnetite, titanite, and apatite are also present. The rock may be broadly termed a quartz monzonite. On the southeast slope of the mountain the rock is typical syenite porphyry, and is believed to grade into the quartz monzonite.

The syenitic rocks intrude the Yukon group and the Mount Nansen group. Evidence of this was noted in many places in Dawson range, the contacts showing dykes of the syenites extending into these groups and xenoliths of the older rocks in various stages of recrystallization, commonly to hornblende-rich masses in the case of the volcanics. They are intruded by the granites in many places, but in the area southeast of Ingersoll island the syenitic rock grades into a granite and a similar relation is also suggested by the granitic phases of the alkaline rocks near Freegold

what

mountain. The syenites are unconformably overlain by Tertiary clastics southeast of Freegold mountain and, in a number of places, by the Carmacks volcanics.

GRANITE

Granite, quartz monzonite, granodiorite, and quartz diorite form large areas. They occur as batholiths, stocks, and smaller bodies. They underlie a very large part of the area and if the Tertiary formations were removed they probably would be found to underlie more than one-third of the district.

Granites Along Pelly River

Two bodies of granite occur along Pelly river. Both consist mainly of a greenish grey granodiorite grading into dark grey, more basic types along their borders, particularly on the northeast sides. The greenish colour is due to development of epidote. Both bodies are much sheared in places and elsewhere are commonly slightly gneissoid.

The body of granite partly displayed at Granite canyon extends northwest and southeast beyond the borders of the district. The predominating rock where least altered is a coarse, grey granodiorite, mainly composed of oligoclase and quartz in approximately equal quantities. Some microcline, biotite, and a little orthoclase are present. Rutile occurs in the biotite, and apatite is present. The oligoclase is usually more or less altered. Alteration converts this rock into a fine-grained mass of epidote and sericite with small quartz grains and remnants of feldspar, and biotite in which the original large quartz crystals and a few large remnants of feldspar are conspicuous. In places the rock is completely crushed and sheared to a green schist.

Tonalite

Along the south side of Pelly river, near the east boundary of the district, the rock is largely dark grey and of medium grain, containing phenocrysts of feldspar and quartz in a fine-grained groundmass. A number of other varieties are intermediate between this and the more typical granodiorite, suggesting the close relationship of all. On the west side of the upper end of Granite canyon the granite grades into a finer grained variety almost identical with some phases of the granite stock situated near the mouth of Pelly river.

The granodiorite occurs a mile south of Diamain lake where, in places, it exhibits a slightly gneissoid structure striking north 68 degrees west and dipping vertically. Elsewhere this is the chief plane of jointing. Areas of a medium-grained rock containing large, white feldspar phenocrysts and little or no quartz are also found in this locality. On the lake shore outcrops of a dark grey, medium-grained rock were found. It is essentially composed of feldspar and hornblende with some biotite. A large proportion of the feldspar appears to be alkaline and the rock to be a syenite.

The typical rock of the stock on both sides of Pelly river near its mouth is medium grained, greenish grey granodiorite. Feldspar, quartz, hornblende, biotite, and titanite are visible to the unaided eye. The rock is normally slightly foliated and in many places is considerably sheared. The chief feldspar is an acid plagioclase, but orthoclase and microcline are also present. The feldspars are much altered, and the rock contains much epidote which gives the rock its greenish tinge. The composition varies considerably and is granitic in some parts. Near the east contact on the south side of the river the rock in composition approaches quartz diorite, contains many small veinlets of epidote, and is cut by small pegmatite dykes.

The contacts of the granitic body at Granite canyon were nowhere seen. It is considered intrusive into the Yukon group, as it contains inclusions of schist like that of the Yukon group. It appears to be overlain by the Tertiary clastics and is cut by Carmacks volcanics. The stock near the mouth of the river intrudes the Mount Nansen group and the Yukon group east of Selkirk and is overlain by the Selkirk volcanics.

Granites along Klaza River and Dawson Range

The granitic rocks lying north of Klaza river from its head westward beyond the border of the district are commonly granodiorite, but in a few places quartz diorite and, at the head of Klaza river, granite. In the Dawson range the outcrops on Hayes creek, about the head of Wolverine creek, and along the north side of upper Big creek are of a pink granite which on Hayes creek is porphyritic. The small area north of Big creek is granodiorite or quartz diorite. The area on the southwest slope of Freegold mountain is largely granodiorite, but also includes some granite. On Bow creek and its tributaries both granodiorite and granite are present. The body partly surrounded by syenite northwest of Klaza mountain is largely granite. The small areas in the vicinity of Nansen and Victoria creeks are largely granite, and the same is true of the outcrops in the southwest corner of the district. The area south of Schist creek is granodiorite.

The typical granodiorite is a grey rock in which white feldspar, some pinkish feldspar, quartz, biotite, hornblende, and titanite are plainly distinguishable. The chief feldspar is a basic oligoclase, but some orthoclase is present. Titanite, apatite, and magnetite are common accessories. GD.

Granites Southwest of Lewes River

In a belt extending from Rowlinson creek to Yukon river the granitic rocks are commonly porphyritic and in many places exhibit some degree of foliation. Foliation is particularly noticeable in the neighbourhood of contacts with the Yukon group. It is markedly developed in the vicinity of Yukon river, in areas between the head of Seymour creek and the mouth of Williams creek and south of Rowlinson creek. The typical porphyritic granite is light grey or pinkish, of coarse grain, and carries scattered, white or pinkish phenocrysts of orthoclase, commonly three-quarters inch long and in places considerably larger. The remainder of the rock is composed of quartz and orthoclase in about equal amounts, plagioclase feldspar, and biotite. Titanite, titaniferous magnetite, epidote, and apatite are present, and patches of clear green epidote are common. Pegmatites were noted to be particularly abundant on the north side of upper Merrice creek. Elsewhere the rock is traversed by narrow pegmatite and aplite dykes and, in places, by veinlets of epidote.

Westward along the ridge north of Crossing creek, and in the vicinity of Big creek, the rock is not porphyritic and is a granodiorite. White feldspar, quartz, biotite, hornblende, and titanite are readily apparent to the unaided eye. Under the microscope it is seen that slightly more oligoclase is present than orthoclase.

On either side of Yukon river, near the west boundary of the district, the rock is largely a granodiorite. It is commonly foliated and contains a great many areas of partly assimilated gneiss and schist. Along its northeast edge considerable areas hold fragments of the Mount Nansen group in various stages of assimilation and recrystallization. A thin section of the granodiorite is much like a section of the granodiorite north of Crossing creek, but there is less orthoclase and some microcline is present.

Contacts between the granite and granodiorite were not seen, but in one place dykes of granite were observed to traverse granodiorite and it is thought that the granite and porphyritic granite are younger than the granodiorite. Both granite and granodiorite intrude the Yukon group, the Mount Nansen group, and the diorites and syenites. They are overlain by the Tertiary clastic beds and by the Carmacks volcanics. Dykes related to the Carmacks volcanics and Tertiary acid intrusives cut them.

Granites Southwest of Tatlmain Lake

An area of granitic rocks lies south of Tatlmain lake and between it and Lewes river. It extends only a few miles east of the district where the contact with rocks of the Yukon group runs north and south. This area is apparently composed of granite, quartz monzonite, aplite, pegmatite, quartz porphyry, and partly assimilated bodies of recrystallized older rocks. The southern and eastern parts of the area are mainly occupied by a coarse, grey granite which commonly is porphyritic.

The typical rock is slightly gneissoid and a few scattered phenocrysts are present. The phenocrysts vary greatly in abundance, making up much of the rock in some localities and being lacking in others. They are composed of orthoclase and microcline. In the groundmass, quartz is the chief constituent. Orthoclase and oligoclase are both abundant and some microcline is also present. Hornblende and biotite occur in variable quantities. Muscovite, apatite, titanite, magnetite, and epidote are present. In composition the rock is a granite, but approaches quartz monzonite.

In the northern parts of the area and over considerable areas in the central part the rock is light grey to white, medium to moderately fine grained, and commonly slightly foliated. Under the microscope quartz is seen to be the main constituent. Acid oligoclase, orthoclase, microcline, biotite, and hornblende are essential constituents, and muscovite, epidote, titanite, and magnetite are accessory. The rock is a quartz monzonite. It forms sheets in the granite and appears to intrude it, though this is not altogether certain. Both the granite and quartz monzonite are cut by narrow pegmatite and aplite dykes in many places and in one place a fine-grained quartz porphyry cuts the granite. The granite and the quartz monzonite contain areas of hornblende gneiss thought to be roof pendants of the Yukon group. They intrude the Mount Nansen group and in places near the contact the volcanics are recrystallized and schistose.

AGE AND CORRELATION OF THE MESOZOIC INTRUSIVES

The Mesozoic granitic intrusives intrude the Mount Nansen group and were exposed by erosion before the laying down of the Tertiary clastic beds. The Mount Nansen group is of late Jurassic or Cretaceous age. The Tertiary clastic beds are correlated with sediments that are probably of Upper Eocene age. The Laberge conglomerates contain pebbles of granite and allied types, but these cannot have come from the Mesozoic intrusives since the Mount Nansen group is younger than the Laberge series and the granitic rocks are younger than the volcanics. The available evidence indicates that the invasion of the Mesozoic intrusives took place some time between late Jurassic and early Eocene time. They thus seem to be contemporaries of the Coast Range intrusives of Whitehorse district.[1]

TERTIARY CLASTIC BEDS

In three localities, on the south side of Seymour creek, west of Wolverine creek, and in Granite canyon, clastics occur that are believed to be of the same Tertiary age.

On the south side of Seymour creek a massive, vaguely stratified conglomerate outcrops. The pebbles are well rounded and up to 12 inches long, and consist, in the outcrops examined, mainly of Mount Nansen volcanics. Pebbles of the directly underlying granitic rocks are scarce. The matrix consists of gravel and sand derived from the same sources. The conglomerate is only partly consolidated. It is over 500 feet thick at the east end of the exposure, but thins as it rises over the ridge to the west. It lies directly upon porphyritic syenite and is overlain by the lavas of the Carmacks volcanics that dip eastward in conformity with it. It appears to have been formed of stream gravels deposited in a valley.

In the hills west of Wolverine creek, tuff, tuffaceous sandstone, grit, shale, and conglomerate dip gently beneath a capping of Carmacks volcanics and are tentatively correlated with the conglomerate on Seymour creek. All the rocks show variable degrees of consolidation. The few outcrops are conglomerate and coarse grit resting on the Yukon group. The pebbles are up to 2 inches long and are of granite, schist, and gneiss. The presence and character of the other members are known only from float. Most of this material consists of light brown, andesitic tuff, brown, tuffaceous sandstones, and shale. Fragments of plants were seen in some of the shales. Some white tuffs at the base of the Carmacks lavas on the summit between Wolverine and Hayes creek are considered to belong to the upper part of the same assemblage. Fragments of similar beds were found on the south side of the head of Bow creek near basal lavas of the Carmacks volcanics.

On the east side of Granite canyon, opposite the Needlerock that stands in mid-stream, in the canyon a mile above the mouth of Needlerock creek, similar strata occur. These are described by R. G. McConnell[2] as . . .

[1] Cockfield, W. E., and Bell, A. H.: "Whitehorse District, Yukon"; Geol. Surv., Canada, Mem. 150, p. 32.

[2] McConnell, R. G.: "The Macmillan River, Yukon District"; Geol. Surv., Canada, Sum. Rept. 1902, pt. A, p. 31.

"soft, yellowish, tuffaceous sandstones and dark carbonaceous shales. The latter at one point near Gull rock (here Needlerock) pass into an impure lignite." The locality was seen by the present writer. The beds exposed consist mainly of the tuffaceous sandstones. They are vaguely bedded, and contain fragments of plants. The dark, carbonaceous shales and the lignite were not observed, but may occur under a recent slide from the higher part of the canyon wall. The beds observed make up some 50 feet or more of strata. They are overlain by conglomerates in which well-rounded pebbles of granite and lava up to 12 inches long lie in a yellowish sandstone matrix. All these beds dip southward under the Carmacks volcanics.

A small area containing abundant float of similar tuff and clastics lies on the west side of Big creek below the mouth of Dark creek and may indicate the presence of this formation. The Tertiary clastic beds show little sign of structural deformation. On Seymour creek, however, they dip to the east at angles of a few degrees. At Granite canyon they dip at a fairly steep angle, but the significance of this feature is unknown.

Age and Correlation

The sediments of each of the three areas are overlain by the Carmacks volcanics and there is no evidence of structural discordance between them and the volcanics. Although the sediments somewhat resemble strata of the Laberge series, they are so closely associated with the Carmacks volcanics that a relationship between the two is strongly suggested. As the Carmacks volcanics are considered to be of early Tertiary age, the age of the clastics must be earlier Tertiary or older. In Granite canyon the contact between the clastics and the underlying rock is not exposed, but the granite pebbles in the conglomerate resemble the Mesozoic granite that outcrops close at hand and shows much more evidence of deformation than the clastics. The conglomerate of Wolverine Creek area contains granite pebbles and is very little deformed. That of Seymour Creek area contains a few pebbles of the underlying syenite and is scarcely consolidated. The clastics are, therefore, considered to be younger than the granite.

In neighbouring districts, notably Sixtymile[1] and Klondike[2] districts, clastics of similar character and relationships have been found and on the basis of fossil evidence from Fortymile district have been considered to be Upper Eocene and the equivalent of the Kenai series.

CARMACKS VOLCANICS

In the vicinity of Carmacks, Cairnes mapped some areas of volcanics to which he gave the name Carmacks basalts.[3] These rocks have been found by the writer to be the fringe of extensive areas of volcanics of various types. For this reason the name has been changed to Carmacks volcanics. The largest areas of these rocks lie southwest of Lewes river,

---

[1] Cockfield, W. E.: "Sixtymile and Ladue Rivers Area, Yukon; Geol. Surv., Canada, Mem. 123, p. 30 (1921).

[2] McConnell, R. G.: "Report on the Klondike Gold Fields"; Geol. Surv., Canada, Ann. Rept. 1901, pt. B, pp. 23-24.

[3] Cairnes, D. D.: "Lewes and Nordenskiöld Rivers Coal District"; Geol. Surv., Canada, Mem. 5, p. 44 (1910).

but smaller bodies occur in all parts of the district. They lie in what appear to be down-warped or down-faulted areas. Some of the masses have great thickness and attain elevations suggesting that originally the volcanics covered practically the entire district.

The lavas are mainly andesites, but range in composition from basalts to dacites, trachytes, and rhyolites. The large area west of Carmacks contains a succession of flows and breccias with some tuff beds lying between flows. The lower flows of the assemblage, outcropping south of the head of Seymour creek and dipping east under younger flows near Carmacks, are light brown or grey, fine-grained andesites, in which few phenocrysts or vesicles can be distinguished by the eye. Under the microscope they are seen to consist of phenocrysts of biotite, pyroxene, and plagioclase in a groundmass of small laths of plagioclase, pyroxene, and devitrified glass. The plagioclases range between andesine and labradorite. The overlying flows farther east are more basic and are largely basalt. They are coarsely jointed, commonly breaking into large blocks, and form conspicuous, castellated outcrops in the unglaciated areas. They weather brown or reddish brown, but on fresh fractures are dark blue-green, dark brown, or black. A few phenocrysts of pyroxene are commonly visible. The microscope shows the basalt to be made up of phenocrysts of augite and hypersthene in a groundmass of the same minerals and laths of labradorite. A little magnetite and patches of carbonate are also present. Cairnes[1] in his description of the rocks near Carmacks, and to the south, mentions the presence in them of olivine and phenocrysts of bytownite. No feldspar as basic as bytownite, nor olivine, was seen in the few sections examined by the writer. The upper parts of the flows are commonly vesicular, the vesicles containing carbonate, zeolites, quartz, and, in some instances, agate. In a few places cliffs expose beds of yellow unconsolidated tuff and sand, a few feet thick, lying between flows, the sand being composed of grains of weathered lava.

Southeast of Five-finger coal mine the flows are more acid than those described. Many of them are lighter in colour and contain numerous, large feldspar phenocrysts, and some of quartz, hornblende, and biotite in a fine-grained, white or light grey groundmass. They may be termed dacites.

The lavas covering the large areas from the mouth of Big creek to mount Pitt, and between the head of Big creek and Klaza river, are of much the same types as those west of Carmacks.

At the head of Wolverine creek south of mount Pitt the lower lavas are light grey or pinkish, and commonly very vesicular, in some instances almost pumiceous. The vesicles are filled to a great extent with zeolites. In some of these lavas phenocrysts of hornblende are visible. Rhyolite, trachytes, dacites, and andesites form a series of flows about 500 feet thick and are overlain by about 1,000 feet of lavas, consisting chiefly of thick andesite and basalt flows which resemble the upper flows in the area west of Carmacks.

The volcanics in the northeast corner of the district are mainly grey to pinkish, porphyritic dacite and rhyolite, in which quartz and feldspar form

[1] Cairnes, D. D.: "Lewes and Nordenskiöld Rivers Coal District"; Geol. Surv., Canada, Mem. 5, p. 44 (1910).

most of the phenocrysts. Both orthoclase and plagioclase feldspar occur in some lavas, but others seem to contain only orthoclase. The groundmass is microcrystalline to glassy. At one locality, on the south face of the hill east of Diamain lake, the lavas are composed very largely of black glass with scattered phenocrysts of feldspar and quartz.

The volcanics at Granite canyon outcrop along the river bank, but probably underlie much of the drift-covered area to the west. They are composed mainly of dark andesite lava flows and breccias, but in two places bodies of light grey to white dacite occur. Two or perhaps more andesite flows are represented. The andesite is porphyritic. Plagioclase (acid andesine or oligoclase), orthoclase, hornblende, and biotite are the chief phenocrysts, and some of quartz and augite are also present. The groundmass is a fine intergrowth of feldspar and appears to be completely crystalline. The dacite also is porphyritic and consists of the same minerals as the andesite, but with a much higher percentage of feldspar and quartz. Fragments of andesite lava were found in the dacite, indicating that some of the andesite was the older, but in other places coarse andesite breccias cut vertically through dacite in the cliffs of the canyon, suggesting a still later eruption of andesite.

The volcanics in the northwest part of the district resemble those of the large areas southwest of Lewes river. On the high point east of Volcano mountain porphyritic dacite or felsite forms dykes, flows, and breccias. The rock is light coloured and bears large feldspar phenocrysts, and some of quartz, hornblende, and biotite that are visible with a lens. Between the south forks of Black creek there occur light-coloured andesite, dacite, and felsite that are similar to the flows below the thick andesite and basalt flows south of mount Pitt.

The total thickness of the Carmacks volcanics is not known. The section west of Carmacks is at least 2,000 to 3,000 feet thick. The bulk of the formation consists of flows most of which are massive lava at the base and pass upward into vesicular lava and flow breccias that weather readily and are rarely exposed. The attitudes of the flows are not everywhere determinable, but in many localities dips of 10 to 20 degrees occur. In a number of places the contacts with older rocks are faults and in places faults cross them in northwest, northeast, and approximately north directions. All these faults appear to be normal faults. The three larger areas southwest of Lewes river form broad, irregular, synclinal basins whose longest axes trend east and west. These structures are better described as warps than folds. Most of the smaller areas are either remnants capping older rocks or down-faulted bodies, and their longer dimensions commonly show a northwest trend.

Age and Correlation

The Carmacks volcanics unconformably overlie the older formations, except the Tertiary clastic beds upon which they appear to rest conformably. They are intruded by small bodies of acid intrusives and they are unconformably overlain by the Selkirk volcanics. After being faulted and warped they were eroded and the erosion surface is that which truncates the older formations and is referred to as the upland surface of the Yukon plateau. This surface is believed to have been completed and uplifted toward the close of the Miocene (*See* page 7), thus indicating that the volcanics are Miocene or older.

The Carmacks volcanics were correlated by Cairnes[1] with the basalt flows at Miles canyon in Whitehorse district, but Cockfield and Bell[2] hold that the basalt flow at Miles canyon was poured out since the valley was cut to approximately its present depth, and, if this is so, the Miles Canyon flow must be considerably younger than the Carmacks volcanics. They may, however, correctly be correlated with the Newer volcanics described by Cockfield[3]. These occur in the valley of Sixtymile river and show the same relationships as the Carmacks volcanics to the other formations and the plateau surface. They may also be correlated with certain volcanics to the west in Klotassin area[4] and with some andesites in Klondike district.[5]

TERTIARY ACID INTRUSIVES

Many small bodies of acid intrusives occur in the Dawson range and in the country along its flanks. Most of them are medium or fine-grained, acid rocks, largely quartz porphyry, fine-grained granite porphyry or granophyre, with some rhyolite.

Those in the vicinity of Nansen and Victoria creeks were mapped and described by Cairnes.[6] He described them as ranging "from dense, cherty rhyolites to medium-grained granite porphyries," and referred to them as being a volcanic group related to the granites. The rhyolitic varieties along the east part of Nansen creek and elsewhere resemble cherts, but in places have distinct quartz and feldspar phenocrysts. They pass gradually into the more coarsely textured granite porphyries. In the legend of Cairnes' map, No. 151A, tuff and breccia are listed with the granite porphyry and rhyolite. Neither tuff nor volcanic breccia was noted by the present writer with the correlatives of these rocks elsewhere in the district. Although in a number of places these rocks resemble lavas, that they are flows was nowhere proved.

The area on Maloney creek appears to be a solid body of granophyre or granite porphyry. A typical specimen is light grey or white, and so fine of grain that hardly any constituent can be distinguished by the eye. The microscope shows it to be composed of small phenocrysts of quartz, orthoclase, microcline, and acid plagioclase in a groundmass that is a fine-grained micrographic intergrowth of feldspars and quartz. Small amounts of biotite, and in some cases hornblende, are present.

In the granophyre along Dawson range phenocrysts of quartz, feldspar, biotite, and hornblende are visible in a groundmass like that of the rock just described. The rocks possessing a cherty appearance are white or cream and commonly are traversed by a network of small veins of

---

[1] Sairnes, D. D.: "ewes and Nordenskiöld Rivers Coal District"; Geol. Surv., Canada, Mem. 5, p. 44 (1910).

[2] Cockfield, W. E., and Bell, A. H.: "Whitehorse District, Yukon"; Geol. Surv., Canada, Mem. 150, p. 33 (1926).

[3] Cockfield, W. E.: "Sixtymile and Ladue Rivers Area, Yukon"; Geol. Surv., Canada, Mem. 123, pp. 31-33 (1921).

[4] Cairnes, D. D.: "Klotassin Area"; Geol. Surv., Canaa, Sum. Rept. 1916, p. 28.

[5] McConnell R. G.: "Report on the Klondike Gold Fields"; Geol. Surv., Canada, Ann. Rept. 1901, vol. XIV, pt. B, pp. 26-27.

[6] Cairnes, D. D.: "Nansen and Victoria Creeks, Nisling River, Yukon Territory"; Geol. Surv., Canada, Map 151A. "Exploration in Southwestern Yukon"; Geol. Surv., Canada, Sum. Rept. 1915, p. 26.

coarsely crystalline quartz. Under the microscope these rocks are seen to be for the most part a mass of very fine quartz in which lie large remnants of quartz and feldspar phenocrysts. These rocks commonly weather reddish brown due to the oxidation of iron sulphides which they contain in many localities.

Rocks similar to those described occur abundantly in a belt extending southwestward from some 8 miles northwest of Klaza mountain across Victoria mountain. Along this belt the Yukon group, the Mount Nansen group, and the Mesozoic granites are cut by numerous bodies of the acid intrusives forming a high percentage of the total volume of rock. They also occur abundantly between this belt and Big and Stoddart creeks.

In the vicinity of mount Pitt these rocks are granitic. They vary widely in grain, size, and appearance, but all specimens collected contain the same constituents. Most of them are of medium or slightly finer grain and are composed of orthoclase, quartz, acid plagioclase, biotite, and hornblende. Accessory constituents are magnetite, apatite, and titanite. In places the rock is porphyritic. In one locality it was noted to be coarse grained and porphyritic, the phenocrysts being orthoclase. Though otherwise a normal granite this rock is distinguished by the presence of numerous empty gas cavities into which the rock constituents project as perfectly formed crystals.

These acidic rocks intrude the Mesozoic granitic intrusives in Dawson range and also the older rocks. In the vicinity of mount Pitt the granite correlated with them intrudes the Carmacks volcanics, but elsewhere these intrusives were not noted in areas of Carmacks volcanics and there is some doubt as to whether all are younger than the Carmacks volcanics. Some may be older than or contemporaneous with the more acid parts of the Carmacks volcanics. On the other hand, it is possible that some of the more acid rocks included in the Carmacks volcanics, as east of Volcano mountain, belong more strictly to the intrusive group. The acid intrusives are indicated by the erosion they have suffered to be older than the Selkirk volcanics. Similar rocks have been described from many parts of Yukon and have been considered to be the youngest intrusives and of Tertiary age.[1]

GRAVELS UNDERLYING SELKIRK VOLCANICS

On the north side of Yukon river, 2 miles northwest of Selkirk, unconsolidated gravels are exposed beneath Selkirk volcanics. They resemble the materials of the river bars except that the pebbles are rust-stained in varying degrees. The upper surface of these gravels is approximately horizontal. Patches of gravel have been picked up by the lava. Stratification is not marked, but where visible is horizontal. In the best exposure the longer axes of the pebbles dip northeasterly.

---

[1] Cockfield, W. E.: "Sixtymile and Ladue Rivers Area, Yukon"; Geol. Surv., Canada, Mem. 123, p. 33 (1921).
Cockfield, W. E., and Bell, A. H.: "Whitehorse District, Yukon"; Geol. Surv., Canada, Mem. 150, p. 35 (1926).
Cairnes, D. D.: Geol. Surv., Canada, Sum. Rept. 1916, p. 88.
McConnell, R. G.: "Report on the Klondike Gold Fields"; Geol. Surv., Canada, Ann. Rept. 1901, vol. XIV, pt. B, pp. 27-28.

SELKIRK VOLCANICS

Massive lava flows form a prominent rock terrace on the north side of Yukon river opposite Selkirk. They extend north and west to the north side of Volcano mountain and up Black creek. Similar lavas with breccias occur on both sides of the lower part of Wolverine creek and are displayed on Lewes river opposite the mouth of this creek. Three smaller areas of similar lavas occur south of Minto on the west side of Lewes river, and a very small remnant of a lava flow occurs at the west border of the district on the north bank of Yukon river.

The lavas of all these occurrences are remarkably alike. The lower, solid part of the flows is a black, dark bluish green, or brown augite basalt in which phenocrysts of augite, and more rarely feldspar, are visible. Under the microscope feldspar phenocrysts are seen to be basic andesine to labradorite. The groundmass is composed of feldspar (largely andesine), augite, magnetite, and pseudomorphs after pyroxene. A certain amount of glass fills the interstices, and a spinel, picotite, is also present in some instances.

Splendid exposures of these lavas occur in the cliffs north of Selkirk. Here five or more practically horizontal lava flows occur one above the other and have a total thickness of more than 500 feet. The individual flows in some places attain a maximum thickness of 100 to 200 feet. The minimum thickness noted is 20 feet. The very base of each flow is a very fine-grained, moderately vesicular zone 2 or 3 feet thick containing engulfed fragments of crustal lava. Above this the lower two-thirds to three-fourths is compact lava in which in places there is a tendency to develop hexagonal, vertical jointing, but the regularity of the columns is not marked. Towards the top of the compact part the lava becomes more and more vesicular and contains numerous fragments of chilled crust. The upper part, one-quarter to one-third of the flow, is a breccia of large and small, rounded pillows and fragments of crust which towards the top are loosely packed together. The pillows have an outer shell about 2 inches thick of fine-grained black lava, almost glassy in appearance, the outer side of which is oxidized and crumbly. Inside the shell the lava grades from the fine-grained material to a dull black, highly vesicular lava that appears to be largely crystalline in the centre of the pillow. The vesicles are spherical, ellipsoidal, and pipe-like. In many cases the outer shells of the pillows have been fractured and some of the interior has been squeezed out through the cracks. Towards the top of the flows the pillows are smaller, oxidized, and inclined to be crumbly, and with them fragments of ropy lava commonly occur.

The oldest flows are probably those occupying the areas south of Minto and in the vicinity of Wolverine creek. A hill on the north side of Wolverine creek, 6 miles from the mouth, is thought to be the remains of one of the earliest vents and the lava around this hill, and to the south, is thought to have come from it. On this hill some of the lava is composed of a lattice of lath-like crystals of feldspar and jet black, probably basaltic, hornblende in a fine-grained groundmass with numerous gas cavities. Many of the feldspar crystals and some of those of hornblende are one-third inch long. South of Minto the lava has been covered by glacial materials and the location of its source is obscure, but probably is the small conical hill that stands out in the valley. On the east side of Lewes river, 4 miles southeast of Selkirk, a roughly conical hill rising about 1,000 feet above the river is formed of bedded tuff and breccia cut by sheets of lava. This hill is thought to be one of the older vents. It is mainly formed of tuff much of which is composed of fragments the size of a pea or smaller, but coarser material, including fragments as large as 12 by 18 inches, is also present. The tuff is light brown and vaguely stratified and the dip in at least some places corresponds to the slope of the hill. At the base of the hill tuff and breccia are interstratified with the lava and contain rounded pebbles of older rocks. The materials forming the hill lie on top of the flows. Presumably the hill originally had a conical form, but it has suffered considerably from erosion. The base of the slopes has been cut away, apparently by Lewes river, and a canyon-like depression extends across the hill top.

The flows north of Yukon river appear to have flowed south down the valleys from the vicinity of Volcano mountain. This mountain is a well-preserved volcanic cone, built of coarse and fine fragments of the same vesicular lava that forms the flows. The top of the mountain is a deep crater $\frac{1}{3}$ mile across at the rim and 300 feet in diameter at the bottom. The highest point of the rim is approximately 450 feet above the bottom. On the northeast side there is a break in the wall of the crater and a low point in the rim occurs in the southwest side. The last lava flow welled up in the crater, broke out on the northeast, and flowed some 3 miles down the valley to the north. A flow of approximately the same age welled up at the foot of the cone on the southwest side and poured out into the valley, there damming it and forming a lake. This lake is drained by seepage through the lava which is very porous. Looking from Volcano mountain westward down the valley that drains to Black creek it appears that successively earlier flows extended farther and farther down the valley. The two youngest flows are practically bare of soil and are unweathered. Lichen and a few plants are the only vegetation over most of their surfaces, though a few birches grow in hollows. The surfaces are rough and irregular and composed of very porous, rough masses of lava. The flows are full of cavities, some large enough to accommodate a man, produced by the draining away of the fluid lava below the rough crust. In the floor of the crater, and here and there on the surface of the flows between the rough masses, patches of ropy lava occur.

The Selkirk flows poured out on to a surface whose topography was much the same as that of today. They filled the bottoms of the valleys near their sources and covered the gravels, soils, and older formations in which the local topography was cut. They overlie the Yukon group, the Mount Nansen group, the Mesozoic granites, and the Carmacks volcanics. The larger flows spread out in the valleys near their vents, but did not form perfectly level areas. Instead, the upper surfaces decline in height away from the source and the flows thin towards their borders. The flows retain the same attitudes as when formed, except perhaps in the case of those extending southward from Wolverine creek. These rise to the southward though no sign of a vent was found in that direction. Their southern parts reach an elevation of 2,500 feet, whereas elsewhere the elevation is not above 2,200 feet except relatively close to vents of higher elevation. This attitude may be due to subsidence in the vicinity of Selkirk.

As the flows occur in the bottoms of the valleys they must have poured out after the topography had essentially reached its present stage. This alone indicates that the Selkirk volcanics are no older than very late Tertiary. The well-preserved condition of Volcano mountain and of the last flows suggests that these features may not be more than a few thousand years old. Some of the flows, however, appear to be much older. Those opposite Selkirk dammed the rivers, forcing the Yukon to cut across a spur of its former valley below Selkirk, the Pelly to cut a course round them above its mouth, and the Lewes to cut a way through them. The channels thus produced are many times greater and required a much longer time to develop than those of Five-finger rapid, and the Bradens and Granite canyons, which are of post-Glacial age. Also glacial grooving was found on the surface of the lavas 2 miles up Pelly river, and the lavas south of Minto are partly buried in glacial debris. It is, therefore, apparent that the extrusion of the Selkirk volcanics commenced in pre-Glacial time, very late Tertiary, or in Pleistocene time, and did not cease until perhaps only a few thousand years ago.

In other areas in Yukon the Selkirk volcanics may be correlated with basic volcanics that were extruded after the region assumed its present general topographical form. The best known of these are the flows of Miles canyon in Whitehorse district.[1]

SUPERFICIAL DEPOSITS

The superficial deposits of the district include a wide variety of materials ranging in age from Tertiary to Recent.

The Tertiary deposits consist of gravels and soil formed before and during the dissection of the upland surface. The broad part of Big Creek valley near its head contains a thick covering of soil, the development of which may extend back to before the dissection of the upland surface.

The Tertiary gravel deposits consist of well-rounded stream pebbles which have no connexion with the glacial or present streams. In the unglaciated parts of the district they lie on the sides of the valleys and even on the tops of ridges. Gravel deposits at the head of Dark creek and on the ridges between it and Big creek occur as high as 4,000 feet elevation, which is close to the level of the upland surface in that locality. They may thus date back to the earliest stage of dissection of the upland surface which was probably Miocene. Along the south side of Big Creek valley from opposite Prospector mountain to the mouth of Stoddart creek and in places on either side of the lower parts of Seymour and Bow creeks gravels occur on remnants of a high rock terrace. Gravels occur on the north side of Yukon river, 15 to 20 miles below the mouth of the Pelly, at elevations up to 2,800 feet, or 1,400 feet above the river and perhaps 500 feet below the upland surface. These gravels originated in the later

[1] McConnell, R. G.: "Whitehorse Copper Belt, Yukon Territory"; Geol. Surv., Canada, Rept. No. 1050, 1909, p. 17; Cockfield, W. E., and Bell, A. H.: "Whitehorse District, Yukon"; Geol. Surv., Canada, Mem. 150, p. 33 (1926).

stages of the dissection of the upland surface and are believed to be late Tertiary. Undoubtedly the different high-level gravels vary considerably in age. In some cases the pebbles are much decayed. In some places gravels rest on rocks older than Carmacks volcanics and some of them may be remnants of the Tertiary clastic beds, but in most instances they lie on Carmacks volcanics and must, therefore, be younger. In Yukon valley certain accumulations of gravel possess a modified terrace-form and are younger than the Carmacks volcanics.

Along Pelly river, in the upper part of Granite canyon and above it, partly consolidated gravels and sands occur in places in the base of the cut banks of the river. They are stratified stream gravels and sands with horizontal bedding. Their base is not exposed, but they occur in the floor of the river valley and they are overlain by glacial till (boulder clay) in Granite canyon, and by unconsolidated late-Glacial or post-Glacial stream gravels in the valley above the canyon. The age of these gravels may range from late Tertiary to early Pleistocene.

A variety of materials are grouped together as being Pleistocene, but some may be partly of earlier age.

In the unglaciated parts of the district accumulations of vegetable matter commonly referred to as "muck" were noted in valleys. No thick exposures were observed, but in a number of places sections several feet thick were seen in the banks of streams. The "muck" is dark brown to black and consists of partly rotted vegetation, chiefly moss and shrubs. Flat bodies of sand, clay, or ice lie in it. It is always frozen a few inches below the surface. The material appears to be accumulating at the present time. No accumulations of this material were noted in the glaciated part of the district. The general lack of it in the glaciated territory is thought to be due in part to the better sub-surface drainage, which enables the ground to thaw to greater depths with the result that the vegetation rots instead of accumulating. The "muck" is presumably in part as old as Pleistocene or earlier.

The oldest glacial deposits occur in the vicinity of Nansen creek. In his report on Nansen Creek district, D. D. Cairnes[1] notes the presence of boulder clay in Nansen Creek valley. At the time of his visit more placer mining was in progress than now, and many fresh cuts afforded good exposures. No boulder clay was exposed on Nansen creek at the time of the present writer's visit. Near the head of Back creek, a tributary of Victoria creek, a fresh cut exposed the following section: at the top muck; under this, rusty stream gravel and sand; below this, brown clay with fragments of rock and, in places, rusty stream gravel and sand; and at the base, blue clay holding fragments of rock. Bedrock was not exposed. The whole section is 8 to 10 feet thick. The blue clay was exposed for only a few inches at the bottom of the cut, except in one place where it had been excavated to a depth of 3 feet. The materials above the blue clay appear to be normal products of present day erosion. The blue clay contains some scattered, angular and rounded fragments of rock. No stratification could be seen. The clay appears to be typical boulder clay. Fragments of schist and granite lying in it are

[1] Cairnes, D. D.: Geol. Surv., Canada, Sum. Rept. 1914, p. 25.

completely rotted and crumble to pieces when touched. Three smooth and rounded fragments, 4 to 12 inches in length, of a very fine-grained andesite of the Mount Nansen group were found. They were roughly faceted and numerous scratches crossed each facet, the scratches following various directions but most of them following one direction. Some of the scratches are in the neighbourhood of one-twentieth inch deep, and appear to be typical glacial striations. Miners report that similar blue clay occurred in the bottoms of many of the placer cuts, that the pay values lay on it, and that no pay was found under it on bedrock. The area shows all the features of an unglaciated country except for certain terraces of sand and certain drainage features. It is believed that the blue clay is a remnant of an old boulder clay buried where the streams have been unable to excavate their courses as fast as the material on the slopes has crept into them. Most of the placers occur at the heads of the creeks where the quantity of water is small and bedrock is not exposed except on the tops of the ridges between the creeks.

In the glaciated country most of the valleys are floored by stream gravels and sand in which the pebbles and boulders are commonly well rounded. These deposits overlie boulder clay in some exposures along the river banks. Similar gravels form terraces in the valleys and on the hill-sides. Elsewhere much of the country is covered by a variable thickness of glacial till and erratics.

Close to the border of the glaciated country, particularly in the vicinity of Nisling River valley, which lies a few miles south of the district, great quantities of sand occur on the bottoms and sides of the valleys. The sand forms terraces whose surfaces slope down stream and also towards the middle of the valley in which they lie. The sand is moderately fine, the greater part of it not coarser than sugar. It is of a rather bright rusty colour and where it is exposed in fresh cuttings it shows no sign of stratification. It is composed of a wide range of materials, but predominantly of quartz and feldspar. This sand occurs in quantities up to approximately the 3,700-foot level in the valleys of the streams that run into Nisling river across the south border of the sheet. It occurs far up them, as for instance in the forks of Victoria creek. Its origin is unknown. On the east side of Lewes river, north of Ingersoll islands, much sand is present. The surface of the area is irregular, with undrained hollows and ridges resembling dunes. This sand was probably deposited in an ice margin lake on top of moraine enclosing stagnant ice.

The sands, gravels, and boulder clays attributed to the last glaciation show remarkably little weathering. In the unglaciated parts of the district, except where stream deposits occur, the soil or loose surface covering is composed of the products of weathering of the local bedrock. In the formation of this material mechanical disintegration is by far the more important factor. Decomposition is relatively inactive so that even where the rock has been reduced to small fragments it is still remarkably fresh.

The typical Recent gravels of the smaller streams of the unglaciated country show a slight degree of rounding and are composed of local rocks. In larger streams such as Big creek the gravels are rounded and contain a variety of rocks.

A layer of white ash occurs over practically the whole district and lies at the surface or beneath a few inches of soil. Towards the southwest it is speckled with a small percentage of dark particles. It has a gritty feel. Dawson[1] says that "it consists chiefly of volcanic glass of pumiceous character, some feldspar, hornblende, and probably other minerals." Along Lewes river, in the vicinity of Minto, its normal thickness is approximately 10 inches, but where it drifted into valleys or settled in the river sloughs it is several times this thickness. It was not observed along the north border of the district, but is present in places in the cut banks of Pelly and Yukon rivers. South of a line through mount Pitt and Tatlmain lake it is conspicuous and in the southwest part of the district in the valleys, as for instance that of Lonely creek, it is present in considerable quantities. A similar layer is mentioned by Capps[2] along White river, Alaska. The writer believes that this is probably the same layer and from the information in Capps paper judges it to be approximately 1,400 years old. In a few places in the cut banks of Lewes, Pelly, and Yukon rivers, a thinner, less regular, and less persistent layer of similar material lies 6 inches to 4 feet below the layer just described. The two are separated by fine soil or sand. The upper layer of white ash owes its origin to a volcano to the west or southwest.

ash

[1] Dawson, G. M.: "Report on an Exploration in the Yukon District, N.W.T., and Adjacent Northern Portion of British Columbia, 1887"; Geol. Surv., Canada, Ann. Rept. 1887-88, pt. B, pp. 40-43.
[2] Capps, Stephen, R.: "Glaciation in Alaska"; U.S. Geol. Surv., Prof. Paper 170-A, 1931.

CHAPTER V

ECONOMIC GEOLOGY

Carmacks district, until the last few years, has not received much attention from prospectors, although it is traversed by the main route of transportation in Yukon. In the last year or so, since lode prospecting has been in progress in one small area, a number of metals have been added to the known mineral resources. Deposits containing gold, silver, lead, zinc, copper, and antimony have been found. Beds of coal have long been known. Placer gold and coal are the only materials that have been produced in any quantity, though the recovery of some hundreds of pounds of copper from a test shipment of ore from prospects at Williams creek is worthy of mention.

GOLD PLACERS

The first prospecting in the district was for placer gold. Miners passing through on their way to the Klondike discovered placer gold on tributaries of Lewes river and along a branch of the overland route known as the Dalton trail. This branch enters the district at Schist creek, crosses Klaza river, traverses the Dawson range west of Klaza mountain, crosses Big creek into the head of Wolverine creek, and continues to Selkirk. In the course of the present work the remains of old placer workings were found along Hayes creek where it traverses rocks of the Yukon group. Here a large spruce was found bearing an inscription dated 1898. The ruins of several old cabins with stone chimneys characteristic of that time are still standing. The results of the early prospecting on Hayes creek are not known. It is reported that the coarseness of the gravels and the fact that they did not freeze sufficiently in winter discouraged the miners, though good pay is said to have occurred in places. Some placer work has been carried on in recent years, from time to time, by one or two miners on Hayes creek near where it crosses the border of the district.

Old cabins thought to have been built by early placer miners were also found on Maloney creek. A cabin on the west fork of Schist creek, which is sometimes referred to as Murray's cabin, contains a considerable quantity of pipe and other steam-thawing equipment. Very little placer work had apparently been done.

The most important placer area yet discovered is that of Nansen and Victoria creeks. It was examined by Cairnes[1] in 1914 and much of the following information is from his report. Placer gold is believed to have been first found on Nansen creek near the mouth of Discovery creek by Henry S. Back, in July 1899. No work was done until he returned in the spring of 1907. The first claim recorded was Discovery on Nansen creek and was staked on June 13, 1910, by Frank H. Back and Tom Bee. Since that time placer work has been intermittently carried on. Practically

[1] Cairnes, D. D.: Geol. Surv., Canada, Sum. Rept. 1914, pp. 25-30, and Map 151A.

all the creeks were staked from end to end, but most of the claims have been allowed to lapse. The gravels, etc., exposed in the placer cuts are described on a previous page. The pay lies on bedrock or on a layer of blue boulder clay where this is present. It is reported that no gold has been found on bedrock where the blue clay occurs. In most of the valleys, particularly their lower parts, large quantities of sand occur in the upper part of the unconsolidated deposits. The gold in the lower placers on Nansen creek is largely fine, but in the lower parts of some of the tributaries a fair proportion of coarse, rounded gold has been reported. In the upper parts of the tributaries it is reported to be fine, rough, or, occasionally, wiry. Galena, barite, pyrite, and zinc blende are reported as commonly caught in the sluice-boxes.

Practically all the gold has been obtained from the upper half of Nansen creek, the tributaries from the east entering this part of Nansen creek, and Back creek, which heads with these tributaries and enters Victoria creek from the west. The courses of these streams head in or close to areas of Tertiary acid intrusives which in many places carry disseminated pyrite. These features strongly suggest that the source of the gold is associated with the acid intrusives.

Some placer gold has been obtained from Seymour creek and some small tributaries to it and Stoddart creek which rise on the slopes of Freegold mountain. These placers have not been of much importance, but it was the placer on Seymour creek that originally attracted prospectors to the vicinity of the present lode prospecting area.

At the beginning of the century placer gold was discovered on Williams and Merrice creeks, but these creeks have long since been abandoned. Small amounts of placer gold have also been recovered from the bars of Pelly river.

LODE PROSPECTING

The most important lode prospecting operations are those in the vicinity of Freegold mountain. Accounts of these activities have been given in the Summary Reports of the Geological Survey since 1931.

During the last few years this has become the most important lode gold prospecting area in Yukon and shows promise of developing a producing mine in the near future.

As most of the prospects are comparatively undeveloped and afford little opportunity for obtaining detailed information, no extensive study of them has been made. However, as new prospects are continually being found, and older ones are being extended, opportunities of gathering new and additional information will be greatly enhanced in the future and the account here is, therefore, to be regarded as of a preliminary character. The following account is a brief summary.

Placer gold was discovered on Seymour creek in 1917 and caused a small, short-lived stampede. No very attractive placers were discovered and the creek soon became deserted. The discovery did, however, continue to hold the interest of a few prospectors. Mr. P. F. Guder, one of these, discovered some float magnetite carrying gold, on the top of the ridge now known as Freegold mountain. He later found the mineralized material in place and in June 1930 staked the first claim, the Augusta. The news of the discovery caused a stampede during the autumn and winter, and by the beginning of 1931 well over one hundred claims had been recorded. Most of the claims were located along the top of the ridge between Seymour and Stoddart creeks, but some were staked northeast of Stoddart creek on what has been called McDade or Tinta hill. Assessment work was done on many of the claims during the next few years, but serious prospecting was done on only a few. The work, carried out in a remote locality and under difficult conditions, was necessarily slow. However, a considerable number and variety of showings were discovered. During 1931 a few engineers visited the locality but were not impressed by what they saw owing to the small amount of work accomplished and the fact that the best assays had been obtained from ore of a contact metamorphic type. During the next two years prospecting rather died down, but a few persistent prospectors held on. They were rewarded by finding mineral that afforded increasingly higher assays in gold, some of which by the end of 1933 ran to 10 or more ounces of gold a ton. Particularly attractive assays were obtained from the Laforma group, owned by Mr. W. J. Langham and his associates. On this group a number of auriferous quartz veins were discovered and one of them gave evidence of maintaining its width and character for a considerable distance. By the autumn of 1933 the results obtained on this and adjoining groups were such as to attract the attention of a number of mining men, and in 1934 the N. A. Timmins Corporation acquired the chief groups and at once began operations.

During the winter of 1934-35 the corporation built a winter tractor road into the locality and began underground development on the Laforma group. In the summer, however, the corporation dropped its holdings and abandoned the district. Almost immediately engineers of other companies visited the property and in the beginning of August the Laforma group was taken over by the Yukon Consolidated Gold Corporation which at once re-commenced development.

The lode prospects cover the upper part of Freegold mountain, its spurs, and parts of some of the neighbouring hills. They embrace a variety of types of deposits, including contact metamorphic deposits and veins carrying different mineral assemblages of high, intermediate, and low temperature types.

The chief mineral of the contact metamorphic deposits is magnetite.

A number of the magnetite deposits have been discovered on the west side of the top of Freegold mountain. Those on which most work has been done are on the Augusta and Margarete claims, owned by Mr. Guder. Others occur on the adjacent Badger and Morning claims. The deposits are exposed in a number of trenches and by one prospect pit a little over 20 feet deep. As they are in the unglaciated part of the district they are deeply weathered. The surrounding rocks are quartzites, schists, gneiss, and small bodies of limestone belonging to the Yukon group, and a variety of intrusive dykes of Mesozoic and Tertiary ages. Silicates, including actinolite, garnet, and epidote, have been developed in these rocks, and occur in places in the mineral deposits. These consist mainly of magnetite, hematite, and abundant limonite. Quartz, pyrite, and chalcopyrite are also present. The gold occurs in the limonite in small specks, sometimes large enough to be visible to the unaided eye. The float of these deposits is widely scattered over this part of the mountain, as if the deposits were of considerable extent. The excavations so far made fail to indicate the form and dimensions of the deposits. The one on which most work has been done may be as much as 30 feet wide and 200 to 300 feet long, and assays carrying several ounces in gold have been obtained from it.

On the Augusta claim, in addition to the magnetite deposits, a vein has been exposed near the west boundary carrying pyrite, chalcopyrite, arsenopyrite, galena, sphalerite, quartz, calcite, siderite, limonite, azurite, and malachite. When examined this vein had been uncovered over a length of 16 feet, and one wall, thought to be the hanging-wall, had been reached.

On the Margarete claim, west of the Augusta claim, another vein has been explored by a shaft 20 feet deep from which it is intersected by a crosscut. The vein is reported to be vertical, 2 feet wide, and to lie between quartzite and schist on one side and quartz porphyry on the other side. It consists of quartz carrying pyrite, arsenopyrite, and chalcopyrite. Several samples taken from this deposit are reported to have carried high gold values, one being as much as 60·3 ounces a ton in gold.

On the lower southeast part of the mountain a large number of quartz vein deposits have been discovered. The majority of them are on two groups of claims, owned respectively by W. J. Langham and associates and A. Brown and associates. The veins have been found by tracing fragments of vein float. Most of the showings are exposed in shallow trenches. The country rock is mainly granodiorite or syenite and, in places, dyke rocks. The largest vein is on the Laforma group. Up to the autumn of 1934 this vein had been exposed in an adit 65 feet long, known as No. 1, and by twelve trenches and excavations at fairly regular intervals over a horizontal distance of nearly 900 feet on the steep mountain side.

The development carried out by N. A. Timmins Corporation was concentrated on the Goose mineral claim of the Laforma group. Here No. 2 adit was driven at an elevation of 3,600 feet, approximately 300 feet below No. 1 adit and some 800 feet south. No. 2 adit runs into the mountain north 35 degrees west for 200 feet. At 150 feet from the portal a west crosscut runs north 70 degrees west for 170 feet and at 170 feet from the portal a drift extends about north 22 degrees east for 400 feet. The end of the drift is approximately 350 feet from a point vertically underneath No. 1 adit. Short crosscuts were put in at intervals of approximately 100 feet on both sides of the drift.

In the trenches and No. 1 adit the vein material varies in width from 20 inches to 10 feet. It is thickest in No. 1 adit and in the trenches on the slope just above it. In the trenches and No. 1 adit the vein is composed of quartz seams up to 4 feet in width accompanied by gouge and seams of iron oxide. Pyrite, arsenopyrite, and free gold can be seen in the quartz. On either side of the vein the granodiorite wall-rock is altered anad impregnated with pyrite. In No. 2 adit the vein material first occurs at 150 feet from the portal and has been followed along the north drift. The drift and crosscuts from it show a shear zone in granodiorite 20 to 30 feet wide, striking north 22 degrees east and dipping vertically to 80 degrees west. The shear zone is followed by veins of quartz, crushed and altered wall-rock, seams of gouge, and seams of sulphide. On the west or hanging-wall side the shear zone is bordered by a quartz porphyry dyke 5 to 8 feet wide. The most persistent vein of quartz is on the east or foot-wall side. It varies in width from 9 inches to 4 feet, and some seams of sulphide and gouge occur where the thickness is greater. In the central part of the shear zone a number of prominent fractures or faults that contain seams of gouge and sulphide occur over a width of approximately 2 feet. On the hanging-wall side of the shear zone adjacent to the dyke other veins of quartz and seams of sulphide are present, and in one place quartz vein material occurs on the west side of the dyke. The west crosscut traverses the shear zone, then three fractures separated by country rock, and then continues across a body of quartz porphyry and into relatively unaltered granodiorite. The three fractures contain variable thicknesses up to 2½ feet of vein materials, including quartz, sulphide, and gouge. The first is 65 feet from the beginning of the crosscut and strikes northeast. The second is 100 feet from the same point and strikes in an easterly direction. The third, approximately 30 feet farther on, strikes northwest. All dip very steeply in northerly directions. The quartz of the veins is fine grained and contains here and there small cavities into which small crystals project. The pyrite in the quartz is fine grained as a whole, but in places crystals one-twentieth inch across occur. It is disseminated and in small seams, scattered through the quartz parallel to the vein walls. Specks of gold were noted in a number of specimens of the vein quartz. The seams of sulphide in the shear zone are composed of a mass of crushed pyrite. They occur with and parallel to the quartz veins and shear fractures. Arsenopyrite, tourmaline, sphalerite, and galena occur in small quantities in the vein material. In the adit, from the portal inward, the granodiorite becomes altered and is impregnated with pyrite, particularly near the shear zone, and the same is the case in the west crosscut. The granodiorite in the shear zone has altered to a mass of soft material composed of kaolin, chlorite, pyrite, and other alteration products. Quartz grains are the only constituents of the original rock remaining unaltered.

The quartz porphyry is a very fine-grained white rock and shows little sign of alteration, though it has been somewhat fractured.

The few assay results obtained by the writer show high values up to several ounces a ton from the vein quartz itself. The underground work shows that the high values continue to the depth attained and are not due to residual surface enrichment, and also confirms the persistent character of the vein.

Several other veins on this group and adjacent claims appear to be of the same type and are reported to carry gold. There appears to be more than a single set of these veins. Some similar veins have been discovered on the southwest part of the mountain, and a vein containing galena and small amounts of sphalerite and chalcopyrite occurs on the Red Fox claim on the west side of the mountain. On the ridge east of Freegold mountain, in the belt of Yukon group close to the granite contact, a shaft has been sunk on a vein carrying coarse stibnite.

In 1931 a large vein was discovered on McDade or Tinta hill, 4 miles east of Freegold mountain. The vein varies between 3 feet and 6 feet in width and has well-defined walls of granite. It strikes north 61 degrees west, dips nearly vertically, and has been traced over a length of more than 4,000 feet. Workings consist of trenches and shallow shafts, the deepest 32 feet. The vein is composed of quartz carrying pyrite, galena, sphalerite, chalcopyrite, and tetrahedrite. It carried some silver, gold, and lead, but not in sufficient quantities to make commercial ore at the time. Work on the vein ceased in 1932.

In the past some prospecting for lode deposits was done on the northwest side of the mouth of Williams creek. The prospects were not visited by the writer and have lain idle for years. They were visited twice by Cairnes[1] and the following account is mainly derived from his reports.

The rocks in the vicinity consist of members of the Mount Nansen group and form a ridge bordering Lewes River valley. Southwest of the ridge is a large area of intrusive granites. The rocks of the Mount Nansen group along the contact with the granite and for a mile or more from it have been recrystallized and converted into amphibolite and allied types of schists. Numerous apophyses of the granites extend into the volcanics.

The mineral deposits occur either at or near the contacts of the two formations and all are alike. They are veins of quartz carrying copper minerals, chiefly bornite, chalcopyrite, and malachite. Particles of free gold are said to have been found on one property. A considerable number of claims were staked. On the Bonanza King group situated about one mile from Lewes river, on the north side of Williams creek, a shallow shaft was sunk and drifts were run having a total length of 150 feet or more. The veins on this group range from a few inches to 6 feet in width, strike northwest, and in addition to copper carried some gold and silver. Similar deposits were also prospected on Merrice creek.

CONCLUSIONS

The study of the district has yielded certain conclusions that may be of value to prospectors. The work done has not been sufficiently detailed to regard any part of the district as being worthless from a prospector's standpoint. However, it is possible to weigh the relative merits of the different formations and parts of the district against each other. The geology strongly suggests that certain parts are more promising than others and the distribution of known mineral deposits gives weight to the conclusions drawn from the geology.

The Carmacks and Selkirk volcanics are regarded as unfavourable for prospecting because no mineral deposits of importance have been found with them or with similar Tertiary rocks elsewhere in Yukon or British Columbia. They do, however, offer some remote possibilities where they have been intruded by younger acid intrusives, as for instance near mount Pitt. Also, small mercury deposits are associated with similar Tertiary rocks in Sixtymile district and in British Columbia.

The Lewes River and Laberge series and Tantalus formation in the southeast corner of the district appear to have no mineral associated with them except coal. Southeast of this district, where they cover large areas, placer and lode deposits are rare.

[1] Cairnes, D. D.: Geol. Surv., Canada, Sum. Rept. 1907, p. 15; Sum. Rept. 1909, pp. 57-60.

Little indication of mineral deposits was observed in the large areas of Yukon group rocks, but these rocks should prove to be as good hosts for mineral deposits as any other formation in the district, especially where they are in contact with later intrusives. Along Pelly river below Bradens canyon quartz veins are common in them, though none of these is known to carry valuable mineral. The areas of the Mount Nansen group must also be judged with reference to the proximity of intrusives, but as in this district they are everywhere close to intrusives they are regarded as promising prospecting ground.

No sign of mineral was seen with the large body of granite southwest of Tatlmain lake and this intrusive is, therefore, not considered as likely a source of mineral deposits as most of the other granitic intrusives. Near its southwest contact along the east branch of McGregor creek it shows more variation in composition and contains more dykes than elsewhere, so that this part is probably the most promising as well as the most accessible. No minerals were noted with the Pelly granites either near Granite canyon or near the mouth of the river, but in both localities the contacts with the older rocks are largely covered. However, the rock shows considerable variation in composition and it seems possible that some mineral may be associated with it.

Nearly all the known mineral deposits of the district are southwest of Lewes-Yukon river and the geology also indicates those parts of the district as most favourable. The intrusive rocks exhibit greater variation in composition and show more signs of mineral. Although the large belt of granitic rocks extending northwest from Crossing creek to Yukon river does not in itself seem promising, mineral deposits have been found near both sides of its contacts, at Williams creek and Freegold mountain, suggesting that further prospecting should be done in the remaining areas adjacent to the contacts. The part extending northwest from Yukon Crossing to Big creek should be particularly examined as it is readily accessible and in the event of a discovery the transportation costs would be relatively low. The best part of the district is believed to be the Dawson range, from the neighbourhood of Victoria and Nansen creeks across to Stoddart creek and northwest to Hayes creek, the head of Big creek, and beyond the district. Along this belt there are numerous contacts between the intrusives and older rocks, the intrusives show the greatest variety of differentiates, and the larger granitic bodies are mainly granodiorite with some quartz diorite. Along this belt the gold placers of Nansen, Victoria, Seymour, and Hayes creeks are distributed and the belt is considered to continue westward where it contains those of Selwyn river, and Britannia and other creeks. Added to these deposits are the lode prospects of Freegold mountain.

The ground around Freegold mountain so far has proved the best in the district and the geological conditions suggest that other equally good areas should be found along this belt.

Mineral was noted along Klaza river below Magpie creek. As this locality is near the contact of the granitic intrusives and the older rocks, it is believed to be very promising, but its inaccessibility would probably render any but very rich deposits worthless.

As mineralized bedrock is the source of placers it follows that placers should be sought in or near the areas already mentioned as being favourable for lode deposits. These areas include a variety of rocks besides those of the Yukon group, with which placers are generally associated in other districts of Yukon. Thus the best known placers of Carmacks district, those of Nansen and Victoria creeks, are mainly in areas of Tertiary acid intrusives.

When searching for placers it is important also to consider whether the country has been glaciated. This particularly applies in Carmacks district as parts of it have escaped glaciation. Placers formed before the glacial period would in most cases be scoured away by ice movement or buried beneath drift deposits. The features of the last glaciation are still fresh and unmodified by post-glacial erosion, showing that the time since the disappearance of the ice-sheet has been too short for placers to form. For this reason the western limit of the last ice-sheet has been indicated on the map.

It has already been mentioned that parts of the district, in the vicinities of Selkirk and Nansen creek, outside the limit of the last glaciation, were subjected to an earlier glaciation. The importance and extent of the earlier glaciations are not fully known. However, the placers of Nansen and Victoria creeks lie on top of the old boulder clay and have, therefore, been formed since the earlier glaciation. For this reason the areas that were subjected only to the earlier glaciation are not to be regarded as being unfavourable for placer prospecting ground.

COAL

Coal has been known in the district since the earliest explorations by Dawson, in 1887[1], who noted the presence of thin seams in the Laberge series at a locality that subsequently became the site of the Five-finger coal mine some 5½ miles above Five-finger rapid. Later, coal was found at what became the Tantalus and Tantalus Butte mines on Lewes river above Carmacks. The Tantalus Butte mine continues to produce a few hundred tons each year, most of which is sold in Dawson, but the other two mines are closed.

Tantalus Mine

This mine is on the south side of Lewes river, a mile above Carmacks, and was operated by the Five Fingers Coal Company. It has been abandoned for some years and its workings were not examined by the writer. The Tantalus conglomerates outcrop along the river bank both above and below the mine, and by their attitudes indicate the presence of a minor anticline west of the mine and a minor syncline to the east. The following account is taken from reports by Cairnes.[2]

"The coal outcrop on the river bank is well situated for economical working. . . . . Three seams have been opened up, only the lower two of which have been worked to any extent. The seams vary somewhat in thickness, but average about 7 feet 6 inches, 6 feet 6 inches, and 3 feet

[1] Dawson, G. M.: "Report on an Exploration in the Yukon District, N.W.T., and Adjacent Northern Portion of British Columbia, 1887"; Geol. Surv., Canada, Ann. Rept. 1887-88, pt. B, p. 147.
[2] Cairnes, D. D.: Geol. Surv., Canada, Sum. Repts.: 1907, p. 28; 1908, p. 14; 1909, p. 28.
"Lewes and Nordenskiöld Rivers Coal District"; Mem. 5, pp. 48-54 and 59-63 (1910).
Guide Book No. 10, pp. 82-87 (1913).

of coal in the bottom, middle, and top seams respectively. The lower two seams have, in places, not more than 4 feet of rock between them, and the middle and top seams are generally about 7 feet apart. The coal is worked by the pillar-and-stall system, from two level entries, which have been driven about 2,000 feet. The beds in the mine workings dip to the east at angles varying from 24 degrees to 40 degrees.

"A 500-pound sample from each of these seams taken by the writer in 1908 was treated and analysed by the Mines Branch, the following being part of the results of this work.

—	Upper seam		Middle seam		Lower seam	
	Raw	Washed	Raw	Washed	Raw	Washed
	%	%	%	%	%	%
Moisture in sample as received in laboratory	0·9	....	0·7	....	0·7	....
Proximate analysis of coal dried at 105 degrees—						
Fixed carbon	58·0	59·9	54·1	60·3	56·0	59·2
Volatile matter	25·0	26·3	26·7	25·7	27·8	28·1
Ash	17·0	13·8	19·2	14·0	16·2	12·7
Ultimate analysis of dried coal—						
Carbon	6·98	....	....	....	71·1	....
Hydrogen	4·0	....	....	....	4·3	....
Sulphur	0·5	0·5	0·5	0·4	0·5	0·5
Nitrogen	0·8	0·8	0·9	0·8	0·7	0·8
Oxygen	7·9	....	....	....	7·2	....
Ash	17·0	....	....	....	16·2	....
Calorific value of dried coal in calories per gramme	6·700	7·110	6·310	7·070	6·790	7·210"

The Tantalus mine was operated from 1905 or earlier until 1922. In earlier years from 3,000 to 8,500 tons a year were produced for a period of seven years or more. Much of the coal was used by the river steamers but was not found altogether satisfactory owing largely to the difficulty of distributing it to coaling points up and down the river, and the steamers reverted to the practice of using wood as fuel. Production dropped in 1918 below 1,000 tons and in succeeding years fell to a few hundred tons, until in 1922 the mine was closed.

Tantalus Butte Mine

The presence of coal seams in Tantalus butte, across the river from Tantalus mine and Carmacks, has been known from about the same time as the Tantalus mine started operation. The Five Fingers Coal Company closed the Tantalus mine in 1922 and opened the Tantalus Butte mine in 1923; because compared with the Tantalus mine it is cheaper to operate on a small scale. Since 1923 this mine has produced from 300 to 600 tons a year, most of which is used for domestic heating in Dawson.

Tantalus butte is composed of conglomerates, sandstones, etc., of the Tantalus formation. The strata strike almost due north and dip at an angle of approximately 50 degrees to the west. Cairnes reports[1] the presence of three seams near the top of the butte, 8 feet 10 inches, 9 feet 10 inches, and 7 feet thick, respectively. He gives the following analysis, made by the Mines Branch, Department of Mines, of samples from each seam.

—	Average outcrop of 8 feet 10 inches seam	Sample of 9 feet 10 inches seam	Sample of best 6 feet of 7-foot seam
Water	13·64	16·32	12·87
Volatile combustible matter	31·84	31·72	31·72
Fixed carbon	51·84	42·13	49·51
Ash	2·69	9·83	5·90
	100·00	100·00	100·00
Ratio of volatile combustible matter to fixed carbon	1·63	1·33	1·56
Potash reaction	Dark	Brownish	Red
Colour of ash	Pale reddish brown	Pale brownish yellow	Yellowish brown
Kind of fuel	Lignite	Lignite	Lignite

These do not give a coherent coke.

In 1932 when the writer visited the locality the excavations exposing the three seams had caved. The mine workings now expose two seams, an upper one approximately 2 feet thick and a lower one that varies in thickness from 7 to 14 feet. The workings consist of a main entry which crosscuts to the lower seam and follows it to a point 700 feet or more in from the portal. The entry is about 350 feet above the river. An upper entry, 135 feet above the lower, runs in on the upper seams for approximately 100 feet to where a winze reaches the lower seam connecting with the rooms in it and providing ventilation. Most of the coal that has been mined has come from parts of the upper seam that are within 300 feet from the surface measured down the dip of the seam.

In 1933 the writer took a sample across the lower seam close to the inner end of the main entry where it had been exposed for over a year. The sample was a channel sample across the whole seam, which here measured 9 feet 9 inches. The best coal is in the lower third. The central part of the seam breaks up easily and is not so clean. The second best part of the seam is the upper part. The sample was analysed by the Mines Branch, Department of Mines, with the following results.

[1] Cairnes, D. D.: Geol. Surv., Canada, Mem. 5, p. 52. Guide Book No. 10, p. 82.

Condition of sample	As received	Dry basis
Proximate analysis:		
Moisture	6·1	....
Ash	8·9	9·5
Volatile matter	31·2	33·2
Fixed carbon (by difference)	53·8	57·3
Ultimate analysis:		
Carbon	69·6	74·1
Hydrogen	5·2	4·8
Ash	8·9	9·5
Sulphur	0·4	0·4
Nitrogen	1·0	1·0
Oxygen (by difference)	14·9	10·2
Calorific value:		
Determined in calories per gramme, gross	6,555	6,980
Determined B.T.U. per lb., gross	11,800	12,560
Fuel ratio, fixed carbon, volatile matter	1·70	
Carbon-hydrogen ratio	13·4	15·5
Coking properties	Agglomerate	
Softening temperature of ash	2,330	

In 1934 seven other samples were collected by Mr. Andrew R. Johnstone and analysed by the Mines Branch, Department of Mines. The results follow:

Laboratory No.	13717		13718		13719		13720	
Condition of sample	R	D	R	D	R	D	R	D
Proximate analysis:								
Moisture .... Per cent	5·4	.....	4·5	.....	3·7	.....	5·6	.....
Ash .... "	10·5	11·1	11·5	12·0	9·1	9·5	11·3	12·0
Volatile matter .... "	30·7	32·5	30·9	32·4	32·9	34·2	33·7	35·7
Fixed carbon (by difference) .... "	53·4	56·4	53·1	55·6	54·3	56·3	49·4	52·3
Ultimate analysis:								
Carbon .... Per cent	....	....	....	....	....	....	....	....
Hydrogen .... "	....	....	....	....	....	....	....	....
Ash .... "	....	....	....	....	....	....	....	....
Sulphur .... "	0·4	0·4	0·3	0·4	0·4	0·4	0·3	0·4
Nitrogen .... "	....	....	....	....	....	....	....	....
Oxygen (by difference) "	....	....	....	....	....	....	....	....
Calorific value:								
Calories per gramme, gross	6,625	7,005	6,660	6,975	6,935	7,200	6,580	6,970
B.T.U. per pound, gross	11,930	12,610	11,990	12,550	12,490	12,960	11,840	12,550
Fuel ratio, fixed carbon, volatile matter	1·75		1·72		1·65		1·45	
Carbon-hydrogen ratio	....		....		....		....	
Coking properties	Agglomerate		Agglomerate		Agglomerate		Agglomerate	
Softening temperature of ash	....		....		....		....	

13717—From 9-foot 4-inch seam, face exposed one year.
13718—From 8-foot 6-inch seam, face exposed 45 days.
13719—From 8-foot seam, face exposed 40 days, face main tunnel.
13720—From 9-foot seam, freshly broken face.

Laboratory No.	13721		13722		13723	
Condition of sample	R	D	R	D	R	D
Proximate analysis:						
Moisture ... Per cent	4·2	....	4·4	....	4·4	......
Ash ... "	10·0	10·5	11·5	12·0	10·0	10·5
Volatile matter ... "	32·8	34·2	32·9	34·4	33·4	34·9
Fixed carbon (by difference) .. "	53·0	55·3	51·2	53·6	52·2	54·6
Ultimate analysis:						
Carbon ... "	....	....	69·5	72·8	....	....
Hydrogen ... "	....	....	4·7	4·4	....	....
Ash ... "	....	....	11·5	12·0	....	....
Sulphur ... "	0·3	0·4	0·4	0·4	0·4	0·4
Nitrogen ... "	....	....	1·0	1·0	....	....
Oxygen (by difference) ... "	....	....	12·9	9·4	....	....
Calorific value:						
Calories, per gramme, gross	6,805	7,110	6,670	6,975	6,810	7,120
B.T.U. per pound, gross	12,250	12,800	12,000	12,560	12,260	12,820
Fuel ratio, fixed carbon, volatile matter.	1·60		1·55		1·55	
Carbon-hydrogen ratio	....	....	14·8	16·5	....	....
Coking properties	Agglomerate		Agglomerate		Agglomerate	
Softening temperature of ash, °F	2290		2280		2295	

13721—Run of 5 tons of hand-screened slack coal.
13722—From last 5 tons mined in year 1934.
13723—From last 5 tons mined in this season, 1934.

Five-finger Mine

The Five-finger mine is on the east bank of Lewes river, 15 miles below Carmacks by river, or 8 miles in a direct line. The mine is abandoned and its workings filled with water. The information here given with regard to it is summarized from reports by Cairnes[1] who visited it in 1907. "Some years ago a slope was sunk about 350 feet and rooms driven off it on the best seam so far found in these measures, and which dips at 16 degrees to the east; the seam in the lower rooms being 3½ to 4 feet thick. A considerable amount of coal was mined and sold, chiefly in Dawson, but the workings have now been closed for several years.

"As the top of this old slope is subject to mud slides—being situated in the steep clay and sand bank of the river—when work was re-commenced in 1906, under new management, it was on safer ground—some distance south. Here a new slope was sunk 783 feet on a seam higher in the measures than the seam in the old workings, and which also dips at 16 degrees to the east. This seam—which in places in the slope is not more than 6 inches thick—at the bottom contains 22 inches of good clean coal, and 24 inches of coal and shale.

"During 1907 and 1908 very little work was done on this property. In the former year a 25-foot winze was sunk at 450 feet down the new slope to a seam of coal 4½ feet thick, which is apparently the same seam as that in the old slope. Since 1908 the mine has been closed.

"The following samples were taken by the writer: sample A is an average of the 22 inches of good coal in the bottom of the 783-foot slope;

1 Cairnes, D. D.: Geol. Surv., Canada, Sum. Rept. 1907, p. 30. "Lewes and Nordenskiöld Rivers Coal District"; Mem. 5, p. 53.

and B is an average of the bottom of the 26-foot winze. Assayed by the Mines Branch, Department of Mines, at Ottawa, these samples gave the following results:

Sample	A	B
Water	5·95	5·29
Volatile combustible matter	40·46	36·14
Fixed carbon	45·16	40·12
Ash	8·43	18·45
	100·00	100·00
Coke per cent	53·59	58·57
Character of coke	Firm Coherent	....
Ratio of volatile combustible to fixed carbon	1 to 1·11	1 to 1·11
Colour of ash	Reddish	Reddish
Kind of fuel	Coal	Coal "

Other Localities

Coal has been reported from two other localities. One of these on the west bank of Lewes river, 5 miles above Selkirk, was reported by Cairnes[1] to display bituminous coal of good quality. This locality was examined by the writer in 1933. The workings formerly consisted of a shaft now filled with water, probably 20 to 30 feet deep, and an adit, now caved in, at the water's edge. Both dumps are small and composed of black shale in which a few pieces of coaly shale or poor coal occur. On the bank is an outcrop of conglomerate containing plant fragments. The shale and conglomerate strongly resemble those of the upper part of the Laberge series and may very well belong to the Laberge coal horizon. The coal-bearing beds probably extend beneath the Selkirk volcanics which outcrop 50 yards to the west but only for a comparatively short distance, as intrusives believed to be younger than the Laberge series outcrop within a mile on almost all sides.

It has been known from the beginning of the century that coal float occurs in the gravels of Mica creek, and McConnell[2] mentions that "a shaft sunk on an easterly branch of Mica creek, about 8 miles from the Pelly, is reported to have passed through several small seams of lignite." The easterly branch mentioned by McConnell is Ptarmigan creek. This locality was visited by the writer in 1934. At the forks of Ptarmigan creek the ruins of two old cabins with the stone chimneys and fire-places characteristic of the first years of the century were found. The creeks follow a canyon-like valley 200 to 300 feet deep in which no outcrops were observed, the walls appearing to be composed entirely of glacial drift. A few hundred yards up the branch coming from the southwest side of Ptarmigan mountain, old piles of logs apparently cut for mine timber were discovered. The workings were probably located on the south

[1] Cairnes, D. D.: Geol. Surv., Canada, Guide Book No. 10, p. 91 (1913).
[2] McConnell, R. G.: Geol. Surv., Canada, Sum. Rept. 1902, pt. A, p. 38.

side of the valley where a small slide has occurred. This branch of Ptarmigan creek contains a quantity of fragments of black and carbonaceous shales and some coal float. A piece of a fossilized tree trunk was also noted. No sign of a dump from the workings was found. The shales in the creek bed are believed to come from the Laberge series, but although no outcrops were found close to this locality the bedrock is believed to be of the Yukon group which outcrops within a few miles on all sides. It is thought that the coal and the Laberge rocks occur only as fragments in the glacial drift. If they do occur in place, the area of coal measures must be very small and the strata must form a small down-faulted block.

The chief reserves of coal in the district occur in the areas of the Tantalus formation and the upper part of the Laberge series in the vicinity of Carmacks and the old Five-finger mine. These areas are probably the most accessible areas of good coal in Yukon. The measures occur at the surface over an area of approximately 25 square miles, all of which is within 5 miles of Lewes river. The number of coal seams in these coal measures is not known, but at least six seams of workable size and quality are present. An additional area in which coal is likely to occur is that of the Tantalus formation on the southwest side of Lewes river south of Minto. This area could best be explored by drilling.

INDEX