MEMOIR No. 31

WHEATON DISTRICT

YUKON TERRITORY

BY

D. D. CAIRNES

GEOLOGICAL SURVEY

DEPARTMENT OF MINES

OTTAWA

1912

With the Compliments of the Writer.

L. J. WEEKS

WHEATON DISTRICT

YUKON TERRITORY

BY

D. D. CAIRNES

1910

Prepared at Yale University, U.S.A., in part fulfilment of the requirements for the degree of Doctor of Philosophy.

CANADA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BRANCH

Hon. Robert Rogers, Minister; A. P. Low, Deputy Minister;
R. W. Brock, Director.

MEMOIR No. 31

WHEATON DISTRICT

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OTTAWA
GOVERNMENT PRINTING BUREAU
1912

22286—A

No. 1228

To R. W. Brock, Esq.,
Director, Geological Survey,
Department of Mines.

Sir,—I beg to submit the following memoir on Wheaton district, Yukon territory. A geological and topographical map accompanies the report.

I wish to express my indebtedness to Dr. J. D. Irving, Professor of Economic Geology; Professor L. V. Pirsson, Professor of Physical Geology; Dr. J. Barrell, Professor of Structural Geology; and Dr. I. Bowman, Assistant Professor of Geography; all of Yale University, for their advice and suggestions, in connexion with the preparation of all portions of this report.

I have the honour to be, Sir,
Your obedient servant,

(Signed) **D. D. Cairnes.**

Ottawa, May 30, 1910.

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NOTE.—The above geological map is only preliminary; the regular geological and topographical maps—now in preparation—will be issued later on.

WHEATON DISTRICT

YUKON TERRITORY

BY

D. D. Cairnes.

INTRODUCTORY.

GENERAL.

During the last few years, Wheaton district has been attracting considerable attention, chiefly on account of finding there—in numerous localities—quartz veins carrying gold, silver, and antimony minerals. During the summer of 1906 the writer examined, and made a reconnaissance map of, a portion of the Conrad and Whitehorse mining districts[1]: which includes the eastern part of this tract; but since then, new discoveries of valuable deposits of minerals have been reported from there, as well as from other parts of the area. In view of these facts, the writer received instructions from the Director of the Geological Survey, to make a careful study, and to prepare a topographical and geological map, of the whole district. The objective of the present report is, to give the results obtained from the performance of this work; which tend to show that this undeveloped field promises to become one of the more important mining districts of southern Yukon.

A base line,[2] about 2 miles long, was measured along a tangent on the White Pass and Yukon railway, commencing about half a mile north of Robinson; and from this base a triangulation was extended over the district. The topography was filled in chiefly

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[1]Cairnes, D. D.—"Report on a portion of the Conrad and Whitehorse mining districts": Geol. Surv. Branch, Dept. of Mines, Can., 1908.

[2]A 300 ft. steel tape was used in measuring this base. The pull on the tape, when used in measuring, was always 16 lbs.; the temperature of the tape was taken for each tape-length; the hubs were all carefully levelled; and all the other necessary precautions were taken to have the results of this work of the requisite degree of accuracy.

by the phototopographic method, supplemented by plane-table traversing. The plane-table method was also employed in surveying all roads, trails, etc.

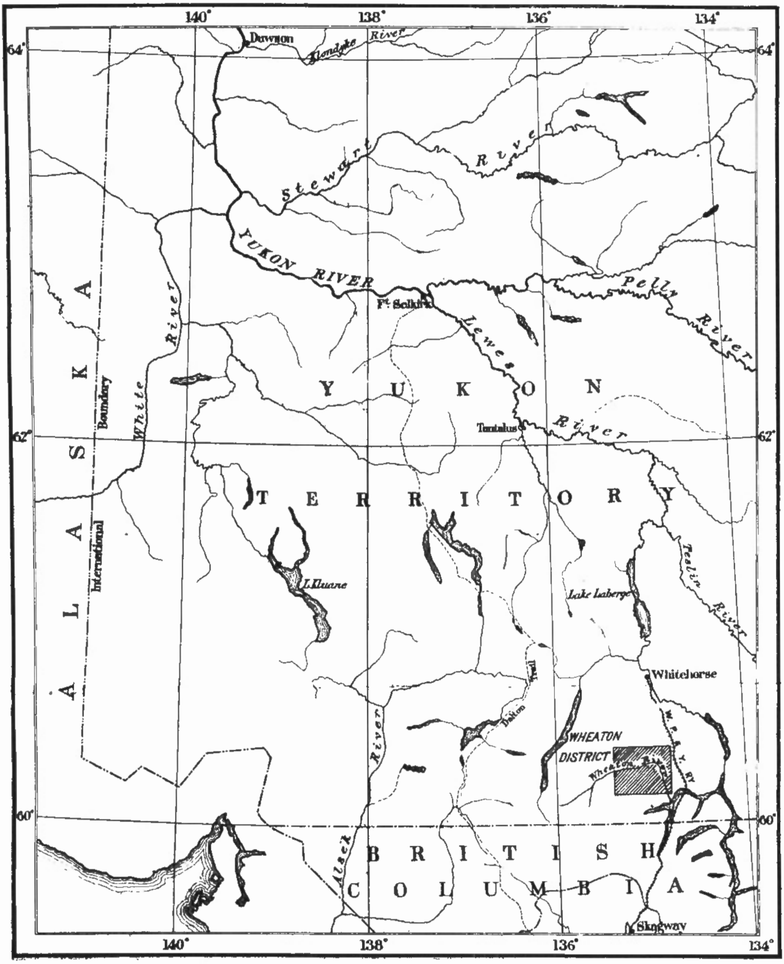
The survey was conducted during the favourable months of the summer of 1909; and during the season the writer was assisted by Messrs. E. W. Banting, B.A.Sc., of Toronto University, and W. A. Bell, of Queens University, who performed in an efficient manner the greater part of the topographical portion of the work. Mr. Bell also assisted, at times, in geological work.

LOCATION AND AREA.

Wheaton district, as shown by the accompanying sketch map (Diag. 1), lies in Yukon Territory, just north of the British Columbia boundary, and Wheaton river, in the lower part of its course, flows in a general direction almost due south and empties into Lake Bennett. Twelve miles above its mouth, the river turns abruptly to the west, forming what is known as the 'Big Bend of the Wheaton,' and from near its head-waters to this point has an easterly, to northeasterly trend. The tract described in this report as Wheaton district embraces that portion of southern Yukon extending 5 to 7 miles on each side of Wheaton river, commencing at Big Bend and continuing about 20 miles upstream. This area includes all the known discoveries of ore, of economic importance, which have been made within several miles of this river, on either side. The area is approximately 20 miles long in an east and west direction, and 15 miles wide from north to south. It flanks the mountains of the Coast range on their eastern side, and extends eastward to longitude 135° 53′, or to within 6 miles of the White Pass and Yukon railway. Its southern edge is from 12 to 15 miles north of the 60th parallel of latitude (the British Columbia-Yukon boundary).

MEANS OF COMMUNICATION.

Wagon roads have been constructed, by the Yukon Government, from Robinson, on the White Pass and Yukon railway, to many parts of the district. One road extends along Wheaton river to Carbon hill which is situated in the most westerly portion of the area, and is between 30 and 35 miles distant from Robinson. A branch from this main road has been built to Stevens' camp, near the summit of Mt.



Diag. 1. Portion of Yukon Territory showing position of Wheaton District.

Scale

STATUTE MILES

22286—p. 2.

Stevens. Another road, 20 miles long, has been constructed from Robinson to Gold hill which lies 3 to 4 miles north of Wheaton river and midway between the latter and Watson river. It will, therefore, be seen that all parts of the district are easily accessible, and that only short, easily constructed, branch roads are necessary to connect all the claims, not already so connected, with the railway.

Robinson is 78 miles, by rail, from Skagway, Alaska, whence several lines of well equipped steamships sail regularly to Vancouver and Seattle, distances of 867 and 1,000 miles, respectively.

HISTORY.

During the years 1895-8 when the influx of gold-seekers to the Klondike was at its height, great numbers of men passed down Lake Bennett, Nares lake, and Lake Tagish, the head-waters of Yukon river, on their way to Dawson. This main line of travel was thus within 6 miles of the southeast corner of Wheaton district. In succeeding years a great number of people followed the same route until 1903, when the White Pass and Yukon railway was completed, and it is probable that occasional prospectors, hunters, and trappers strayed to the west along Wheaton river. The earliest prospecting or exploring in this vicinity of which there is definite record, however, was performed by Frank Corwin and Thomas Rickman.

These two prospectors spent part of the summer of 1893 in the district, and located a number of claims on Carbon hill, Chieftain hill, Idaho hill, and perhaps elsewhere. They did considerable prospecting on some of their claims, particularly on those situated on Carbon hill, where a number of old cuts, trenches, etc., made at that time can still be seen. Returning afterwards to Juneau, with good samples of antimony ore obtained on Carbon and Chieftain hills, and also with some very rich gold-quartz which assayed over $1,200 per ton, they reported their finds, which they apparently believed to be of considerable value, to the manager of the Treadwell mines; but before any steps had been taken to investigate their discoveries, both prospectors died suddenly without having disclosed the exact location of their claims.

Numbers of men searched for these discoveries of Corwin and Rickman, but it was some years before any of them were found. In 1898, Mr. W. F. Schnabel and others discovered one of the old camps, on Schnabel creek, but were unable to find the rich ore. Some quartz veins were, however, located on Idaho hill, to the north of and adjoining Schnabel creek. These claims were more or less continuously held until 1903, when four others were staked, two of which are still held by Mr. Schnabel and partners, and comprise the Union mines. Original location notices of Corwin and Rickman have been found on these claims; but ore similar to the samples of gold-ore taken to Juneau by these early prospectors has, so far, been discovered only at Gold hill which is 4 miles to the west of Idaho hill.

With the exception of the Union mines, Wheaton district was but little known until the summer of 1906. During the early part of that season the discovery of quartz carrying free gold and gold-silver tellurides on Gold hill, by D. Hodnett and J. Stagar, created considerable excitement which resulted in the staking of over 500 claims in 90 days in Wheaton district. The first claim located was the 'Gold Reef' on Gold hill, staked June 21. A number of the claims staked at this time are still held, and most of these are located on Gold hill, Mt. Hodnett, Mineral hill, Big Bend mountain, and Mt. Stevens.

In August of this same season, while prospecting farther up Wheaton river, to the west of the belt in which these discoveries had been made, Mr. H. E. Porter found the old locations and workings of Corwin and Rickman on Carbon and Chieftain hills, and immediately staked eighteen claims in the vicinity. A stampede to this locality ensued, and a great number of locations were made, a large proportion of which are still in force.

The only descriptions of Wheaton district. that have been published, refer chiefly to the eastern part of the area, and are embodied in a report of work performed by the writer during the season of 1906.[1]

[1]Cairnes, D.D.—Summary Rep. Geol. Surv., Can., 1906.—"Report on a portion of the Conrad and Whitehorse mining districts, Yukon Territory" 1908, Geol. Surv. Branch, Dept. of Mines, Can.

SUMMARY AND CONCLUSIONS.

TOPOGRAPHY.

Wheaton district is a portion of what is believed to be an uplifted and deeply-dissected peneplain, the valleys of which have been greatly modified by glacial action, and as the extent of undissected upland is generally in excess of the eroded portions, considerable areas of gently rolling plateau remain.

In apparently late Tertiary time, after being maturely eroded during a long period of crustal stability, the region was uplifted over 3,600 feet. The uplift, which was of the nature of an upwarp, since the movement was greater in the western than in the eastern portions of Wheaton district, gave renewed life and energy to the streams which soon made deep incisions in the uplifted surface. Glacial ice then invaded the district, and occupied all the main depressions which were both widened and deepened, and given typical U-shaped cross sections; and such well known forms as cirques, hanging-valleys, roches moutonnées, terraces, pot-holed valley-floors, etc., were produced. Morainal and other materials were deposited in the valley bottoms, and blocked the stream-courses in different places to such an extent that, as yet, the drainage system has not become completely graded, and numerous lakes, often surrounded by muskeg or tundra, occupy a number of the depressions.

Since the retreat of the ice, V-shaped incisions have been etched in the valley-walls and at the margins of the upland-surface, resulting in the production between them of pronounced facetted forms. The main streams have also somewhat depressed their channels in the unevenly distributed valley-floor deposits, so that occasional sand, gravel, silt, or clay banks and terraces occur. Otherwise the topography is virtually as the ice left it, and the forms which resulted from the action of valley-glaciation still exist in an unusual state of perfection, so that this district is a most favourable one in which to study glacial phenomena.

GENERAL GEOLOGY.

The district is situated along the eastern edge of the Jurassic, Coast Range granitic batholith, and the rocks composing this igneous mass are exposed over the greater part of the area. In the western part of the district, more recent volcanics of Tertiary, and perhaps late Cretaceous age have invaded, and covered, the granitic rocks to a considerable extent, while in the northeastern corner, Jura-Cretaceous sediments overlie them. In numerous localities dykes and other small intrusives, as well as some extrusive volcanics occur, that are more recent than the granitic batholith. Otherwise, the rocks of Wheaton district consist of the Jurassic granitic materials and small areas of the rocks into which these have been intruded; and a study of the structural features of the batholith, its methods of invasion, and its relation to these older rocks constitutes the main, and perhaps the most interesting problem in the study of the general geology of the district.

The present surface of the eastern portion of Wheaton district very nearly coincides with the original top of the batholith, so that there a few remnants of the roof still exist. Portions of walls of older materials that separate subjacent portions of the granitic mass extend in a northwesterly direction, parallel to the edge of the intrusive mass, and are incised by the stream-valleys to depths of between 3,000 and 4,000 feet. Scattered over the eastern portion of the district are numerous small, isolated masses of the old invaded materials which are distinctly seen to be inclusions, as they occur at all elevations. Toward the west, and thus toward the centre of the batholith, all traces of these older rocks disappear, since the granitic mass rose considerably higher along its axial line than along its margins, and, therefore, the roof and included older materials have there all been removed by erosion.

The principal method of mechanical batholithic invasion appears to have been that of the breaking free of roof-fragments, and their sinking in the molten material which possibly rose to fill the spaces the detached blocks originally occupied. The magma may have exerted a pressure on its containing walls greater than their resisting strength, and so, to some extent, pressed them apart to make room for itself. However, the intruded rocks are all plutonics without any known connected contemporaneous flows, and remnants still exist of a cover which apparently originally completely roofed the batholith.

Further, granitization has not taken place in the portions of the roof that still remain, and there is no evidence that material was added to the original cover, so as to allow of its lateral extension during the invasion-process. It is thus not considered that the pressing apart of the walls has been a dominating factor in the batholithic invasion, since it is difficult to conceive that a roof could have remained over this igneous mass which is 30 to 40 miles wide, if its walls were forced apart this distance—particularly as no mashing or foliation has been caused by the magmatic invasion.

ECONOMIC GEOLOGY.

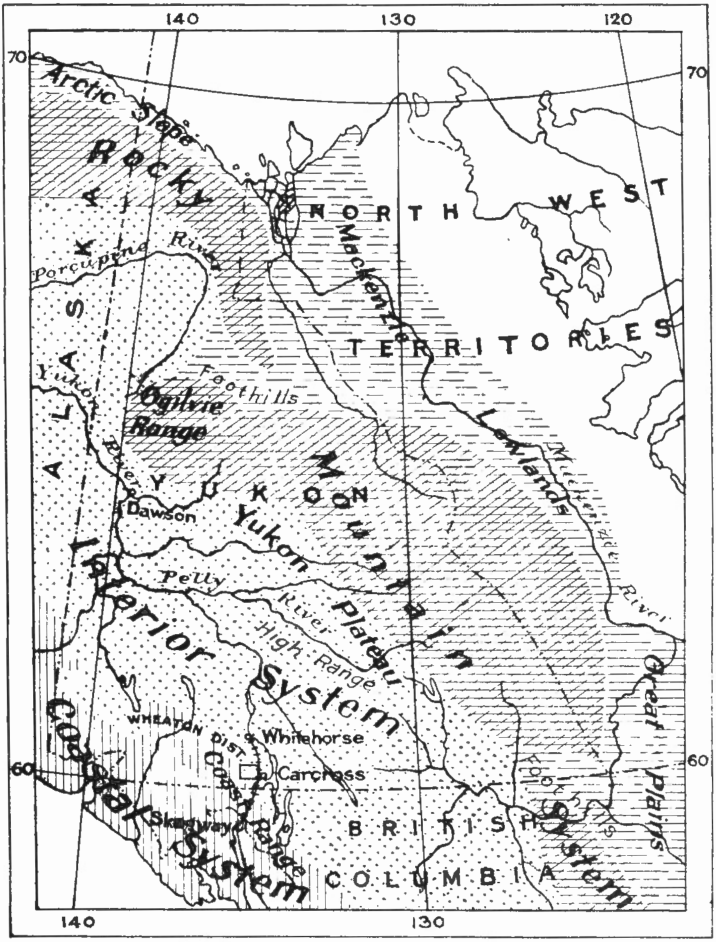
From the standpoint of economic geology, Wheaton district is chiefly of interest for its ore-deposits, but, in addition, some coal-seams have been discovered. The ore-deposits may be considered as belonging to four classes, viz.:—

(1) Gold-silver quartz veins.
(2) Antimony-silver veins.
(3) Silver-lead veins.
(4) Contact-metamorphic deposits.

The gold-silver veins are the most extensive, and are of particular interest in that they contain not only native gold, but various tellurides. The gold content of these ores is generally of considerably greater value than the silver. The antimony-silver veins belong to a rare type of deposit, in that they are antimony deposits the ores of which contain both antimony and silver in economically important amounts. Such deposits are known in only a few localities in the world, and have been named in Germany the 'Mobendorf type.' The silver-lead veins contain silver and lead in important amounts, and are mainly metasomatic replacement deposits. They thus differ considerably from the two types of veins just mentioned, which are prevailingly cavity-fillings. The contact-metamorphic deposits have been discovered on only one claim, but are noteworthy since, although the mineral-combination, the form of occurrence, etc., are those usually encountered in such deposits, the formation in which the ore-materials occur is a calcareous hornblende-gneiss. Limestone is the usual rock in which such secondary ore-materials are produced, and occurrences in quartzite and shales are known, but the occurrence of contact-metamorphic deposits in a gneiss of purely igneous origin is believed to be something new in the history of ore-deposits. Economically the ores are of interest, mainly on account of the copper they contain.

Seams of semi-anthracite coal, from a few inches to several feet in thickness, were discovered by the writer on the eastern face of Mt. Bush; these have not been at all developed so far, but should prove of local value.

Few of the mineral deposits have been at all closely prospected, so that little is really known concerning the mining properties of this district; and the area, as a whole, has been only very superficially looked over by a few men, so that it is improbable that all the better deposits of ore have yet been discovered.



Diag. 2. The physiographic provinces of Yukon.

NOTE.—The small square indicates position of Wheaton district.

GENERAL CHARACTER OF THE DISTRICT.

TOPOGRAPHY.

General Account.

REGIONAL.

Yukon territory is, for the greater part, divisible into three physiographic provinces which are continuous with similar divisions in northern British Columbia, to the southeast, and Alaska, to the west. Taken in order from southwest to northeast these are: the Coastal system, the Interior system, and the Rocky Mountain system. These terranes constitute the Cordillera of the northwestern portion of North America, and follow in a general way the configuration of the coast line. They, thus, all have a northwesterly trend in British Columbia, a westerly trend through Alaska proper, and in Yukon, in between, follow a course intermediate between the two. Lying to the north, northeast, and east, of the Rocky Mountain system are various plains or lowland tracts—the Arctic Slope region, the Mackenzie lowlands, and areas of broken, wooded, plains possibly belonging to the Great Plains (see Diag. 2).

From about the 50th to near the 60th parallel, the Coastal system embraces only the Coast range, if the island range to the west is considered to be part of the Coast range,[1] but the simplicity of this western province is interrupted near the head of Lynn canal, whence northward and northwestward, the Coastal system consists of two or three main ranges in some instances separated by wide valleys, as well as other subordinate mountain masses. The Coast range, after following the coast line from Mexico to near the head of Lynn canal, a distance of over 2,000 miles, passes behind St. Elias range, and, for the remainder of its course northward, constitutes the most easterly portion of the Coastal system; north of Lynn canal, the range gradually becomes less prominent, until it merges into the Yukon plateau, near Lake Kluane, at latitude 61° and longitude 138° 30′.

The Coast range consists, in a general way, of an irregular complex of peaks and ridges, that possess but little symmetry other than

[1]Dawson has separated the Vancouver range from the Coast range: Trans. Roya Soc. Canada, 1890, Vol. 8, sec. 4, p. 4.

a rough alignment parallel to a northwesterly-trending axis. The range has everywhere a precipitous and jagged aspect, and consists largely of knife-like crests, rugged or even needle-like summits, and sharply incised valleys. The summits in southern British Columbia rise to uniform altitudes of from 8,000 to 9,000 feet above sea-level, but toward the north gradually decrease in elevation, until in Yukon they stand at only 5,000 to 6,000 feet; though the change in altitude is apparently great, it is so gradual as not to break the general uniformity of summit-level which, however, bears no relation to structural features. This terrane has thus been considered by a number of geologists[1] who have studied it topographically, to represent a peneplanated or at least a mature to old surface of erosion, subsequently elevated. Other geologists, however, maintain that this terrane shows no evidence of having ever been peneplanated.

The great interior upland which has been designated the Yukon plateau, is a northern member of the Interior system of plateaus and mountains, which extends through British Columbia, Yukon, and Alaska to Bering sea. The Yukon plateau, which in Yukon Territory is 250 to 300 miles wide, follows Yukon river from its headwaters to the sea, and stretches from the inland members of the Coastal system to the ranges of the Rocky Mountain system. In northern British Columbia, some well-defined ranges lie within this Province,[2] and in Yukon and Alaska numerous individual peaks and minor ranges[3] rise above the plateau-level.

Into this upland-surface, in Yukon territory, the drainage courses have incised channels, varying from 1,500 to 4,000 feet in depth, giving a very irregular topography. The summits of the unreduced hills and ridges, lying between the waterways, mark a gently rolling plain which slopes toward the north and northwest. The plateau is best seen from a summit that stands at about the level of the upland, when the observer will be impressed with the even sky-line, sweeping off to the horizon, and broken only here and there by isolated, residuary masses that rise above the general level. So even and flat-

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[1]Dawson, G. M.—"Report on the area of the Kamloops map sheet, B.C.": Ann. Rep. Geol. Surv., Can., Vol. VII, 1894, p. 10 B.

Hayes, C. W.—"An expedition through the Yukon district": Nat. Geog. Mag., Vol. 4, p. 128.

[2]Dawson, G. M.—"Report on an exploration in the Yukon district, N.W. T., and adjacent portions of British Columbia": Ann. Rep. Geol. and Nat. Hist. Surv. of Can., Vol. III, pt. I, p. 13 B.

[3]Fortymile atlas sheet, U.S. Geol. Survey.

Spurr, J. E.—"Reconnaissance in southwestern Alaska": 20th Ann. Rep. U. S. Geol. Surv., pt. VII, 1898-99, pp. 238-242.

topped are the interstream areas, that they might in places be mistaken for constructional surfaces. This plane, however, bears no relation to rock-structures, erosion having bevelled the upturned edges of the hard as well as the soft strata; in fact its surface is entirely discordant to the highly contorted, metamorphic rocks that make up much of the plateau, and, as is more fully discussed later, is evidently an uplifted and dissected peneplain, produced by long continued subaerial erosion during a period of crustal stability. This plateau-province near the head-waters of the river stands at about 6,000 feet above sea-level.

Along the northern portion of the Coast range the general summit-level merges into that of the Yukon plateau, in a manner suggesting the synchronous planation[1] of these two provinces, a view that is held by Brooks, Spencer, and others; but during the various vertical movements that have affected these terranes, the uplift has been greatest along the axis of the Coast range, and least along that of the Yukon plateau, which terrane is thus given the contour of a huge flaring trough whose axis is in a general way marked by the present position of Yukon river from near its head-waters in northern British Columbia to Bering sea.

Wheaton district, as here considered, occupies a position along the western edge of the Yukon plateau, thus flanking the Coast range on the east; and the northern boundary of this area is only 12 to 15 miles north of the 60th parallel. There exists here no distinct line of demarcation between plateau and mountain province; but the more rugged, western, granitic portion is, for geological and topographical reasons, assigned to the Coast range, and the territory to the east is considered as belonging to the plateau.

LOCAL.

The description just given of the Yukon plateau, in general, aptly applies to that portion of it represented by Wheaton district, where the striking features of the topography are the elevated and but slightly undulating, plain-like character of the land-surface and the numerous, irregularly distributed, wide, deep, steep-walled valleys that dissect it. This upland-surface here, as elsewhere in the Yukon plateau, bears no relation to rock-structure, and

[1]Spencer, A. C.—Bull. Geol. Soc. Amer., Vol. 14, p. 132.
Brooks, A. H.—Prof. Paper, No. 45, pp. 286–290, U. S. Geol. Survey.

the greywackes, granites, schists, limestones, andesites, etc., have been truncated, regardless of their respective degrees of hardness or their structural features (Fig. 1).

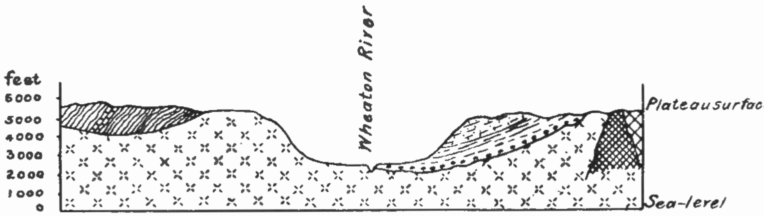

Fig. 1. Diagrammatic section showing the plateau-surface truncating the different rock formations, and cut by Wheaton River valley.

In spite of dissection and erosion, the plateau-surface is, in many places, well preserved, and it is easy for one standing on its surface, well back from the edges of any valley wall, his field of vision including the upland, but entirely above the deeply trenched valleys of the district, to picture the depressions refilled, or to forget that they have ever existed. The topography, as seen from such a vantage point, has very slight relief, and, obviously, was produced by a long-continued period of erosion, at the end of which a mature to old stage, in the physiographic cycle, was reached.

Nearer the edges of the present valleys, pronounced topographic unconformities[1] everywhere meet the eye. Chieftain hill (Plate XIII) is a typical locality; small creeks have incised the eastern side of the hill, so as to produce a number of long points which extend from one-fourth to one-half mile toward Wheaton valley. The surfaces of these ridges have the gentle grades characteristic of a mature topography, but on nearing the edge of the valley conspicuous shoulders are encountered, beyond which are abrupt descents to the lowland of the river. These mountain spurs, if traced backward to the main mass of the mountain, are there seen to unite to form an even and slightly undulating plain, which is a portion of the upland-surface of this area. It is thus quite apparent that the plateau represents a land-surface which formerly must have stood at a considerably lower elevation than at present, and after being maturely eroded was uplifted to its present elevation.

[1]Salisbury, R. D.—"Three new physiographic terms"; Jour. Geol., Vol. 12 pp. 707–715, 1904.

Occasional hills rise above the general level, such as Mt. Bell and Mt. Reid, which represent the only considerable unreduced masses that erosive agencies left standing above the old surface. The uplift of the region interrupted the base-levelling process at this point, so that now these generally rounded, mountain remnants occur as monadnocks, rising above the surrounding upland.

The upward warping of the district rejuvenated the streams, so that they at once commenced actively cutting and sinking their channels in their elevated valleys, and deep incisions were rapidly produced. In Wheaton district two main valleys and numerous tributaries dissect the plateau. The larger and more important of these master-depressions, Corwin valley, is from 1 to 2 miles wide, and trends in a direction a few degrees east of south. This valley follows the eastern edge of the district, and extends beyond both its northern and southern boundaries. The lower reaches of Wheaton river follow this depression, but at Big Bend the river turns at about right angles to its previous course and, from near its head-waters to this point, flows in a much narrower valley, only one-fourth to one-half mile wide, which maintains a general northeasterly course. In addition to these two principal depressions, there are a few tributary valleys, such as those occupied by Fenwick and Becker creeks, which are of considerable length and deeply cut into the upland.

Glaciation accentuated the topography produced by peneplanation and subsequent uplift and dissection. Glacial ice occupied the main valleys and was effective in deepening and widening these main depressions, steepening their walls, and giving them decided U-shaped cross-sections; while subordinate masses of ice existed in the larger tributaries and affected them to a corresponding degree. At the heads of some of the streams well-defined cirques were formed, in a number of which small, round lakes occur. A hanging relation,[1] due to glaciation, was also produced at the mouths of tributary streams, the channels of which were once occupied by ice; the smaller the tributary the less the amount of ice it contained, and the greater the amount by which its valley was left hanging above that of the master stream. The result is that the smaller streams, as Stevens creek on Mt. Stevens, while flowing over the upland-surface, have the wide,

[1]This will be more fully discussed in the portion of this chapter on topography under 'Detailed Account'.

flaring valleys and gentle grades characteristic of a mature topography; but on coming to the edge of the plateau-platform, they plunge suddenly over the edges, by a succession of falls, through exceedingly steep-sided gorges, to join the master streams below.

The ice also acted in a constructional capacity and contributed a vast amount of morainal and other material, consisting of gravels, sands, silts, clays, etc., which have to a great extent filled these depressions. Since the retreat of the ice, the streams have been at work removing this material, but Wheaton river has not, as yet, succeeded in trenching its channel to bed-rock. The bed of the stream is from 2,000 to 2,500 feet below the general level of the plateau-surface.

A striking feature of the main depressions is the terraces that occur in many places, and at various elevations up to 700 or 800 feet above the valley bottom. These can be traced in some instances almost continuously for several miles.

Detailed Topography.

RELIEF.

The Upland-surface.—The upland-surface of Wheaton district, to be observed to the best advantage, must be viewed from inter-stream points back from the edges of the master-valleys, and from such positions the even, gently rolling character of the plateau is strikingly apparent. This surface bears no relation to rock structure, and the pre-Devonian, contorted schists and gneisses, the massive Jurassic grano-diorites, the Jura-Cretaceous sandstones, shales, conglomerates, etc., and various volcanics, are all equally truncated, regardless of their structure, hardness, composition, etc.

The upland thus represents a region that during a long period of crustal stability was almost completely base-levelled and was reduced to a state of old age, and at the time of planation must have formed a portion of a plain whose edge was at, or nearly at sea-level.

A few generally rounded summits, such as Mt. Bell, Mt. Pugh, and Mt. Reid, rise as monadnocks above the general level, and are the only conspicuous elevations that erosive agencies left to break the monotony of the former landscape. The base-levelling process which tended to reduce the entire district to sea-level was interrupted before the reduction of these remaining hills, by an uplift which

22286—p. 14.

Looking west from Mt. Pugh toward the Coast range of mountains. The gently rolling character of the upland is well seen, as it gradually increases in elevation and finally merges with the more rugged mountain to the west.

affected a great portion, at least, of Yukon territory and Alaska. The exact date of this movement is undeterminable in Wheaton district, as is discussed under 'Historical Geology.'

The amount of the uplift is also somewhat indefinite. Wheaton river at its mouth is about 2,100 feet above sea-level, and Lewes and Yukon rivers, which carry this water to the sea, have grades much in excess of rivers traversing a district in its old age. Further, it seems very improbable that the region, prior to the uplift, was drained by a longer water-system than the present circuitous one; in fact, recent investigations tend to show that the area was drained into the Pacific by a much shorter system. The general surface of Wheaton district was thus probably less than 2,100 feet above sea-level when the uplift commenced, while now the upland has an elevation of about 5,700 feet. The vertical extent of the movement was, therefore, greater than the difference between 5,700 and 2,100 feet or 3,600 feet, and was less than 5,700 feet; it probably was 4,700 to 5,200 feet in amount.

When the Yukon plateau and adjoining terranes were uplifted, at the beginning of the present erosion cycle, the land-surface was given the form of a broad, shallow trough sloping downwards from the east and west to a northwesterly trending axial line, approximately coinciding with the present position of Yukon river and its tributary, Lewes river. The results of this differential upwarp are well seen in Wheaton district, which lies to the west of this axial line, and whose surface consequently inclines upwards toward the west, until the mountains of the Coast range are reached (see Plate I). The level of the upland along Corwin valley, at the eastern edge of the district, is about 5,500 feet above sea-level; but at Mt. Reid, to the west, its elevation is 6,000 feet, a rise of 500 feet in 16 miles.

Some time after the uplift of the district, and the development of the present valley systems, a climatic change caused glaciers to form in the higher mountains to the west and south, and great tongues of ice moved from these gathering grounds down the main valleys of Wheaton district. The upland was, however, only little affected by these glacial streams, but the presence of occasional erratics and small patches of foreign materials show that, at least occasionally, bodies of ice did pass over portions of the plateau surface.

However, during Pleistocene and Recent times, the plateau surface, although but slightly modified by moving ice, has been considerably affected by accumulations of snow. At no time, apparently, did snow gather on the surface in sufficient quantities to form any considerable masses of ice, but for the most part it seems to have been blown by the winds into the valleys and depressions.

The effect of névé snow is to convert shallow V-shaped valleys into flat U-shaped ones, to efface their drainage lines without material change of grade, and to in this manner produce general smoothness of surface. Since the snowdrifts have no sliding motion, there is consequently no transportation of material by them; however, because of excessive frost-action, and continued alternations of freezing and thawing, the rocks at the peripheries of the quiescent snow are finely comminuted and removed by innumerable rills to fill neighbouring depressions. These effects of the occupation by quiescent névé, called nivation,[1] have resulted in grading, to a considerable extent, the already gently-rolling surface of the plateau in Wheaton district (see Plate II), and account for the great amount of fine material that fills all the minor depressions in the upland surface. The presence of the snow also tended to preserve the smooth outlines of the topography, by protecting the surfaces from stream action.

The Valleys.—After having considered the gently undulatory character of the upland, the observer will be impressed by the pronounced topographic unconformities that present themselves at the contacts of this surface with the high, steeply-inclined walls of the various valleys that intersect it (Plates III and VII).

The last great uplift, probably in Pliocene time, which affected this district, gave the streams of the district renewed life and energy, and they immediately began vigorously trenching their channels in the uplifted surface. Throughout the area deep incisions were rapidly made, which, in Pleistocene time, were invaded by glaciers from the mountains to the west and south. Although the ice produced but little effect upon the upland-surface, it had a profound influence upon the valleys.

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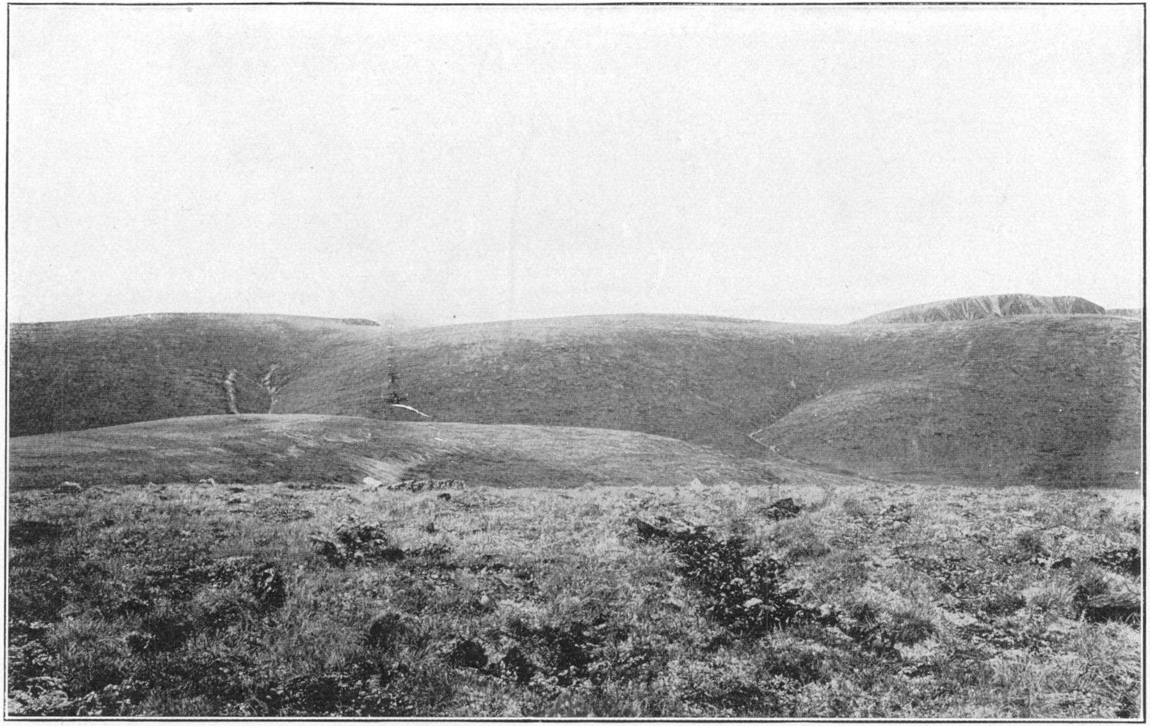
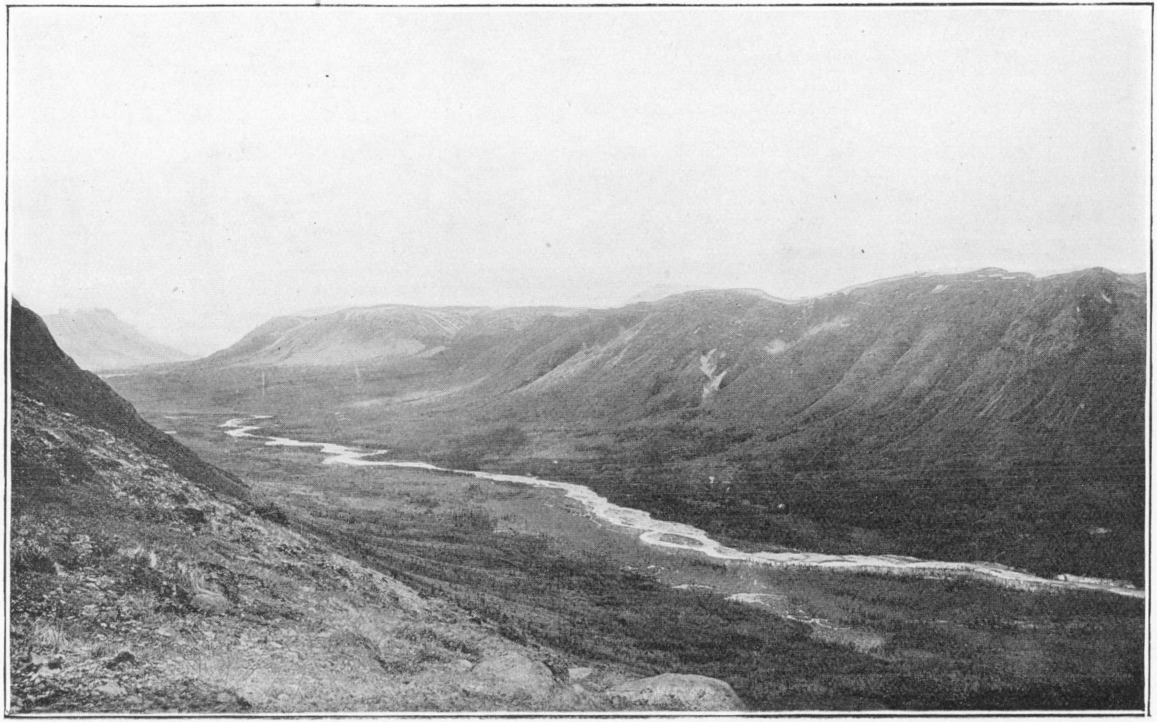
[1]Nivation in its different phases, relations, results, etc., is discussed in the two following articles:—

Matthes, F. E.—"Glacial sculpture of the Bighorn Mts., Wyo.": U. S. Geol. Surv., 21st Ann. Rep., pt. 11, 1899, pp. 173–190.

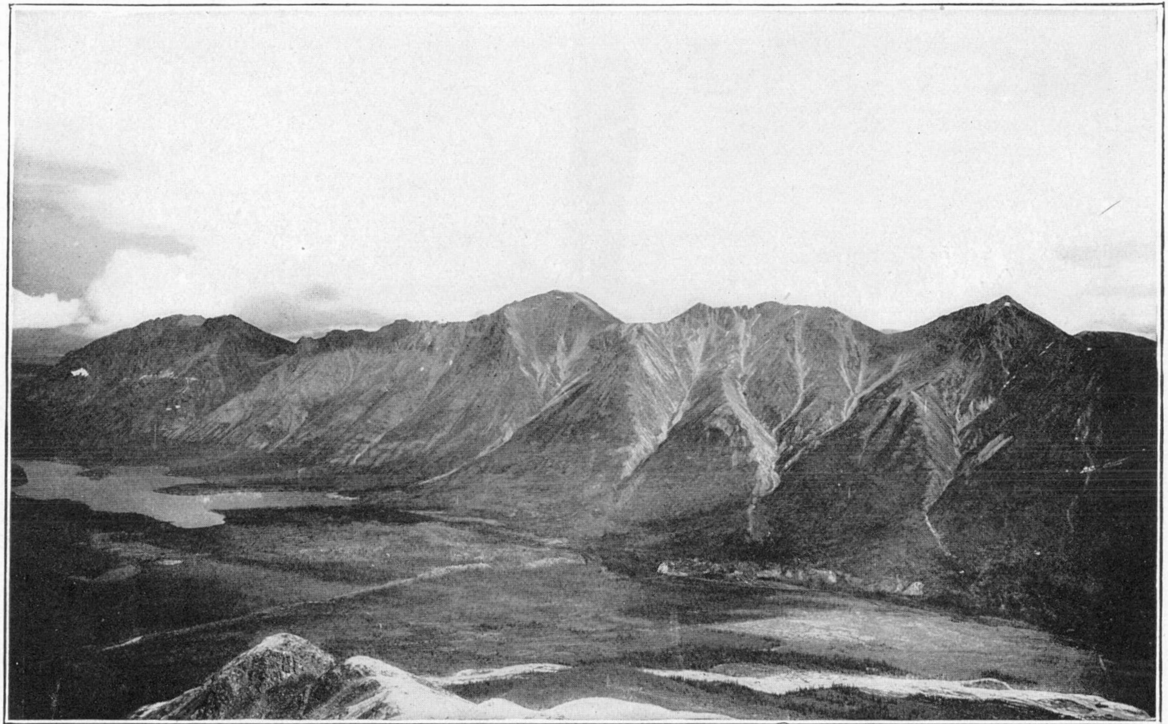
Hobbs, W. M.—"Cycle of mountain glaciation": Geog. Jour., Feb. 1910, pp. 147–163.



Showing the almost flat character of a typical portion of the upland surface, with its smooth, well-rounded slopes and stream gradients.



Looking in a southeasterly direction down Wheaton River valley toward "Big Bend". The view shows the pronounced U shaped character of the master valley, the even character of the upland surface, and the striking topographic unconformity displayed at the top of the valley wall.



Looking in an easterly direction across Corwin valley and Annie lake, at the western face of Gray ridge. The view shows the steep character of the valley walls with their pronounced facets, due to glacial truncation of marginal spurs, and post-glacial dissection by small tributary streams.

When a broad ice-sheet covers a district this has the effect of moderating the topographic features and reducing the relief, by eroding material from the higher elevations and depositing it in the depressions. However, where the ice occupies only the valleys, much greater and different results are seen. Here the interstream areas maintain their even character, unaffected by the ice, while the valleys are widened and deepened; and the maximum effects of glaciation are produced in areas such as Wheaton district, where the topography indicates that it has been previously prepared to receive the ice, by having deep valleys already made, in which the ice can most advantageously operate. The V-shaped valleys are then transformed into wide, deep, steep-walled, U-shaped depressions, and hanging-valleys, cirques, roches moutonnées, and other well known glacial forms are produced.

Corwin valley is the widest and most prominent depression in Wheaton district, the eastern portion of which it traverses in a northerly direction. This valley extends a number of miles beyond both the northern and southern boundaries of the district, and has within it a nearly flat floor, about 1½ miles in average width, from which the valley-walls rise abruptly over 3,000 feet to the upland surface. Wheaton river, below the 'Big Bend,' flows in this valley to Lake Bennett.

The ice moved northward through this depression, and for some reason, probably on account of numerous confluent streams from the west, the greater mass of the material seems to have pressed against the Gray ridge on the eastern side of the valley, where scouring and plucking have been greater than along the western wall. For 18 miles, along the entire length of this ridge, all points, spurs, and projections have been planed from the valley-wall, as by some huge instrument (see Plate IV). The western side of the valley is not nearly so regular, probably owing to the streams entering from this side, as just mentioned. The eastern wall of Corwin valley distinctly curves outwards toward the east opposite the point where Wheaton river joins it from the west; this was apparently caused by the excessive erosion at this point, due to the added weight of the confluent ice-stream.

Wheaton river above the 'Big Bend,' or the point where it joins Corwin valley, follows a southerly course, and occupies a somewhat irregular valley that has, however, a general northeasterly trend.

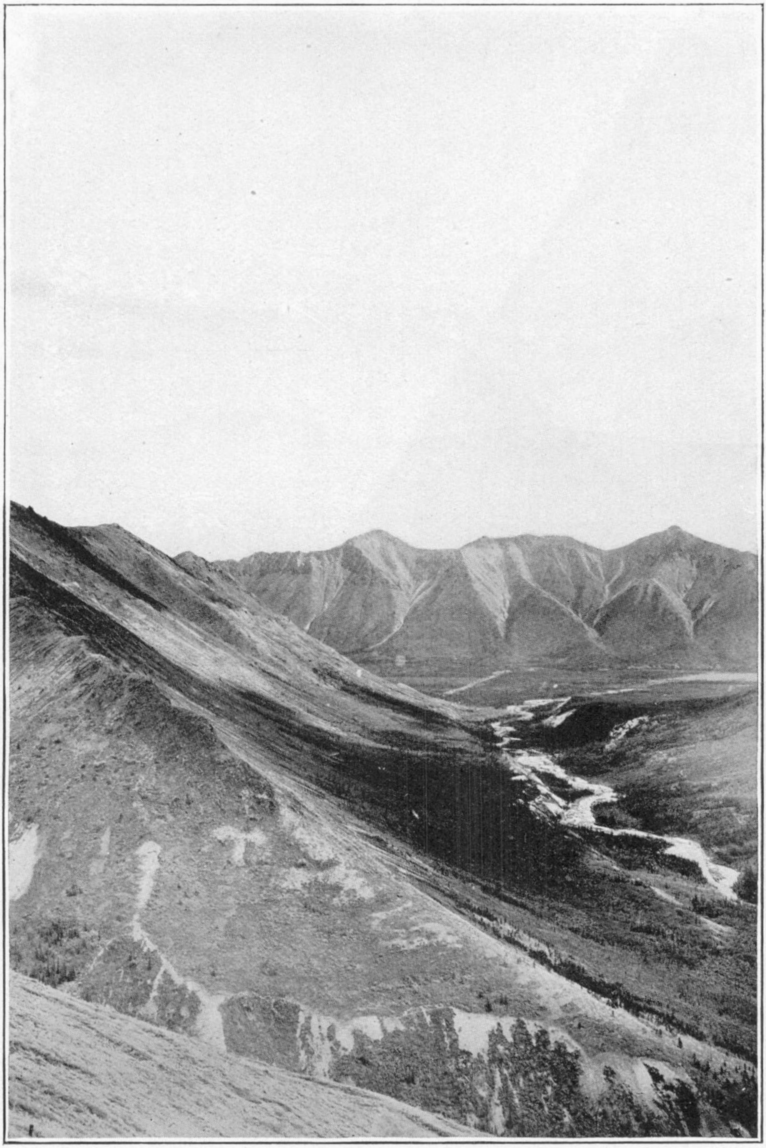
This depression is designated in this report 'Wheaton River valley,' as the river after which it is named traverses its entire length. This valley in Wheaton district has a floor that is generally from 2,000 to 4,000 feet wide, from which the walls rise abruptly for 3,000 feet to the plateau-surface which for 15 miles west of Corwin valley increases in elevation at about the same rate as the valley-floor. The valley has been greatly modified by ice which moved down it from the head-waters of the present river, truncated the spurs and other points projecting from its walls; and gave the valley a smooth, well-rounded, U-shaped form (see Plates III and V).

Hodnett Lakes valley is probably the most prominent of the higher, short valleys. It is about 6 miles long, trends westerly, has an average width of over 2,000 feet, and is divided at its western end by a long narrow granitic ridge. This depression is flat-floored, and its walls rise rapidly for about 2,000 feet to the upland surface. It joins at its eastern end with the narrower valley of Thompson creek, and connects, to the west, with Summit Creek pass which trends north and south, and constitutes a low divide between Wheaton and Watson rivers. The summit of this divide is at about the point where the pass is joined by Hodnett Lakes valley, and from there the grade falls rapidly to Watson and Wheaton rivers, to the north and south, respectively. The pass has an average width of about half a mile.

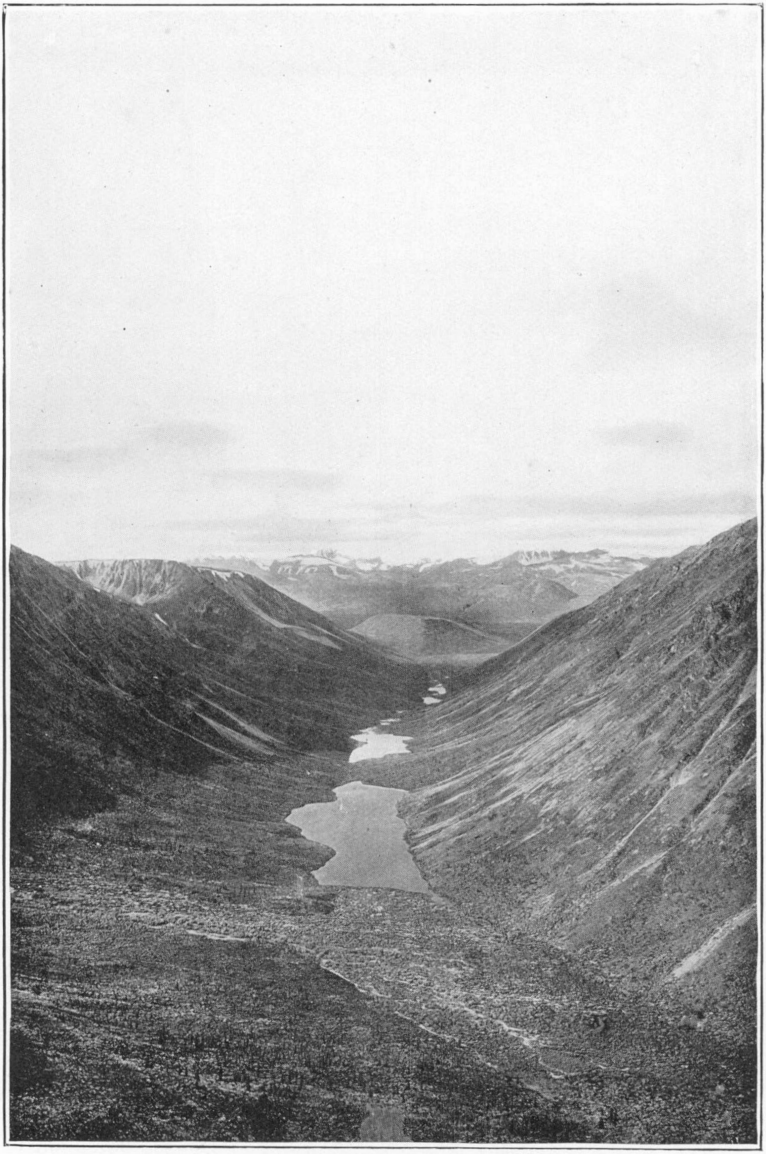
Fenwick creek, which is nearly as large as Wheaton river above their point of confluence, joins the main stream in the southwestern portion of Wheaton district, and is considerably the largest tributary which this river receives. The valley of Fenwick creek is wide of floor, deep, and similar to that of Wheaton river, and during Pleistocene time a large ice-stream moved down this depression in a northerly direction to join Wheaton River Valley glacier.

The valleys of Becker creek and Partridge creek, joining Wheaton river from the south, are also somewhat prominent in this district, and contained, during glacial time, proportionately smaller masses of ice, which accordingly performed less work. The other valleys of the area are smaller than these, and in size grade down to mere ravines, or nicks in the walls of the master-valleys. These smaller depressions will be later discussed when considering their hanging relationships.

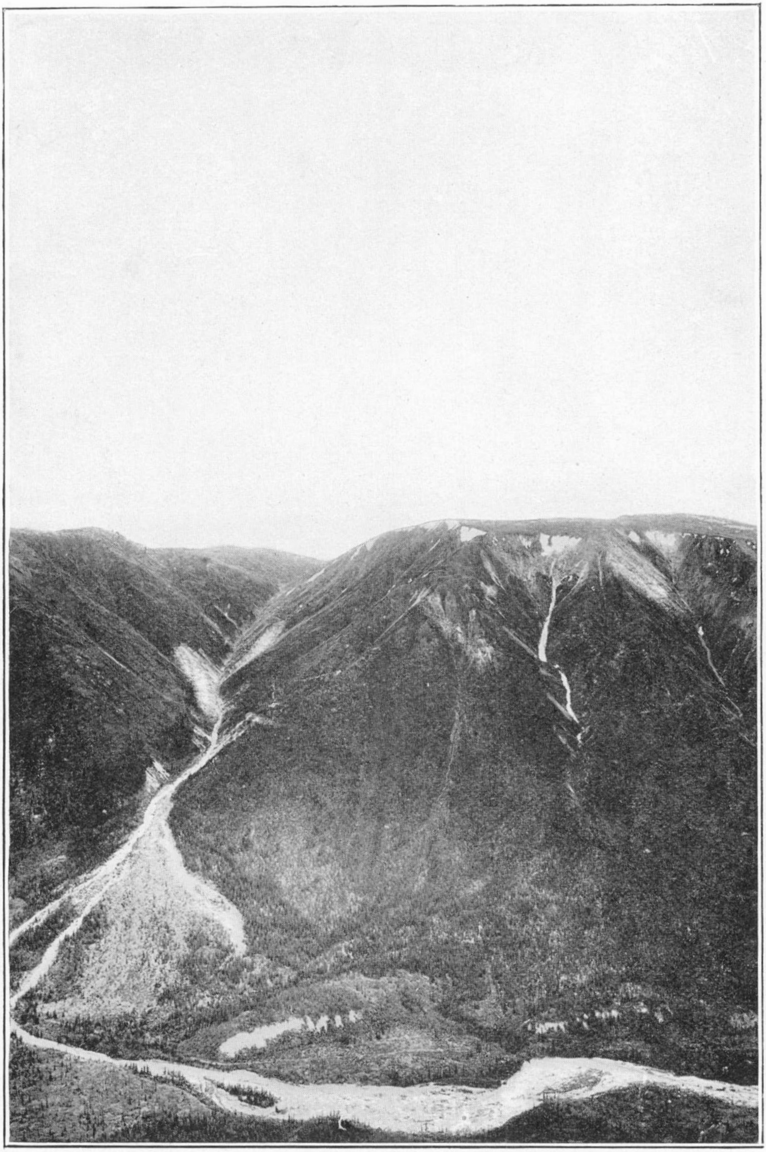
All the ice in southern Yukon passed eventually northward or



Looking down Wheaton River valley from a short distance above "Big Bend", and showing Gray ridge across Corwin valley. The beautifully curved, and U shaped character of Wheaton River valley is here well shown, as well as the facetted spurs in the valley walls.



Looking in a westerly direction up Hodnett Lakes valley. The U shaped character of the valley, and the unorganized character of the drainage, are well shown.



Looking across Wheaton River valley and up Tally-Ho gulch. The hanging nature of the tributary is well illustrated; also a well-defined alluvial fan is being formed by the creek at its junction with the master stream below the post-glacial nick on the margin of the main valley.

northwestward, through the master-depressions, but in the tributary valleys it moved in various directions, just as the water of the streams does to-day, although it all finally flows down Yukon river.

In addition to being mainly destructive, the glaciers also acted in a constructive capacity, and contributed vast amounts of morainal and other materials which deeply covered the floors of the master-depressions. Since the retreat of the ice but little erosion has occurred, and considerable portions of these valleys are still almost as the ice left them, and the larger the valleys the more material they have received. In Corwin valley, particularly to the east and west of Annie lake, the valley bottom is extremely and minutely rough, and is characterized by pot-holes and irregularly distributed morainal ridges which are often over 100 feet high. In the smaller valleys these forms occur more rarely and are less extensive.

Hanging Relationships of Tributary Valleys.—The small streams that traverse the upland flow over this surface in wide, flaring depressions, with gentle gradients, but on coming to the edge of this elevated platform they plunge suddenly, by successive falls, through gorge-shaped incisions, to join the master-streams below. In other words, the tributary streams have hanging-valleys[1]; and the smaller the tributary, the less the eroding power of the stream, either of ice or water, which it contained, and the more its valley was left hanging above that of the master-stream.

Small streams like Stevens creek and Tally-Ho (see Plate VII) creek, have only well nicked the edges of the master-valleys at their point of junction and fall precipitously for 2,000 feet in joining Wheaton river. The valleys of larger tributaries, such as Becker creek, have been occupied by much larger streams of ice and water, and the hanging relationship is much less pronounced. Fenwick creek is nearly as large as Wheaton river above the confluence of these streams, and no hanging relationship is noticeable at the mouth of the tributary. All gradations between these different conditions are to be found.

Cirques.—Perfectly developed and well preserved cirques occur plentifully, and exist prevailingly along the edges of the master-

[1]Davis, W. M.—"The sculpture of mountains by glaciers": Scottish Geographical Magazine, Feb. 1906.
Hobbs, W. H.—"The cycle of mountain glaciation": Geog. Jour., Feb. 1910, Vol. XXXV, No. 2.

depressions. A notable feature in connexion with these forms in this district is that they are invariably found along the sides of the larger valleys, or at what might be considered the heads of the almost insignificant sub-tributaries. The cirques that originally existed at the heads of the larger tributaries have, in all cases noted, been successful in gnawing headward to meet others moving in an opposite direction, and cols or passes have resulted. Such are well seen in the Summit Creek pass, Partridge pass, at the head of Schnabel creek, at the head of the north fork of Perkins creek, at the head of Antimony creek, and elsewhere.

Along the sides of these creeks pronounced cirques exist. Some of the best occur on the north sides of Mt. Perkins, Mt. Pugh, and Johnson hill, and at the northwest corner of Tally-Ho mountain. Small lakes occur at the foot of many of the cirque walls owing to the reversed slopes in these places. These lakes, however, are all being rapidly filled in and reclaimed by materials sliding down the cirque walls (Plate VIII).

Glaciation has generally extended practically to the top of the cirque-walls, but above and back of this only nivation has been operative. The snowbanks are always the forerunners of glaciers, and when they accumulate on favourable hillsides the comminuted material produced is removed, not as in the case of drifts on the upland surface to fill minor depressions nearby, and so to moderate the topographic relief, but instead innumerable rills carry the finely broken material to larger waterways which distribute it widely. As this continues, the drifts enlarge their containing nooks, and nourishing catchment basins for glacial ice are soon produced, and in this way many cirques are formed. The boundary between the quiescent névé snow and the glacier is marked in cirques by the well known bergschrund, or semicircular, irregular crack that occurs approximately conforming to the contour of the cirque, but standing some distance from its walls. Matthes has calculated that the névé must be 125 feet thick and on a 12 per cent grade before motion commences.

In Wheaton district these cirque forms are so numerous along portions of some of the valley-walls, that they give a distinctly frayed or fretted appearance to the upland edges (Plates IX and XI) which stand out in sharp contrast to the plateau back of them.

A typical cirque on the northern side of Mt. Perkins. The view shows the small glacial lake at the foot of the cirque walls, which is being rapidly filled and reclaimed.

The view shows the typical fretted character of the upland near the edges of the master valleys, due to the presence of numerous cirques of various shapes and sizes. This is here seen contrasted with the flat, gentle character of the plateau surface away from the main depressions.

Terraces.—In a number of places, particularly along the Wheaton River valley, and the valleys of Partridge and Becker creeks, terraces were noted, which are often quite persistent and exist up to 700 or 800 feet above the valley-bottoms. These are peculiar in that, although from a distance, preferably from the opposite side of the valley to that in which they occur, they may be quite evident and even somewhat striking on account of their persistency, still when a person is actually on the spot where they occur, it is often difficult to tell exactly where they lie, since only slight amounts of terrace-tops or platforms remain.

Generally, several of these terraces can be seen clinging to the valley-walls, and in a few places four or five may exist, one above the other. Of these, the majority extend but a short distance. However, along the southern face of Mt. Follé, on the northern side of Wheaton river, one terrace is distinctly traceable, with very few breaks, for nearly 4 miles. Similarly, on the eastern side of Becker creek, although other short terrace-remnants exist, the valley slope is particularly characterized by one, and in places by two terraces which occur about midway between upland and lowland, and extend from near Wheaton River valley southward for over 4 miles (Plate X). These are the most noticeable terraces seen in the district, but many others occur along most of the master-valleys.

Owing to the fragmentary character of these terraces, no absolutely decisive information was obtained as to their origin, but similar terraces are of common occurrence in most of the main valleys throughout the Yukon Plateau region, and have been described by a number of writers.[1] Everywhere the origin of these terraces is somewhat in doubt. Dawson and Spurr consider that subsequent to the uplift of the Yukon plateau, and after the valleys had become deeply trenched, a submergence occurred in late Pliocene or Pleistocene time. The valleys are thus thought to have become partly filled with gravels, sands, silts, etc. After a brief period, elevation commenced, and as the streams cut down through the debris terraces were left clinging to the valley-walls—the amounts of the subsidence and uplift being indicated by the terraces.

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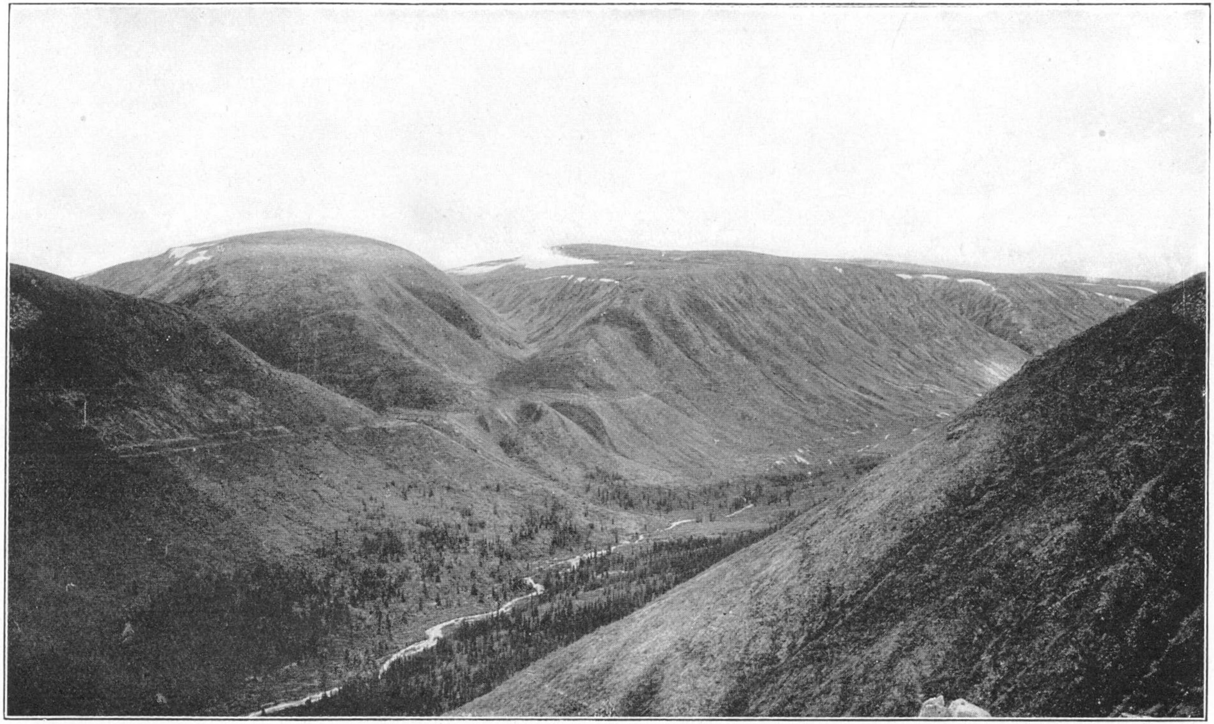
[1]Dawson, G. M.—Trans. Roy. Soc. Can., Vol. VIII, Sec. 4, 1890, pp. 36–41, 48, 49.
McConnell, R. G.—Ann. Rep. Geol. Surv., Can., Vol. IV, 1888–89.
Russell, T. C.—Bull. Geol. Soc. of Amer., Vol. I, p. 139.
Spurr, J. E.—"Geology of the Yukon Gold district": Eighteenth Ann. Rep. U. S. Geol. Surv., pt. 111, 1896–97, pp. 268, 269.
Nordenskjold, Otto—The Amer. Geol., Vol. XXIII, pp. 290–298.
Brooks, A. H.—Prof. Paper, No. 45, 1906, U. S. Geol. Surv., p. 296.

The postulation of a submergence and subsequent uplift appears to the writer to be quite uncalled for, to explain the origin of these terraces. It is true that a certain amount of uplift has occurred in recent times and may be still in progress, as indicated by recent rock terraces along Yukon river above Dawson and elsewhere, but these appear to have had an origin quite distinct from the gravel, sand, and silt terraces which characterize many of the valleys of northern British Columbia and Yukon. In whatever manner the terraces were formed, they must have originated since the glacial period, otherwise the valley glaciers would have entirely obliterated them. It is further evident that no great amounts of material have been deposited in many of the valleys since glacial time, as in depressions such as along the White Pass and Yukon railway between Carcross and Whitehorse, and around Annie lake, the valley floor is pot-holed and minutely rough, and possesses still the characteristic appearance of a surface that has been overlain by ice.

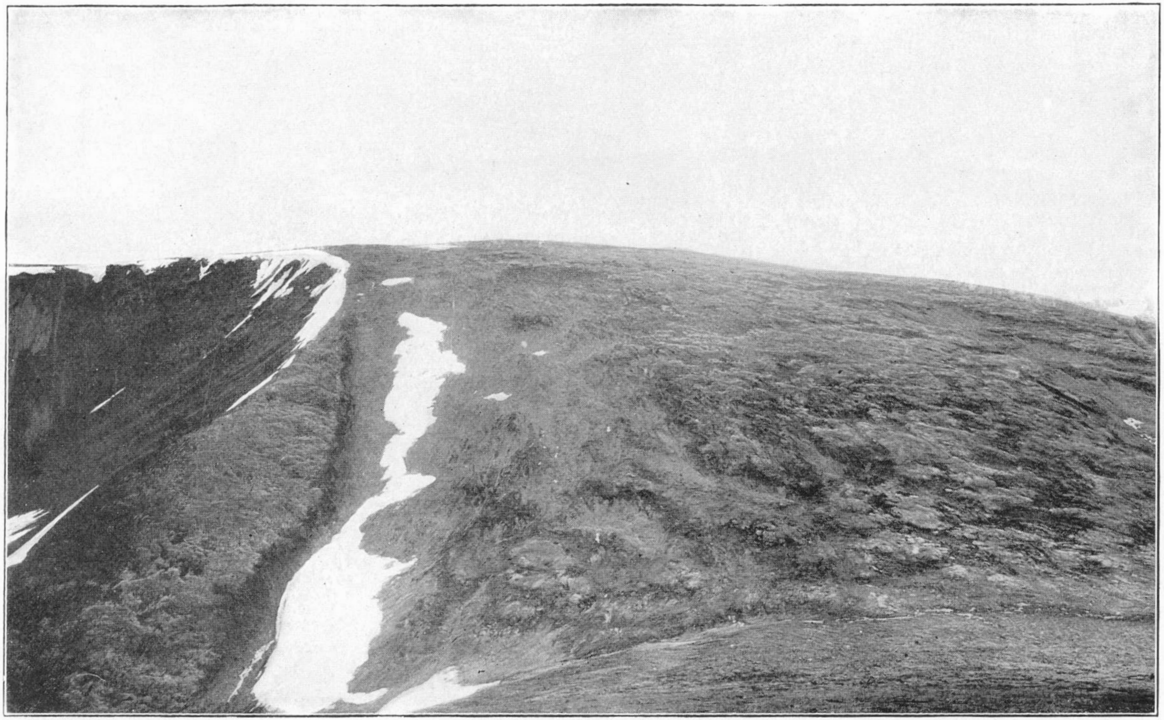
Brooks and others have supposed the terraces to be due to changes in the erosive powers of the stream, and in places this appears to be true, but in the portion of Yukon territory where the terraces reach high up on the valley walls, this theory calls for the former existence of vast amounts of material over the present valley floors, which, as shown above, cannot be true, in some localities, including Wheaton district.

It has also been supposed that the terraces are remnants of lateral moraines formed along the edges of the valley glaciers, and consist thus partly of ground up debris accumulated by the ice itself, and partly of materials that rolled down the sidehills from above, and gathered along the upper surface of the ice. As the ice retreated, and stood at successively lower elevations, other accumulations would tend to form, and those left above would remain in the form of terraces clinging to the valley walls. The most persistent and prominent of the terraces would thus mark elevations at which the ice maintained constant elevations for exceptionally long periods.

In certain valleys where the terraces have been but poorly preserved it is difficult to disprove this theory. However, at points along Becker creek (Plate X) and elsewhere, quite extensive flat-topped terrace accumulations remain in the mouths of the tributaries, and extend out flush with the edge of the walls of the master-valley. If the terraces originated due to ice action, the ice would also have



This view shows the southern wall of Becker Creek valley, along which two terraces extend, between 600 and 700 feet above the valley floor.



Shows the upper edge of one of the many cirques that are found along the higher portions of the slopes of the master valleys, and which give the margins of the upland their decidedly fretted appearance. A snow cornice marks the upper edge of the precipitous drop to the foot of the cirque wall.

invaded the mouths of the tributaries, and the entire lower portions of such would not now contain flat-topped accumulations.

It thus seems evident, as suggested by Nordenskjold and others, that these terraces are dominantly, at least, lake terraces, and represent successive elevations at which the water stood in post-glacial time. This calls for a damming of the drainage system somewhere along the lower Yukon river. As the terraces indicate that the period of submergence was only brief, the damming was probably due to accumulations of ice or other glacial materials.

Facetted Forms.—The great masses of ice which occupied the master-depressions, as mentioned above, planated the valley sides, reducing all projecting spurs, ridges, etc., and bringing them into alignment to form often quite regular walls. Since the close of the glacial epoch, the numerous small tributary streams from the upland have been cutting channels in these walls and enlarging the preglacial incisions in them. The result is that, cut in these steeply-inclined valley slopes are numerous V-shaped, trench-like forms, and between these are facetted forms carved in the valley-walls.

These features are quite pronounced along the eastern side of Corwin valley (Plate IV), at most points along Wheaton River valley (Plate V), and along all the other glaciated valleys of the district, and represent forms produced by a combination of glacial and post-glacial activities.

DRAINAGE.

Wheaton river drains practically all the district; however, the surface waters of a small portion of the extreme northwestern corner of the area are carried into Watson river to the north. Wheaton river is a typical mountain stream, and is subject to rapid floods, so that wide gravel and sand flats and bars are characteristic of its channel. It is a fairly rapid stream with an average current of perhaps 4 miles an hour.

The channel of the stream is entirely in glacial materials, and at only few points along its course are rock-ledges encountered; so that very small obstacles, such as beaver-dams, fallen trees, etc., cause the course of the stream to be deflected. The result is, that the channel is extremely sinuous, and deep, quiet stretches alternate with much more rapid ones.

Relatively little dissection of the glacial sands, gravels, etc., which floor the valley-bottom, has been effected since their deposition. Wheaton river has trenched its meander belt a few feet, but the width of this depressed portion is often considerably less than that of the valley-bottom, and so benches are left on either side. At 'Big Bend,' where the river comes into Corwin valley, a terrace about 15 feet in height marks very definitely the amount of this downcutting by the river, as in Corwin valley above this point practically no dissection of the glacial materials has occurred.

This terrace extends from the western side of Corwin valley to near its eastern edge, and follows, in a broad curve, the general trend of the river, keeping in most places from one-fourth to one-half a mile to the north of the stream. On approaching the eastern part of the valley, the terrace continues parallel to the river's course, turning to the south and continuing along the eastern side of the valley. In places the terrace is stepped, indicating different meander periods, but in many cases the last of these meanders has been the greatest, and in such instances the terrace appears as a single escarpment.

In different places along Wheaton River valley the stream, in addition to sinking its meander belt, has had previous irregularities in the glacial floor to overcome, and when these have been dissected, as between Carbon and Chieftain hills, sand and gravel banks as much as 50 feet high are seen.

Thompson, Perkins, Schnabel, and other smaller creeks empty into Corwin valley above 'Big Bend' of Wheaton river, but on reaching the valley-bottom they flow directly into Annie lake, or become, to some extent, lost in the low swampy tundra lying to the north and south of it. One creek with a decided current flows through this flat and enters Annie lake from the north, and a considerable amount of other water reaches the lake by innumerable, small, partly underground water-passages. No current is noticeable in the lake, but a considerable amount of water is conveyed from it to Wheaton river to the south, mainly by slowly-moving swamp-processes. The great amount of glacial materials has so blocked the drainage that it has as yet not become differentiated. Wheaton river is believed to have formerly flowed northward through Corwin valley, including the portion now occupied by Annie lake, instead of in a southerly direction as now, and to have joined the former Yukon river by a shorter road than at present. The accumulation of glacial material has caused the drainage to become reversed, has altered the course of various other rivers in southern Yukon, and has produced the reversed slopes which now contain the chain of lakes of which Lake Bennett and Lake Tagish are members.

Hodnett lakes also owe their existence to the production of small reversed slopes, caused chiefly by the deposition of glacial materials. Tundra exists over a considerable portion of this valley-bottom, due to the ungraded condition of the drainage.

The largest tributary of Wheaton river is Fenwick creek which enters the parent stream just above Carbon hill and is almost as large as the Wheaton above the confluence. Becker creek is a much smaller stream but is of importance on account of its length, which is known to be over 20 miles. The other creeks of the district, as such, are of no particular individual interest, and their main characteristics have been discussed in considering their hanging relationships to the master-streams.

CLIMATE.

The climate of Yukon has been, in the past, and by many people still is, greatly misunderstood. In fact, until recently this territory has been popularly believed to be a region extremely difficult of access, and covered by almost perpetual snow and ice. Winter photographs, sensational newspaper descriptions of the Chilcoot pass and the building of the White Pass and Yukon railway, and stories, generally exaggerated, of the privations suffered by those who joined in the early rush to the Klondike, are mainly responsible for these opinions. It is certainly true, that from 1896 to 1898, when the influx to Dawson was at its height, great hardships were endured and many lives were lost, but when it is remembered that the majority of the gold-seekers were accustomed neither to a mountainous region nor to encounter difficulties in northern latitudes; that prospectors frequently set out on their quest with only the vaguest notion of the route to be traversed; that the route chosen was often the worst possible under the circumstances; and that a large proportion of the travellers made the trip during the most unfavourable season; it is not amazing that there was loss of life, but that there was so comparatively little.

Now, since the White Pass and Yukon railway has been constructed over the White Pass summit, and lines of steamers have been placed on the lakes and Yukon river, the district has come to be better known and information concerning it is more wide-spread.

The climate of southern Yukon is, during the summer, particularly delightful. On account of the northern latitude, there is almost continuous daylight during June and July; and for five months typical warm summer weather is experienced. The amount of rain varies widely in different localities, according to their elevations and proximity to mountain ranges.

Since Wheaton district is rather high and borders the Coast range, the rainfall here is considerable. During the past four years there has been, on an average, more or less rain on 10 days in each month, from May 1 to October 1. During the same periods rains were of rare occurrence and the climate semi-arid along Yukon valley, to the north.

Plant growth along the lowlands of southern Yukon is luxuriant and extremely rapid. The growing season seems short in number of days, but when the length of time the sun remains above the horizon, and the consequent increase in the number of hours of insolation is considered, this will not appear so remarkable.

The rivers generally open early in May, but the ice remains until the first week in June on some of the lakes. Slack water stretches freeze over any time after the middle of October, but in some years the rivers remain open until well on in November.

The climate of Wheaton district is similar to that of many parts of British Columbia and other northerly, but prosperous, mining camps; and few more difficulties have to be met there in actual mining operations than in localities farther south. At least six months in each year are suitable for surface working and for the necessary outside operations contingent on mining and similar industries. Further, during part of the summer months, work can be continued by night almost as well as by day without the aid of artificial light. The ground is continually frozen to varying depths, but this does not interfere with mining operations, except while being conducted at or near the surface.

The following table of temperatures is compiled from the Meteorological register kept by Mr. Percy Reid, Mining Recorder, who was stationed at Conrad from January 1, 1907, to March 1, 1908, and has since been at Carcross. Both Conrad and Carcross are situated in southern Yukon near the southeastern corner of Wheaton district:—

TEMPERATURES.

—	1907.				1908.			
	Mean Max.	Mean Min.	Extreme Max.	Extreme Min.	Mean Max.	Mean Min.	Extreme Max.	Extreme Min.
January....	....	18·7	....	—40·0	17·1	11·5	40·0	—21·0
February..	19·6	20·8	42·0	—42·0	15·4	13·3	44·0	—33·0
March......	20·0	10·0	38·0	—30·0	20·6	13·1	40·0	—31·0
April	41·1	19·7	52·0	—14·0	37·8	18·3	52·0	7·0
May	59·1	35·7	73·0	26·0	54·6	28·5	72·0	20·0
June.......	65·7	35·5	76·0	30·0	66·0	39·1	82·0	28·0
July	66·7	38·0	76·0	35·0	67·8	40·5	82·0	34·0
August.....	62·2	38·7	72·0	31·0	66·0	41·5	76·0	28·0
September..	53·5	34·7	63·0	26·0	51·6	33·4	71·6	20·0
October	45·5	29·7	59·0	— 8·0	35·5	21·0	51·0	— 8·0
November..	32·0	13·9	59·0	— 7·0	29·2	15·1	41·0	— 8·0
December..	22·7	9·9	44·0	—12·0	25·3	13·9	65·0	—37·0

—	1909.				1910.			
	Mean Max.	Mean Min.	Extreme Max.	Extreme Min.	Mean Max.	Mean Min.	Extreme Max.	Extreme Min.
January....	18·5	30·8	24·0	—56·0	18·7	11·3	36·0	—26·0
February..	11·5	19·0	35·0	—44·0	11·2	18·9	30·0	—39·0
March......	28·9	10·9	40·0	—18·0	30·4	18·9	46·0	—30·0
April	34·6	17·6	45·0	— 8·0	38·2	17·0	52·0	— 3·0
May	54·1	31·1	67·0	22·0	52·1	31·2	72·0	20·0
June......	61·4	37·9	76·0	25·0				
July	63·4	42·3	75·0	35·0				
August.....	59·4	40·3	69·0	33·0				
September..	52·7	34·8	68·0	25·0				
October	38·7	25·0	51·0	8·0				
November..	19·9	15·3	40·0	—40·0				
December..	27·0	23·1	44·0	—40·0				

FLORA AND FAUNA.

Wheaton district, as a whole, is but sparsely forested. Trees are chiefly found in the valley bottoms, but in many places they extend up the hillsides to an elevation of 4,000 feet[1] above sea-level, where they begin to decrease, and in 200 to 300 feet more have ceased completely. By far the greater amount of timber occurs in the valleys traversed by Wheaton river, including the wide depression in which Annie lake occurs, and which is the northerly exten-

[1] The valley of Wheaton river, at Big Bend, is about 2,600 feet, and between Carbon and Chieftain hills it is 3,400 feet. above sea-level.

sion of the valley that contains the lower reaches of the river. The valleys of the larger creeks such as Fenwick, Thompson, Summit, Becker, and Partridge creeks, also contain considerable timber, and a small amount exists on some of the small streams such as Schnabel, Dawson-Charlie, and Van Summers creeks. All the upper slopes and the entire plateau surface, with the occasional peaks rising above it, are bare.

There exists in the district, however, a plentiful supply of timber for all mining purposes for many years to come; and for those claims located on the higher elevations it can generally be obtained in the nearest valley, but is everywhere present along the main waterways.

The forest of the district consists chiefly of eleven species, eight of which attain the dimensions of trees; the others are possibly better considered as shrubs. These are the white spruce (*Picea alba*), black spruce (*Picea Nigra*), balsam fir (*Abies subalpina*), black pine (*Pinus Murryana*), balsam fir (*Populus balsamifera*), W. balsam poplar (*Populus trichocarpa*), aspen poplar (*Populus tremuloides*), white birch (*Betula Alaskana*), dwarf birch (*Betula glandulosa*), and two species of willows (*Salix*).

Of these, the white spruce is the most widely distributed and most useful tree, and grows at all elevations up to timber line. The best groves are generally found on the river flats and in depressions along the lower slopes of the ridges, where it occurs straight and well grown. Individuals are not generally larger than 12 inches in diameter, 3 feet from the ground, but specimens with 24 inch stumps were noticed. This tree furnishes strong, easily worked timber, and is well suited to the usual mining needs, and purposes of construction generally.

Balsam fir is next in importance to the white spruce and also supplies a fair grade of timber. Specimens were noted having 12 to 14 inch stumps, but the average of the larger individuals does not generally exceed 10 inches in diameter, 3 feet above the ground. Trees of this variety are often quite plentiful on the mountain slopes, and appear to thrive best at 200 or 300 feet below timber line, decreasing in size above and below this elevation.

The black spruce occurs in some places associated with the white spruce, but rarely attains a workable size. Black pine is occasionally found either interspersed with the spruce or forming separate groves, and generally grows on sandy benches along the main streams. Trees of this variety rarely have in this district more than a 10 inch stump, and they supply a timber that is not so strong or durable as that of the white spruce.

The white birch occurs very rarely, and is never of large size. The poplars are relatively plentiful, and grow chiefly along the alluvial flats of the main valleys and are seen in all stages of growth from small shrubs to a considerable forest tree 8 to 10 inches in diameter. The aspen are found over a considerable portion of the valleys and on the majority of the hillsides up to timber line. The poplar and aspen make good fuel, but are too soft and irregular in form to be of use for constructional purposes.

Willows and dwarf birch represent the principal shrubs of the district. The former are quite plentiful in the valleys, but do not extend far above the level of the larger streams. The dwarf birch occurs chiefly in the higher valleys along the upper slopes, above timber line proper; and in some places extends to the main plateau level. This shrub forms an undergrowth 2 to 4 feet high in many localities, so dense that to walk through it becomes extremely tiresome.

Several varieties of wild fruits were noted in this district. Of these, crow or heather berries (*Empetrum nigrum*), high-bush cranberries (*Viburnum pauciflorum*), and low-bush cranberries (*Vaccinium Oxycoccus*) were quite plentiful in places; and black currants (*Ribes Hudsonianum*), red currants (*Ribes rubrum*), gooseberries (*Ribes lacustris*), blueberries (*Vaccinium*), strawberries (*Fragaria cuneifolia*), raspberries (*Rubus strigosus*), and Saskatoon berries (*Amelanchier florida*) were noted.

Until within the past two or three years Wheaton district abounded in several varieties of big game, including moose, caribou, sheep, and bear, and few places in North America would have been more attractive to sport-loving hunters. Since 1906, however, the prospectors and others frequenting the district have killed great numbers of the larger animals, and those remaining have been to a considerable extent driven back to the western and northwestern portion of the area and the adjoining territory, where, however, they are still to be found in great numbers. Fresh, well-worn runways are everywhere to be seen throughout the district.

Moose, and sheep (*Ovis dalli*), as well as black, brown, and grizzly bear are still fairly plentiful, but caribou (Osborn's caribou, *Rangifer osborni*) are less often seen, having mostly migrated to the adjoining country to the northwest. Wolves, wolverine, beaver, otter, martin, and lynx are common, and red, cross, silver, and even black foxes are occasionally to be found. Ptarmigan are exceedingly plentiful and three varieties were noted: the rock ptarmigan (*Lagopus rupestris*), and white-tailed ptarmigan (*Lagopus leucurus*) are found above timber line, and during the summer months live mainly on the highest, often snow-capped, summits; the willow ptarmigan (*Lagopus lagopus*) live during the summer months at about timber line. Blue grouse or Richardson grouse (*Dendragopus Richardsonii*), fool hens or Franklin grouse (*Canachites franklinii*), willow grouse or Oregon ruffed grouse (*Bonasa umbellus sabini*) are fairly plentiful, and occasional prairie chicken or northern sharp-tailed grouse (*Pediaecetes phasianellus*) were also seen; these live mainly in the timber and preferably in the valley flats. Rabbits, abundant a few years ago, were during 1909 extremely scarce.

The streams are generally fairly well supplied with fish, chiefly greyling (*Thymallus signifer*); and in the lakes in this and the adjoining districts lake trout (*Solvelinus Namaycush*) and whitefish (*Coregonus Nelsoni*) abound.

GENERAL GEOLOGY.

GENERAL STATEMENT.

REGIONAL.

As stated in the portion of this report dealing with topography, the physiographic provinces of Yukon territory are continuous with those in northern British Columbia to the southeast, and with those of Alaska to the west, and follow in a general way the trend of the Pacific coast line (Diag. 2). As topographic features are, to a certain degree, often expressions of the bed-rock structure and composition, it might be expected that in all probability the same general geological horizons which compose the cordillera in British Columbia might extend through Yukon and Alaska, and, to a limited extent, this has been found to be true.

Dr. G. M. Dawson[1] has shown that there is a certain continuity and lithologic uniformity along the strike of some of the geologic terranes in the Cordilleran belt in British Columbia. In addition, a geological map of western Canada,[2] which has been published by the Geological Survey, Canada, largely from the results of the work of Dr. Dawson and Mr. R. G. McConnell, also shows that the distribution of the more important geological features exhibits, in a broad way, a marked parallelism, and agrees roughly with the main physiographic features. Mr. A. H. Brooks[3] has further shown that this, to some degree, holds true in Alaska, although not to the same extent as farther to the southeast, and that certain of the larger geologic features extend through British Columbia, Yukon, and Alaska. In Yukon, this persistency of geologic terranes, and their parallelism to the strike of the physiographic provinces, are only apparent when a broad tract is considered, and are most evident when the entire territory is viewed, including the Coastal, and Rocky Mountain systems.

[1]"Geological record of the Rocky Mountain region, Can.": Bull. Geol. Soc., America, Vol. 12, p. 60.
[2]Geol. Map of the Dominion of Canada, Western sheet, No. 783, Geol. Surv.,Can.
[3]"The Geography and Geology of Alaska": Prof. Paper, No. 45, U. S. Geol. Surv.

For the purpose of the present discussion, viz., the elucidation of the relationships of the geologic formations and structures of Wheaton district to those of the broader geologic features of which they form a part, a consideration only of those terranes in the southwestern part of Yukon is necessary. The extreme southwestern part of Yukon territory includes a portion of St. Elias range (Diag. 2), which seems to be built up of complexly folded sedimentaries, probably chiefly Palæozoic, together with many intrusives.[1] This terrane is situated far to the southwest of Wheaton district, however, and possesses a history and structure so dissimilar to the latter, that it will not be further considered in this report. The geology of only the northern part of the Coast range, and the southwestern part of the Yukon plateau (Diag. 2) will be described.

The Coast range consists of an igneous complex of granitic rocks intruded mainly as a great batholitic mass over 1,000 miles long, that reaches from south of the 49th to nearly 100 miles north of the 60th parallel (the British Columbia and Yukon boundary). This batholith extends along the western portion of Wheaton district, and is the one really prominent geologic feature in the southwestern portion of Yukon that has any marked trend parallel to the coast line and to the main physiographic provinces of the district. In fact the main geologic belt of these granitic rocks is also practically the Coast Range topographic province, although in places marginal portions of these rocks have been planated and extend out into the Yukon plateau. A number of irregular detached areas of the granitic materials also occur well within the plateau province.

The formations composing the Yukon Plateau province of northern British Columbia and southern Yukon, show in only a few places any tendency to parallelism with the topographic terranes, but instead are generally very irregularly distributed throughout the district. Only a few areas in the southwestern part of Yukon have been mapped or at all closely studied, so that the geological information concerning this district is very incomplete. Still, the general distribution of some of the larger subdivisions of the geological column is fairly well known, and the geologic formations have been discovered to range in age from lower Palæozoic or older, to Recent. The most ancient rocks consist of a series of pre-Devonian schists,

[1]Op. cit., p. 253.

gneisses, and limestones, which have suffered intense dynamic-metamorphism, and represent rocks of both sedimentary and igneous origin. These are chiefly, or entirely, of lower Palæozoic age, but some members may possibly be Pre-Cambrian; they form small, isolated outcrops, which generally occur along the eastern margin of the Coast Range batholith.

The sedimentary rocks of the southwestern part of the Yukon plateau, with the exception of those included in the old metamorphic groups, can be divided into three classes: those of Palæozoic, those of Mesozoic, and those of Quaternary age. The igneous rocks comprise both intrusive and extrusive members, and have an age-range from approximately upper Palæozoic to Recent.

The Palæozoic sediments consist of a series several thousand feet thick, of Devono-Carboniferous[1] limestones, cherts, slates, quartzites, etc. The lower members, probably of Devonian age, appear to be chiefly quartzites, slates, and cherts, with some limestone bands, whereas the Carboniferous beds are principally heavy-bedded limestones. The Devonian (?) rocks are nowhere very prominent, and have been recognized in only a few localities; but the Carboniferous limestones form important ranges, in some instances, having a decided northwesterly trend parallel to that of the Coast range to the west. One such range borders the Lewes river chiefly along the eastern side from its headwaters, northwestward for a distance of over 100 miles.

The Mesozoic sediments consist of conformable series of conglomerates, sandstones, arkoses, shales, tuffs, and breccias, of Jura-Cretaceous age. These are, in places, as much as 6,000 feet thick, and cover extensive tracts in the southern portion of Yukon, and toward the north gradually increase in extent and relative importance as the volcanics decrease.

The Quaternary deposits consist of Pleistocene and Recent members which are lithologically nearly identical, and in some instances grade into each other. Geological studies have, in most

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[1]Dr. G. M. Dawson collected Fusilinae from the limestones which extend along the east side of Windy arm, showing them to be Carboniferous. The quartzites, slates, and cherts lie beneath the Fusilinae horizon. Dawson, on lithological and palæontological grounds, also correlated these limestones, quartzites, etc., with the Devono-Carboniferous Câche Creek series of British Columbia. See:—

Dawson, G. M.—Rep. of Prog., Geol Surv., Can., 1876–77, pp. 55–58.

Dawson, G. M.—Ann. Rept., Geol. Surv., Can., Vol. III, Pt. B, 1887–88, pp. 170–171.

Dawson, G. M.—Ann. Rept., Geol Surv., Can., Vol. VII, Pt. B, 1894, pp. 37–49.

places, not proceeded to an extent to allow of their differentiation. The Pleistocene accumulations consist of unconsolidated gravels, sands, silts, and till, considerable thicknesses of which occur in all the larger valleys of southern Yukon. The Recent materials consist of fluvial and littoral sands, gravels, and silts of the present waterways, ground-ice, peat, muck, volcanic ash, and soil, which compose a thin mantle that covers the greater part of the entire district.

The most extensive series of intrusives are the Coast Range granitic rocks which comprise an igneous complex chiefly of granites, grano-diorites, and diorites which in addition to composing the Coast Range batholith also occur as outlying stocks in the plateau-region to the east and north. They are believed to have been intruded in late Jurassic time, and constitute possibly the most prominent geologic feature of southwestern Yukon. A few small areas of pyroxenite and amphibolite also occur in southern Yukon, which are believed to have been injected in pre-Jurassic time. In addition, during the Tertiary a number of dykes and stocks of granite, and syenite-porphyry, which constitute the Klusha series, have invaded the older formations. These porphyries, pyroxenites, amphibolites, and Coast Range intrusives, are the only intrusive rocks known to exist in southern Yukon that are not accompanied by flows and tufaceous accumulations. All the volcanics occur to a limited extent as dykes, but they occur prevailingly as extrusives.

The extrusives are of various types and ages. The oldest members consist of a series of andesites, and andesitic tuffs, concerning the age of which it is only known that they are older than the Jurassic Coast Range intrusives, and newer than the lower Palæozoic metamorphic rocks. They are locally of considerable extent, particularly in the extreme southern portion of Yukon territory. More recent than these, is an extensive series of andesites, andesitic tuffs, and related volcanic breccias, which are contemporaneous with and newer than the Jura-Cretaceous sediments, and older than the more recent volcanics. In addition to these, some late Tertiary or Pleistocene basalts have occurred as extensive flows in certain portions of the territory. One such occurrence forms the walls of the well known Miles canyon near Whitehorse. The most recent extrusives consist of a series of rhyolites which have pierced the older rocks, and poured over the country in places, generally in sheets 50 feet or less in thickness, and are accompanied by great quantities of tuffs and breccias.

LOCAL.[1]

Representatives of all the different groups, series, or other divisions of rocks, which have just been described as occurring in the southwestern portion of Yukon territory,[2] are to be found in Wheaton district, except the limestones, quartzites, cherts, slates, etc., of Devono-Carboniferous age. The geology of the district is complicated and intricate, by reason of the diversity in age and character of the various formations occurring within its boundaries. The rocks include pre-Devonian schists, gneisses, and limestones; probably Devonian andesites, and andesitic tuffs; Jurassic granitic intrusives; Jura-Cretaceous conglomerates, sandstones, shales, arkoses, and tuffs; andesites and tuffs of late Mesozoic, or early Tertiary age; Tertiary basalts and breccias; and Quaternary sands, gravels, silts, till, peat, ground-ice, volcanic ash, muck, etc.

The oldest known rocks occurring in the district are included in the Mt. Stevens group, and are chiefly sericite and chlorite schists, mashed basic volcanics, gneissoid quartzites, hornblende-gneisses, and limestones. They occur in a number of localities, but generally form only small, isolated outcrops that represent parts of the walls dividing subjacent portions of the Jurassic granitic batholith, or are remnants of the roof of, and inclusions in, this igneous mass.

The sericitic and chloritic rocks are generally soft and friable, range in colour from pale greyish-yellow to dark green, are fine-textured, and generally highly fissile. The mashed eruptives present the appearance of laminated basic andesites, are dark green in colour, generally fine-grained, and, although decidedly schistose, are rarely fissile, but in most cases break into irregular fragments. The quartzites are generally white in colour, have a typical gneissoid structure, and may be finely and evenly textured and, when so characterized, are generally greyish in colour; in other places, however, as on

[1]What follows under this heading contains in condensed form the main facts of the general geology of Wheaton district, and is written particularly for those readers who do not wish to follow the details of the geology, but rather wish to obtain in a few pages the main points concerning this subject, and so be in a position to turn at once to the chapter on economic geology.

[2]Where in this report, the southwestern portion of Yukon territory is mentioned, it is intended, unless otherwise stated, to exclude the small portion of St. Elias range which occurs in the extreme southwestern portion of the territory, since it possesses no immediate interest in the discussion of Wheaton district.

Tally-Ho mountain, they are very coarse. There the colour varies greatly, depending upon the amount of hornblende present, which mineral occurs prevailingly in small distributed masses often over an inch long and resembling crushed phenocrysts. In places, the hornblende constitutes the greater part of the rock, in others the lighter coloured constituents, chiefly the feldspars and quartz, predominate. The limestones occur intimately associated with the schistose members, and have an aggregate thickness on Mt. Stevens, where they are most extensive, of approximately 700 feet. They occur in heavy, massive beds, and vary from white to bluish, and from crystalline to subcrystalline.

All the members of the Mt. Stevens group suffered prolonged dynamic metamorphism, were much disturbed and plicated, and afterwards were subjected to a long period of erosion, concerning which very little is known. During this erosive interval andesites, andesitic tuffs, and pyroxenites of the Perkins group, invaded the Mt. Stevens members and buried them in places under considerable thickness of lava and tufaceous materials.

In the eastern part of Wheaton district the rocks of the Perkins group are of considerable prominence and extent, and are generally found associated with the Mt. Stevens rocks, and adjoining the Jurassic granitic members. The andesites are invariably dark green to almost black in colour, are fine-textured, and generally extremely hard and brittle. The pyroxenites are dark green to dark brown holocrystalline rocks, are often coarsely crystalline, and consist chiefly of augite.

The Coast Range granitic batholith intruded itself into these older formations in, it is thought, late Jurassic time. This batholith, which is over 1,000 miles long, reaching from south of the 49th parallel to a point over 50 miles north of the northern edge of Wheaton district, extends completely across the western portion of this area. Thus by far the greater portion of the rock outcrops of the western part of the district are of these granitic materials, and where these do not actually outcrop they, in most places, are believed to underlie the rocks which are exposed at the surface. It will thus be seen that the formation composing this batholith is the most prominent and extensive one in the district. The rocks composing it consist of an igneous complex of granites, grano-diorites, and diorites, which are generally fresh and unaltered in appearance, and predominantly greyish in colour. In places they are quite porphyritic, and contain feldspar phenocrysts 1½ to 2 inches long. The greater number of the mineral-bearing quartz-veins of the district occur in this formation.

At the close of the Jurassic dynamic revolution, during which this Coast Range batholith was intruded, the entire Wheaton district was above the sea, and a short period of erosion ensued. This was followed by a far-reaching period of depression in Jura-Cretaceous times, which continued until the entire district was submerged.

The sedimentary accumulations of this Jura-Cretaceous period in Wheaton district consist chiefly of tuffs, arkoses, conglomerates, sandstones, and shales. These members embrace the Tantalus conglomerates, and Laberge series, which together are as much as 5,000 feet to 6,000 feet thick at certain points along Wheaton river. The Laberge series consists prevailingly of medium-textured, greenish-grey, heavily-bedded tuffs and arkoses, which frequently alternate with fine-grained shales and slates, and some sandstone beds. This series also contains some conglomerates, the component pebbles of which are chiefly of volcanic materials, are sometimes as much as 6 inches in diameter, and are generally firmly cemented together to form a firm, durable rock. The Tantalus conglomerates overlie the Laberge beds, have an aggregate maximum thickness in the district of about 1,800 feet, and consist chiefly of heavy, massive beds of conglomerate, the pebbles of which consist entirely of quartz, chert, and slate. Associated with these conglomerates are some sandstone and shale beds which contain a number of coal-seams.

During the time these Tantalus and Laberge beds were being laid down, vulcanism again became active, and great quantities of ashes and brecciated materials of an andestitic character, were deposited with the normal sediments. Andesitic flows were also formed, apparently during the period of deposition. A dynamic revolution terminated the Jura-Cretaceous period of sedimentation, and at the close of this disturbance the entire district was above the sea. Degradation again became active, and a long period of erosion commenced and continued until a nearly base-levelled surface resulted. This was followed by uplift and dissection as described under 'Historical Geology.'

Vulcanism persisted during, and continued for a considerable time after, the Jura-Cretaceous upheaval; dykes pierced the sediments, and great masses of andesites and tufaceous materials buried them deeply in numerous places. The andesitic materials of this period, which in Wheaton district are named the Chieftain Hill volcanics, consist chiefly of mica-, hornblende-, and augite-andesites, and andesitic tuffs and breccias, and vary from mica-andesites with a generally grey to reddish groundmass in which are well-defined plagioclase and biotite phenocrysts, to finely textured, aphanitic, dark green augite-andesites with corresponding tufaceous types.

Subsequent to the Jura-Cretaceous disturbance the district was subjected to at least three volcanic invasions. As a result of the first period of volcanic activity, a series of basalt dykes, belonging to the Carmack basalts, pierced the older rocks in a few places. In other parts of Yukon territory, these basalts formed extensive flows, as well as great accumulations of basalt tuffs. About the same time, also, the Klusha intrusives, consisting of numerous dykes of granite-porphyry, cut the older formations in numerous places. These, typically, are light grey, coarsely crystalline rocks. More recent than the Carmack basalt dykes are the Wheaton River volcanics, consisting of rhyolites, tuffs, and breccias, which occur as dykes cutting the basalts, and also as extensive flows and accumulations of breccia. The Wheaton River rocks appear to be related to the Klusha granite-porphyries, and may have been synchronous with them, but definite data on this point were not obtained.

During Pleistocene time the mountains to the west and south of Wheaton district became gathering grounds for glaciers, and huge tongues of ice came down from them and occupied the valleys of Wheaton river and its main tributaries. These depressions were deepened and widened by ice-action, and considerable thicknesses of morainal and other glacial accumulations were deposited on the floors and along the lower portions of the walls of these valleys. The channels of the present streams are still entirely in these glacial gravels, sands, silts, etc., sufficient time having not yet elapsed for the waters to remove them. In fact, such enormous quantities of these materials were deposited in some of the pre-glacial master waterways, that the streams have been entirely diverted from considerable stretches of these depressions, with the result that in such places no transporting action has as yet commenced.

Overlying these Pleistocene deposits are the Recent accumulations, composed of fluvial and littoral sands, gravels, and silts of the present waterways, ground-ice, muck, volcanic ash, and soil. The volcanic ash, which has been described in practically all reports on any portion of southern Yukon, is a notable feature, and consists of a single, extremely evenly distributed and wide-spread layer, which is 3 to 6 inches thick along Wheaton river, and is evidently due to one continuous, but short, outburst of volcanic activity. It is more recent than the silts—the most of the recent glacial deposits; in fact it is almost at the very surface, and the grass-roots extend down into it.

TABLE OF FORMATIONS.

System.	Formation.	Lithological character.
Quaternary.		Gravels, sands, boulder clay, silts, muck, peat, volcanic ash, and soil.
Tertiary.	Wheaton River volcanics.	Rhyolites, tuffs, and breccias.
	Carmack basalts.	Basalt.
	Klusha intrusives.	Granite porphyry.
Jura-Cretaceous.	Chieftain Hill volcanics.	Andesites, tuffs, and breccias.
	Tantalus conglomerates.	Conglomerates chiefly, with some sandstones, shales, and coal seams.
	Laberge series.	Conglomerates, sandstones, arkoses, tuffs, and shales.
Jurassic.	Coast Range intrusives.	Granites, grano-diorites, and diorites—chiefly grano-diorites.
Probably all upper Palæozoic.	Perkins group.	Andesites, andesitic tuffs, pyroxenites, and amphibolites.
Pre-Devonian—Probably all lower Palæozoic.	Mt. Stevens group.	Chiefly sericitic and chloritic schists, mashed basic volcanics, schistose and gneissoid quartzites, hornblende gneisses, and limestones.

DETAILED DESCRIPTIONS OF FORMATIONS.

Mount Stevens Group.

DISTRIBUTION.

The rocks of the Mt. Stevens group occur chiefly in a single, northwesterly-trending belt which is from one-half to slightly over a mile in width, is about 10 miles long, and extends from the southern edge of Tally-Ho mountain to the northern side of Mt. Hodnett. On Mineral hill, just to the north of this belt, is a small area, and to the south of the belt are two important occurrences on Mt. Stevens and Dickson hill. The Mt. Stevens area is about 8,000 feet long by 3,000 feet wide, while that on Dickson hill is oblong in form, and of about one-third this extent. In addition, ten other small occurrences of these rocks have been indicated on the map; they range in size from 300 or 400 feet in diameter to nearly a mile long. The largest and most important of these forms a part of the top and northern face of a small ridge which faces Wheaton river from the south, and lies just west of Becker creek; it is about a mile long, and in places may be nearly as wide. Also four small areas occur on Mt. Anderson, and in addition one occurs on Big Bend mountain, one on Johnson hill, one on the adjoining mountain to the west, and one on the extreme northeast corner of Chieftain hill. Other smaller areas were noted in several places, but are too small to be shown on the map.

As discussed in more detail below, this series consists of a number of members which differ widely, not only in general appearance and mineralogical and chemical composition, but also in age. They are all, however, old and extremely altered, unlike any other rocks in the district, and have been metamorphosed and subsequently eroded to such an extent that their mode of origin has been almost completely obscured.

The rocks on Mt. Stevens are of considerable importance on account of the mineral-bearing quartz-veins they contain, and consist mainly of chlorite-, sericite-, and greenstone-schists. The members on Dickson hill are all hornblende-gneisses, while those on Tally-Ho mountain are hornblende-gneisses, greenstone-schists, and limestones. The gneisses occupy the northwestern portion of the area, while the limestones occur mainly in a single belt up to 700 feet wide, which extends from about the centre of the northern portion, and thence crosses Wheaton river, and appears again on the opposite side. The other members of this series on Tally-Ho mountain are greenstone-schists which comprise the rock formation of most of the eastern and southern portion of the area. The long, narrow belt running from Wheaton river to Mt. Hodnett is composed almost entirely of greenstone schists with occasional thin, intercalated limestone bands, generally less than 10 feet in thickness. On Gold hill, however, some sericitic quartzites were found associated with other members. The area on the ridge to the west of Becker creek consists entirely of hornblende-gneisses, while the occurrences on Mt. Anderson consist chiefly of greenstone-schists, but include also some gneissoid quartzites. The members of the Mt. Stevens series on Johnson hill are mainly gneissoid quartzites, and those on the adjoining hill to the west, on Chieftain hill, Big Bend mountain, and on Mineral hill are mainly greenstone-schists.

LITHOLOGICAL CHARACTERS.

The members of the Mt. Stevens group consist mainly of sericite-schists, chlorite-schists, greenstone-schists, sericitic quartzites, gneissoid quartzites, hornblende-gneiss, and limestone.

Sericite-schists.—The sericite-schists are light grey, soft, friable, generally fissile rocks which have prevailingly a bright and glistening appearance, due to the great amount of mica they contain. They cleave readily along their foliation-planes, and large plates one-eighth to one-fourth of an inch in thickness are readily obtainable. In places these schists contain considerable iron-ore which oxidizes and gives them a decidedly reddish colour.

Under the microscope, these rocks are seen to consist mainly of quartz and sericite, but contain also some orthoclase, plagioclase, and secondary calcite. The original feldspars have been for the greater part alkali feldspars and have been largely replaced mainly by sericite and to some extent also by calcite. A few distinct breccia-fragments were noted both megascopically and microscopically, but these are generally small. The rocks appear to have been rhyolite-breccias that have been mashed and transformed into sericite-schists.

Chlorite-schists.—The chlorite-schists are pale to dark greenish, soft, friable, fissile rocks often having a decidedly smooth, soapy feel, and a bright, somewhat silky appearance. They generally break readily along their foliation-planes, and produce a talus composed of thin plates. They occasionally have a reddish cast due to the presence of a certain amount of limonite.

Microscopically, these rocks seem to be composed chiefly of calcite and chlorite, and it is the chlorite that gives the green colour to the schists. A considerable amount of iron ore is present in places. The rocks are of unknown origin, but the great amount of calcite and the entire lack of quartz indicate that they are derived from somewhat basic materials that have been metamorphosed to produce the calciferous chlorite-schists at present existing.

Greenstone-schists.—The term, greenstone-schists, has been adopted as a convenient field-name to include all schistose materials that have the appearance of mashed, diabases, andesites, and related rocks. These in no way resemble the sericite-, and chlorite-schists, quartzites, gneisses, etc., and form a distinct class of rocks. Microscopically, they are seen to have had various origins, and to have considerably different compositions, nevertheless they resemble each other much more than they do any of the other members of the Mt. Stevens group, and the various members of the greenstone-schists are so intimately associated that in the field it was often found impossible to separate them.

Megascopically, they are fine to medium textured, greenish rocks that have an andesitic or diabase-like appearance, and are prevailingly firm and compact. They have always a laminated structure, but are never fissile, and may or may not cleave along their foliation-planes, but generally break into sharp, angular fragments.

Under the microscope several types are distinguishable. The greenstone-schists of Mt. Stevens appear to be mashed andesites, and consist chiefly of plagioclase, a small amount of quartz, considerable fibrous chlorite, some calcite, and accessory iron ores. Distinct remains of a holocrystalline, porphyritic texture are preserved, in which large plagioclase phenocrysts have been prominent. Fine particles of magnetite are also liberally peppered through the groundmass of the original rock.

The greenstone-schists of Hodnett mountain have also a holocrystalline porphyritic texture, but are prevailingly somewhat coarser textured than the members of the class seen elsewhere. Large particles of augite and plagioclase occur, as well as considerable amounts of zoisite, chlorite, and accessory iron ores. The rocks are decidedly mashed basic volcanics, and appear to have originally been andesites.

On Tally-Ho mountain two types of these greenstone-schists were noted, both of which are finely textured and thinly laminated. The first class are sheared, epidotized, sericitic rocks which are extremely altered. Between metamorphosed bands of the original materials, layers and veinlets of secondary quartz have been introduced to such an extent that they comprise a considerable portion of the rock. The rock-bands consist chiefly of plagioclase, augite, and secondary sericite, chlorite, and calcite, and indicate that the primary material was of the nature of a basalt or augite-andesite.

The second type of these Tally-Ho Mountain greenstone-schists may be closely related to the first, but contains much less sericite and more calcite, and lacks the secondary quartz veinlets, etc. The specimens examined are entirely composed of secondary materials which are mainly epidote and chlorite, with some calcite and limonite. Remnants of a porphyritic structure are distinctly preserved, and the rocks are of basic volcanic origin, so, possibly, have been derived from augite-andesites or a basalt, but in their present condition may only be described as sheared, epidotized, calciferous rocks.

Sericitic Quartzites.—On Gold hill are some generally dark greenish, fine grained, closely foliated rocks which only occasionally cleave along their planes of schistosity, and prevailingly break into angular fragments.

An examination of thin sections of these, shows them to be schistose, sericitic quartzites grading into silicified slates or rocks originally containing much argillaceous material, but which have, by mashing or shearing, received their schistose structure. The specimens examined are all decidedly of sedimentary origin, and the banding, in some cases, appears to be due to bedding, rather than to shearing or mashing.

Gneissoid Quartzites.—Near the summit of Mt. Anderson bands of quartzites occur, which in places are coloured reddish by limonite, but are otherwise light greyish to almost white in colour. These rocks have a fine, gneissoid structure, and, megascopically, appear to consist entirely of quartz. Microscopically, they are seen to consist chiefly of irregularly shaped quartz-grains, intergrown with which are some of feldspar that are much altered to sericite, and, therefore, were originally alkali feldspar. A few grains of plagioclase also occur but are mainly transformed to calcite. Numerous shreds of brown biotite also were found, as well as accessory zircon and magnetite.

Hornblende-gneisses.—Hornblende-gneisses occur in two localities as mentioned above, namely, on the northwestern portion of Tally-Ho mountain, and on a ridge lying to the west of Becker creek and facing Wheaton river. The rocks differ considerably in appearance and composition in these two places.

The Tally-Ho Mountain members are coarsely-textured rocks, and vary in appearance from varieties consisting chiefly of quartz and feldspar, in which masses of hornblende up to an inch in length occur, to others that consist mainly of hornblende in which feldspar crystals up to an inch in length are embedded. The rocks may thus have a very dark or a moderately light mottled appearance, and have everywhere a decided gneissoid structure.

Microscopically, these rocks are seen to be composed mainly of relatively varying, but not always important, amounts of plagioclase, quartz, and hornblende. Augite also is generally present, and some of the hornblende, at least, has been derived from this mineral. In addition, large idiomorphic crystals of apatite are generally present, and magnetite in idiomorphic forms occurs plentifully. Where any considerable amount of feldspar and quartz is present, these minerals have always a typical consertal arrangement, and are always in allotriomorphic grains. The hornblende has rarely idiomorphic outlines. The rocks have been subjected to great pressure and are much crushed and broken, and originated from some basic igneous rock, probably of the gabbro type.

The hornblende-gneisses that occur on the ridge to the west of Becker creek, and in which the contact-metamorphic ore-deposits on the Fleming claim occur, are finely textured, light greyish rocks that have a gneissoid structure and the general appearance of crushed, fine-grained grano-diorites.

Under the microscope, they are seen to consist of plagioclase, quartz, and common green hornblende, in about equal amounts. These rocks are, in places, much altered to calcite due to the alteration of the plagioclase. Secondary chlorite also occurs. These gneisses have been derived from some deep-seated, igneous rock, apparently from a lime-rich granite or a quartz-monzonite.

Limestone.—The limestones vary from white to light bluish, and from subcrystalline to crystalline, and can generally be distinguished for long distances on account of their light colour. In places they are somewhat argillaceous, but more frequently are siliceous in composition, due to metamorphism. They generally occur in heavy massive beds, but in some places, where considerable admixtures of argillaceous matter occur, they become somewhat flaggy.

STRUCTURAL RELATIONS.

All of these schists, gneisses, and quartzites of the Mt. Stevens group are much folded, broken, and distorted, and have everywhere a laminated structure. Some of the rocks are more altered than others, but everywhere they show the results of intense metamorphism. Even the limestones are folded, crumpled, and so involved with other rocks that their relative ages are uncertain.

The main outcrop of these rocks occurs in the form of a long narrow belt, and is, apparently, the surface of a wall dividing subjacent portions of the Jurassic granitic batholith. Some of the smaller areas of the Mt. Stevens members in this district are believed to constitute remnants of the roof of, and others occur as inclusives in this plutonic mass which has, for the greater part, been stripped by erosive agencies of its former cover. The rocks constituting these relatively small exposures have been so metamorphosed and so highly disturbed that it is now practically impossible to decide anything definite regarding their relative ages or modes of occurrence. Certain types are clearly of sedimentary, others of volcanic origin, while still others are of deep-seated origin. Beyond this, nothing is definitely known of them. However, extensive areas of similar rocks are known to the north and west of Wheaton district, in the vicinity of Dawson and in Alaska, and there they have been studied in considerable detail.

AGE AND CORRELATION.

In Wheaton district no fossils have been found in the members of the Mt. Stevens group, and it is only known that these comprise the oldest rocks exposed in the area; however, from the descriptions of McConnell,[1] in Dawson district, and of Brooks[2] and others, in Alaska, it is evident that the Mt. Stevens rocks correspond with the lower

[1]McConnell, R. G.—"The Klondike gold fields": No. 884, Geol. Surv., Canada, p. 17.

[2]Brooks, A H.—"The geography and geology of Alaska": U. S. Geol. Surv., Prof. Paper, No. 45, pp. 208–218.

Palæozoic terranes of these districts. Different members of McConnell's 'Older Schistose Rocks' are, lithologically, apparently quite similar to those of the Mt. Stevens group. The hornblende-gneisses of Tally-Ho mountain appear to belong to the Pelly gneisses,[1] at first considered to be Archæan, but now believed to be much more recent and probably Palæozoic. Certain limestone bands carrying Silurian fossils occur intercalated in the schistose rocks in Alaska, and these limestones, both in their association and occurrence, resemble those of Wheaton district. As the limestones in the Wheaton district are believed to be among the most recent members of the Mt. Stevens group, these rocks are all considered to be pre-Devonian and, probably all, lower Palæozoic.

In the writer's report on a portion of Conrad and Whitehorse Mining districts, rocks corresponding to the Mt. Stevens group are described under the name 'Older Schistose Rocks,' and are there considered to be pre-Ordovician. There seems, however, to be a possibility that the limestones may be Silurian, and, therefore, as in the Wheaton district, the group might preferably be placed under pre-Devonian.

Also in the writer's report on the Lewes and Nordenskiöld Rivers coal area, rocks in all probability corresponding in part to the Mt. Stevens group are described under the name Razor Mountain group, but since only a single small outcrop occurs in this district, its correlation with the Mt. Stevens members is somewhat uncertain.

Perkins Group.

DISTRIBUTION.

The rocks of the Perkins group occur mainly in the eastern part of Wheaton district, and the largest area which they cover forms a northwesterly-trending belt about 11 miles long. At its southeastern end, on the edge of Corwin valley, this belt is only three-fourths of a mile wide, but it gradually widens to the northwest, until on Red ridge, facing Watson River valley, it has a width of 2½ miles. One other irregularly shaped area of the same rocks occupies a large part of Mt. Stevens, Dickson hill, and Tally-Ho mountain, and has an average width of about 2½ miles and extends past the southern boundary of Wheaton district. There are

[1] McConnell, R. G.—The American Geologist, Vol. XXX, July, 1902.

numerous small occurrences on Big Bend mountain, Mt. Pugh, Mt. Hodnett, and Mt. Anderson, and in addition a great number of areas, too small to map, were noted on the hills to the east of the mouth of Dail creek, on Mt. Anderson, on the hills on both sides of the mouth of Dawson-Charlie creek, and elsewhere.

The oblong area on Tally-Ho mountain, mapped as surrounded by Mt. Stevens rocks, consists of intrusive pyroxenite, and is shown as 4,000 feet long by 2,000 feet wide. However, as bed-rock is deeply covered here in many places by superficial deposits, contacts were seen only in a few places on the south and west, so the real extent of this area is only approximately known. The greater portion of the round hill between Dickson hill and Mt. Stevens is composed of amphibolites. With these two exceptions, all the areas shown on the map of Wheaton district as underlain by the Perkins group are occupied by andesitic members.

LITHOLOGICAL CHARACTERS.

Andesitic types—

Macroscopic.—The andesitic members of the Perkins group are prevailingly homogeneous-appearing, dark greenish, finely textured, hard, compact rocks which are generally megascopically aphanitic. Occasionally, feldspar phenocrysts, discernible with the naked eye, have developed, and in places these become as much as one-eighth of an inch in length. Instead of being greenish, these rocks in some instances have a peculiar reddish-brown colour, and the green and brown types frequently alternate. Dykes, representing an acid differentiation product of the andesitic magma, occur plentifully, and appear very similar to the fine grained, greenish and brownish andesites, but, in addition, have fine, lath-shaped, feldspar phenocrysts abundantly distributed throughout the fine groundmass. In a few places, as on the eastern toe of Mt. Pugh, and on Mt. Bush, these rocks constitute the greater part of the formation, and occur as numerous narrow dykes from 2 or 3 inches to 12 or 15 feet wide. The feldspars in some cases are $\frac{3}{16}$ of an inch in length and in size range from this down to microscopic, slender crystals. These dykes always occur too intimately associated with the containing rocks, or are too narrow, to be shown separately on the accompanying map, and so are included under the geological colour representing the Perkins group. Occasionally, as on the northeast corner of Mt. Stevens, decided tufaceous phases of these materials are found; the fragments range from microscopic to 6 or 8 inches in diameter, and consist, for the greater part, of materials such as have just been described, the porphyritic types being plentifully present.

Microscopic.—When examined under the microscope, the andesites are seen to be porphyritic rocks containing phenocrysts of plagioclase, hornblende, diopside, and biotite, lying in a hypocrystalline or holocrystalline groundmass. The feldspar of the first generation is prevailingly labradorite, but ranges from andesine to bytownite, and exhibits twinning according to the albite, pericline, and Carlsbad laws. Zonal structures are also of frequent occurrence, and represent variations in the amount of lime present. The phenocrysts are generally abundant and well formed, and range in size from those entirely invisible macroscopically to those one-eighth of an inch in length. Common green hornblende is the most abundant of the coloured constituents, and is generally present. Biotite occasionally occurs associated with the hornblende, or may be the only ferromagnesian mineral in the rock, while diopside is found but rarely. Accessory apatite and magnetite are common.

The groundmass is frequently pilotaxitic in structure, and consists of a felt-like web of plagioclase needles, hornblende or diopside crystals, and iron ore grains. Often a certain amount of a brownish glass is mixed in with these other materials, giving the groundmass a hyalopilitic structure.

The rock constituents are, in most instances, considerably altered, so that the rocks consist to a great extent of chlorite, epidote, calcite, biotite, and iron ore. Fine shreds and specks of secondary biotite due to metamorphic processes occur scattered all through the rock, and iron ores are frequently peppered throughout the groundmass. This fine distribution of biotite and magnetite characterizes the majority of these rocks.

The tuffs corresponding to these andesites are of wide-spread occurrence, and consist chiefly of andesite fragments cemented either in a glassy or a fine grained andesitic groundmass, as though the broken materials, the result of volcanic explosions, prevailingly fell back either in the molten or cooled andesites, but rarely into the sea, a conclusion that is strengthened by the general absence of sedimentary material.

The associated dyke rocks are holocrystalline-porphyritic in structure, and consist chiefly of plagioclase and hornblende, occurring in two generations. Brown biotite in minor amounts also exists, as well as accessory magnetite and apatite. The feldspars of the groundmass are typically elongated, and suggest somewhat the appearance of a fine ophitic structure, except that upon close examination they are seen to have irregular boundaries and the other constituents instead of enclosing them are irregularly distributed about them. These rocks, on account of their origin and composition, are considered to be malachites.

The andesitic rocks in certain instances are quite fresh appearing, but in most places have been much altered to aggregates of epidote and chlorite, while quartz, calcite, serpentine, etc., have been deposited in various minor fractures which intersect them. These features in some places serve to distinguish them from the Tertiary andesites.

Pyroxenites.—The pyroxenites are very homogeneous, generally coarsely textured, dark green to nearly black, plutonic rocks, in which nothing is megascopically visible but pyroxenite and its alteration products. Under the microscope, these materials are seen to be equigranular, coarse grained types, and to consist almost wholly of large allotriomorphic grains of diopside. Zoisite, epidote, and magnetite are generally present, as well as serpentine which, commencing to form at the surface and along cracks, continues until, in some instances, the rock is entirely changed to this secondary substance.

Amphibolites.—The amphibolites are also dark greenish rocks, and in appearance are very similar to the pyroxenites, but are prevailingly finer textured. Under the microscope, they are found to be equigranular rocks composed chiefly of hornblende of which two varieties occur: one variety consists of large allotriomorphic grains of a brown hornblende, which occur distributed throughout the rock, and have every appearance of being primary; the other variety composes most of the rock masses, is a green, fibrous actinolite. occurs to some extent in the form of small veinlets cutting the brown amphibole, and also may be primary. Considerable magnetite is also present as well as secondary calcite, chlorite, and serpentine.

The field relations of the amphibolites and pyroxenites indicate that possibly the amphibolites may have been derived from the pyroxenites, but no proof of this could be established.

STRUCTURAL RELATIONS.

Only one fault having any considerable displacement has been recognized in these rocks, and this is the most important dislocation that has been identified in Wheaton district. The fault is of the normal type, strikes in a northerly direction, and dips at 40° to 60° to the east; it extends from the southern edge of Mt. Follé to Red ridge, a distance of over 6 miles, and apparently continues farther in both directions, and wherever this break has been seen the Perkins andesites outcrop along its western edge. On the eastern side of Mt. Bush these rocks are brought up to a level with the Tantalus conglomerates, showing a displacement of 5,000 to 6,000 feet, and on Mt. Follé, Mt. Perkins, and Red ridge similar displacements occur.

The andesitic rocks were nowhere seen in contact with the deep-seated pyroxenites and amphibolites, and no evidence was obtained as to their relative ages. They both, however, cut the different members of the Mt. Stevens group, and are themselves invaded by the Jurassic Coast Range intrusives.

The rocks of the Perkins group occur as walls separating subjacent portions of the Jurassic granitic batholith, and also exist as remnants of the roof of, and as inclusions in, the granitic mass. These broader structural features, however, will be more fully discussed under structural geology.

ORIGIN.

The andesites originally occurred chiefly as flows, which still cover considerable tracts in Wheaton district and adjoining portions of Yukon territory. These rocks have been so extensively eroded that it is now impossible to say how thick they were originally, but in places masses of them, 2,000 to 3,000 feet deep, can still be seen, and occasionally flow-structures are quite evident, and different lava-streams can be readily distinguished. The evidence is also imperfect as to whether these volcanics came to the surface chiefly through elongated fissures, or mainly from circular craters, as the formations that are older than these rocks are, in Wheaton district, of very limited extent. The form of these accumulations in the adjoining Windy Arm district, however, quite clearly indicates that there, at least, the lavas came chiefly from craters.

AGE AND CORRELATION.

Concerning the age of the members of the Perkins group, it is only known definitely, as stated above, that they are all younger than the Mt. Stevens group, considered to be Silurian or older, and older than the Jura-Cretaceous sediments and the Coast Range intrusives. However, they may be of somewhat widely different ages, but the andesitic members, as shown below, are almost certainly upper Palæozoic.

In the writer's report on Conrad Mining district, which includes Windy Arm district, the Perkins members there are included in the Devonian, lower Câche Creek series, which also contains cherts, slates, and other sediments. Since such sediments and cherts do not occur in Wheaton district, the new name, Perkins group, has been given to the igneous members of the lower Câche Creek series of Conrad district.

In Whitehorse district, a few miles to the northeast of Wheaton district, McConnell[1] has described rocks under the name of 'Porphyrites,' which are more recent than the Carboniferous limestones and appear to correspond with the andesitic members of the Perkins group.

Coast Range Intrusives.

DISTRIBUTION.

The Coast Range intrusives are the most widely distributed rocks of Wheaton district, and their distribution may be best described by defining that of all the other formations, and saying that the Coast Range intrusives occur everywhere else. In the main valleys Quaternary materials cover the bed-rock, and in the western portion of the district volcanics of Tertiary, and perhaps late Cretaceous age, have invaded and covered the granitic rocks over considerable areas. In the eastern portion of the district walls of older rocks separate subjacent portions of the granitic batholith, and in a few places overlie it, constituting remnants of the roof of, or occurring as inclusives in this plutonic mass. Jura-Cretaceous sediments also cover these granitic rocks in the northeastern part of the district.

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[1]McConnell, R. G.—"The Whitehorse Copper Belt, Yukon Territory": Geol. Surv. Branch, Dept. of Mines, Canada, 1909, pp. 9–12.

LITHOLOGICAL CHARACTERS.

The Coast Range intrusives are generally fresh and unaltered in appearance, are predominantly greyish in colour, and have the general appearance of typical, medium to coarse grained granites. In a few places the orthoclase becomes sufficiently important to give these rocks a pinkish colour, but this is exceptional. Frequently they become porphyritic in structure, and contain numerous large feldspar phenocrysts which in places were noted to be as much as 1½ to 2 inches long. Hornblende particles are generally present, and biotite is of common occurrence; both of these minerals are readily seen megascopically.

When examined under the microscope, these rocks are seen to generally consist chiefly of an acid plagioclase, quartz, hornblende, biotite, and orthoclase. In most cases plagioclase is the chief feldspar, and orthoclase, although generally present, is prevailingly in minor amounts. Quartz is in most cases fairly plentiful. Green hornblende is nearly always present, and may or may not be accompanied by biotite which sometimes is the only ferro-magnesian mineral present. Zircon, apatite, and magnetite, are frequent accessories. The rocks have either a typical granitic structure, or may contain large feldspar-phenocrysts in a granitic groundmass, and so have a holocrystalline porphyritic structure.

The rocks have thus predominantly a mineralogical composition midway between granites and quartz-diorites, and have been called grano-diorites. Occasionally, with increasing orthoclase and decreasing plagioclase, typical granites are found; also, in a few places, the plagioclase increases and the orthoclase disappears and so diorites occur. In places it is difficult to say whether the rocks are more appropriately termed porphyritic grano-diorites, or grano-diorite porphyries; but since the rocks everywhere are coarsely textured and always have a typical granitic habit, the term porphyritic grano-diorites has been adopted in all cases. Similarly, porphyritic granites and porphyritic diorites occur.

The term monzonite has been adopted by the United States Geological Survey, and is used by many American geologists for rocks midway in composition between granites and diorites, and according to this nomenclature, these rocks are prevailingly quartz-monzonites, and porphyritic quartz-monzonites or quartz-monzonite-porphyries.

The name Adamellite has been used by Brögger[1] as a convenient term to signify an acid-quartz-monzonite.

ORIGIN.

The granitic intrusives in Wheaton district constitute a portion of the eastern edge of the great Coast Range batholith which is known to extend from southern British Columbia to the vicinity of Kluane lake, 50 miles north of the northern edge of Wheaton district, a total distance of over 1,000 miles.

This igneous mass penetrated the rocks of the Mt. Stevens group and the Perkins group, but is apparently older than all the other rocks in the district, and on its eroded surface the Jura-Cretaceous sediments have been laid down. The structural relations of this granitic batholith to the other rocks of the district will be discussed under structural geology.

AGE AND CORRELATION.

This granitic batholith has been studied in detail in British Columbia and Alaska, and there is now a general concensus of opinion that it was intruded in Jurassic, and probably in late Jurassic time. Wheaton district furnishes no definite data on this point further than establishing the fact that it antedates the Jura-Cretaceous period of sedimentation.

Laberge Series.

DISTRIBUTION.

The rocks of the Laberge series are, with one small exception, restricted to the northeastern corner of the district, and occur in two belts on opposite sides of and facing Corwin valley. The more easterly belt appears to occupy nearly the entire northern half of Gray ridge, of which only the eastern half lies within Wheaton district. On the accompanying geological map this area is shown as being 6 to 7 miles long and about 1 mile wide. The belt to the west of Corwin valley extends from Wheaton River valley to Red ridge, and apparently continues beyond the northern boundary of the district. The belt is, within the limits of the district, about 7 miles long and 6,000 to 8,000 feet wide.

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[1]Brögger, W. C.—"Die Eruptionsfolge der triadischen Eruptiongesteine bei Predazzo in Südtyrol"; p. 61.

On the northern summit of Carbon hill, these beds underlie a small outcrop of Tantalus conglomerates, outcropping around, and for some distance past, the edges of the overlying rocks. The Laberge beds are here limited to a circular area about 1,500 feet diameter.

LITHOLOGICAL CHARACTERS.

Macroscopic.—The Laberge series consists chiefly of arkoses, tuffs, breccias, conglomerates, sandstones, and shales, which have a maximum aggregate thickness in Wheaton district of at least 5,000 feet. These beds can be roughly divided into lower, middle, and upper portions, as follows:—

Upper beds.—	Thickness,	1,500 feet, chiefly sandstones.
Middle beds.—	"	1,700 feet, chiefly shales, with some sandstones and arkoses.
Lower beds.—	"	1,800 feet, chiefly arkoses and tuffs, with intercalated shales, and conglomerates.

These divisions are only approximate, and the thickness of each varies; but in a general way they are found to hold true. The 'lower beds' consist chiefly of arkoses, tuffs, shales, and conglomerates. The arkoses are predominantly light to dark grey, or pale greenish in colour, but occasionally reddish-grey and dark greenish-grey beds are found. They may have a dense and megascopically aphanitic texture, or may resemble in appearance a medium textured sandstone; and all gradations between these extremes occur. They are firm, compact rocks, and occur in heavy, massive beds in which the stratification planes are frequently only distinguishable from a distance.

Associated and interbedded with these arkoses are some tuffs which so much resemble them that it is generally difficult or impossible to megascopically tell the two apart. These rocks also grade into one another, so that in places breccias occur, which have almost equal claim to be called arkoses and tuffs.

The lower 1,000 feet of the 'lower beds' of the Laberge series consist chiefly of these arkoses, breccias, and tuffs; but the upper 800 feet contain a considerable development of conglomerate and shale. The conglomerate occurs in thick, massive beds, and consists of materials varying widely in size. The pebbles and boulders range in size from that of sand-grains to larger than a man's head, and are chiefly of andesitic fragments derived, for the greater part, from the Perkins volcanics. Pebbles of the Coast Range grano-diorites are also frequently found. These materials have been cemented together by binding materials that are generally siliceous in composition, and have formed hard, dense rocks.

The shales range from light grey through dark green to almost black in colour, and occasionally occur thinly bedded. They are predominantly hard, dense rocks which at times resemble flint, and often possess a decided slaty cleavage. It is common to find 20 to 50 or even 100 feet of shales overlain by arkoses or conglomerates of equal or greater thickness, and these again followed by more shales, etc. The different members never occur intimately associated, i.e., when shales or arkoses, for instance, occur they have a thickness of at least 20 or 30 feet, and generally more, before giving place to a dissimilar member.

The 1,700 feet of 'middle beds' consist chiefly of shales like those described above, but characteristically iron-stained and generally presenting a red appearance. When broken, however, they generally are seen to be dark grey to almost black, dense, hard, and brittle, and break into sharp angular fragments. They occur prevailingly in layers ¼ to 1 inch in thickness and are associated, to some extent, with arkoses and sandstones, but the shales predominate.

The 'upper beds' of the Laberge series consist almost entirely of medium textured, somewhat friable sandstones which are prevailingly greyish, yellowish to light brownish, or even pale greenish in colour, and occur in heavy, massive beds. These differ greatly from the hard, dense, compact rocks that are noted in the 'lower' and 'middle' beds.

Microscopic.—A number of sections of the arkoses, tuffs, and related rocks were examined microscopically. The arkoses were seen to consist chiefly of rounded and angular particles of plagioclase, as well as some of quartz, and a few rock fragments, all cemented by a matrix that consists chiefly of kaolin, and some calcite. In some cases the matrix contains a great amount of secondary biotite, produced by metamorphic processes. The tufaceous rocks contain a much greater percentage of rock fragments, as well as particles of devitrified glass with the conchoidal fracture typical of tuffs. Between these decided arkoses and tuffs are materials of which it can only be said that they are highly feldspathic, and microscopically appear as breccias. In some instances these appear to be true water-laid sediments, in others they seem to represent mainly either showers of ashes that fell directly into the sea, or similar materials brought by streams and deposited in the salt water.

STRUCTURAL RELATIONS.

The Laberge rocks of Wheaton district occur in two, parallel, northerly-trending belts, each about 7 miles long, and occurring on opposite sides of Corwin valley. Throughout the more westerly area the beds dip to the west at angles varying from 50° to 75°, and on the eastern end of Red ridge are seen overlying the eroded surface of the Jurassic granitic intrusives. Nowhere else in the district were the lowest members of the series seen, and here the lower beds of the Laberge series are much thinner than on Mt. Follé and Idaho hill, as they have not the great accessions of ash materials, which elsewhere gives them their great thickness. The structure of the beds on the western part of Gray ridge is very obscure, but the rocks appear, in a general way, to be gently inclined to the west.

The Laberge beds are cut off all along their western edge by a northerly-trending, normal fault which dips at 40° to 60° to the east, and brings these rocks with the overlying Tantalus conglomerates in juxtaposition with the Perkins volcanics. The faulting has been the means of preserving this area of Laberge rocks; had it not occurred, these beds would have been eroded away during the base-levelling period, as has this series in other portions of the district.

The members of the Laberge series overlie the Coast Range intrusives, and are older than the greater portion, and perhaps all of the Chieftain Hill volcanics. However, the tufaceous materials included in the Laberge beds closely resemble those of the Chieftain Hill volcanics, and indicate that possibly the volcanic activity producing these rocks may have commenced before the withdrawal of the Cretaceous sea from this district.

AGE AND CORRELATION.

Numerous specimens of *Prioncyclus woolgari* have been found in the shales on Mt. Follé and Idaho hill, and of these Whiteaves said: '*Prioncyclus woolgari* (Mantell)—Several crushed specimens

Looking in a southerly direction across Wheaton River valley. The western face of Carbon hill occupies the centre and left hand portion of the view, and it is here, and particularly on the steep face as shown in approximately the centre of the picture, that the greater number of the antimony-silver veins occur.

of an ammonite, that are possibly very young individuals of this species. In the upper Missouri country, and elsewhere in the United States, *P. woolgari* is regarded as a characteristic fossil of the Fort Benton group.'

In Tantalus coal area and Braeburn-Kynocks coal area,[1] approximately 100 miles to the north of Wheaton district, the Laberge beds also occur, and much resemble those here being described. A number of somewhat poorly preserved fossils were collected from these northern districts, and were examined by Mr. Whiteaves, who classed them all as Jura-Cretaceous.

The Tutshi series of Conrad Mining district corresponds, to some extent, to the Laberge series, but does not include some of the bedded tuffs and other tufaceous materials that are intimately associated with the sediments, and includes the Tantalus conglomerates.

Tantalus Conglomerates.

DISTRIBUTION.

The Tantalus conglomerates are of very limited extent in this district, but are particularly interesting because generally they contain coal measures. The most important area of these rocks lies on the eastern side of Mt. Bush, and is lozenge-shaped, 6,000 feet long by about 2,000 feet wide at the centre. Across Schnabel creek is another similarly shaped, but slightly smaller area, separated from the former by less than 1,000 feet. Both these areas have a northern trend, and are the largest in the district.

The entire circular summit of Mt. Bell is composed of these rocks in the form of a large, flat-lying cake that covers an area about 2,000 feet in diameter.

A somewhat pear-shaped area forms the top of one of the small summits of Carbon hill, and is about 2,500 feet in its largest dimension. A much smaller body of these rocks forms the top of the northern summit of Carbon hill, and is not over 1,000 feet in diameter.

LITHOLOGICAL CHARACTERS.

The series known as the Tantalus conglomerates consists chiefly of massive beds of conglomerate, but also contains sandstones, shales,

[1]Cairnes, D. D.—"The Lewes and Nordenskiöld Rivers coal district, Yukon" Geol. Surv. Branch, Dept. of Mines, Canada, 1910.

and coal seams, and has an aggregate thickness in Wheaton district of 1,700 to 1,800 feet. These conglomerates differ from all others so far found in Yukon territory, in that the pebbles composing them consist entirely of chert, quartz, and slate. The pebbles are generally cemented by a siliceous binder forming a hard resistant rock which breaks along planes passing indifferently through the pebbles and matrix. These conglomerates have also a noticeably constant appearance for such coarse-grained rocks, due to their uniform texture and the slight variety in the materials composing them. The component pebbles are remarkably similar in size, being seldom larger than 2½ inches in diameter, and predominantly between 1 and 2 inches. The associated sandstones consist of the same materials as the conglomerates, but in a finer state of division. The shales occur chiefly in the vicinity of the coal seams, and are generally finely textured slaty rocks. Just west of the coals, however, some light coloured, thinly bedded shales with excellent slaty cleavage occur, which break readily into large plates one-eighth of an inch or less in thickness. They were noted in the one place only, and are less than 50 feet in thickness.

STRUCTURAL RELATIONS.

The Tantalus conglomerates on Mt. Bush and Mt. Follé overlie, apparently conformably, the Laberge series on the east, and dip to the west at 60° to 80°. Along their western edge, they are cut off by the easterly dipping, normal fault above referred to, and are brought into juxtaposition with the Perkins group, showing that a displacement of as much as 5,000 or 6,000 feet has occurred. To the west of the fault these beds have been entirely removed by erosion in most places, but a few scattered outcrops indicate that in all probability they at one time covered the entire district.

Part, if not all, of the Chieftain Hill volcanics are more recent than the conglomerates, but as explained in discussing the Laberge series, there is evidence that the Chieftain Hill period of vulcanism commenced before the close of Jura-Cretaceous sedimentation.

AGE AND CORRELATION.

No fossils have been found in the Tantalus conglomerates in Wheaton district, but a number of plant remains were collected by the writer from the walls of the coal seams at the Tantalus mine on the Yukon river, midway between Whitehorse and Dawson. These coals correspond to the Mt. Bush seams, and occur in the Tantalus conglomerates which, on account of their marked features, are readily correlated over large areas. The fossils were examined by Dr. D. P. Penhallow, who reports: 'All the material appears to be the same as the specimen of *Thyrsopteris elliptica* (Fontaine), as figured by Ward in the "Status of the Mesozoic Floras of the United States," vol. XLVIII, pl. LXXI, figs. 12 and 13; and to this the present specimens are provisionally referred. It is to be observed, however, that there seems to be some question as to the correctness of Ward's reference, since the specimen cited is quite distinct from the original type of *Thyrsopteris elliptica* as described by Fontaine (in "Potomac Flora, vol. XV, p. 133, pl. XXIV, figs. 3, 3*a*"), and it is quite possible that further and more complete specimens may show this to be an entirely new species. A somewhat related flora was described by me in 1898 as obtained by Mr. J. B. Tyrrell from the Nordenskiöld river. All the specimens shown, however, were specimens of *Cladophebis*, and they indicate Cretaceous age.' 'The specimens from the Tantalus mine present a flora with the same facies as those from the Nordenskiöld river, and the whole conform to the flora of Kootanie age.'

As the Kootanie is by some geologists included in the upper Jurassic, and by others in the lower Cretaceous, and as the Tantalus conglomerates overlie the Laberge beds which are only known to belong to either the Jurassic or Cretaceous, the Tantalus conglomerates are also included in the Jura-Cretaceous.

These conglomerates occur in Lewes and Nordenskiöld Rivers coal area, and have been described by the writer in the report on that district. The name 'Tantalus conglomerates' was there first employed, and was adopted because the coals of the Tantalus mine occur in these beds. These rocks are also described in the writer's report on a portion of Conrad and Whitehorse Mining districts, where they were included in the Tutshi series.

Chieftain Hill Volcanics.

DISTRIBUTION.

The Chieftain Hill volcanics occur chiefly in the western portion of the district, though a few small areas occur in the eastern part. The largest single occurrence covers the greater part of Cirque mountain and some of the adjoining hills to the south, and was not traced to its limits toward the west or north. The area has a very irregular form, and, as far as explored, has an average diameter of about 2½ miles.

The rocks belonging to the Chieftain Hill volcanics also outcrop over a considerable portion of the eastern face of Chieftain hill, and a narrow strip extends along its southern edge. A long, narrow, easterly-trending belt extends along the top of Carbon hill, and continues part way over the western face of the hill toward Wheaton river. This belt is about 3 miles long, and ranges in width from 100 to 4,000 feet. The occurrences on Chieftain and Carbon hills are interesting, because in them a number of the antimony-silver veins occur. All of these areas include intrusive and extrusive andesitic rocks as well as tufaceous accumulations.

The round top of Idaho hill consists of andesitic tuffs and breccias, and adjoining these to the east and north is an occurrence of intrusive andesites. The combined area is about 4,000 feet long and 2,000 to 3,000 feet wide.

Beds of andesitic tuffs also form the top of one of the small southern summits of Mt. Stevens. This area is about 1,500 feet long by 500 feet wide.

Other small areas of tuffs occur, as on the northeastern spur of Mt. Anderson, and on a low ridge forming the southeastern point of Johnson hill. Also on the western face of Mt. Bell a small area of red, iron-stained intrusive andesites occurs. Dykes of these rocks occur very plentifully throughout the district, but are generally only 5 to 25 feet in width—too small to be shown on the geological map accompanying this report.

LITHOLOGICAL CHARACTERS.

Macroscopic.—The Chieftain Hill volcanics are mainly mica-, hornblende-, and augite-andesites, and andesitic tuffs and breccias. They vary considerably in appearance and composition, showing many shades of red, blue, green, and brown, but generally have a typical andesitic habit. A distinct porphyritic structure is prevailingly noticeable, and phenocrysts of feldspar are generally visible, while those of hornblende and biotite frequently occur. Some augite-andesites occurring in Chieftain gulch and elsewhere, however, are dark greenish, dense, finely textured rocks, in which none of the mineral constituents are discernible, and in which phenocrysts do not appear. These closely resemble basalts both in appearance and composition. Rocks with a dense, aphanitic, reddish, greyish, or greenish groundmass, in which well formed plagioclases are abundant, are the commonest types.

In some places, as on the eastern slope of Cirque mountain, flow-structures are well preserved in, generally, reddish to reddish-brown, finely textured andesites. The andesites also occasionally contain a great amount of pyrite and other iron ores which oxidize, causing the formation of limonite and giving the rocks a distinct reddish to reddish-brown appearance. On the west face of Carbon hill, and on the southwest side of Mt. Bell, in particular, bright red areas occur, which are distinguishable for long distances. In these places the andesites have contained a considerable quantity of pyrite which has oxidized and has been influential in causing the alteration of the other rock components, so that at the surface the rocks are so weathered that it is difficult to find a specimen sufficiently fresh for identification.

Tuffs and breccias are of wide-spread occurrence, and vary in texture from microscopic tuffs, to coarser rocks in which individual masses several feet in diameter are found. These clastics consist mainly of andesitic materials, but in many places contain a considerable admixture of foreign matter. Where the tufaceous fragments fell on surfaces covered with erosion products, the resulting clastics contain boulders and pieces of whatever materials were exposed on the old surface. For instance, ashes, lapilli, etc., were showered over the eroded granitic rocks now seen on the eastern face of Cirque mountain, and there, consequently, are mixed with a great number of grano-diorite boulders and particles, as well as with other rock debris.

In other places the fragmental materials fell upon an andesitic surface, and in such cases the resulting rocks contain no foreign matter. In still other places, as on Idaho hill and Mt. Stevens, the ashes, lapilli, etc., must have fallen into the water, as they contain a considerable admixture of sedimentary materials. These tufaceous rocks are occasionally roughly bedded, but generally show no planes of deposition.

Microscopic.—When examined under the microscope the andesites are seen to have a considerable range in structure and mineralogical composition, but consist chiefly of plagioclase, occasional orthoclase, hornblende, biotite, and diopside. The plagioclase is the chief component of the rocks and occurs always in both generations. The phenocrysts are predominantly labradorite, but range from andesine to bytownite, and are generally in large well formed crystals that are twinned according to the albite and, frequently, the Carlsbad and pericline laws as well. Zonal structures are also plentiful. In the mica-, and hornblende-andesites, the plagioclases are generally megascopically quite large, but in some places augite-andesites occur in which they are only microscopically discernible. An acid plagioclase is always present in the groundmass of the rocks, and is prevailingly andesine, but oligoclase and labradorite occur. Orthoclase also occasionally occurs in large, well defined phenocrysts, and is frequently present in the groundmass. Microperthite was noted in a few specimens, but is not at all characteristic of these rocks.

Both common green hornblende and brown basaltic hornblende frequently occur; but of the two the green variety is the more often encountered. They occur in both generations, and may or may not be associated with biotite, but were nowhere seen in the same specimen with diopside. Brown biotite, which is probably quite as generally distributed in these rocks as the hornblende, is occasionally the only ferro-magnesian mineral present, and exists in both the first and second generation. The pyroxene present in these rocks is always a colourless, or nearly colourless, diopside, and, although it forms quite distinct phenocrysts, these are seldom of sufficient size to be seen with the naked eye. When present, this is generally the only ferro-magnesian mineral in the rock, but brown biotite occasionally occurs associated with it. Olivine also was noted in a few specimens of augite andesites. As accessories, magnetite is always present, and frequently occurs peppered all through the groundmass. Pyrite is also at times abundant, but is not as universally present as the magnetite. Zircon and apatite are also common accessory minerals.

Many of the minerals are frequently much altered, and the plagioclase, hornblende, and diopside are always to some degree affected. The plagioclase is changed mainly to calcite and epidote, and, in some cases, is almost entirely replaced by these. The hornblende alters mainly either to chlorite and epidote, or chlorite, calcite, and quartz. The diopside is transformed chiefly to chlorite which generally commences at the periphery of the crystals, and frequently continues until the whole mineral is replaced. These processes result in altering considerable portions of these rocks, in places, to masses chiefly of chlorite, epidote, and calcite.

In structure, the rocks are always porphyritic, and the phenocrysts, which have been described, are generally fairly abundant, so that the fabric might be described as predominantly dopatic to sempatic.[1] The groundmass varies considerably and ranges from hypohyaline, or partly glassy, to holocrystalline, but is rarely coarser than microcrystalline. Pilotaxitic structures are very characteristic of the groundmass, and in such cases the feldspars have somewhat the appearance of a number of small shoe-pegs irregularly distributed, and filled in between with, chiefly, augite prismoids, and iron ore grains. At times a certain amount of brownish glass is also present, and in such instances, the structures are referred to as hyalopilitic. In a few places, andesites also occur having a microgranitic groundmass which consists chiefly of plagioclase, orthoclase, quartz, and biotite. In the hypophyaline groundmasses, spherulites are frequently present, and, at times, occur in bands or layers exhibiting flow-structures.

The tuffs and breccias, as mentioned previously, at times contain a considerable amount of foreign material, and, in places, embrace more or less sedimentary matter. However, they generally chiefly consist of andesitic particles embedded in a fine-grained, often dense and partly glassy, groundmass.

ORIGIN.

The andesites have apparently come to the surface through fissures, and have overflowed from these openings and covered extensive tracts. Numerous dykes of these materials are found, and in a few places, as in Chieftain gulch on Chieftain hill, fissures filled with them can be seen penetrating the older granodiorites, and extending upward to great masses of similar andesites that have flowed from these fissures. It is probable, however, that these lavas flowed chiefly from certain portions of these fissures, and did not pour out uniformly along them. This is indicated by the distribution of these rocks, which is somewhat localized.

[1]Cross, Whitman, Iddings, J. P., Pirsson, L. V., Washington, H. S.—"The texture of igneous rocks": Jour. of Geol., Vol. XIV, No. 8, Nov.-Dec., 1906.

Explosive forces sent great showers of ashes, lapilli, etc., into the air, and these fell back under various conditions, and gave rise to the various tuffs and breccias described above.

AGE AND CORRELATION.

The majority of these volcanics, at least, are more recent than all the Jura-Cretaceous sediments, but these sedimentary beds are more or less tufaceous in places, as on Idaho hill, and much resemble the Chieftain Hill clastics. In fact some of the Chieftain Hill breccias on Carbon and Chieftain hills, so much resemble some of the tuffs and arkoses of the Laberge series, that these rocks are difficult to distinguish. It thus seems quite possible that the Chieftain Hill period of vulcanism may have commenced during the existence of the Jura-Cretaceous sea in Wheaton district.

The Chieftain Hill volcanics are cut by the Carmack basalts and Wheaton River volcanics, and so are older than these; their age is, therefore, Cretaceous or early Tertiary.

These rocks correspond, apparently, to the Hutshi group and Schwatka andesites of Braeburn-Kynocks, and Tantalus coal areas. There the Schwatka andesites include mica-, and hornblende-andesites, and the Hutshi group includes chiefly augite-andesites. However, the lithological peculiarities which served to distinguish these two types of rocks to the north, do not exist in Wheaton district, where the new name 'Chieftain Hill volcanics' is used to include all these andesitic materials.

The andesitic rocks in a general way also correspond to the Windy Arm series, as described in the writer's report on Conrad Mining district, but the Windy Arm series includes a number of tuffs which in Wheaton district are considered as more properly classed with the sedimentary rocks, and are placed in the Laberge series.

Carmack Basalts.

DISTRIBUTION.

The Carmack basalts, although extensive in other portions of Yukon territory, are represented in Wheaton district by only a few scattered dykes that are generally too narrow to be shown on the geological map. The most important dykes occur on the eastern face of Chieftain hill and on the western face of Carbon hill.

Looking in a southwesterly direction across Wheaton River valley toward the eastern face of Chieftain hill on which the Morning and Evening antimony-silver vein occurs.

LITHOLOGICAL CHARACTERS.

These basalts, in Wheaton district, are usually compact, dark greyish to reddish-brown rocks which are generally megascopically aphanitic, though occasionally augite can be distinguished in them with the unaided eye.

Microscopically, they are seen to be porphyritic rocks in which the groundmass generally consists of a mixture of variable quantities of augite, plagioclase, and iron ore, and in most cases, is typically pilotaxitic in texture. Occasionally, a certain amount of brownish glass is present, causing the fabric of the groundmass to become hyalopilitic. The phenocrysts are chiefly bytownite and augite, with olivine in subordinate amounts. The chief alteration products are calcite and chlorite.

ORIGIN.

In a number of districts in Yukon territory these basalts form extensive flows. The famous Miles canyon, in Whitehorse district, has been cut by Lewes river in one such occurrence; also these basalts and associated tuffs are among the most prominent rocks in Tantalus coal area.

However, in Wheaton district the Carmack basalts are only represented by a few narrow dykes, generally less than 15 feet wide. In one place on Vesuvius hill, however, a small area, perhaps 6 feet square, was seen which appeared to be a portion of a large body of these rocks underlying the Wheaton River tuffs.

AGE AND CORRELATION.

These rocks have been studied in several parts of Yukon territory, and everywhere the evidence indicates that they are of late Tertiary or Pleistocene age. In Wheaton district they cut the Chieftain Hill volcanics, and are in turn intersected by the Wheaton River rocks, conditions consistent with a late Tertiary origin.

These rocks have been described in the writer's report on the Braeburn-Kynocks, and Tantalus, coal areas, where the name Carmack basalts was first used, and also in the report on a portion of the Conrad and Whitehorse Mining districts, under 'Scoria and Basalt.' McConnell has also described these rocks in the Whitehorse district, under the name 'Basalt.'

Klusha Intrusives.

DISTRIBUTION.

The Klusha intrusives are found only in the eastern half of Wheaton district, and, with one exception, occur as dykes. What appears to be a small stock outcrops on the eastern spur of Mt. Perkins, and has an exposed diameter of 1,500 feet, but may be much larger, as the bed-rock is there extensively covered by superficial deposits.

The dykes are generally from 10 to 50 feet in width, and so are often too narrow to be shown on the accompanying map. One dyke about 700 feet wide occurs on the eastern face of the hill situated between Mt. Perkins and Mt. Pugh; and numbers of smaller ones outcrop on the same hill as well as on Mt. Puhg, Mt. Perkins, Wheaton mountain, and elsewhere.

LITHOLOGICAL CHARACTERS.

The Klusha intrusives are granite-porphyries that are prevailingly greyish in colour and of a coarsely granular habit, so that all the principal mineral-components are distinctly discernible with the unaided eye. Under the microscope the rocks are seen to possess a holocrystalline, porphyritic structure, and to consist of a microgranitic or micropegmatitic, quartz-feldspar groundmass, in which alkali feldspar and lime-alkali feldspar phenocrysts are plentiful, and in which biotite and hornblende commonly occur.

The feldspars are mainly orthoclase and microcline, which occur in about equal amounts, and are in most cases only slightly altered; but a certain amount of transformation to muscovite, and occasionally to kaolin, has generally occurred. The orthoclase shows frequent Carlsbad twinning. In addition to these alkali feldspars, minor amounts of an acid plagioclase are always present, prevailingly andesine, although albite and oligoclase may be found. These occur mainly in the first generation, and exist as large well formed phenocrysts which are twinned according to the albite, and frequently according to Carlsbad law as well, and are changed chiefly to epidote, calcite, and quartz, and also in a small degree to muscovite. Brown biotite also frequently occurs in both generations, and is generally much altered to chlorite. Common green hornblende is the only other ferro-magnesium mineral that has been found in these rocks, and it is less common than the biotite, and alters mainly to chlorite, calcite, and quartz. Accessory apatite and zircon are often present. These rocks are thus either hornblende granite-porphyries, or mica granite-porphyries.

The groundmass is generally microgranitic, but a sample from a narrow dyke, near the summit of Mt. Follé, showed micropegmatitic, quartz-feldspar intergrowths.

OCCURRENCE.

These rocks have been identified at numerous points in Yukon territory, and always occur as small stocks or dykes. In the eastern part of Wheaton district a number of dykes occur, generally from 30 to 50 feet in width, and at the eastern spur of Mt. Perkins a body outcropping with a diameter of 1,500 feet was found piercing the Laberge beds, and appears to be the top of a stock from which the overlying sediments are being gradually removed.

AGE AND CORRELATION.

The Klusha intrusives are very recent and may, with the exception of the unconsolidated Quaternary materials, be the newest rocks in Wheaton district. Whether they are older or newer than the Carmack basalts is not known but, since they are so nearly related to the Wheaton River rhyolites, and differ from these chiefly only in texture, as explained later, it is thought that both may really belong to the same period of igneous activity. If so, the Klusha rocks are more recent than the basalts; but in any case are of late Tertiary, and possibly of Pleistocene age.

The name Klusha intrusives was first employed in the Braeburn-Kynocks coal area, to represent a series of syenite-porphyries, that much resemble the granite-porphyries of Wheaton district. Similar rocks have also been described in the writer's report on a portion of Conrad and Whitehorse Mining districts, under the name 'Granite Porphyry,' and in that district were found to grade from granite into syenite-porphyries without any marked difference in their general appearance; merely a decrease in the amount of quartz occurred.

Wheaton River Volcanics.

DISTRIBUTION.

These rocks outcrop extensively in the western part of Wheaton district, and one important area occurs in the eastern portion. They cover practically the entire top of Chieftain hill, and extend over all the adjoining mountain to the west, thus including an area over 6 miles long and from 1 to 2½ miles wide. They also extend to the west considerably beyond the western boundary of the district mapped.

Another large area which is probably connected, under the Quaternary deposits, with the one just mentioned, includes all Vesuvius hill and a portion of the adjoining hill to the east. This area has an average diameter of about 2½ miles.

Small areas less than one-half mile in diameter occur on McNeil hill and Cirque mountain.

An irregular area about 2 miles long and from 6,000 to 3,000 feet wide also occurs on the eastern portion of Carbon hill and on the adjoining hills to the west.

A large outcrop of these rocks also occurs adjoining, and to the west of Dail creek, and between it and Mt. Follé. This area is very irregular in outline, and occupies about 2 square miles.

Numerous small outcrops of these rocks occur particularly in the western part of the district, and dykes are very plentiful in many places. On the ridge just to the east of the mouth of Dail creek dykes of these Wheaton River volcanics are so abundant as, in places, to constitute about half of the formations.

LITHOLOGICAL CHARACTERS.

Macroscopic.—The Wheaton River volcanics include rhyolites, and rhyolitic tuffs and breccias, which are light coloured, felsophyric rocks, i.e., they have a megascopically aphanitic groundmass. In places these rocks contain considerable pyrite which oxidizes to limonite and gives them a bright red to brownish or yellowish red appearance. Where the rhyolites are not iron-stained, they are prevailingly nearly white to light grey in colour. The tuffs are, at times, distinctly bedded or banded, and as the different layers contain varying amounts of iron, hills, like Vesuvius hill, on which these rocks occur, have in places a bright varicoloured appearance.

The rhyolites have always a felsophyric groundmass in which phenocrysts of quartz, orthoclase, and plagioclase occur. The quartz exists frequently in distinct dihexahedrons which are as much as one-thirty-second of an inch in diameter. Well formed megaphenocrysts of orthoclase and plagioclase also occur, but those of the alkali feldspar are much the more plentiful. The rocks when considered as to their relative amounts of phenocrysts and groundmass might be described as varying from perpatic, or those extremely rich in groundmass, to dopatic, in which the groundmass is dominant.

The tuffs and breccias consist chiefly of fragments of rhyolitic materials, which vary in size from microscopic to several inches in diameter. These rhyolitic clastics contain considerable amounts of foreign materials, particularly where they are found overlying older rocks. On the hill to the east of and adjoining Vesuvius hill, near the contact of the tuffs with the Jurassic granodiorites, the clastics contain large boulders and fragments of granite, andesite, schist, etc., some of them several feet in diameter, showing that the tuffs were showered over a land surface covered with these erosion products.

In places the rhyolites, as well as the tuffs, show distinct flow-structures, which are strongly emphasized by weathering. The weathering agencies are enabled to accentuate the original somewhat banded flow-structures, largely owing to two factors: first, the different layers contain varying amounts of iron; second, the amorphous, glassy bands have more retained potential energy than those that have given up energy in crystallizing, and are, therefore, chemically the more active, and weather more readily. These two factors give rise to fine red bands that correspond to the original flow-structures in the rocks.

In many places, as on Vesuvius hill, the tuffs in particular weather with extreme rapidity to, chiefly, kaolin and limonite, so that it is almost impossible to obtain a specimen the identity of which is recognizable. In such places, the hillsides are so deeply covered with talus, which is predominantly of tabular form, that to climb the slopes becomes very difficult.

Microscopic.—Microscopically, the rhyolites are seen to always have a porphyritic structure, the phenocrysts being generally megascopic. Orthoclase is considerably the most abundant mineral of the first generation, and occurs in large idiomorphic forms which often exhibit Carlsbad twinning, and are frequently considerably altered to muscovite. Quartz exists mainly in six-sided and four-sided crystals, which often show considerable corrosion. Large acid plagioclase individuals occasionally are seen, and are generally much altered to kaolin and quartz. Accessory iron ores are also commonly present, and apatite and zircon occur.

The groundmass is generally holocrystalline, although in some instances it is hypohyaline, and might then be described as ranging from percrystalline (extremely crystalline with some glass) to docrystalline (dominantly crystalline). A micropegmatitic fabric is the most characteristic of these groundmasses, and beautiful intergrowths of quartz and feldspar are seen, representing the crystallization of eutectic mixtures of these minerals. Microgranitic fabrics also occur, but are less common than the micropegmatitic. In such cases, the groundmass is holocrystalline granular, and consists chiefly of quartz and alkali feldspar. In the hypohyaline varieties, more or less devitrified spherulites commonly occur, and are often in bands or layers parallel to the original flow-structures. In other cases, the glass is more or less evenly distributed throughout the groundmass.

The clastic rocks are seen to consist chiefly of rhyolite fragments which frequently exhibit typical conchoidal fractures, and, at times, are definitely the broken or exploded portions of vesicular masses of rhyolitic lavas. In places these rocks contain fragments of andesite, granitic rocks, etc., which occur associated with the other materials. A considerable amount of partly devitrified glass also occurs in them, both as matrix and as fragments.

ORIGIN.

The Wheaton River volcanics occur mainly as dykes, volcanic necks, surface flows, and tufaceous accumulations. The flows are often less than 10 feet thick, but are at times considerably more; and appear to have come chiefly from the fissures which occur plentifully on Chieftain and Carbon hills, and from which thin streams of liquid rhyolites poured forth.

A small volcanic neck is cut by the creek which runs along the north side of Mt. Bell. This intrusive area appears to be about 4,000 feet in diameter, and lavas and associated tufaceous materials have spread over the surrounding surface for some distance. A somewhat similar, but irregularly shaped plug occurs between Dail creek and Mt. Follé, and connected with it are a great number of dykes, only a very small portion of which can be shown on the accompanying geological map.

All the observations made in this district go to show, that although the great bulk of the lavas of the Wheaton River series have come from fissures, the outpourings have been from localized points, and have not been evenly distributed along any considerable portions of the fissures.

A roughly circular crater occurs on the summit of Vesuvius hill, but the materials derived from it are mainly the tuffs and breccias, which compose the greater part of the hill, and are generally roughly bedded.

The occurrence on McNeil hill differs from all the others encountered. What appears to be really a stock, that measured at the level of Wheaton river is 2,500 feet wide, cuts through the Jurassic granitic rocks. If this body of rhyolite originally reached the surface it would have probably overflowed, but no indications that it did so were discovered. Toward the summit of the mountain, about one-third of the rhyolite is still capped by a thin cover of granitic materials, and in all probability the whole mass was originally so covered.

The tuffs are much thicker than the true flows, and on Chieftain hill, Cirque mountain, and Vesuvius hill are from 100 to at least 1,000 feet in thickness. These, to a great extent, appear to have come from Vesuvius hill, but are also to some extent apparently derived from the hills on which they occur.

AGE.

The Wheaton River volcanics are the most recent consolidated rocks in the district, except possibly the Klusha granite-porphyries. There is no decided evidence in the district to show which of the two is the older, but since they are of almost identical composition, and differ chiefly in texture, it is most probable that they are nearly, if not quite, synchronous.

The Wheaton River volcanics came to the surface before the glacial period, but after the district had reached almost its present state of topographical development, and the lava-streams of this time, except in the valleys, have since been but slightly eroded; so that in places, as on the eastern portion of Carbon hill, the original form of the flows is still well preserved. These volcanics are thus of late Tertiary, or Pleistocene age.

Quaternary.

DISTRIBUTION.

Corwin valley and Wheaton River valley, within the limits of Wheaton district, are floored with Pleistocene deposits, the thicknesses of which can only be surmised, as they have nowhere been penetrated to the underlying bed-rock. Terrace exposures in adjoining districts indicate, however, that these materials may be several hundred feet thick. Great thicknesses of these deposits also occur in the valleys of Fenwick creek; of Summit creek between Cirque mountain and Vesuvius hill; and of the lower portions of others of the larger streams tributary to Wheaton river, such as Becker, Berney, Thompson, and Partridge creeks. Pleistocene materials occur, in addition, along the lower portions of the walls of Corwin valley, Wheaton River valley, and the lower parts of some of the larger tributary valleys. Terraces composed partly of lateral moraine accumulations occur along Corwin valley, Wheaton River valley, and the valleys of Partridge, Becker, and Fenwick creeks, up to heights of 700 or 800 feet above the elevation of the Wheaton river at the nearest point. Occasional boulders and minor amounts of Pleistocene deposits occur even on the plateau-surface.

A thin mantle of Recent material covers the surface of the district nearly everywhere, except on steep slopes and escarpments.

On the geological map accompanying this report the colour representing Quaternary is used only where the nature of the underlying bed-rock is uncertain, so that the areas coloured Quaternary are really those where the main Pleistocene deposits occur, as the Recent materials are rarely sufficiently thick or extensive to conceal to any extent the pre-Quaternary formations.

LITHOLOGICAL CHARACTERS.

The Pleistocene and Recent terranes of the district are lithologically in many places nearly identical, and sometimes grade into each other so that, in most cases, they are not differentiated but are regarded as a stratigraphic unit.

The Pleistocene deposits in Wheaton district consist chiefly of gravels, sands, and boulder-clays, and as these have been only very slightly dissected, in most places cross-sections of them are almost lacking; generally only the surfaces of these materials are to be seen and they are, in many cases, nearly as the ice left them. The present master-valleys are floored with materials whose visible surfaces consist chiefly of sands and fine gravels which are cross-bedded and show every indication of having been deposited in swift water. The moraines, which are abundant in Corwin valley especially, consist of unsorted sands and gravels. Boulder-clay probably occurs associated with and underlying the other materials in most places in the main valleys, but was nowhere seen in this district.

The Recent deposits are composed of the fluvial, and littoral sands, gravels, and silts of the present waterways, ground-ice, peat, muck, volcanic ash, and soil. The sands, gravels, and silts are exposed along the present streams and lakes, and the ground-ice is practically everywhere present a few inches or a few feet beneath the surface. Peat and muck occur mainly around the lakes, as these occupy imperfectly drained portions of the valleys, and are favourable localities for such accumulations. The partly frozen peat, muck, etc., overlying frozen materials, such as occur around Annie lake, and on which shrubbery may or may not be present, constitute the tundra of the district. This covers a considerable area in the upper portions of Corwin, Summit Creek, and Hodnett Lakes valley. A thin layer of soil forms the uppermost geological deposit in the valleys and on some of the level portions of the upland.

A peculiar feature of southern Yukon is a layer of volcanic ash or pumiceous sand. This material has been noticed as far south as Lake Bennett, where it is about one inch thick, but it increases in thickness to the north and west, until at a distance of 200 miles it is 2 feet thick. It is calculated that this ash covers about 25,000 square miles and has a volume of at least one cubic mile. It is remarkably homogeneous and of more recent age than the silts which are the latest of the glacial deposits. In fact, this ash has fallen since the present waterways cut their courses to approximately their present depths, and the trees and vegetation are rooted in it. From its very even distribution, it would appear to have fallen very tranquilly, somewhat like snow, and to have all come at one time, as in it, as originally deposited, no intercalated layers of foreign materials exist. It is occasionally, however, found somewhat mixed with other surface deposits, where it has been washed from the hillsides into the valleys below. Mt. Wrangel is the nearest known volcano at present active, and the ashes appear to increase in that direction; it seems probable, therefore, that it came either from that mountain or from some yet undiscovered, or now extinct, volcano in the vicinity. In Wheaton district this material is from 1½ to 3 inches thick, and is thickest in the northern and western parts of the area.

STRUCTURAL GEOLOGY.

General.

A study of the structural geology of Wheaton district resolves itself, for the greater part, into a consideration of the relations of the Jurassic granitic rocks to the other geological terranes. Sedimentary rocks are preserved over only a relatively small portion of the district, and their structures, as shown by the geological map and sections accompanying this report, are quite simple. The igneous materials of more recent date than the Jurassic plutonics are the ordinary types of andesitic, rhyolitic, and basaltic volcanics to be seen in many districts, and their structural relations have been discussed undre 'General Geology' in connexion with their detailed descriptions. This section on structural geology, in which only the general structural relations of the district are intended to be considered, will, therefore, treat mainly of faulting and of the invasion of the granitic batholith which underlies the entire district, and outcrops over the greater part of it.

The Granitic Batholith.

Wheaton district is situated along the eastern edge of the great Coast Range batholith, and thus furnishes a favourable position in which to observe the relations of the granitic intrusives to the invaded materials, as in spite of erosion considerable portions of these still remain. In the eastern half of the area, remnants of the roof of the batholith are still to be found, and two huge walls separating subjacent portions of this great igneous mass, as well as numerous inclusions, still exist.

Farther west the older rocks do not occur, as the intrusives have risen considerably higher along the central portions of the batholith than at its margin, and in such places erosive agencies have worn sufficiently deep into the granitic body to have removed all portions of the older materials which originally existed as roof, projections, and inclusives.

A study of the Coast Range batholith at various points in British Columbia, Alaska, and Yukon, as well as investigations of other granitic batholiths in the Cordillera of western North America, have tended to show that in no case, so far as known, did these intrusive bodies rise to the surface, but in all instances cooled under a cover of older rocks. In places the existence of the roofs has been definitely proven, and their thicknesses have been estimated to within a few hundred feet.[1] In Wheaton district in no instance have any remains of synchronous extrusives been discovered, and some quite distinct roof-fragments still exist (see section C-C, in back of this report), which apparently are portions of a cover that originally completely roofed the intrusives. There thus appears to be little doubt that these granitic materials cooled beneath older rocks.

The manner in which the invading materials attacked the overlying formations is also well exhibited in this district (see sections A-A, B-B, and C-C, in back of this report). Two long, relatively narrow walls of pre-Jurassic rocks occur in the batholith, and trend parallel to its eastern margin. These have been incised by Wheaton River valley to a depth of over 3,000 feet, and at the valley floor are practically the same width as at their highest points. The granitic rocks have been injected upwards between these walls in the form of a huge dyke having an average width, for over 12 miles, of about 8,000 feet. At a number of points in the district small, irregularly shaped patches of older rocks were noted, which since they outcrop at all elevations cannot represent portions of the roof, but are inclusions that have become involved in the granitic magma. It would appear thus that the invading magma intruded the overlying rocks in the form of great tongues, dykes, etc., from which were given off smaller branching portions which penetrated the older materials to a considerable degree in some places. This is well seen in the case of the inclusions, in which a number of dykes can generally be found.

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[1]Smith, G. O. and Mendenhall, W. C.—"Tertiary granite in the northern Cascades": Bull. Geol. Soc. America, Vol. II, 1900, pp. 223–230.
Barrell, Joseph—"Geology of the Marysville mining district, Mont.": Prof. Paper, No. 57, U. S. Geol. Surv., pp. 167–173.

However, the minute interfingering of magma and older rock, that is to be seen in connexion with the Pre-Cambrian batholiths of the Laurentian area in Canada and elsewhere, and in the Palæozoic batholiths of the New England states and other districts, is not here found. Further, the invaded rocks have apparently received no additions from the magma except in the form of distinct dykes, sills, and other forms of considerable size. No granitization is apparent, i.e., the addition of chiefly feldspar and quartz, minutely introduced along an infinite number of irregular spaces, has not been a feature of the batholithic invasion here, as in the cases just mentioned. The only apparent effect that the granitic magma has had on its walls is to cause a recrystallization of materials to some extent, and thus give them a denser texture. Even this metamorphism extends only a few feet from the intrusive border. That a certain amount of marginal assimilation occurred seems evident by the fact that the granites for a short distance from the contacts with the darker rocks, particularly the andesites, have an increasingly darker appearance as the wall is approached, until at the contact all are often a dark green colour. It is not thought, however, that this process has been operative to any great extent, as 20 or 30 feet away from the contact the composition of the batholith appears to have been unaffected by its walls. However, to definitely decide the extent to which assimilation has been effective, a large number of rock analyses would require to be made, which has not been done for this district.

The method of mechanical batholithic invasion that has been mainly effective here appears to have been that of the breaking away of blocks from the roof, and their sinking in the intrusive magma which probably rose as they sank to fill the places they had occupied. That this process is not only a possible one, but one that has in all probability been chiefly operative in the case of the majority, at least, of the batholiths of western North America, has been shown by Daly, Barrell,[1] and others. Daly[2] has shown that blocks of an average rock sink in a magma of average composition, owing to its temperature and consequent less density. Accordingly in this district, as the intrusive has about an average composition and as the walls are, in most cases at least, decidedly more basic, these would readily sink.

[1]Op. cit.

[2]Daly, R. A.—"The mechanics of igneous intrusion": Amer. Jour. Soc., Vol. XV, Apr., 1903, pp. 269–299.

The walls of the batholith may have been to some extent forced apart by the pressure exerted by the invading materials upon them, but it is not considered that this has been an extensive factor in the invasion process, because the batholith is 30 to 40 miles wide and, as stated above, a cover is believed to have remained over the magma until it had cooled, which could hardly be conceived as possible if its walls were forced apart such great distances. The absence of all foliation and mashing in the portions of the roof that still remain also tends strongly to show that no such lateral force has been operative. It is thus apparent, at least, that the granitic magma must be now occupying the space that originally contained other rocks, and since these have apparently not been forced apart, they must have been removed either upward or downward. There is no evidence that they were belched out on the surface, in fact, none could have been if the batholith cover was preserved. Therefore, they appear to have sunk in the magma, and to have been broken from the roof by the process of overhead-stoping, which answers all the requirements of the field of observations in this district.

Faulting.

Numbers of faults of considerable displacement may occur in this district, but where these intersect only the massive igneous rocks at the surface their presence is difficult to detect, and the amount of their movement cannot be measured. Thus only one prominent break has been identified, and this is recognizable since it intersects sedimentary rocks. This fault has been traced from Wheaton River valley on the east side of Mt. Stevens, in a northwesterly direction to Red ridge, a distance of nearly 10 miles, and it may extend considerably farther beyond the northern edge of the district mapped.

The amount of the displacement along the eastern sides of Wheaton and Stevens mountains cannot be measured, as there, granodiorites are in contact with andesites, and both are massive materials. However, to the north of Wheaton river the displacement is at least as much as 5,000 to 6,000 feet on Mt. Bush and Mt. Follé, as the upper members of the Tantalus conglomerates are brought into contact with the Perkins group, showing a movement at least equal in amount to the combined thickness of the Laberge, and Tantalus beds.

The fault is of the normal type, i.e., the hanging-wall moved downward in relation to the foot-wall, and it is inclined to the north-east at angles varying from 45° to nearly 90°.

An interesting feature in connexion with this great break is that its location appears to have been decidedly influenced by the position of the contact between the andesitic rocks and the granitic intrusives. The andesites, as above explained, project as a great wall down into the granitic batholith, and it is the eastern face of this wall that appears to have controlled to some extent the location of the fault-plane.

Explanation of Geologic Sections.

Observations in the field necessarily reveal conditions only at the actual surface, but a compilation of all the data that can be obtained, combined with general geological experience, allows of inferences being made concerning the general relations of the formations underground, which approach almost to the degree of certainty obtained by observation. Thus, in spite of their inferential character, geologic cross-sections of a region are of great value as showing the relations of the various formations to each other, and their probable structure. The sections shown in the geological map accompanying this report are constructed from the ideas of geologic relationship and structure developed in the preceding discussion, but a few points may here be worthy of mention in way of review and explanation.

Cross-sections B-B and C-C show several inclusions in the granitic mass underground. These are, of course, not known to exist in the actual position shown, but since similar small bodies are found scattered over the surface at all elevations, it is only reasonable to assume that others occur under similar conditions beneath the exposed portions of the batholith.

Cross-section B-B shows an irregular apophyse of the granitic rock invading the andesites. The structure of this intrusive body is, of course, conjectural, but surface observations show that the granitic rocks have in many places invaded the older andesitic materials in this fashion, and they thus very probably have here a form resembling that shown, which is, however, intended to represent a general rather than a specific attitude of the rocks toward one another.

Cross-section A-A shows the granitic rocks underlying the invaded andesites, and the roof is given a stepped form as if an angular block had just been removed. As overhead stoping is believed to be the chief method of mechanical batholithic invasion, such forms would most naturally result.

Other similar explanations might be given, but these will probably be sufficient to make clear the object the writer has had in compiling these sections, viz., to present as clearly as possible his ideas of the general structural relationship of the various formations. The underground details as presented are only to convey an idea of the general structure, rather than specific details.

HISTORICAL GEOLOGY.

The succession of geologic events in Wheaton district will now be briefly reviewed, and in doing so, all the more important facts concerning the structure and stratigraphy will be presented. The matter is, of necessity, somewhat fragmentary, and the records of long periods have been almost entirely destroyed; still a systematic treatment of the available data may help to make more apparent the many vicissitudes which the district has undergone.

The oldest records are contained in the Mt. Stevens group, which are more poorly preserved in Wheaton district than in other parts of Yukon and Alaska, to the north and west, so that appeal to them there will be necessary to supplement the information that is available here. The Mt. Stevens rocks only show that at an early stage in the history of the district the bed-rock formation consisted of quartzites, slates, argillites, and limestones, which were invaded by granites, gabbros, rhyolites, andesites, diabases, etc. The relative ages of these various members are but imperfectly revealed, as all are greatly metamorphosed, plicated, distorted, and eroded.

Similar terranes have been carefully studied in Yukon and Alaska to the north and northwest of this district, by a number of Canadian and United States geologists,[1] who have shown that in

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[1]McConnell, R. G.—"Report on the Klondike Gold Fields": Geol. Surv., Can., pp. 18–20.

Spurr, J. E.—"The Geology of the Yukon gold district": 18th Ann. Rep. U. S. Geol. Surv., pt. 3, 1900.

Prindle, L.M.—"Gold Placers of the Fortymile, Birch Creek, and Fairbanks regions": Bull. U. S. Geol. Surv., No. 251.

Brooks, A. H.—"Reconnaissance in Tanana and White River basins": 20th Ann. Rep. U. S. Geol. Surv., pt. 2, 1900.

these districts thousands of feet of arenaceous and argillaceous matter, followed also by great thicknesses of calcareous material, were accumulated in lower Palæozoic times, and that vulcanism was active during sedimentation. Silurian fossils[1] have been found in the limestones which appear to be at the top of the series. There is a possibility that the gneisses of the terrane may be Pre-Cambrian, but this is not considered at all probable.

Throughout a great part, at least, of Yukon territory, sedimentation is known to have been terminated in late Silurian or early Devonian times by a wide-spread, dynamic revolution which caused extensive deformation and metamorphism, and was accompanied by considerable volcanic activity. The rocks of the Mt. Stevens group may have received their schistose and crystalline character, and some of the intrusives may have been injected at this time. However, the records of this time are here sadly dimmed and time-worn, and it is only actually known that these old rocks are lithologically very similar to the lower Palæozoic rocks described elsewhere in Yukon and Alaska, as mentioned above, and that they were highly metamorphosed and deformed, and to a great extent removed by erosion, before they became invaded by the Jurassic granitic intrusives.

Where the records are still legible, they show that at the close of the Silurian disturbance a considerable area was above the sea, and a long erosion interval ensued. Some time before the middle Devonian, however, a great part of Yukon sank beneath the sea, and at about that time vulcanism became active at a number of points. The older members of the Perkins group may have then been intruded.

This sea-invasion, which commenced in Devonian time, continued at least well into the Carboniferous, and only 3 or 4 miles to the east of the eastern edge of Wheaton district considerable thicknesses of Carboniferous[2] limestones exist, and 15 or 16 miles to the east, several thousand feet of Devono-Carboniferous quartzites, cherts, slates, and limestones occur. However, if any of these sediments were deposited during this period in Wheaton district, they were removed before the deposition of the Jura-Cretaceous beds, and have left no traces of their former presence.

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[1]Brooks, A. H.—"The Geography and Geology of Alaska": Prof Paper, No. 45, U. S. Geol. Surv., 1906, p. 264.

[2]The broad term Carboniferous, in this report, includes both the Mississippian and Pennsylvanian formations and is used where the available information is too indefinite to allow of a more exact name being employed.

Since the time interval between late Silurian and the beginning of Jura-Cretaceous deposition is not represented by any sediments, Wheaton district may thus have been a land area, subjected to erosion and intermittent volcanic invasions throughout this entire time. The andesitic members and possibly also the pyroxenites and amphibolites of the Perkins group, all of which are thought to be of upper Palæozoic age, invaded the older rocks and buried them under flows and tufaceous accumulations of considerable thickness.

A wide-spread disturbance in Jurassic and apparently in late Jurassic time, interrupted all sedimentation over vast areas, including the southwestern part of Yukon, and was accompanied by the injection of vast amounts of igneous materials, including the great batholith of the Coast range, the greatest in the history of Yukon territory. A considerable area was above the sea at the close of this disturbance, and, what was probably a short period of erosion, ensued. This was followed by a gradual sinking of the land in Jura-Cretaceous time, which continued until an extensive land-mass, including Wheaton district, was submerged.

The materials that accumulated in this Jura-Cretaceous[1] sea in Wheaton district were chiefly such as have produced, upon consolidation, arkoses, tuffs, conglomerates, sandstones and shales. These have a maximum thickness at present of possibly 6,000 feet, but a great amount has been removed by erosion. In the extreme southern portion of Yukon, the volcanics play a very important rôle, but these gradually disappear toward the north, until at 100 miles north of the 60th parallel the sediments include but little tufaceous matter. In Tantalus coal area,[2] which is situated a few degrees to the west of north, and 120 miles distant from the Big Bend of the Wheaton, the Jura-Cretaceous conglomerates, sandstones, shales, etc., are at least 5,000 feet thick at present, and have been extensively eroded.

This Jura-Cretaceous period was also characterized by volcanic activity, as evidenced by the ash-beds and volcanic breccias found intercalated with the normal sediments. These volcanics all appear

[1]The term Jura-Cretaceous is of necessity employed in this memoir. Numbers of fossils have been collected from different localities and persistent efforts have been made to find others; nevertheless, the plant and animal remains so far collected, have afforded but indefinite and unsatisfactory results, and the great accumulations referred to are only known to be of upper Jurassic or Cretaceous age.

[2]Cairnes, D. D.—"Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district": Geol. Survey Branch, Dept. of Mines, Canada, Memoir No. 5, 1910, pp. 30–38.

to be andesitic in character, and are, in places, accompanied by andesitic flows. This vulcanism persisted until after sedimentation was brought to a close, as dykes are found cutting all the Jura-Cretaceous beds. Great masses of andesites are also found in Tantalus and Braeburn-Kynocks coal areas,[1] 100 to 120 miles to the north-east of Wheaton district, overlying eroded surfaces and edges of the uppermost Jura-Cretaceous sediments.

This Jura-Cretaceous period of sedimentation was terminated by a wide-spread deformation, at the close of which a considerable area, including Wheaton district and the greater part at least of southern Yukon, was above the sea. Degradation became active, and from that time to the present no evidence has been obtained to show that any portion of southwestern Yukon has been subjected to marine conditions. The historic records in Wheaton district from the time of the Jura-Cretaceous disturbance until the Pleistocene are but few and indefinite, and show mainly that the Jura-Cretaceous beds were considerably deformed and metamorphosed, that erosion continued until a nearly base-levelled surface was produced, and that this surface has been subsequently uplifted and dissected. Since, however, no sediments occur that are more recent than the Jura-Cretaceous beds, and are older than Pleistocene, there is no evidence within the district to indicate either during what period the planated surface was elevated or whether or not there has been more than one erosion cycle and subsequent uplift.

Following the Jura-Cretaceous disturbance, and mainly, it is thought, during Tertiary time, Wheaton district was subjected to at least three volcanic invasions, but the order in which these occurred is not definitely known. What appears to be the first, resulted in dykes of basalt being injected into the older formations in many places. In other parts of Yukon, these basalts poured over the land in the form of extensive flows, and, in places, hundreds of feet of tufaceous material accumulated. About this time, also, numerous dykes of granite-porphyry pierced the older formations. In addition, some rhyolites cut the older rocks and flowed over the land surface, generally as thin sheets, and were accompanied, in places, by great amounts of related tuffs and breccias.

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[1]Cairnes, D. D.—"Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district": Memoir No. 5, Geol. Surv. Branch, Dept. of Mines, Canada, 1910 pp. 38–43.

In upper Cretaceous time a transgression of the sea took place along the present Yukon basin to the north of Wheaton district, and also probably extended to other portions of Alaska and northern Yukon. Deposition continued well into the Eocene, although 'in the Upper Yukon basin, the Eocene is represented only by fresh-water beds which seem to have been laid down in isolated basins.'[1] In Eocene or Miocene time, a gradual uplift occurred which, though of an orographic character, was accompanied by volcanic activity and by a considerable local disturbance of the Eocene beds. The exact date of this orogenic movement is somewhat in doubt. Dawson[2] refers the uplift to the Eocene, but Brooks[3] has produced considerable evidence to show that the dynamic revolution occurred during late Eocene or early Miocene time. A long period of crustal stability ensued, during which what is now the Yukon plateau, as well, possibly, as the Coast range and other adjoining tracts,[4] were reduced to a nearly featureless plain which was subsequently elevated. Dawson[5] maintains that the planation was accomplished during the Eocene epoch, that the Miocene was a period of vulcanism, deposition, and accumulation, and he agrees with Brooks[6] in considering that the subsequent uplift occurred in Pliocene or early Pleistocene time. Spurr, however, shows that the erosion of the Yukon plateau was contemporaneous with the deposition of the Miocene strata in the lower valley of Yukon river, and, therefore, urges that the Yukon plateau was planated in Miocene time and was subsequently uplifted in late Miocene or early Pliocene time.[5] It is not known, however, to what extent Wheaton district was affected by these various movements and disturbances, but it is probable that the Jura-Cretaceous sediments were largely deformed by the Eocene or Miocene (post-Laramie) dynamic movements, that the district was peneplanated during Eocene or pre-Pliocene post-Eocene time, and that this planated tract was uplifted to practically its present position during late Miocene, Pliocene, or early Pleistocene time.

[1]Brooks, A. H.—Prof. Paper, No. 45, U. S. Geol. Surv., 1906, p. 266.

[2]Dawson, G. M.—"Geological record in the Rocky Mountain region of Canada": Bull. Geol. Soc. of Amer., Vol. 12, p. 79.

[3]Brooks, A. H.—Op. cit., pp. 292-293.

[4]Spencer, A. C.—"Pacific Mountain System in British Columbia and Alaska": Bull. Geol. Soc. of Amer., Vol. 14, Apr., 1903, pp. 117–132.

[5]Dawson, G. M.—Trans. Roy. Soc. of Can., 1890, Vol. VIII, sec. 4, 1890, pp. 11–17.

[6]Brooks, A. H.—Op. cit., pp. 290, 292, 293.

[7]Spurr, J. E.—"Geology of the Yukon gold district, Alaska": Eighteenth Ann. Rep., U. S. Geol. Survey, pt. III, 1898, pp. 260, 262, 263.

During the long period of crustal stability previous to this last important uplift, the topography was reduced to the form of a broad and gently undulating plain, and only occasional unreduced hills and ridges remained projecting above the general level. This lowland surface then became transformed into an upland tract, and the streams of the district were thus given renewed life and erosive powers, and, consequently, immediately commenced sinking their channels in the uplifted peneplain. Soon, numerous deep incisions were carved, which intersected the region in various directions. The interstream areas became more and more individualized, and assumed gradually the aspect of separate mountains and ridges.

The uplift of the Yukon plateau, including Wheaton district and the adjoining Coast range on the west (Diag. 2), was of a differential character and was thus really an upwarp, and was so conditioned that the resultant topography had the contour of a broad shallow trough, the approximate axis of which is occupied by Yukon river and its tributary the Lewes, while the Coast range lies along its western rim. It thus happens that the westerly portion of Wheaton district was more uplifted than parts farther east.

The higher tracts to the west and south of Wheaton district, during the Pleistocene, became the gathering grounds for glaciers, and huge tongues of ice moved down Corwin and Wheaton River valleys and their main tributaries. These valley-glaciers accentuated the topography produced by uplift and subsequent erosion, and deepened and broadened the depressions they occupied, steepened the valley-walls, and sculptured the land-forms in a manner characteristic of ice-action. Vast amounts of morainal and other glacial materials were also deposited over the floors and along the sides of the main depressions of the district.

After the retreat of the ice, the topography was practically that of to-day. The master-streams have been since employed in removing the burden of glacial sand, gravels, silts, etc., from their valleys, but Wheaton river and its main tributaries have, as yet, not succeeded in trenching their channels to bed-rock.

A thin veneer of Recent materials forms the surface nearly everywhere. This consists chiefly of sands, gravels, and silts of the present waterways, ground-ice, muck, volcanic ash, and soil. This volcanic ash is an interesting occurrence, and forms a layer 2 inches to 4 inches thick, very near the surface.

ECONOMIC GEOLOGY.

Wheaton district is of interest, from the standpoint of economic geology, for its ore-deposits and its coal-measures. The former will be here first considered.

ORE-DEPOSITS.

Introduction.

For convenience of description, the ore-deposits of this district may be classified as follows:—

(*a*) Gold-silver quartz veins.
(*b*) Antimony-silver veins.
(*c*) Silver-lead veins.
(*d*) Contact-metamorphic ore-deposits.

GENERAL.

The great majority of the ores of the district belong to the first three classes, and consist chiefly of veins, the economic importance of which depends on their gold, silver, or antimony contents. Quartz is, in these veins, nearly everywhere, the most important and generally the only gangue mineral. In a few places barite and calcite also play this rôle. The only representatives of the last class, the metamorphic ore-deposits, are found on a property near the junction of Becker creek with Wheaton river, and occur replacing bands of mica-gneiss, generally near their contact with the Jurassic granites. These ores consist chiefly of magnetite, hematite, and chalcopyrite, associated with garnet, epidote, calcite, and other secondary metamorphic minerals.

Over 500 claims[1] have been located in this district since the early part of the summer of 1906, and a large portion of these are still being held. Some promising discoveries have been made, and, in several places, good or even high-grade ore has been found. Still

[1]The records of the Mining Recorder at Carcross, Y. T., showed on Feb. 3, 1910, that 543 claims had been recorded, to date, in Wheaton district. Of this number only 6 were recorded previous to 1906, and 167 of the 543 were still in good standing.

no shipments have as yet been made, except a few test samples of 10 tons or less each, and no plant has been erected in the district for treating these ores.

RETARDED DEVELOPMENT.

All the mining done has been of a prospecting nature, and considering the number and character of the discoveries made, the amount of development that has been performed is exceedingly small. This is due to several causes, among which the following are probably the most prominent:—

The freight rates charged by the White Pass and Yukon railway have been such that it has been practically impossible to ship out of the territory any but the highest grade ores; and to bring in equipment and supplies for extensive working meant excessive expenditure. Not only have the rates been high, but mining men have been unable to obtain guarantees from the railway company that even the rates, at any time fixed, would not be raised in the near future.

When the discoveries were first made in Wheaton district there were no roads, and few trails, extending into this section of country.

A considerable portion of the rolling upland-surface of the district is covered with superficial deposits which obscure the various vein outcrops and render prospecting difficult. This is much emphasized by the fact that this surface mantle of soil, partly decomposed bed-rock, etc., is frozen the greater part, if not all the year, making stripping, trenching, etc., much more expensive than in more southerly districts. The frost does not interfere with underground mining, but is a considerable detriment to prospecting.

Still another element might be mentioned, and this is that a considerable number of the men in the district attempting development work are either entirely untrained in mining methods or, what is more generally the case, are placer miners, and to some extent are trying to apply placer methods to quartz mining.

PRESENT CONDITIONS.

The above-mentioned matters will, however, all right themselves, but some time is required, as the district is still new and comparatively unknown; and it is hoped that the properties containing workable ore will be producing in the near future. During the summer of 1910 the railway commission decided that the freight rates on ore from Whitehorse and Caribou to Skagway shall not exceed $2 and $1.75, respectively, per ton. The Yukon Government has also constructed wagon roads to different parts of the Wheaton district, so that now all the claims are on, or may be easily connected with, one of these roads, and are distant not more than 12 to 35 miles by road from Robinson on the Whitehorse Pass and Yukon railway. Finally, the men mining in the district are becoming more experienced, and more quartz miners are coming into the country, so that a lack of practical workers will also soon become a thing of the past.

Gold-Silver Veins.

SUMMARY.

Under this heading it is intended to give a brief summary of the more important facts, free from inference, concerning these gold-silver veins.

These veins are of wide-spread distribution in southern Yukon, and constitute the major portion of the ore-deposits, not only of Wheaton district but also of Windy Arm district to the southeast. They occur in Wheaton district throughout a northwesterly trending belt 16 miles long and 8 to 9 miles wide. The majority of the deposits occur in a strip, 2 miles wide, which extends up the centre of this belt and includes Mt. Stevens, Wheaton mountain, Tally-Ho mountain, Gold hill, and Mineral hill. Other veins have been found on Mt. Anderson and Red ridge to the west and east, respectively, of this 2 mile belt.

The majority of the veins strike, in a general way, parallel to the belt in which they occur, which in turn parallels the trend of the Coast range of mountains to the west. The veins are generally steeply inclined and dip, prevailingly, to the east.

These deposits are found chiefly in the Coast Range intrusives, but also exist in the schistose members of the Mt. Stevens group—principally in the chloritic and sericitic schists and the greenstone-schists. The veins in the granitic rocks occur as fissure fillings and are prevailingly regular and persistent in their various characteristics, such as strike, thickness, mineral composition, etc., for considerable distances. One vein has been traced over 3,000 feet and may extend much farther, and contains from 4 to 5 feet of vein-material throughout this distance. How far the majority of the other veins may extend is not known, but some have been traced upwards of 1,500 feet. They vary in thickness from a few inches to 7 or 8 feet, but the average vein in the granite is from 3 to 4 feet thick. When veins occur, however, in the schists the minerals have been deposited either in lens-shaped masses between the foliation-planes of the enclosing rock, or in irregular fissures which may occur connecting these lenses or may be independent of them. So that the deposits in these schistose rocks are extremely irregular in form, but have a general trend parallel to the strike of the mineral belt in which they occur. The bulk of the ore occurs in lenses which appear to have an average width of 6 to 8 feet and are from 20 to 40 feet long. One exceptional lens on the Acme claim is about 100 feet long and 30 feet wide. Veins in this formation have been traced over 1,000 feet, consisting of a succession of lenses and connecting fissures.

The vein-fillings consist, in nearly all cases, mainly of quartz which with subordinate amounts of calcite, constitute the gangue minerals. The quartz may present a massive appearance and be so finely crystalline that no distinct crystals can be seen with the naked eye; or it may consist chiefly of large, well-formed prisms which are either interlaced or pointed in a parallel manner toward the centre of the vein, thus forming distinct comb-structures. All gradations between these types of structure may be found.

Galena is the most characteristic metalliferous mineral, and is the only one occurring in any considerable amount. It may be very finely crystalline, when it is known as 'steel-galena,' or may occur as cubes up to half an inch to the edge. Pyrite and chalcopyrite occasionally exist in scattered particles. Native gold and sylvanite, as well as hessite, petzite, and telluric ochre also occur, but have been identified in only two localities, Gold hill and Mt. Stevens. The gold is generally very fine and occurs apparently both as a primary mineral and as an oxidation product of the tellurides.

The native gold and tellurides have so far only been found in small pockets on the Gold Reef claim on Gold hill, and in some float-quartz, which comprised chiefly a large mass of several tons, found near the summit of Mt. Stevens. Some of the samples of pockets of these ores have assayed several thousand dollars per ton in gold and silver. The source of the rich quartz on Mt. Stevens has not as yet been discovered; but it seems probable considering the large size of the main mass found and its angular character, that the vein from which it is derived is present on the hill on which it was found. It is not known, within close limits, what average amounts of gold and silver the different veins in the district carry; but selected ore from the more promising claims on Mt. Stevens, Wheaton mountain, Mineral hill, and elsewhere, contains from $20 to $80 per ton.

The zone of vein oxidation is very shallow, and does not appear to have had any appreciable economic effects upon these deposits. Unoxidized minerals often occur at the surface and have always been encountered above the 30 foot level; also no zone of surface enrichment due to weathering has been detected.

Mining in Wheaton district, as mentioned above, is everywhere in the prospect stage as yet; and, although the gold-silver veins have been exploited more than the other classes of deposits in the district, on only five claims has 100 feet or more of work been performed. On the Gold Reef claim on Gold hill there are a number of drifts, cross-cuts, raises, shafts, etc., aggregating several hundred feet. On four other claims, 75 to 350 feet of work has been executed, chiefly in the form of drifts. Three of these drifts have been driven on the veins, and the fourth is intended to cross-cut the ore. In all other cases where any work at all has been done it is chiefly as assessments and in the form of small shafts, less than 20 feet deep, open-cuts, trenches, etc. For this reason, although a number of promising claims have been located, and some good ore has been found, it is not definitely known that any of the properties possess ore in sufficient quantities and containing the requisite values to allow of their being profitably mined to any considerable extent under present conditions.

DETAILED DESCRIPTIONS.

The Vein-fissures.—The gold-silver quartz veins are of two types, each restricted in its occurrence to one type of rock. These are (1) simple gold-quartz veins in the Jurassic granitic intrusives, (2) lenticular veins in the Mt. Stevens schists. These two types contain similar minerals, belong to the same vein-system, and are contemporaneous in formation. Their differences are due, as will be explained later, to the effect of the containing rock on the formation of the fissures.

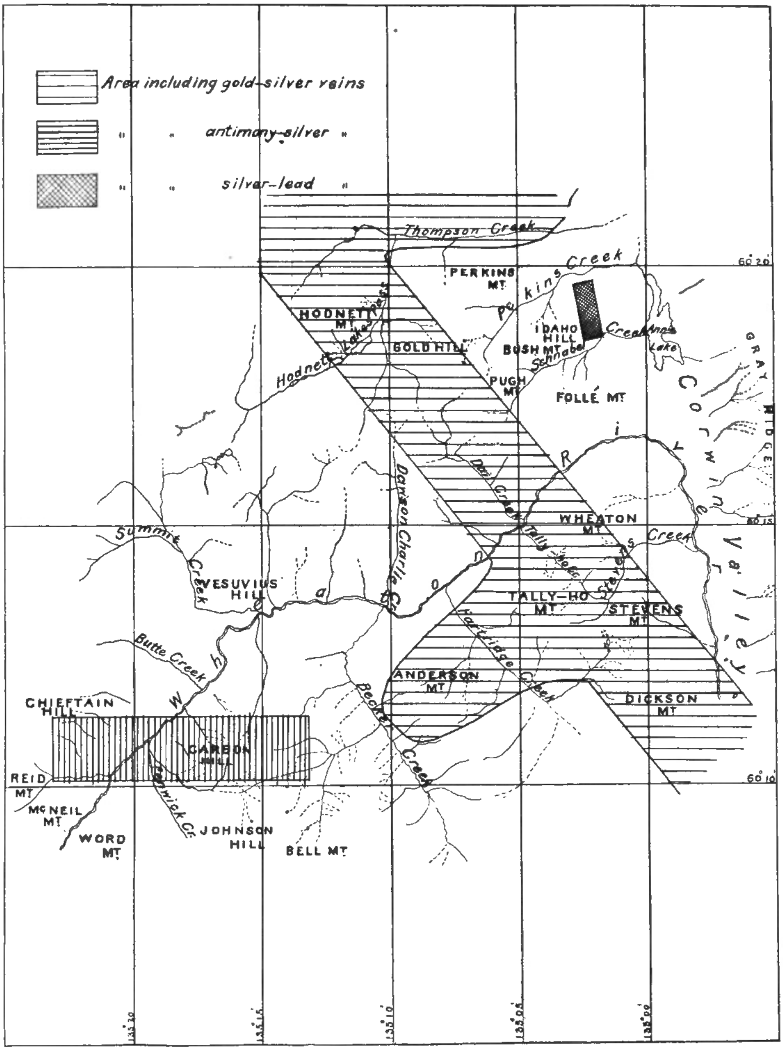
Distribution.—The majority of these fissures are limited in Wheaton district to a belt 16 miles long by 2 miles wide. This belt extends in a southeasterly direction from Watson river, on the north, to the southern portion of Mt. Stevens, which are points at the north and south edges, respectively, of Wheaton district. Ten miles farther to the southeast, and in line with the general direction of this mineral belt, are a number of similar veins, in Windy Arm district. Also, ores which probably belong to this class are reported to have been found to the north of Watson river and in a line with those known to the south. So that when this portion of southern Yukon has become more explored it will probably be found that these veins exist throughout an area greatly in excess of that existing in Wheaton district.

The narrow belt above described includes portions of Mt. Stevens, Tally-Ho mountain, Wheaton mountain, Gold hill, Hodnett mountain, and Mineral hill. In addition, a few veins have been found some distance on either side of this area. The most distant of importance, so far discovered, is that seen on the Rip, and Wolf claims on Mt. Anderson, about 4 miles to the west of the main belt. Veins were also noted on the eastern end of Red ridge and elsewhere, 2 to 3 miles to the east of this belt. So that altogether these fissures occur throughout an area of 8 or 9 miles wide, extending to the west to include Mt. Anderson, and to the east to the eastern edge of Red ridge (Diag. 3).

Formations in Which the Fissures Occur.—These ore fissures occur in the Coast Range intrusives which are chiefly granites and granodiorites, and also in the chloritic and sericitic schists and greenstone-schists of the Mt. Stevens group.

Strikes and Dips.—All of these fissures so far as is known strike in a general direction parallel to the trend of the belt in which they occur. They dip in all cases, except as mentioned below, to the northeast, and are generally steeply inclined, the angles of inclination to the horizontal varying from 60° to nearly 90°. Veins in the schists, however, are liable to dip to the southwest, but the only one known that does so is that on the Gold Reef claim. This irregularity is mentioned later.

Influence of Containing Rocks.—The containing rocks have a very marked influence in determining the form of the deposits. The fissures



Diag. 3. Mineral-bearing localities, Wheaton map area, Yukon.

found in the granitic formations are fairly straight and often quite persistent for considerable distances. The veins in the schists, on the other hand, are very irregular, and the greater part of the ores they contain occur as lens-shaped deposits between, and conformable to, the foliation-planes of the enclosing rock. The lenses are often more or less connected by irregular fissures, so that the entire

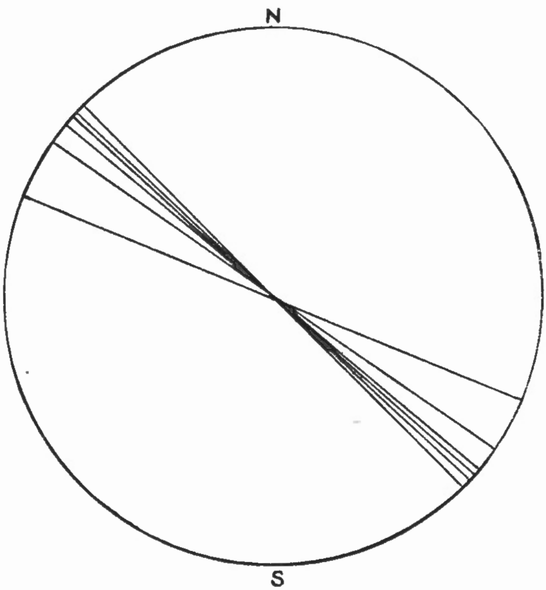


Fig. 2. Diagram showing strikes of gold-silver vein fissures.

veins, when such can be traced any considerable distance, have a general trend parallel to those in the granitic rocks, but consist partly of lenses, conformable to the schist laminæ, and partly of fissures cutting the latter and connecting the lenses. Sometimes these connecting fissures are well mineralized and constitute part of the vein proper, and again they are nearly or entirely barren. Lenses also occur which are apparently entirely unconnected with each other. It thus happens that when the foliation planes of the schists are parallel, or approximately so, to the general trend of the deposits or mineral belt, as on Gold hill, that the greater part of a vein, along its outcrop and for a variable depth, may be conformable to the lamination of the wall rock. This gives the most regular type of vein in the schistose formations (Fig. 4). But when the schists strike at considerable angles from the general trend of the veins, these become very irregular and may appear as disconnected lenses, or lenses joined more or less completely by veins cutting the foliation planes of the schist, and having a strike considerably at variance with that of the lenses (Fig. 3). The shape of the deposits in the Mt. Stevens group thus depends upon the character of the members of this formation, which is generally much metamorphosed, distorted, and plicated. The erratic character of these veins, both at the surface and when followed down along their dips, is, therefore, to be expected. Even the simple fissures in these rocks, as in most schistose formations, are very irregular in outline, and the veins, which in a place or so on Mt. Stevens, continue in them for considerable distances, partake also of this character.

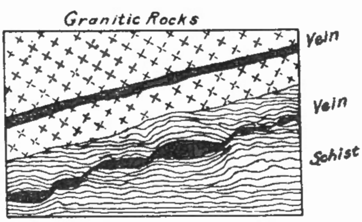


Fig. 3. Type of irregular vein in the schists.

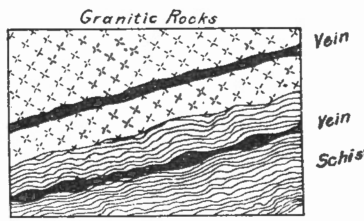


Fig. 4. Type of more regular vein in the schists.

Persistency of the Fissures.—One vein in the granitic formation on Mt. Anderson was traced over 3,000 feet and may extend much farther, as neither end was found. Throughout this distance it contained 4 to 5 feet of quartz and its associated metalliferous minerals. No other vein seen in the district has been followed as great a distance. The Gold Reef vein on Gold hill, in the Mt. Stevens group, outcrops at least 1,000 feet; and another vein in similar rocks on the east side of Mt. Stevens is traceable for upwards of 1,500 feet. Most of the other veins have only been followed 200 or 300 feet or less. But no systematic attempts have been made in this direction; so others may extend as great or a greater distance than the 3,000 feet given above as a present observed maximum.

Width of the Fissures in the Granitic Rocks.—The veins in the granitic rocks vary in thickness from a few inches to 7 feet or more, but 3 to 4 feet seems to be the average. The McDonald Fraction vein, one of the best appearing in the district, is, where opened up, only 2 feet thick; the vein on the Legal Tender, on Mineral hill, is 3 to 3½ feet; the Silver Queen vein on Wheaton mountain is about 3 feet; and that on the Sunrise on Stevens mountain, although 7 feet in one place, will not average over 3 feet in thickness. These are examples of some of the best veins in the Coast Range intrusives.

Dimensions of the Lenses in the Schistose Rocks.—Since most of the quartz-lenses in the schistose rocks have been cross-cut or exposed in only few places if at all, very little is known concerning their dimensions. The largest lens discovered, that on the Acme claim on Mt. Stevens, appears to be about 100 feet long and 30 feet thick at the surface. The other larger lenses appear to have average maximum thicknesses of from 6 to 8 feet, and to have lengths generally of 20 to 40 feet.

Intersections.—No intersections of members of the gold-silver veins have been noted.

Faulting.—That the fissures in the granitic rocks in which the gold-silver ores occur are fault-fissures, is shown by the fact that the fissure-walls are generally distinctly slickensided, and in places are covered with gouge; in addition, the material between the walls of the Tally-Ho vein consists to a great extent of brecciated material. The granitic walls of the fissures, however, afford no clue as to the extent of their displacement; but since schists overlie this formation in places (being remnants of the roof of the granitic batholith) if any extensive movements had taken place such would probably be evidenced in the overlying rocks. However, no marked, or even definite movements of any extent have been detected, except along the mineralized fissures in the schists, where movements, apparently of only a few inches but at most 2 to 3 feet, were noted in a few places. It would, therefore, appear that the displacements along the fissures, in both schists and intrusives, are, probably, only slight.

Structural Features of the Fissures in the Granitic Intrusives.—The only properties that have afforded any information concerning the shape, regularity, etc., of the fissures in the granitic rocks below the surface are the Tally-Ho, Legal Tender, and the Rip, on which drifts of 100 to 250 feet have been driven on the veins. These workings show that the fissures, as far as they have been followed, are remarkably persistent as concerns strike, dip, distance apart of walls, etc. No foot, or hanging-wall stringers or branching fissures were encountered, and no close, parallel fissures have been discovered such as occur in connexion with lodes, and are produced by compression. It would thus appear that these gold-quartz fissures, in the majority of instances at least, are simple in form.

Origin of the Fissures.—These ore-containing fissures all occur along the eastern portion of the granitic batholith; the majority strike in a direction parallel to the general trend of the eastern edge of this intrusive mass; and all the fissures in the granitic rocks dip to the northeast, away from the centre of the intrusive area. Chiefly from these facts, an attempt is made to determine the origin of the fissures containing the gold-silver veins, and those in the Coast Range intrusives will be first considered.

The forces operative in the earth's crust that are known to produce fissuring are those of torsion, tension, and compression—all more or less aided by gravity. Daubrée[1] has demonstrated experimentally, that whenever torsional forces are effective, two systems of fracturing tend to be produced, nearly at right angles to each other. Becker[2] and Van Hise[3] have also shown that compressive forces operative in an approximately homogeneous substance, such as granite, also result normally in two sets of fissures being formed. These occur at about 45° to the direction of the applied force, and, therefore, at about 90° to each other. However, all the gold-quartz veins of the district appear to exist in a single system of fissures that occur parallel to the general structure of the region, and no evidence of cross-fissuring was detected.

Such an extensive, single system of parallel fissures would seem to be most probably the result of tension, more or less assisted by gravity. Only two possible explanations suggest themselves as being efficient to cause such a force or forces to become exerted in this district. The first is that these fissures are the result of contraction due to the cooling of the granitic body. As shown by W. H. Weed[4] and Joseph Barrell,[5] such huge masses of rock cool slowly as

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[1]Daubrée, A.—"Études Synthétiques de Géologie Expérimentale": pp. 507–527.

[2]Becker, Geo. F—"Finite homogeneous strains, flow, and rupture of rocks": Geol. Soc. Am. Bull., Vol. IV, pp. 13–90, 1893.

[3]Van Hise, C. A.—"Principles of Pre-Cambrian N. Amer. geology": Sixteenth Ann. Rep., pt. I, U. S. Geol. Surv., pp. 633–682.

[4]Weed, W. H.—Trans. Am. Inst. Min. Eng., Vol. 33, 1903, p. 745.

[5]Barrell, Joseph—"Geology of the Marysville Mining District, Montana": Prof. Paper, No. 57, 1907, U. S. Geol. Surv., pp. 105–106.

a whole, and have no tendency to form wide contraction cracks; but still as the marginal portion and the contact-metamorphic zone cooled, there would be a tendency for these portions to shrink away from the surrounding rocks, and a system of fissures, parallel to the contact, would be formed, dipping away from the centre of the cooling body. In some cases a system of fissures is found, which strikes at right angles to the edge of the intrusive, due to cooling and consequent shortening of the marginal portion of the mass. However, this is not a necessary accompanying phenomenon, and all the contraction may well be taken up, particularly in the case of such persistently linear masses as the Coast Range batholith, by a single system of fissures parallel to the contact line. Gravity would also in all probability be effective in causing foot-wall portions to sink, in places, and fault-fissures would be produced resembling, in all the observed particulars, these in Wheaton district which are being considered.

The second theory for the formation of these fissures attributes their origin primarily to causes differing considerably from those just enumerated; but still all may have acted more or less simultaneously, so that it is conceivable that they may have been very intimately associated and that a combination of them may have been the true cause of the production of these fissures.

It has been shown in the chapter on 'General Geology,' that the northwestern part of Yukon territory suffered an extensive dynamic revolution in about late Jurassic time, and as a consequence, the whole tract was uplifted. This disturbance was accompanied by volcanic activity on a profound scale, and during this period the Coast Range batholith was intruded. It is also known that the portion of the district that is now occupied by the Coast range (which is composed of the granitic batholith) was considerably more uplifted than the adjoining area to the east. Such differential uplifts are known to frequently determine lines of weakness between the upper and lower divisions of the upraised tracts, which is liable to result in the gradual relative resettling of the less uplifted area, producing normal faulting. As the fissures in Wheaton district that are being discussed lie 10 or 12 miles to the east of the mountain front of the Coast range, the forces, due to this cause, acting to cause them, would at this distance have become dissipated, and would cause in all probability only slight displacements, such as characterize these faults in this locality. Also as normal faults would be produced with dips consequently away from the mountains, the faults would in every way correspond to those that here exist.

What might be considered a third explanation, but which amounts in reality to nearly that just given, is developed by Chamberlain and Salisbury.[1] They suggest that great land masses are at times 'relatively elevated above the plane of isostatic equilibrium, and, as the mass of the interior, though solid, is not absolutely rigid, there is ground for the presumption that the excess of gravity in the protuberant portions was gradually relieved by their slow sinking.' 'A direct movement downward, which would be the primary phase of an isostatic movement, would, however, tend to develop thrust, but because of the protuberance, a lateral creep is postulated.' Such a lateral creep, acting along the edge of the Coast Range batholith in Wheaton district, would cause normal faulting of small displacement, in all probability, such as is here observed.

Therefore, whether these fissures are primarily due to contraction of the granitic mass on cooling, or to an isostatic readjustment subsequent to crustal disturbances, must for the present remain an open question; but it is quite conceivable that both causes have been operative. In any case, the effective forces appear to have been those of tension, or stretching, combined with differential vertical forces, or gravity.

The ore-filled cavities in the schists are believed to have had in a general way a similar origin to the fissures in the intrusives. But as the schists are always foliated and often fissile, the cavities in them, containing the ore-materials, differ widely in character from those in the more homogeneous intrusives, and are extremely irregular. As mentioned above, the veins in the schists consist chiefly of quartz-lenses, conformable to the laminations of the containing rock, more or less connected by irregular fissures cutting the foliation directions; but, in places, fissures were found independent of lenses. Still in all cases, as far as is known, these veins, as a whole, have a general trend parallel to those in the granitic intrusives. Also the veins in the two formations, as discussed more fully above, are, almost beyond a doubt, of the same age. Slight displacements not exceeding 1 or 2 feet, and possibly only a few inches in amount,

[1]Geology, Vol. II, Earth History, p. 131.

were further noted in a few places in the schists. Thus, although the cavities containing the individual lenses are believed to have had a special and somewhat independent origin, the general trend of the veins and the actual fissures are thought to be due to the same agencies that caused the fissures in the granitic rocks; and the veins probably represent the upward extensions or continuations, in some cases at least, of the veins in the intrusives, and resemble the latter as nearly as rocks of this schistose habit are able to reproduce such.

The various lens-shaped spaces in the schists, which have become filled with quartz and associated minerals in such a way that the rock curves outward on either side to enclose the ore-materials, probably owe their origin to more than one source. As the schist laminæ are very irregular in form, the movement of one over the other might cause intervening spaces to be formed. The same thing occurs when irregularly-shaped fissure-walls move relative to one another, so that a curved surface comes opposite one curved in the opposite direction, producing a cavity between them. Still phenomena of this kind do not appear here to have been important factors. The quartz is typically massive in structure, as if formed under such conditions that no open space existed at the time of crystallization. Further, the walls of these cavities are rarely noticeably striated, showing that, at least, the majority of these spaces were not produced by movements of their containing walls over each other.

Pressure applied to the ends of schist laminæ will cause them to bulge apart in places, producing lens-shaped spaces between them. Also it has been shown[1] that the force exerted by a crystal while forming is equal to that required to crush it when consolidated, and that many fissures have been considerably altered by the growing force of minerals being deposited in them. It will thus be seen that once a small opening is produced, sufficient for quartz-containing solutions to enter and deposit even a small amount of their burden, the force of crystallization would be sufficient to gradually force its walls apart to make room for itself and more incoming solutions. So, in this way, lens-shaped, mineral-filled cavities may be produced. Pressure commences the process, causing the mineralization to be localized, and is succeeded by the force of crystallization of the mineral matter introduced by the solutions. Quartz deposited in

[1]Becker, Geo. F. and Day, Arthur L.—"The linear force of growing crystals": Wash. Acad. Sci., Proc., Vol. 7, pp. 283–288, 1905.

this manner will crystallize with a massive structure and its walls will not necessarily be striated. The quartz and associated minerals found in the lenses in the Mt. Stevens schists were introduced by solutions, as discussed below, so that in the manner here outlined the lenses could have and are believed to have originated.

Irregular Dips.—The apparently irregular dips of veins in the schistose rocks, referred to previously, can now be readily explained. These veins, when conformable to the laminæ of the enclosing rock, may incline either to the northeast or southwest. This is accounted for by the fact that mineralizing solutions on emerging from a fissure in the granitic rocks will tend to continue upward following the readiest plane of circulation. If such happens to be a foliation plane, this is just as liable to dip one way as the other. The Gold Reef vein is the only one of any extent, however, that is known to dip to the southwest.

Fissure-fillings and Mineralogy.—The vein materials of these gold-silver veins consist predominantly of quartz with some calcite, galena, pyrite, chalcopyrite, zinc-blende, and, in some few cases, gold and sylvanite. Galena is the only metallic mineral which ever comprises any considerable percentage of the vein-filling, the others occurring as sparsely disseminated particles. Gouge occurs on the walls of some of the veins, and brecciated wall-rock is also found constituting a part of one.

Gangue-minerals.—Quartz is always the chief and, in most cases, the only gangue-mineral, but calcite is occasionally associated with it in minor amounts. In the lenses in the schists, the quartz has always a massive appearance, but in the fissures in the granitic rocks it is often coarsely crystalline, and long, well-formed crystals frequently occur pointing from the walls towards the interior of the veins, forming typical comb-structures. An interlacing of long quartz prisms is also often to be noted, and is particularly well seen in the Legal Tender and Tally-Ho veins. Structures of the latter variety have considerable inter-crystal space, in which other minerals are at times deposited. Such crystal development shows that open space existed between the fissure walls at the time of the quartz deposition.

Metallic Minerals.—The metallic minerals are generally present in relatively small amounts, and rarely constitute any considerable percentage of the vein-filling. Where these minerals are fairly abundant in the ores in the granitic formation they exhibit often a rough alignment, parallel to the walls; this does not occur in the quartz lenses in the schists, where the metallic minerals are irregularly distributed through the gangue.

Galena is the only metallic mineral that occurs at all extensively and, in places, as on the McDonald fraction, the Tally-Ho, and elsewhere, it constitutes, for limited distances, the greater part of the vein-matter. Such occurrences appear to be in the form of pockets which vary in size from a few feet in length to those of considerable size, and may even attain the proportion of shoots; but nowhere has sufficient development as yet been performed to afford definite information on this point. The galena may be very fine, or may occur in cubes as much as half an inch in thickness. A considerable portion, at least, of this mineral is silver-bearing and also appears to be associated with the gold content of the ore, as quartz containing no galena rarely, if ever, carries appreciable amounts of gold; but where even scattered particles of galena are found, however, the ore is liable to assay well in gold. Pyrite and chalcopyrite occur but sparsely distributed through the quartz, and in most places are rarely encountered.

On the Gold Reef claim on Gold hill, and on the Buffalo Hump group on Mt. Stevens, telluride minerals have been discovered. On the Gold Reef these occur in pockets from the size of a man's head to one of 800 or 900 pounds weight. Very few pockets have been found, not nearly sufficient to pay for working the property, as the vein is elsewhere very low grade. The principal tellurium mineral found is sylvanite, but hessite and petzite have been identified in the laboratory. Telluric ochre also occurs as a result of the weathering of the other tellurium minerals.

Sylvanite is monoclinic in crystalline form, and often occurs in branching arborescent forms resembling written characters. It is also bladed and imperfectly columnar to granular; has excellent cleavage; is brittle and very soft, having a hardness of 1·5–2, i.e., generally somewhat less than that of gypsum; has a specific gravity of 7·9–8·3, and has a brilliant metallic lustre and colour, with streak pure steel-grey to silver-white, inclining to yellow. In composition this mineral is the telluride of gold and silver $(Au, Ag) Te_2$ with 62·1 per cent tellurium, 24·5 per cent gold, and 13·4 per cent silver.

Hessite is the silver telluride, Ag_2Te. It is isometric when crystalline, but is usually massive, compact or fine-grained. It has distinct cleavage; can be readily cut with a knife; has a hardness of 2·5–3, and a specific gravity of 8·31–8·45; and has a colour between lead-grey and steel-grey.

Petzite is a rare gold-silver telluride $(Ag, An)_2 Te$ with the silver: gold = 3 : 1. It is massive, and granular to compact; slightly sectile to brittle; and has a hardness of 2·5–3; and a specific gravity of 8·7–9·02. Its colour is steel-grey to iron black.

The telluric ochre occurs as a whitish to yellowish coating on the rock surface. When pure it consists of tellurite, TeO_2, which forms slender, orthorhombic, prismatic crystals, and small spherical masses; is soft, and white or yellowish-white in colour; and has an adamantine lustre and excellent cleavage. However, it is generally associated with numbers of impurities, as lead carbonate, iron oxide, etc., and then has a more yellow to reddish appearance.

Free gold occurs with these minerals in the form of small particles, generally entirely invisible to the naked eye, or in a few cases, in larger grains or spongy masses. The latter and some of the more minute particles occur surrounded by the tellurides and have been set free from these by oxidation. Solid particles of bright gold with normal characteristics were also noted in the Gold Reef and elsewhere, which are apparently of primary origin. These pockets of telluride ores are extremely rich, assaying often thousands of dollars per ton, but the amount of ore in each pocket is small, averaging perhaps not more than 50 pounds each.

On the Buffalo Hump group on Mt. Stevens a number of tons of float-quartz was found, near the summit of the hill, which contained, in addition to some galena, disseminated particles of sylvanite and free gold. It is not known what this ore averaged, but assays from $100 to several times this amount per ton are reported. The gold here occurs generally as very minute particles, as on the Gold Reef, and is partly primary.

Assay Values.—What the average ores in the various gold-silver veins will assay is not known, but selected ores from the McDonald Fraction, the Tally-Ho, the Sunrise, the Rip, the Legal Tender, and others of the more promising properties contain generally from $20 to $80 per ton in gold and silver, the gold being generally considerably in excess of the silver.

Gouge and Breccia.—From one-fourth to one inch of a clayey gouge has been deposited on the walls of some of the veins. This consists of comminuted wall-rock, ground by movement of the walls on one another. The broken particles have been afterwards decomposed by circulating waters, which have been influential in altering the feldspars to clay, sericite, etc., forming the pasty selvage so characteristic of many veins. The vein most noticeable for its selvage is on the Tally-Ho group; this is also the only one of these gold-silver veins that is characterized by any considerable amount of brecciated material. On this property a fault-zone, from 4 to 12 feet in thickness, occurs, which consists largely of fragments of wall-rock, the size of which varies from microscopic to 8 or 10 inches in diameter; through this broken material and along the walls of the fault-zone several seams of gouge, up to one inch in thickness, occur. The quartz which constitutes the main vein on the Tally-Ho follows the foot-wall, and also has been deposited, to some extent, between the breccia-fragments.

Age of the Veins.—As to the age of these veins, it is known that they were formed after the outer portion, at least, of the granitic mass had cooled, as they cut this rock. Also they are older than the Carmack basalts, the members of the Wheaton River series, the Klusha intrusives, and the Chieftain Hill volcanics, as an andesitic dyke belonging to the oldest of these, the Chieftain Hill volcanics, is known to cut the vein traversing the Rip and Wolf claims on Mt. Anderson. This fixes the age of the veins as late Jurassic or later, but earlier than late Cretaceous or early Tertiary.

As explained later, these veins are also believed to be genetically connected with some series of igneous rocks. The Chieftain Hill andesites which cut them are the oldest known igneous rocks in the district, that are more recent than the Jurassic granitic intrusives in which the ores occur. It follows, by elimination, that the veins are probably associated with the granitic rocks which are cut by them. Moreover, as explained more fully later, these veins in the field appear to be everywhere intimately associated with these granitic intrusives, which is taken as further evidence of their genetic connexion. These points indicate that the veins were formed after the outer portion of the granitic batholith had cooled, but while the interior was still hot; if this is so, the veins are of late Jurassic age.

Synchronous Age of the Veins in the Schists and Granitic Rocks.—The veins in the schists and granitic rocks, as shown above, have in a general way parallel strikes and occur closely associated in the same long, narrow, mineralized belt. Also the mineral contents of the veins are practically identical in both formations. Even the rare telluride minerals, particularly sylvanite, have been found both on Mt. Stevens, in a vein in granite, and on Gold hill in the Gold Reef vein in schist. It would thus appear that the veins in these two formations have had a common origin and are synchronous in age. No vein, however, has so far been traced from one rock to the other, but this is not considered significant, as such a large proportion of the surface is covered with superficial deposits, and further, the areas of the schistose rocks are only small and scattered.

Alteration of Wall-rocks.—Compared with many other districts, but little metasomatic alteration appears to have taken place in the walls of these fissures as a result of vein-formation. The granitic rocks are prevailingly greyish in colour, but, in places, due to considerable amount of contained pink orthoclase, are distinctly reddish. These rocks, in some cases, have been somewhat altered for a few inches or even 2 or 3 feet, from the vein on either side, the amount of alteration decreasing with the distance from the ore-material. As a result of this alteration the walls are rendered slightly softer and are bleached to a light grey or almost white appearance. In no case observed, however, did alteration extend to the point of masking the character of the rock. The exact nature of the chemical and mineralogical changes which have taken place has not been determined. The schists have been even less affected than the intrusives, and at no place was any decided or marked alteration apparent in these rocks adjacent to the vein materials.

Oxidation.—The zone of vein-oxidation is prevailingly shallow. In the majority of mining districts the limit of complete oxidation, as a rule, coincides with the water-level, and in many cases the process may partly, if not completely, alter the veins for considerable distances below the water-surface. Here, in these gold-silver veins, oxidation has only appreciably affected the ores very near the surface. In places, unaltered sulphides are reached in 4 or 5 feet, and, in all the cases reported, they have been encountered in less than 30 feet. Several causes may be suggested to account for this.

In the first place, on account of the northern latitude of this district, the ground is, in most places, continuously frozen to considerable depths. Under these conditions, chemical action proceeds slowly and to a slight degree.

The drainage may also have an important bearing upon oxidation in this district. As shown in the descriptions of the topography, the mountains are prevailingly steep-sided, so that the run-off from the hill-tops is, in most places, rapid and complete. This naturally tends to diminish the effects of oxidation, as the waters are so rapidly conveyed from the uplands to the main valley-depressions that they have relatively little opportunity to act upon the mineral-deposits.

Still another point should be mentioned in this connexion. As stated previously, the chief metallic mineral occurring in these veins is galena; pyrite is but rarely encountered, and marcasite was not identified. Recently H. A. Buehler and V. A. Gottschalk[1] have demonstrated experimentally, that galena alone is oxidizable with difficulty under ordinary surface conditions; but that, like many other common sulphides such as zinc-blende and chalcopyrite, it is readily oxidized in the presence of pyrite or marcasite. The fact that galena in these gold-quartz veins is generally unassociated with these minerals may, in part, account for the slight amount of oxidation that has occurred.

At the surface, the slight amount of pyrite that is present is altered to limonite, and the chalcopyrite is changed to some extent to azurite and malachite.

Leaching and Enrichment.—In gold-silver veins of the calcite type, it is common to find a decided enrichment in the oxidized part of the deposit, due to the reduction in volume of the ore by solution, and the removal of certain constituents—chiefly the soluble carbonate and sulphides. In the gold-silver veins of Wheaton district there is no indication of an enrichment of the oxidized zone. This may be explained by the fact that these deposits contain very little calcite and only small amounts of sulphides, and, further, the cold waters existing at this northern latitude do not dissolve sulphides at all readily, particularly when little or no pyrite is present, as just mentioned when considering the oxidation of these veins.

Also, since the metallic minerals of these deposits have been but slightly leached near the surface, there is little chance of finding any

[1] "Oxidation of Sulphides": Econ. Geol., Vol. V, No. 1, Jan., 1910.

considerable zone of secondary enrichment with depth at or near the water-level, due to the deposition of these minerals dissolved from above.

Persistency and Probable Vertical Extent.—Considering the shallow zone of oxidation, the apparently slight amount of leaching that has been effected, and the improbability of any important zone of secondary enrichment being encountered with depth, it appears that these veins should maintain, for a considerable portion of their vertical extent, the characteristics and mineralization which distinguish them near the surface. Further, it has been observed that in few places in the world do veins extend downward for a distance greater than their length at the surface. So in all probability this will be found to hold true in Yukon; and the veins which are the most persistent at the surface will also extend the farthest downward.

Genesis.—In recent years a number of geologists have studied the various vein-forming minerals with a view to determining their mode of occurrence, and believe that certain mineral combinations are characteristic of each of the vein zones in which ores are found. Also, certain individual minerals are diagnostic of particular zones, but as such minerals are prevailingly of rare occurrence, the mineral combinations are the more useful in considering the genesis of an ore-deposit.

In these gold-silver veins, none of the minerals are found that are characteristic of the deeper vein zone, such as albite, amphibole, biotite, diopside, garnet, hornblende, scapolite, spinel, topaz, graphite, ilmenite, pyrrhotite, specularite, etc. Further, there is a decided lack of the minerals characteristic of pneumatolytic veins, i.e., those that are now recognized to be directly connected with plutonic intrusive rocks, and have been derived from them through the agency of magmatic gases dissolved in them at the time of the intrusion, and existing, therefore, at high pressure and above the critical temperature of water. Some of the minerals that are most useful in distinguishing such deposits are tourmaline, fluorite, apatite, spodumene, muscovite, alkali feldspars, cassiterite, wolframite, molybdenite, magnetite, bornite, and arsenopyrite.

It follows by a process of elimination that these gold-silver veins belong to the upper vein zone. The minerals composing the deposits are quartz calcite, galena, pyrite, chalcopyrite, free-gold, and certain tellurides. Of these, the quartz, pyrite, chalcopyrite, and native-gold are known to be frequent deposits of all the zones and so, by themselves, afford little information. The galena and calcite are also somewhat persistent in their occurrence, but tellurides are only known to occur in the deeper vein and upper vein zones. Further, the association of the minerals is such as is only encountered in the upper vein zone; to which, for the above reasons, it is considered that these deposits in all probability belong.

A study of former topographies, and of the geological occurrence of these ores, also assists to some extent in the study of their genesis, although not to the same extent as in other types of ore-deposits found in Wheaton district.

That ore-bearing quartz veins are deposited from circulating waters containing dissolved gases and metalliferous compounds, is a now well recognized fact. It is further generally supposed that these waters are connected with the intrusion of igneous rock. In the case of these gold-silver veins, it has been shown in a previous portion of this chapter, that all the igneous rocks of the district that are newer than the granitic intrusives in which the veins occur are more recent than the veins themselves. It is, therefore, apparent that if these deposits are associated with any of the known igneous materials of the district, these must be the Jurassic granitic rocks. In the field the veins appear everywhere to be intimately associated with these intrusives, so that the genetic relationship between them appears certain. If this be true, the solutions depositing the ores traversed the fractures in the outer, cooler portions of these granitic rocks, and also in all probability extended up into the overlying schists as well, and distributed their load of dissolved mineral-matter, while the interior of the granitic mass was still in a highly heated condition. In the formation of the veins, the rock-formations were but little, if at all, replaced, and the material was practically all deposited between the fissure-walls.

Further, the portions of the veins that are exposed to view all occur near the top of the batholith, either in the intrusive rock itself or in the schists, and are believed to have formed shortly after the intrusives of the granitic mass. There is no direct evidence in this district to show at what depth below the surface this granitic material consolidated, but investigations that have been made in recent years tend to show in many places, at least, in the Western

Cordillera of North America, that the upper portions of these great batholithic bodies are intruded to very near the surface, and do not cool, as formerly thought, in the abyssal depths.

Barrell[1] has shown that the great Boulder batholith of Montana in places approached to within 2,000 feet of the surface. Smith and Mendenhall[2] have also noted the instance of a batholith in the Cascades that was covered, at the time of its intrusion, by only a series of extrusive andesites. Other similar observations have been made in other places.[3] So it is quite possible that these veins which occur in the upper portions of the Coast Range granitic batholith may have penetrated to within 2,000 or 3,000 feet, or even less of the surface.

DESCRIPTIONS OF MINING PROPERTIES.

The mining properties hereunder considered are mentioned in order, commencing at the southeast and proceeding to the west and north. No attempt is made to include all the claims in the district that belong to the gold-silver class. A number only of the more promising are described.

Mt. Stevens.—The Hawk Eye group of three claims, owned by the 'Tally-Ho Boys,' is situated on the Wheaton River slope of Mt. Stevens. Two veins have been discovered on the property, in chloritic and sericitic schists, which have average thicknesses where exposed of 20 inches, and 3 to 4 feet, respectively. The vein-material consists of quartz impregnated, to some extent, with galena and chalcopyrite. It is not known what the ore will assay.

The Acme claim, owned by O. Dickson, is situated on the top of Mt. Stevens, and contains the largest quartz-lens noted in Wheaton district. This lenticular mass occurs in chloritic and sericitic schists, is 30 feet wide in one place, and appears to be about 100 feet long. On account of drift, neither end of the lens was seen, and it is not known whether quartz continues farther than the 100 feet in either direction or not. In places some galena and pyrite occur, but the bulk of the quartz contains practically no metalliferous minerals.

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[1]Barrell, Joseph—"Geology of the Marysville mining district, Montana": Prof. Paper, No. 57, U. S. Geol. Surv., p. 166.

[2]Smith, G. O. and Mendenhall, W. C.—"Tertiary granite in the northern Cascades": Bull. Geol. Soc. Amer., Vol. 1, 1900, pp. 223-230.

[3]Hague, Arnold—"Early Tertiary volcanoes of the Absaroka Range": Pres. Address, Geol. Soc. Wash., 1899, pp. 23, 29.

The Buffalo Hump group, owned by Mr. Geo. Stevens, consists of three claims, the Sunrise, Golden Slipper, and Wheaton. These all adjoin, and are located in line, forming a group, three claims in length, in an east and west direction, along the north end of Mt. Stevens. This is the most widely known property on Mt. Stevens.

On the Golden Slipper claim several tons of quartz were discovered, which was thought at first to form part of a vein in situ, as it had distinct granitic walls and was but little broken. Subsequent development showed this quartz and its associated rock-material to be all transported material. This overlies similar rocks which belong to the Coast Range intrusives, occurs near the summit of the hill, and does not appear to have travelled any considerable distance. A drift was commenced in the direction of the supposed origin of the quartz, and in August last (1909) had been driven 85 feet, and from it 20 feet of cross-cuts had been run, but no vein was encountered.

This quartz, in addition to a small amount of disseminated galena in fine grains, also contains some free-gold and sylvanite. The gold occurs either as small, spongy masses, usually surrounded by sylvanite, or in the form of minute, bright particles, often too small to be detected with the naked eye. The spongy gold has been derived by oxidation from the sylvanite, but some of the gold occurs, apparently, as a primary ore. The telluride exists in small bunches, scattered throughout the quartz.

At several places on this and adjoining claims, smaller masses and pieces of high-grade quartz have been found, all of which are angular in form, do not appear to have been transported far, and are found chiefly near the summit of the mountains. For these reasons, it is thought that the rich quartz was probably originally derived from some portion of Mt. Stevens.

On the Surprise claim is a quartz vein, in a fissure in granite, which carries some galena and native gold. Both of these latter minerals occur sparsely distributed throughout the gangue, and are here, so far as has been discovered, not associated with any of the telluride minerals found on other veins showing native gold.

The vein is 7 feet thick in one place, where a small open-cut has been made, but will not average more than 2 or 3 feet in thickness for the 50 feet that the ore has been traced. The amount of gold and silver this quartz will average per ton is not even approximately known.

Wheaton Mountain.—The McDonald Fraction, situated near the western edge of Wheaton mountain, is probably the most promising prospect on this hill. Outcropping here, in a fissure in granite, is a vein of quartz which strikes N. 47° W., and dips to the northeast at angles approaching vertically. The vein is well mineralized, chiefly with argentiferous galena which, in places, constitutes the greater part of the vein-filling. The minerals occasionally exhibit a distinctly banded structure. The quartz varies from fine to coarsely crystalline, and where most dense is very massive in appearance, and individual crystals cannot be distinguished. In other places, distinct comb-structures and well-formed interlacing prisms are characteristic. It is claimed that this ore contains gold and silver in very encouraging amounts.

A shaft, possibly 20 feet deep, constitutes practically all the development so far performed on this property.

The Silver Queen and Gopher claims are situated on the western part of Wheaton mountain, near the McDonald Fraction, and are the principal claims in a group of seven owned by the 'Tally-Ho Boys.' On the Silver Queen is a quartz vein, in granite, which, where it is exposed, is 3 feet thick, and contains galena and pyrite. On the Gopher, is an irregular, lenticular mass of quartz in greenstone-schist, which, at the widest point discovered, is 7 feet from wall to wall. The quartz is very massive and carries scattered particles of galena. Neither of these veins has been developed to any extent, and it is not known, on account of superficial, frozen material, how persistent or extensive they are. The quartz from both claims is reported to carry encouraging amounts of gold and silver.

Tally-Ho Gulch and Vicinity.—Tally-Ho Group.—On the west side of the Tally-Ho gulch, which extends along the western end of Wheaton mountain, a group of eight claims, the Tally-Ho group, has been located by Adam Birnie, C. J. Irvine, C. I. Burnside, W. M. Hair, and F. T. McGlashan, who have formed a partnership for prospecting and mining purposes, and are known throughout the district as the 'Tally-Ho Boys.'

All the assessment and other work for the entire group has been performed in the development of a single vein, that was considered the most important on the property. The ore occurs in a brecciated fault-zone, 4 to 12 feet thick, in the Coast Range granitic formation.

The zone strikes in a northwesterly direction, and dips to the north-east at 60° to 70°, and along it a drift 290 feet in length has been driven, leading from which are a 40 foot raise and a 15 foot cross-cut.

Both walls of the faulted zone are coated with a clayey gouge one-fourth to one inch thick, and several similar seams occur distributed through the broken material. The granitic fragments vary in size from that of sand-grains, or smaller, to 8 or 10 inches in diameter, and the larger pieces have been cemented together by the more finely-ground material. A varying, but always small amount of quartz has been introduced between the various granitic fragments, but the greater amount occurs as a vein of varying thickness deposited along the foot-wall. In the first 100 feet of the drift, the vein is from 12 to 20 inches in thickness, then for 6 feet it is from 30 to 36 inches, whence it rapidly decreases to 12 inches, and for the last 150 feet does not average more than 6 inches in thickness.

The thickness of the quartz has been apparently conditioned by the amount of original available space in which to crystallize. As fissure-walls have invariably irregular surfaces, when faulting occurs cavities or spaces are produced between them that tend to become filled with the fragments that are produced by the grinding of the walls on each other; the Tally-Ho fault-zone, on account of the great amount of breccia formed, would in this way become much more compact in some places than in others, and the mineral-bearing solutions travelling along the foot-wall would on this account be able to deposit their dissolved quartz and associated minerals most readily in certain places. The force of crystallization of the quartz, referred to under the 'Detailed Descriptions' of these gold-silver veins, has apparently been sufficient to press back the larger pieces and more consolidated portions of the brecciated matter where not under too great pressure, thus rearranging these rock-materials to some extent, and making room for the quartz to continue forming along the foot-wall in a layer of varying thickness. It would appear probable from these considerations that if this fissure is followed, other places will be found where the rock-materials give place to quartz, and the vein is again of workable thickness.

The quartz carries considerable argentiferous galena which occurs, generally, fairly evenly disseminated, and in a fine state of crystallization. No other metallic mineral occurs in appreciable quantities. Near the surface, for 8 or 10 feet, the galena has been partly altered to lead carbonate. The quartz generally assays from $9 to $80 per ton in gold and silver, and it is thought that considerable of it, if not all, will average approximately $20 per ton.

Other veins have been found on these claims, but they have not been developed, and nothing definite is known concerning them, except that some large pieces, 6 to 8 inches in diameter, of almost solid galena, were seen which came from them.

Mt. Anderson.—On the east side of Becker creek, and on the west face of Mt. Anderson, is a strong, well-defined quartz vein contained in a fissure in granite. The vein strikes approximately N. 68° W., and dips at about 80° to the northeast. It can be traced

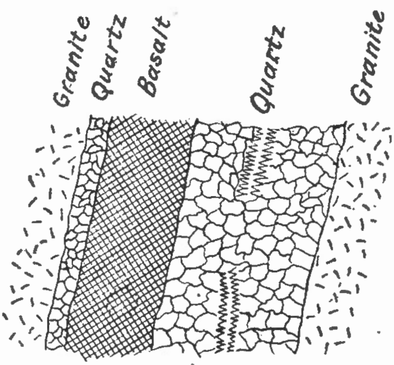

Fig. 5. Section of vein at entrance to drift on Rip claim.

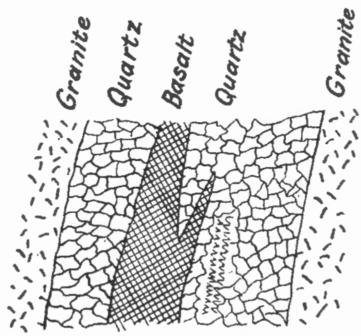

Fig. 6. Section of vein on Wolf claim.

for about 3,000 feet, or practically the entire length of the Rip and Wolf claims which are located along it, and neither end has yet been found.

A dyke of fine-grained basalt, 2 feet thick, cuts this vein longitudinally, and persists along it for the entire length so far found. It in places occurs near the hanging, and in other places near the foot-wall, and also occupies various intermediate positions; and is not always in the form of a single, simple dyke, but gives off branches, all of which occur in the quartz. Wherever the entire vein has been cross-cut, it contains from 4 to 5 feet of quartz which is, in most places observed, well mineralized with argentiferous galena. The dyke appears to have had no effect on the ore other than of subdividing it.

It is not known what average value the vein has, but the better mineralized portions of it generally assay from $20 to $40 per ton in gold and silver.

On the Rip claim, owned by Wm. McGrew, a drift 90 feet long has been driven on the vein, keeping to the foot-wall side of the dyke which in this distance crosses from one side of the vein to the other.

On the Wolf claim, owned by Messrs. Clark, Dickson, and Johnson, the basalt dyke splits the vein into two about equal parts, one of which is again divided by a small offshoot from the main dyke. Approximately 40 feet of open-cutting and drifting have been done on this property.

Gold Hill and Vicinity.—Considerable excitement was created during the season of 1906 by the finding of quartz carrying free-gold and gold-silver tellurides, on what is now the Gold Reef claim, on Gold hill, midway between Watson and Wheaton rivers, and 20 miles from Robinson. This was the immediate cause of considerable prospecting in this locality, and resulted in the staking of practically all the claims in Wheaton district, except those comprising the Union mines.

The Gold Reef.—The vein on the Gold Reef strikes about N. 55° W., and dips to the southwest at 50° to 60°. It occurs in greenstone-schists along the northeast side of Gold hill for upwards of 1,000 feet, and throughout this distance has an average width of possibly 4 to 5 feet. This is perhaps the most regular of the veins so far found in the schistose formation, and for distances of 100 to 200 feet it maintains a fairly uniform thickness. The strike of the vein, in a general way, coincides with that of the formation in which it occurs, so that the greater part of the quartz has been deposited along the foliation planes of the rock, and lies conformable to the enclosing laminæ. The vein, in places, cuts across the strike of the schist for a few feet, and thence continues between other laminæ than those previously followed.

The quartz presents a particularly dense, massive appearance and, with the exception of occasional particles of pyrite, in most places, contains practically no metalliferous minerals. A few pockets of rich ore have been found, from the size of a man's head to one of about 600 pounds weight. These contain native gold, sylvanite, hessite, petzite, and telluric ochre. The gold in the pockets occurs either as small, spongy masses, when it is apparently derived by oxidation from the tellurides, or in minute, bright, solid particles which are almost certainly of primary origin. The telluric ochre, as well as some of the gold, is a product of the decomposition of the tellurides.

The Gold Reef vein, except for the pockets, carries only small amounts of gold and silver, and the rich ore has not been found in nearly sufficient amount to pay for the development of the property. Up to the present, several hundred feet of development, in the form of drifts, cross-cuts, shafts, etc., have been performed, and less than a ton of pay-ore has been discovered.

The Legal Tender is the only other claim of the large number located in this locality in 1906 and since, on which any development work other than assessments has been performed.

This property was one of the first claims staked during the excitement of 1906, and was located by Mr. J. Perkins. It is situated on the northern face of Mineral hill, and overlooks Watson river from the south. The walls of the river-valley rise abruptly from its floor, over 1,700 feet to the plateau-level, and it is on this steep, rugged, southern slope of the valley, and about 1,000 feet above the level of the river, that ore was first discovered on this claim, and near the original discovery practically all the development work has since been performed.

The vein on the property is in a fissure in granite, strikes in a northwesterly direction, and is inclined to the northeast at angles approaching the vertical. The fissure-filling consists chiefly of quartz and argentiferous galena which occurs, in places, quite plentifully disseminated through the gangue, and is prevailingly finely crystalline. The quartz often occurs in large well-defined crystals which, in some instances, form a network of long, interlacing prisms, and in places have developed typical comb-structures. Besides these minerals, scattered particles of chalcopyrite also occur. The arrangement of the minerals is such, occasionally, as to give a roughly banded appearance to the ore.

A drift 100 feet long has been driven on the vein which, for this distance, remains fairly persistent in dip, strike, thickness, mineralogical composition, etc. The ore is claimed to average $30 to $40 per ton in gold and silver.

The Lucky Boy is situated on the upland-surface, on the eastern side of Mineral hill. In the schists of the Mt. Stevens group a mass of quartz has been exposed, which carries chalcopyrite, copper glance, and malachite. The vein appears to strike in a northwesterly direction, but as an area of only about 6 or 7 feet square of the quartz has been uncovered, little is known concerning the find. The surrounding bed-rock is covered somewhat deeply with frozen, superficial materials.

Antimony-Silver Veins.

GENERAL.

Classification of Antimony Ores.—These antimony-silver veins belong to an unusual type of ore-deposit, known in but few localities in the world, and occupy a somewhat unique place in the classification of antimony ores. To bring out the connexion between these and other related ores, the following classification is offered, under which it is believed all antimony ore-deposits so far discovered can be conveniently placed. It is not intended, however, to include deposits containing only insignificant percentages of antimony-minerals, which belong properly to gold, copper, or other types of ores.

Classification of antimony ore-deposits:—

I. Fissure-veins and other ore-containing cavities.

(*a*) Those that are valuable chiefly, or entirely, for their antimony-content.

(*b*) Those that are notably gold-bearing, the stibnite being auriferous.

(*c*) Those containing both antimony and silver in economically important amounts.

II. Metasomatic replacements.

Most deposits of antimony ores belong to division I. Those coming under division II occur chiefly in limestone formations, and have been found in very few localities. With few exceptions, the ores of division I belong either to subdivisions (*a*) or (*b*), which have themselves been separated almost wholly for practical reasons. In the one case (*b*), the ores are mined chiefly for gold, and when treated seldom yield any returns for their contained antimony. In the other case (*a*), the ores are worked mainly or entirely for their antimony content. The veins of these two types are closely related, and grade into each other. These ores of subdivision (*a*) represent merely the extreme, or gold-poor, facies of the deposits of division I.

In rare instances the ores of antimony, instead of being associated with gold, occur as extreme developments of the rich silver veins. The ores of Carbon and Chieftain hills are of this type which is represented by subdivision (*c*). An occurrence of this kind was worked until the sixties at Mobendorf,[1] in Saxony, 7 miles northwest of Freiberg, which Friesleben has designated the Mobendorf type. Almost the only other veins of this character that are known to be mentioned in geological literature occur east of Broken hill, in the Barrier range of New South Wales.[2] In both of these localities, the ores occur in crystalline metamorphic rocks, while those on Carbon and Chieftain hills are found in granites, andesites, and andesitic breccias, and thus possess essential characteristics not previously described.

Summary Description.—These antimony-silver ores occur distributed throughout a westerly-trending belt about 5 miles long by 1½ miles wide, which includes all the southern portion of Carbon hill and extends to the west across Wheaton river and embraces the central portion of the eastern face of Chieftain hill (Diag. 3.) The greater number of the veins, however, have been discovered on the western face of Carbon hill, on an area about one mile in diameter. These ores occur in the Jurassic Coast Range granitic rocks, and in the Chieftain Hill andesites and volcanic breccias. The veins have, with one exception, a general westerly trend and are either perpendicular in attitude or dip to the northeast.

Two of the veins are traceable for over 2,000 feet on the surface, but other outcrops are generally covered with superficial materials, so that 200 feet is the farthest that any of them have been followed, but a number probably extend much greater distances.

The veins vary in thickness from 2 or 3 inches to 6 feet, but 1 to 3 feet is generally about the average of the more valuable. The fissures, in all the cases so far discovered, appear to be simple in form and without any foot or hanging-wall stringers or branching fissures.

The ores consist chiefly of quartz, calcite, barite, stibnite, sphalerite, Jamesonite, galena, and grey copper. Stibnite constitutes the greater part of the vein-fillings in parts of some of the veins, and in such cases is generally associated with minor amounts of

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[1]Müller, H.—"Erzlagerstätten bei Freiberg": Cotta's Gangstudien, I, 1850, p. 104.
[2]Smith, G.—Am. Inst. Min. Eng., Vol. 26, 1896, p. 69.

sphalerite and Jamesonite. Wherever any gangue is present, it is generally chiefly quartz, barite and calcite occurring only in subordinate amounts. The veins that are richest in silver consist of a quartz gangue impregnated with more or less galena and grey copper, and very few antimony minerals. In fact, the ores high in silver are generally low in antimony, and vice versa. But there are places where both antimony and silver occur together in considerable amounts.

Assays running over 500 ounces of silver to the ton have been obtained, but they are very exceptional. Samples of the better class of ores containing galena and grey copper often carry from 100 to 200 ounces. The better grades of the stibnite ores contain 50 per cent to 65 per cent of antimony. The ores rarely contain more than a few cents per ton in gold. It is not known what the ores will average over any considerable portion of their outcrops, nor what they will assay more than 10 feet below the surface.

The zone of vein-oxidation is prevailingly shallow, and unaltered sulphides generally occur within a few inches or 4 or 5 feet of the surface. Only a slight amount of leaching appears to have taken place in these ores.

DETAILED DESCRIPTIONS.

The Vein-fissures.—Distribution.—The fissures containing these antimony-silver veins, so far as has been discovered, are limited, in Wheaton district, to a westerly trending belt, 5 miles long by 1½ miles wide. This area includes the central portion of the eastern face of Chieftain hill and a zone extending through Carbon hill from its extreme western to its eastern edge (see Diag. 3). The greater number of these ore-containing fissures, however, have been found on the western face of Carbon hill, and are included in an area not more than a mile in diameter. Further prospecting may considerably extend the boundaries of this mineral belt, as but little search for ore has been made in the surrounding district, throughout much of which the geological conditions appear to be similar to those on Carbon and Chieftain hills.

Formations in Which the Fissures Occur.—These fissures occur in the Jurassic Coast Range granitic rocks, and in the andesites and andesitic tuffs and breccias of the Chieftain Hill volcanics which are of late Cretaceous or early Tertiary age. The most persistent fissures, and those containing the richer silver ores, have been found, so far, chiefly in Coast Range granodiorites. Otherwise, the ores occurring in the fissures of the different rocks just mentioned are practically indistinguishable.

Strikes and Dips.—As the outcrops of these fissures are in most places covered with superficial materials, and as most of the veins, that were examined, had been but slightly prospected, in only a few cases could the strikes of the fissures be determined at all definitely.

The fissure containing the Morning and Evening vein, the prin-

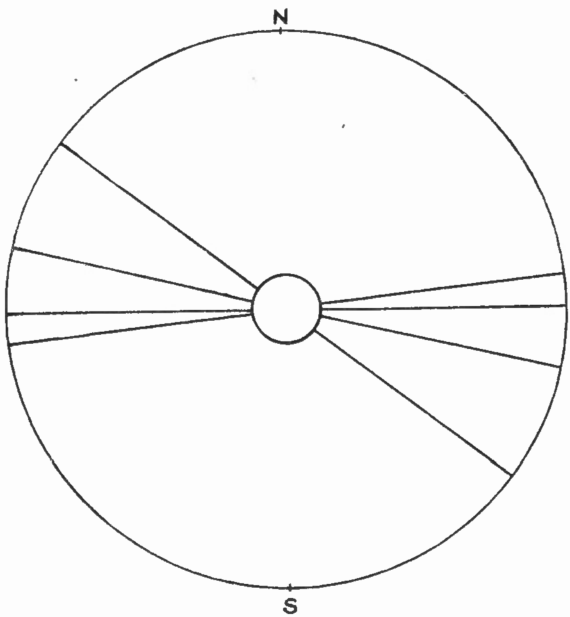

Fig. 7. Diagram showing strikes of antimony-silver vein fissures.

cipal one on Chieftain hill, strikes due west. On Goddell's claim, on the northern side of Carbon hill, are two parallel veins not more than 20 or 30 feet apart, that have a strike about 7° south of west (S. 83° W.). The three veins being developed on the Porter group, on the southwest portion of Carbon hill, strike 13° north of west (N. 77° W.). Near the lower end of Chieftain gulch, on Chieftain hill, a small, economically unimportant vein was noted, that had a strike of about N. 52° W. These were the only strikes that could be at all accurately determined, but all the other ore-fissures found on

Carbon hill appeared to strike in a westerly direction. So that, with the exception of the one small vein in Chieftain gulch, all the fissures apparently strike due west, or within a few degrees of this direction. (Fig. 7.)

The fissures on the Porter group dip to the northwest at 50° to 55°, but all the other vein-fissures in the district are practically perpendicular in attitude.

Persistency.—The two parallel veins on Goddell's claims, above mentioned, can be traced for about 2,000 feet along the steep side of a gulch on the western face of Carbon hill, where the conditions are favourable for outcrops. The other veins discovered in this vicinity are not as favourably situated in this respect. One of the veins on the Porter group has been traced for over 200 feet, and has every appearance of continuing much farther in both directions, but superficial materials cover the outcrop. The ore-fissure on the Morning and Evening claims on Chieftain hill is exposed to the north of Chieftain gulch for about 200 feet. None of the other veins have been followed for over 50 feet. It is quite probable, however, that further development will show numbers of these fissures to possess considerable persistency.

Widths of the Fissures.—The fissures vary in width from 2 or 3 inches to 6 feet. The thickest vein on the Porter group is 14 inches to 3 feet wide, and the narrower fissures on this property range from 6 to 14 inches. The Morning and Evening vein is 5 feet wide at one point, and Goddell's veins vary from 2 to 6 feet. The more promising vein-fissures in most places, however, range in width from 1 to 3 feet.

Faulting.—The walls of the fissures were, in several places, distinctly slickensided, showing that the fissures are, in most cases at least, fault-fissures. This feature was not noted in some of the outcrops on account of surface weathering, but where solid walls were to be seen, slickensiding was generally in evidence. A thin layer of clayey selvage one-eighth to one-fourth of an inch in thickness, also occurs in places on the walls of the Porter veins. This also indicates faulting.

As the fissures all occur in massive igneous rocks, it is impossible to say what the displacement of the walls, due to faulting, has been. However, no surface evidences of movement were noted, and none of the veins, so far found, contain brecciated wall-rock materials.

Further, the veins on the top, and east side, of Carbon hill occur in the Chieftain Hill clastics which are, in this vicinity, not over 100 feet in thickness, so the displacements in these places must have been somewhat less than this amount, or the underlying granitic rocks would somewhere be seen in contact with the clastics, in spite of the mantle of superficial materials that, in most places, cover the surface. No such evidence of faulting was discovered. For these reasons, it is thought that the displacements of the walls of the ore-fissures are slight and generally, at least, under 50 feet, and probably much less.

Intersections.—Although the fissures do not, in most cases, diverge more than 20° from being parallel, still, if persistent, they must intersect. No intersections had, however, been encountered at the close of the field season of 1909.

Origin of the Fissures.—Little data is available concerning the origin of these vein-fissures. They have in most cases a westerly strike, and so bear no relation to the main structural features of the district, which have a generally northwesterly trend. The fissures have a tendency to occur in groups composed of a number of closely parallel members. Further, although the principal veins have a decided tendency to parallelism and to have a westerly strike, one vein was found striking N. 52° W., and the Porter veins strike N. 77° W.; so it is possible, when more strikes have been determined, that two or more systems of fissures will be found to exist here.

It is also to be noted that the fissures in the different formations are intimately related, and whatever has caused one has, in all probability, caused all, regardless of the rocks in which they occur. This close association is strongly marked by the decided parallelism of the important fissures which occur in andesites, andesitic breccias, and granodiorites. In fact all the field observations indicate the synchronous origin of these fissures. These are the only facts that appear to bear on the question of origin. It is not even known whether the faults are normal or reverse in character, i.e., whether the hanging-walls have moved up or down, relative to the foot-walls.

Torsional forces, as shown by Daubrée,[1] have a tendency to produce radiating sets of fissures which are characteristically arranged in fan-like groups, and are often cut by others occurring at

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[1]Daubrée, A.—"Études Synthétiques de Géologie Expérimentale".

right angles to them. No such arrangement has been detected among these antimony-silver fissures. Tension[1] tends to produce breaks at right angles to the direction of the force applied, therefore generally results in a single set of parallel fissures. In connexion with the ore-fissures on Carbon and Chieftain hills, it is hard to conceive of tensional forces acting at 40°–60° to the main structural features of the district. Further, as just pointed out, there appear to be two sets of fissures which differ in their general trend by 40°. So that tensional forces could not normally account for all the fissures.

The only other forces that are known to produce faulting in the earth's crust, are those of compression and gravity. Gravity acts in conjunction with torsional, tensional, and compressive forces, but is not alone productive. When a body is in compression, breaks tend to result at 45°[2] to the line of the applied force, and so two sets of fissures form, theoretically at right angles to each other[3]; but friction and gravity operate to make the angle less than 90°. Further, the main fissures, so produced, are liable to be accompanied by others arranged parallel and close to them. These characteristics are clearly possessed by the antimony-silver fissures. Therefore, considering the facts in hand, forces of compression such as result from ordinary orogenic movements seem to best account for the origin of these fissures.

Fissure-fillings and Mineralogy.—General.—These antimony-silver veins consist chiefly of quartz, barite, calcite, stibnite, Jamesonite, grey-copper, sphalerite, argentiferous galena, arsenopyrite, and antimony ochre which occurs only near the surface. In places, the entire vein-filling consists chiefly of stibnite, with which may be associated subordinate amounts of sphalerite and Jamesonite. Some veins consist chiefly of gangue minerals with only small amounts of metallic minerals. Quartz is, in all places, the chief gangue mineral; barite and calcite occur only in minor amounts.

The ores are of value for their silver and antimony contents, but with the low prices paid now for antimony, they derive their present worth chiefly from the silver they contain.

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[1]Van Hise, C. A.—"Principles of Pre-Cambrian N. Amer. Geology": Sixteenth Annual Rep., Pt. I, U. S. Geol. Survey, pp. 633–682.

[2]On account of friction this is actually always less than 45°.

[3]Van Hise, C. A., Op. cit.

Gangue Minerals.—As just mentioned, portions of some of the veins consist wholly of metallic minerals, but where any considerable amount of gangue is present, quartz is always the chief mineral playing this rôle; barite and calcite occur only in minor quantities.

The quartz has frequently a massive appearance, and in such cases no crystal outlines can be detected. Often, however, this mineral consists of large well developed prisms which may form a network of interlacing crystals, or may occur in parallel fashion, pointing toward the centre of the vein, and so forming typical comb-structures. When the crystals are well developed, considerable inter-crystal space often exists, in which the metallic minerals are at times deposited. Such crystal development also shows that at least a certain amount of open space existed in the fissures at the time of the ore deposition.

The barite and the calcite have practically always a typical granular appearance. The calcite is generally easily distinguished by its well developed rhombohedral cleavage.

Metallic Minerals.—Of the various metallic minerals, stibnite is much the most common, and is the only one found making up any considerable portion of the vein-fillings. In places, in a number of veins, such as the 'big vein' on the Porter claim, the Morning and Evening vein, some on the Empire, and one found on the extreme easterly portion of Carbon hill, stibnite constitutes nearly the entire vein-filling. Sphalerite generally accompanies this mineral, and Jamesonite also often occurs. The ores of these veins which run high in antimony, tend to be low in silver.

Other veins, as the two narrow ones lying just below the 'big vein' on the Porter claim, show little or no stibnite, and consist chiefly of a quartz gangue through which are scattered particles of argentiferous galena and grey copper. Such ores have high silver content, but are low in antimony.

The veins on Goddell's claim consist chiefly of a quartz gangue, containing disseminated particles of Jamesonite and arsenopyrite. One vein on the Empire claim consists of a quartz and barite gangue containing a liberal amount of granular particles of sphalerite as well as some Jamesonite.

It is thus seen that the mineral content of these veins varies considerably, and ranges from chiefly stibnite, to entirely quartz, galena, and grey copper. In most places, if not everywhere, both the galena and the stibnite are silver-bearing.

The stibnite occurs prevailingly in long, well developed prisms which frequently exhibit beautiful columnar, and radial structures. All gradations are found, however, from this condition to purely granular. The galena exists generally in the form of small cubes scattered through the gangue. The grey copper always occurs as small, evenly distributed particles. The Jamesonite is found either disseminated through the ore, or constituting fine granular masses, or feathery aggregates. Arsenopyrite was noted only on Goddell's claim, and here exists in small, crystalline particles, evenly, but sparsely, distributed through the quartz. The zinc blende is commonly coarse to fine granular, but is massive and cleavable in places, and has everywhere a brownish colour and resinous lustre. The antimony ochre appears to be composed mostly of stibiconite, $H_2Sb_2O_5$, and is a pale-yellow to yellowish-white, earthy-appearing substance. This material occurs only at the very surface, and is derived, by weathering processes, from the stibnite and Jamesonite.

Other Fissure-filling Materials.—Vein-filling materials other than those just mentioned, viz., the metallic and gangue minerals, are entirely lacking, except for thin layers of gouge one-eighth to one-fourth of an inch thick, which occur on the walls of some of the veins. This material consists of comminuted wall-rock, ground by movement of the walls on each other. The thus disintegrated particles have since been more or less decomposed by circulating waters which have been influential chiefly in altering the feldspars to clay, sericite, etc., and thus forming the pasty selvage so characteristic of many veins.

No masses of included rock have been, so far, found in any of the veins.

Assay Values.—All the samples of these ores that have been assayed, and concerning which the writer has definite information, have been taken at, or within 10 feet of the surface. A cross-cut has recently been driven on the Porter claim, and it is reported that some of the veins on this property have been tapped at depths ranging from 150 to 200 feet, and that the ores at this level have values similar to those obtained at the outcrops; however, the writer has no positive assurance concerning these reports.

The outcrops even have not been systematically sampled for any considerable distances, but a large number of average and other samples taken from various places have been tested.[1] A few results, running over 500 ounces of silver to the ton, have been obtained, and several samples of the better class of ores containing galena and grey copper assayed from 100 to 200 ounces. Selected ore from the 'big vein' on the Porter claim carries 50 per cent to 65 per cent antimony, and one sample from this claim containing both silver and antimony in important amounts, gave when analysed, 50·40 ounces in silver, 31·40 per cent of lead, 18·75 per cent antimony, and $0.80 in gold. There is generally a decided tendency here, however, for ore running high in antimony to be low in silver, and vice versa, owing to the fact that grey copper and galena rarely occur at all closely associated with the stibnite. None of these ores have been found to carry more than a few cents to the ton in gold.

Synchronous Age of the Veins in the Different Formations.—Veins containing the same minerals similarly arranged, occur in the granodiorites and volcanic breccias of Carbon hill, and in the andesites of Chieftain hill; and so similar are these ores that it is often impossible to tell, from samples, in which formations they originated. Among other mineralogical characteristics long, well developed prisms of stibnite, possessing beautiful columnar, and radiated, structures, are typical of a number of the veins, regardless of their habitat, and in several places comprise the greater part of the vein-material. Nowhere else in Yukon territory have similar antimony ores been discovered. For these reasons, it seems evident that these veins must all have been formed at the same time and under like conditions.

Age of the Veins.—Some of the veins occur in the Chieftain Hill volcanics, and since they cut them, are more recent than these rocks which are thought to be of late Cretaceous or early Tertiary age. In a few places, as in Goddell's claims, the veins are, in turn, intersected by the Wheaton River volcanics, considered to be probably of late Tertiary and possibly of Pliocene age. It has been shown above, that the veins are apparently all of the same age; they, therefore, would seem to be all more recent than late Cretaceous, and to antedate late Tertiary times.

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[1]These assays were made by Mr. Robert Smart, Government assayer, Whitehouse, Y. T., and by the Department of Mines, Ottawa; the greater number were made by Mr. Smart.

Influences on the Wall-rocks.—Compared with many other districts in which ore-containing fissures occur, the wall-rocks of the antimony-silver veins on Carbon and Chieftain hills are but slightly affected by the mineral veins they contain. The granitic rocks have been slightly bleached and rendered somewhat more friable, adjoining the veins; but even this slight alteration disappears gradually, and is not noticeable at distances of more than 2 or 3 feet at most. The clastics and andesites are even less affected than the granitic materials, and in places no decided or marked alteration appears to have taken place adjoining the veins. The exact nature of the mineralogical and chemical changes that have occurred, have not been determined. In no case has the change progressed to the stage of masking the character of the wall-rock.

Oxidation.—The zone of oxidation is prevailingly shallow. In the majority of mining districts the limit of oxidation, as a rule, coincides with the water-level, but, in many cases, the process may partly, if not completely, alter the character of the veins for considerable distances below the water-surface. Here, in the antimony-silver veins, oxidation appears to have appreciably affected the ores, generally, only very near the surface, but they may be oxidized to considerable depths along occasional more or less open fissures which serve as trunk-channels for circulating waters. The depth to which the stibnite is oxidized can generally be measured in inches, and unaltered galena, sphalerite, Jamesonite, and grey copper are found within a foot or so of the outcrops. However, galena is, to some extent, oxidized for at least 8 to 10 feet, and the grey copper and Jamesonite may be, also; but opportunities for deciding this point are practically lacking. Several causes have been suggested above, in discussing the gold-silver veins, to account for the general shallowness of the oxidized zone there; these causes all apply equally well here, and will be briefly restated.

In the first place, on account of the northern latitude of this district, the ground is, in most places, continually frozen to considerable depths. Under these conditions, chemical action proceeds slowly and to a slight degree.

The drainage may also have an important bearing upon oxidation in this district. As shown in the descriptions of the topography, the mountains are prevailingly steep-sided, so that the run-off from the hills is, in most places, rapid and complete. This noticeably tends to diminish the effects of oxidation, as the waters are rapidly conveyed from the uplands to the main valley-depressions, and so have relatively little opportunity to act on the mineral deposits.

Still another point should be mentioned in this connexion. As previously stated, the chief metallic minerals occurring in these veins are stibnite, galena, sphalerite, Jamesonite, and grey copper; pyrite and marcasite are rarely, if ever, encountered. Recently, H. A. Buehler and V. A. Gottschalk[1] have demonstrated experimentally, that the ordinary natural sulphides, as galena and sphalerite, are oxidizable with difficulty under ordinary surface conditions; but that, in the presence of pyrite or marcasite, they are readily oxidized. The marked absence of pyrite and marcasite may, to a considerable extent, account for the shallowness of the oxidized zone in these deposits.

The following are the more important changes that have taken place in these deposits due to oxidation. The galena, in places, is oxidized to lead carbonate which often remains in the spaces originally occupied by the galena, but may be carried down and deposited at a lower level. The stibnite, at the very surface, is altered to a whitish-yellow to yellow, earthy substance, known as antimony ochre, but which appears to consist chiefly of stibiconite ($H_2Sb_2O_5$). The Jamesonite is also, to some extent, transformed into lead carbonate and antimony ochre. Malachite was noted in small amounts, in a few places, due to the oxidation of the grey copper. Definite alteration products of the sphalerite were not noted.

Leaching and Enrichment.—In many veins of the calcitic type, it is common to find a decided enrichment in the oxidized part of the deposit, due to a reduction in volume of the ore by the solution and removal of the soluble constituents. No such surface enrichment occurs in connexion with these antimony-silver veins. In fact, no surface sample is known to have assayed more than one dollar in gold per ton; and silver and antimony do not become concentrated at the surface.

The argentiferous galena and grey copper are to some extent oxidized at the surface, as mentioned above, and their silver content is, in all probability, partly dissolved out and deposited lower down in the vein. This leaching process, however, appears to have been

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[1] "Oxidation of Sulphides": Econ. Geol., Vol. V, No. 1, Jan., 1910, pp. 28–36.

very superficial and not at all extensive, so in all probability no considerable secondary enrichment will be encountered at the top of the zone of unaltered sulphides.

Persistency and Probable Vertical Extent.—Considering the shallow zone of oxidation, the apparently slight amount of leaching that has taken place, and the improbability of any secondary zone of enrichment being encountered with depth, it appears probable that these veins should maintain for a considerable portion of their vertical extent, the characteristics and mineralization, which distinguish them near the surface.

Generally veins do not extend downward for a greater depth than their extent on the surface, and in all probability this will be found to hold true in Wheaton district; so that the veins that are the most persistent at the surface may be expected to extend the farthest downward.

Genesis.—A consideration of the mineral-combination in these ores assists materially in the study of their genesis. None of the minerals—such as albite, amphibole, biotite, diopside, garnet, etc., characteristic of the deep-vein zone deposits,[1] occur, nor the minerals characteristic of pneumatolytic deposits, such as tourmaline, fluorite, spodumene, muscovite, etc. Such deposits are directly connected with plutonic intrusive rocks, and have been derived from them through the agency of magmatic gases dissolved in them at the time of their intrusion, and existing, therefore, at high pressure and above the critical temperature of water.

The minerals that are present all indicate that the ores belong to the upper-vein zone. Stibnite is practically diagnostic of shallow-vein deposits, and is known to be at present forming at Steamboat Springs where it is deposited by hot ascending waters on gravel pebbles within 30 feet of the surface.[2]

A study of the past and present topographies of the district affords but little definite information concerning the depth at which these veins were formed, as there is considerable doubt as to the

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[1]For a discussion of the different mineral-zones and of the minerals existing in each see:—

Emmons, W. H.—"A genetic classification of minerals": Econ. Geol., Vol. III, No. 7, pp. 611–627, and

Lindgren, Waldemar—"The relation of ore-deposition to physical conditions": Econ. Geol., Vol. No. II, pp. 105–127.

[2]Lindgren, Waldemar—"The occurrence of stibnite at Steamboat Springs, Nevada": T. A. I. M. E., 1905, pp. 27–32.

number of orogenic movements and erosion cycles that have occurred since the formation of the deposits.

It is known, however, that the materials such as compose these veins are deposited by circulating waters containing dissolved gases and metalliferous compounds. It is also generally supposed that these waters derive their mineral-contents from some molten or highly heated igneous intrusives. These antimony-silver veins are cut by, and are, therefore, older than all the known igneous rocks of the district, that are more recent than the Chieftain Hill materials. They would appear for this reason, to be associated with these, if they are connected with any of the igneous rocks known to exist in this locality. The fact that these veins always occur either in or near the Chieftain Hill volcanics also gives weight to this idea. It is, therefore, quite probable that the materials composing the veins were deposited in the granitic rocks and already cooled andesites and breccias, while the underlying magma, from which the andesites and breccias were derived, was still in a highly heated or molten condition, and that the material comprising the veins was derived from this molten material. Since, however, the Wheaton River volcanics and the Klusha intrusives probably represent later products of the reservoir from which the Coast Range intrusives originated, and as the Klusha and Wheaton River rocks were formed after, and the Coast Range rocks before the antimony-silver veins, it would appear that a vast granitic magma remained in a highly heated and fertile condition during the period in which the veins were produced, and may possibly have been the source of the material composing them.

DESCRIPTIONS OF MINING PROPERTIES.

A large number of claims have been located in the district, and a considerable portion of them are still being held. On only a few, however, has any development work been performed, and these are, in most cases, the only ones that afford any definite information concerning the ore-deposits of the vicinity. A number of the more promising are described in the following pages.

Carbon Hill Claims.—The Porter Group.—This group includes three claims, the 'Porter,' the 'Empire,' and the 'Excelsior,' which are owned by Mr. H. E. Porter and Mr. W. J. Fleming. These properties present the most promising surface indications in the vicinity, and on them the bulk of the development work of the entire camp has been performed.

On the Empire claim are the old workings of Corwin and Rickman,[1] and it is there that their first discoveries are supposed to have been made. The different cuts, trenches, pits, etc., when visited by the writer in September, 1909, were so caved, and the rocks so decomposed, that little definite information could be obtained concerning the veins on the property. The ores occur in an andesite that contains considerable iron, and that for several feet from the surface is so badly decomposed that its nature is almost completely masked. This rock presents a bright-reddish to yellowish appearance, and is much disintegrated in many places. However, at three or four points masses 6 to 10 inches in diameter of almost solid stibnite were found, associated with more or less sphalerite, quartz, and barite. One vein appeared to consist chiefly of quartz, impregnated with sphalerite and small particles and feathery aggregates of Jamesonite. Outcrops of several veins, apparently from 6 inches to 2 feet in thickness, have been discovered on the claim.

On the Porter claim, six veins have been discovered, and others will probably be found when the ground is more thoroughly prospected. The veins occur in the Jurassic granitic rocks, and appear to have parallel strikes, but the outcrops of two of the veins were small, so that their direction of strike was not definitely determined. The other four veins are practically parallel, strike N. 77° W., and dip at 50° to 55° to the northeast.

The most promising looking of these veins, the 'big vein,' ranges from 14 inches to 3 feet in thickness, and can be traced for at least 200 feet on the surface, and probably continues much farther; but superficial materials cover the remaining portions. The vein consists chiefly of quartz and stibnite, with sphalerite and Jamesonite in minor amounts; and portions of it 12 to 14 inches thick consist of almost pure stibnite.

Five feet below the 'big vein' is another, from 6 to 12 inches thick, and similar to the former, but not so highly mineralized. There are also two other veins below these, at distances of 95 to 130 feet, respectively, measured in a horizontal distance from the 'big

[1]The discoveries of these early prospectors are described in the introductory portion of this report.

vein.' These are 2 inches and 6 inches thick, respectively, where they outcrop, and consist chiefly of quartz containing disseminated particles of galena and grey copper.

Practically the only surface development that has been performed on this claim is in the form of an incline shaft about 10 feet deep, on the 'big vein.' A cross-cut was being driven when the claim was visited, that was intended to tap the four parallel veins just mentioned. The 'big vein' would be encountered farthest from the mouth of the cross-cut, and at a calculated depth vertically below the surface of 180 feet. It is reported that some of the veins have been cross-cut this winter (1909-10), and that very encouraging ores were encountered.

It is not known what any considerable portion of these outcrops will assay, though a large number of samples taken from the surface and from the 10 foot shaft have been tested, and afford some information. A few assay[1] returns running as high as 500 ounces of silver per ton have been obtained, and several samples of the ores containing considerable galena and grey copper gave from 100 to 200 ounces; the majority of the samples that have been tested, however, contained less than 50 ounces of silver per ton. The ores from the 'big vein,' in places, contain 50 per cent to 60 per cent antimony, and one sample from this claim, containing both silver and antimony in important amounts, upon analysis gave 50·40 ounces of silver, 31·40 per cent lead, 18·75 per cent antimony, and $0.80 gold. The ores rarely contain more than a few cents per ton in gold. The galena and stibnite are both silver-bearing in places, and may be everywhere.

Goddell's Claims.—The claims referred to in this report as 'Goddell's claims,' constitute a group situated on the Wheaton River slope of Carbon hill, about one mile to the north of the Porter claim.[2]

Two parallel veins, not more than 20 or 30 feet apart, outcrop in a gulch on these claims, and are distinctly exposed to view, extending up the mountain side for a distance of over 2,000 feet. They occur in the Jurassic granitic formation, strike S. 83° W., and have an almost perpendicular attitude.

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[1]These assays were made by Robert Smart, Gov. Assayer, Whitehorse, Y. T., and by the Department of Mines, at Ottawa.

[2]Mr. Charles Goddell is believed to own a number of other claims in the neighbourhood of Chieftain and Carbon hills.

The veins consist chiefly of quartz, impregnated with Jamesonite and arsenopyrite, and are 2 and 2 to 6 feet thick, respectively.

Some open-cut work and a cross-cut, 20 to 30 feet long, comprise the development work on this property. The veins are, however, fortunately situated on the rugged mountain side, so that nature has done considerable surface stripping, and so exposed them for a much greater distance than any other veins in the locality.

Chieftain Hill Claims.—The Morning and Evening Claims.—The only claims on Chieftain hill on which ore of any importance has so far been discovered, are the Morning and Evening, which adjoin one another on the same vein. The vein occurs in a fissure in a fine-grained, greenish andesite, strikes due west, and has an almost perpendicular attitude. Where it crosses Chieftain gulch the vein is 5 feet thick, and consists chiefly of quartz and stibnite, with subordinate amounts of zinc blende; 2 feet of this thickness is composed almost entirely of stibnite which exhibits beautiful columnar and radiated structures. Fifty feet away in either direction the vein is not more than 6 inches to 1 foot in thickness. The only development work that has been performed on these claims consists of a little surface stripping.

Silver-lead Veins.

GENERAL STATEMENT.

The silver-lead veins have been found chiefly in a northerly-trending belt about 3,000 feet long and 1,000 feet wide, which is situated on the eastern face of Idaho hill, and is chiefly included by two mineral claims that comprise the Union Mines group. A few veins have also been found to the south, on the adjoining Nevada group, and one similar deposit is reported to occur on the north face of Mt. Follé, half a mile to the southwest of the Union mines.

These veins all occur in a generally finely textured, grey to pale-green feldspathic rock which, in most places, is a typical arkose. The deposits, in most cases, strike about N. 12° W., dip at approximately 70° to the west, and in a general way coincide in these respects with the containing formation.

At least twelve veins have been discovered on the Union Mines property. Of these, the majority, for the greater portion of their extent, are from 4 to 12 inches in thickness, and can be traced from

10 to 200 feet along the surface, and surface stripping may show that some extend much farther. The veins generally are fairly regularly tabular in form, but close examination shows in many places a lack of definition between the walls and the ore. The vein-materials penetrate the enclosing rock in an irregular manner—in some instances only microscopically discernible, and in others quite extensive. In several places veins which for considerable distances are only a few inches in thickness, suddenly widen out into irregularly-shaped ore-masses 4 to 6 feet wide and up to 20 feet or more in length.

The vein-materials consist chiefly of quartz, calcite, galena, arsenopyrite, zinc-blende, pyrite, and chalcopyrite. Quartz is, in most places, the chief gangue-mineral, and arsenopyrite and galena are the principal metallic constituents of the deposits. Included portions of wall-rock are plentiful in places, particularly along the edges of the veins. The ores generally contain only a few cents in gold to the ton, and seldom, if ever, have more than $2; so that silver and lead are their economically valuable constituents. Assays of the better grades of galena ore yield approximately 50 ounces of silver and 40 per cent lead, but higher returns have been obtained from selected samples. It is thought that considerable portions of the surface ores, and all of the exposed parts of some of the veins, will average between $15 and $20 per ton in silver and gold—the gold being always relatively small in amount.

The ore-minerals are somewhat oxidized at the surface, but as the development work has not exposed any of the veins to a depth of more than 6 or 7 feet, it is not known how deep the oxidized products may extend, but unaltered sulphides occur plentifully at the surface.

The deposits were formed, for the greater part at least, by metasomatic replacement; i.e., the solution of the walls and the deposition of the vein-materials took place simultaneously. The mineral-bearing solutions appear to have travelled chiefly along the bedding-planes of the clastic rock in which the veins occur, but in a few cases followed cross-fractures in the rock. Practically all that is known concerning the age of the deposits is that they were formed later than the Jura-Cretaceous rocks in which they occur.

DETAILED DESCRIPTIONS.

Distribution.—The silver-lead veins occur chiefly on the eastern face of Idaho hill—the eastern portion of the easterly-trending ridge situated between Schnabel and Perkins creeks which lie on its southern and northern sides, respectively. Idaho hill overlooks Annie lake to the east, and forms a part of the western wall of Corwin valley, the widest and most important depression in Wheaton district (Diag. 3, also map of Wheaton district).

Another vein, reported to resemble those on Idaho hill, has recently been located about half a mile to the south, on the northern slope of Mt. Follé, but it was not seen.

The majority of the silver-lead veins occur on two claims comprising the Union Mines group, and are distributed over a northwesterly-trending area about 3,000 feet long by 1,000 feet wide.

Eight other claims, forming the Nevada Mines group, have been located as extensions to the Union Mines, and are situated chiefly to the south of this property. Ore-veins are believed to have been found on the Nevada group only in a few places, but those that have been discovered are quite similar in appearance to the deposits on the Union Mines ground, with the exception that generally they contain less galena. The writer saw only two veins on this group, both within 1,000 feet of the southern edge of the Union Mines ground, and on the steep, southern slope of Idaho hill, facing Schnabel creek.

Formation in Which the Veins Occur.—The veins all occur in light grey to pale green, generally fine-grained, homogenous appearing feldspathic beds which belong to the Jura-Cretaceous Laberge series, and under the microscope are generally seen to be typical arkoses, but, in places, contain considerable tufaceous material.

Strikes and Dips.—The veins, in a general way, all appear to follow the dip and strike of the clastic rocks in which they occur, although, in places, this is not at first evident, because the rocks are generally heavily bedded, and in many cases their bedding-planes can only be distinguished from a distant view-point. The majority of the veins thus strike about N. 12° W., and dip from 60° to 70° to the southwest. One vein, however, was noticed that departed considerably from this general strike, but it appeared to extend only a short distance, following, apparently, a minor fissure in the rock-formation.

Persistency and Dimensions.—These veins are in many places very irregular in form, and generally have indefinite walls which are invaded and pierced by the ores. The centres of the veins are nearly all ore, but approaching the walls more and more rock-material becomes intermixed until the vein-matter has disappeared. The deposits here and there suddenly widen in this way, from 8 to 10 inches to 3 or 4 feet, or even more in thickness. Figure 8 is a somewhat diagrammatic sketch of one of these deposits, in which the ore-mass cross-cuts and intersects the rock-structure.

Some of the veins are, however, fairly regular in outline and maintain nearly uniform thickness as far as they are exposed. The veins, generally, are from 4 to 12 inches thick, and can be traced

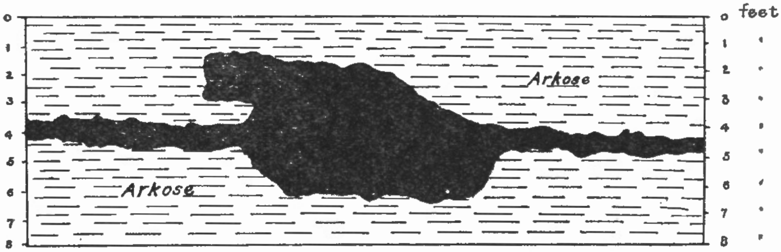


Fig. 8. Diagrammatic sketch of a silver-lead deposit.

from 10 to 200 or 300 feet. In some instances the occurrence of a number of similar outcrops in line for 700 or 800 feet suggests that they may be portions of the same vein. In most cases, it is more probable that these different vein-portions represent several deposits lying en echelon. Surface stripping would readily decide such points, but, as yet, very little work has been done on the deposits.

As many as twelve veins in all have been found. One of these is, where exposed, 2 feet 6 inches in thickness; the others throughout the greater part of their lengths vary in thickness from 4 to 12 inches; but in a few places masses of ore containing rock-material were noted ranging from 2 feet to 4 feet thick, and from 5 to 20 feet long, or possibly longer. One irregular area, possibly 12 feet wide and 20 feet in length, was noted, which appeared to be possibly half ore-material.

Intersections.—As these veins are nearly all practically parallel, there is but little chance of finding points where they intersect. One vein was noted, however, that had a definite strike in a direction nearly at right angles to the general trend of the deposits. This vein did not appear to extend far and was not observed to intersect any other deposit, but an intersection may occur underneath the superficial materials.

Spacing.—As previously mentioned, with two or three exceptions, all the veins that are known to have been discovered occur within an area about 3,000 feet long and 1,000 feet wide. The greatest number of deposits seem to occur toward the centre, and fewer toward the ends of the belt. In an average section across the area near the centre, there are from four to eight veins, fairly evenly spaced. To the north and south this number gradually decreases, and near the ends of the 3,000 feet probably two or three only will be found. Further developments may, however, reveal many more deposits than are at present known.

Faulting.—No evidences of movements of the vein-walls, relative to one another, have been detected. Faulting may have occurred, but it must have been a minor factor in connexion with the formation of the spaces in which the ores have been deposited, as no slickensiding, fault-breccia, selvage, etc., were seen.

Gangue Minerals.—Quartz is the chief gangue mineral in most of the deposits, but calcite also occurs plentifully in places, and in some instances exceeds the quartz in amount. In the majority of the veins, the gangue materials are considerably greater in amount than the metallic constituents. But portions of a number of the deposits consist mainly of metallic ingredients.

The quartz is characteristically massive in appearance, but well defined crystals occur. Irregularly distributed geodes or vugs are characteristic of the ores, and are always lined with well formed, clear, glassy, quartz prisms, pointed toward the centres of the cavities. The calcite is practically always massive and cleavable.

Metallic Minerals.—Arsenopyrite, galena, zinc-blende, pyrite, and chalcopyrite, with their surface oxidation products, comprise the metallic minerals of the deposits. Arsenopyrite and galena are the most plentiful. Zinc-blende is generally present in minor amounts, but pyrite only occasionally, and chalcopyrite is rarely found.

The arsenopyrite is always characterized by its peculiar tin-white colour, and is prevailingly massive to finely-granular in appearance. It occurs intermingled with the other ore-minerals and wall-rock fragments, but also in many cases forms solid ore-masses that comprise considerable portions of the vein-material. These masses are in places somewhat tabular in form, and occur roughly parallel to the walls of the deposits, but they are prevailingly quite irregular in outline, and bear no relation to the form of the ore-bodies.

Galena is abundantly present in a number of the veins, and since it is silver-bearing is, with the exception of gold which occurs in very small amounts, the one economically valuable mineral in the deposits. In places it is very finely textured, presenting almost the appearance of a fresh fracture in a piece of steel, and in this form is known as 'steel-galena.' In other places it is quite coarse and exists as cubes as large as one-eighth of an inch in diameter. All gradations between these extremes are encountered. The galena occurs either disseminated through the gangue minerals, or forming, alone or with other materials, almost solid metallic ore-masses; it is found generally intimately associated with the arsenopyrite, either intermingled with it, or forming masses adjoining it. The galena-masses are generally very irregular in outline, but are occasionally tabular in form, parallel to the general strike of the veins and the original bedding-planes of the wall-rocks. Both the arsenopyrite and galena in many places distinctly penetrate and apparently replace the walls of the veins of which they form a part.

The sphalerite is always dark-brown to black in colour and is either massive or foliated in structure. It occurs frequently as disseminated particles associated with the galena and occasionally with the arsenopyrite and pyrite as well, and is also found scattered throughout the quartz and calcite materials, either in fine grains or in compact masses up to 2 inches in diameter.

Pyrite generally occurs in minor amounts, chiefly as irregular, finely crystalline to massive aggregates. Particles of chalcopyrite occasionally are associated with the pyrite.

Included and Unreplaced Areas of Wall-rock.—Numerous portions of wall-rock occur included in the vein-materials, particularly along the edges of the deposits. These masses are very irregular in form, but generally the sharp edges or corners have been removed during the process of replacement, as later explained. The ores penetrate the walls, and the rock fingers into the ore in a corresponding manner. This interfingering of ore and rock is, in places, only microscopically discernible, and in such cases the ores appear to have quite definite walls, but in other places the ores pierce the containing rock for several feet. These features and their causes and origin will be further discussed when considering the genesis of these deposits.

Assay Values.—As none of these deposits have been developed below the surface, only outcrop samples have been tested; from these, assays running as high as 150 ounces in silver to the ton have been obtained, but 50 ounces is more nearly the average of the better grades of surface-ores. Samples have been tested containing as much as 70 per cent lead, but these are very exceptional and represent only small masses of almost solid galena; considerable portions of some of the veins, however, carry upwards of 40 per cent lead. Gold exists in these veins in only small amounts; many of the samples taken show only traces of this metal, but some go as high as $2 per ton. The better mineralized portions of the veins are believed to carry approximately $20 per ton in gold and silver.

Age of These Veins.—These deposits occur in rocks in which numerous specimens of *Prioncyclus woolgari* are found; and for this reason, as discussed more fully under 'General Geology,' this horizon is assigned to the lower, or lower-middle Cretaceous. The veins, since they cut these beds, must have been formed after the rocks themselves, and are, therefore, more recent than this period. This is all that is definitely known concerning the age of the deposits, as none of the volcanic rocks of Cretaceous, or later age, have been found cutting them.

However, as explained in more detail in considering the genesis of these deposits, there are important reasons for believing that they are genetically associated with either the Klusha intrusives or the Chieftain Hill volcanics, and were formed after one or both of them had consolidated. This would make the veins of late Cretaceous or early Tertiary age.

Oxidation.—Compared with similar veins in the majority of mining districts in the world, these silver-lead deposits have been but slightly affected by oxidation processes; in fact considerably the greater part of the surface ores, the gangue excluded, consist of unaltered sulphides. One of the chief reasons for this appears to be the cold northern climate, which causes the ground to remain permanently frozen to considerable depths, and greatly retards chemical activity. Another cause is the steep-walled character of the valleys, as a result of which the water is rapidly carried off, and so given little opportunity to attack the ore-deposits. These points have been discussed more in detail, in considering the gold-silver veins.

Small as are the effects of oxidation in these deposits, they appear to be somewhat greater than in the antimony-silver and gold-silver veins. Considerable portions of the silver-lead deposits have been much altered at the surface, and oxidation extends down as far as the ores have been developed, which is, however, only 6 or 7 feet. At this depth, oxides and oxygen salts are quite plentiful, which is not the case with the other types of deposits mentioned above. This difference in amount of oxidation may possibly be accounted for by the fact that there is more pyrite in these silver-lead veins, which, as mentioned in discussing the gold-silver ores, Buehler and Gottschalk have recently shown, causes other natural sulphides to become much more readily oxidized.

Here, as elsewhere, oxidation transforms the sulphides to oxygen salts which may be further changed or carried away by surface waters. The pyrite is most readily attacked, yielding sulphuric acid and ferrous sulphate which oxidizes freely to ferric sulphate and finally to ferric hydrate and free acid. Arsenopyrite is attacked with more difficulty, but has, to some extent, been changed to limonite, arsenic trioxide, and a dark green, hydrous, ferric sulphate. The arsenic trioxide occurs in small amounts, either as a white, earthy powder, or as thin white crusts. The dark green sulphate is very plentiful and characterizes the ores nearly everywhere. It appears to result both from the pyrite and the arsenopyrite, and occurs as a powder, or paste, filling the cracks and coating the surfaces of the ores.

Galena and zinc-blende are less readily attacked than the iron minerals, and no place was noted where oxidation products of the sphalerite could be identified, although it is, in all probability, changed, to some extent, to zinc silicate. The galena is altered to yellow, earthy, lead carbonate, which generally continues to occupy the position in the ores originally held by the galena. The chalcopyrite is, to some extent, oxidized to malachite. The portions of wall-rock included with the ores are much oxidized and altered chiefly into kaolin and quartz. In places, large masses of almost pure kaolin occur.

Leaching and Enrichment.—The veins are, in places, somewhat porous, and show that certain of the more soluble portions of the ores have been taken into solution and removed. To what extent the process has been carried is only approximately known, as the veins are only exposed in a few places, and nowhere for more than 6 or 7 feet below the surface.

An estimate of the amount of material removed might be made from calculations of the porosity of the outcrops, but it is not known how much of the material removed was metallic, and how much unmetallic. Further, the leached materials may have been, to a great extent, removed by surface waters. It is, therefore, impossible to estimate the amount of valuable constituents in the ores lower down in the veins. The great proportion of entirely unaltered sulphides at the surface, and the probability that the zone of oxidation is very shallow, indicate that no considerable zone of secondary enrichment is to be expected at the top of the zone of unaltered sulphides. It is to be expected, therefore, that the veins will be found to maintain for a considerable portion of their vertical extent, the mineralogical characteristics that distinguish the unoxidized portions at the surface.

Genesis.—For the sake of clearness, all the facts bearing on the origin of these deposits will now be stated, though the greater part of them have been mentioned before.

(1) The veins, in a general way, follow the bedding-planes of the clastic rock in which they occur.

(2) There is a lack of definition between the walls and the ore-materials.

(3) The deposits are in many places very irregular in outline; they penetrate the walls in various directions, and cross-cut the structures and the breccia-fragments composing the rock.

(4) The ores are distinctly secondary to the country-rock, and consist chiefly of quartz, calcite, galena, arsenopyrite, zinc-blende, pyrite, and chalcopyrite.

(5) All ores of this character are deposited by circulating solutions containing dissolved gases and metalliferous compounds.

(6) Before such ores can be formed the solutions carrying them must have a place in which to deposit their mineral burden.

(7) There has been apparently no movement of the walls relative to one another, so the cavities were not produced by faulting.

(8) The irregular shapes of the deposits preclude the possibility of the spaces they occupy having been originally cavities produced

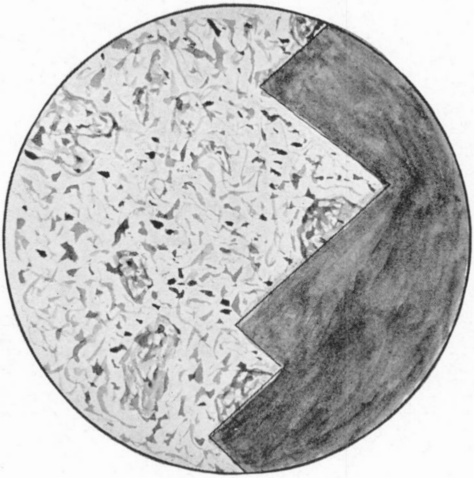
by rock-fracturing, and show that they could only have been produced by solution (see Fig. 8).

(9) An examination of thin sections of these ores under the microscope shows sharply defined crystals of arsenopyrite, galena, and other ore-materials penetrating the fragments of wall-rock, and cross-cutting the clastic particles in such a manner that no space exists between the secondary crystals and the original rock materials (Plate XIV.) The spaces for these crystals could not have been made by fracturing nor by the force of crystal-growth, as the original clastic grains are in no way distorted. Further, if it is supposed that solutions first produced the cavities, and that the ores were deposited in these spaces later, this attributes an almost human understanding to the solutions. It is inconceivable that they would know, while dissolving the rock, the kind of minerals that would be deposited in it, and so sculpture cavities exactly the size and shape of the crystals that were to occupy them. The only satisfactory explanation of the origin of these deposits seems to be that solution and deposition were, for the greater part at least, concurrent. The solutions apparently travelled along the bedding-planes of the clastic rock, filled with mineral-deposits any small spaces that may have existed, and replaced the materials on either side. This accounts for the crystals penetrating the breccia-fragments, the ores extending into the wall-rocks, etc.[1]

As to the source of the vein-forming materials; it is generally believed that these materials are derived from intrusive igneous rocks, and are carried in solution to the places where they become deposited. On Idaho hill and vicinity, the Chieftain Hill volcanics and the Klusha intrusives are the only known igneous rocks that are more recent than the Laberge rocks in which the silver-lead ores occur. Of the two, the Klusha granite-porphyries are the less prominent in the neighbourhood of the deposits, but a genetic relationship between them and the ores is possible. An area of andesites belonging to the Chieftain Hill volcanics, occurs in close proximity to these deposits, also andesite dykes occur, on Mt. Follé, on the ridge to the west of Idaho hill, and elsewhere in the vicinity; so that it is possible these rocks may be related to the silver-lead deposits. The data at hand, however, are insufficient to decide the matter

[1]For a very excellent discussion on replacement, including all the known criteria for recognizing this process in ore-deposits, see:—

Irving J. D.—"Some features of replacement ore-bodies and criteria by means of which they may be recognized," Jour. Can. Min. Inst., Vol. XIV, 1911, pp. 395-472.



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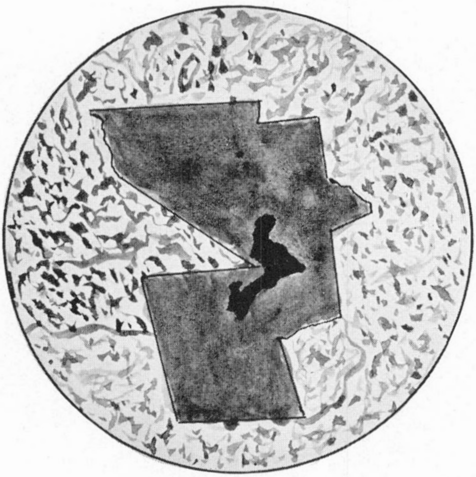

B.

Drawings of portions of thin sections from the walls of a typical lead-silver vein, as seen between crossed nicols. The country rock consists chiefly of a mixture of quartz and feldspar, much altered to sericite.

A. Shows arsenopyrite, (the dark mineral) replacing the country rock, and crosscutting the breccia fragments composing it.

B. Shows the same as A, but in addition, the large dark arsenopyrite crystal has, included, some sphalerite, (the black irregular portion near the centre of the arsenopyrite.)

definitely, but it is thought that the ore-bearing solutions were probably connected with late Cretaceous or Tertiary intrusive rocks.

Concerning the depth at which these veins are formed, the mineral combination indicates with some certainty that they were deposited in the upper, cooler portion of the earth's crust, and in the upper-vein zone.[1] A study of the past and present topographies, and the geological formations of the district, affords but little definite information concerning this matter, as there is considerable doubt as to the number of orogenic movements and erosion cycles that may have occurred since the formation of these deposits.

MINING PROPERTIES.

The Union Mines.—Since the majority of the silver-lead veins already described occur on the Union Mines property, the foregoing discussion of these deposits practically all refers to the Union Mines deposits, hence no further consideration of them is here necessary.

The property consists of two claims owned by W. F. Schnabel and Mr. Northrop. A cross-cut has been commenced, but in September, 1909, had only been driven 15 or 20 feet, and no veins had been encountered. With this exception, all the development on these claims consists of a certain amount of surface stripping and open-cut work. Nowhere have the veins been exposed to a depth of more than 6 or 7 feet.

The Nevada Mines.—This group is owned by Charles Bush and W. F. Schnabel, and consists of eight claims which were located as extensions to the Union Mines group, and lie chiefly to the south of this property. Only two veins were seen by the writer on the Nevada group, and these were similar in appearance to those at the Union mines, except that they contained much less galena, and so consisted mostly of quartz, calcite, arsenopyrite, zinc-blende, pyrite, and chalcopyrite. Other veins are believed to have been discovered.

Some underground work has recently been performed on these claims, so that by the spring of 1910, 50 to 75 feet, or possibly more, of drifting is expected to have been performed.

[1]The mineral combinations of the different vein-zones are more fully discussed under the gold-silver, and the antimony-silver-veins.

Contact-Metamorphic Deposits.

GENERAL STATEMENT.

These contact-metamorphic deposits have, so far, been discovered only at one place in Wheaton district, and all the known outcrops are limited to a northwesterly-trending area, perhaps 500 feet long and 100 feet wide, which is included on the Fleming mineral claim. This claim is situated on the top and northerly slope of a small ridge that faces Wheaton river on the south, about one mile west of Becker creek.

The ore-materials occur in pre-Devonian, finely textured, light green to grey hornblende-gneisses, near their contact with Jurassic, intrusive granodiorites. The deposits follow, in a general way, the strikes and dips of the gneisses, and occur in bands trending N. 42° W., or approximately at right angles to the granodiorite-gneiss contact, and inclined from 60° to 90° in either direction.

The largest deposit is about 30 feet wide, but its length is unknown, as superficial materials cover the greater part of the surface. The ore-matter is actually exposed for 8 or 10 feet only, but the occurrence of float indicates that it extends much farther, perhaps several hundred feet. Near this deposit, two smaller bands 4 to 6 feet wide were noted.

The secondary material constituting the mineral deposits consists chiefly of magnetite, specularite, chalcopyrite, pyrite, quartz, calcite, epidote, actinolite, and a yellow garnet, apparently grossularite. The central portion of the large deposit consists chiefly of iron and copper minerals, and contains, at a depth of 4 feet from the surface, perhaps one per cent copper. This metal, and gold which has not been found in quantities exceeding $2 per ton, comprise the economically valuable materials in these ores.

The minerals have been to some extent oxidized, and limonite, azurite, and malachite have been produced. The copper minerals have been entirely leached out at the actual surface, but at a depth of 4 feet, the greatest as yet reached in the development of the Fleming claim, chalcopyrite is somewhat abundant, so that the zone of oxidation is thought to be shallow, and to be unimportant economically in these deposits.

DETAILED DESCRIPTIONS.

Geological Occurrence.—The northern face, and parts of the top of the ridge on which the Fleming claim is located, are composed of chiefly finely textured, light greenish to greyish hornblende-gneiss, which belongs to the Mt. Stevens pre-Devonian group. The southern portion, and probably the bulk of the ridge, as well as the hills to the south, are composed of the Jurassic granodiorite intrusives. The contact-metamorphic ores occur replacing bands of the gneisses in the vicinity of the granitic rocks. These gneisses are particularly rich in lime, owing to the high percentage of lime-alkali feldspars which they contain.

The gneiss-bands are somewhat distorted, but generally strike about N. 42° W., or approximately at right angles to their contact with the granodiorite, and are inclined from 60° to 90° in either direction.

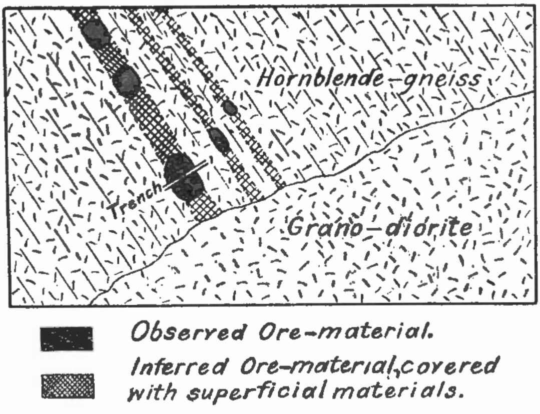

Fig. 9. Diagrammatic sketch of the ore deposits on the Fleming mineral claim.

Dimensions.—When visited in September, 1909, a trench about 40 feet long, 2 to 4 feet wide, and 1 to 4 feet deep constituted practically all the development work that had been performed on this property. As the surface is in most places covered with superficial materials, little is known concerning the dimensions, or other characteristics of the deposits.

The trench, just mentioned, crosses one band of ore-material about 30 feet wide, at a distance of possibly 100 feet from the granitic contact, and striking about at right angles to it. Drift covers the area between the granitic rocks and the deposit which was only exposed for about 10 feet along its strike; but farther to the north, over the surface of the hill toward Wheaton river, several iron-stained patches noted may cap similar ore-material continuous with that at the place trenched, or en échelon to this deposit. Within a few feet of the main exposure and to the east of it, two smaller outcrops of similar ore, 4 to 6 feet wide, were noted, but could not be traced more than 10 or 15 feet, on account of surface materials.

Mineralogy.—The ore-materials exposed in the trench consist chiefly of magnetite, specularite, chalcopyrite, pyrite, malachite, azurite, calcite, quartz, epidote, chlorite, actinolite, and yellow garnet. Toward the centre, the iron and copper minerals constitute the greater part of the deposit, but toward the edges more quartz, calcite, epidote, etc., are found, and these gradually give place to unaltered, highly calcareous, hornblende gneiss.

The specularite generally occurs in radiating forms and rosettes. The magnetite is prevailingly massive, but is also, in places, somewhat granular. The chalcopyrite generally appears as blotches distributed through the magnetite, epidote, chlorite, etc., but also occurs finely disseminated through these materials. Pyrite is found in only minor amounts mostly associated with the chalcopyrite, and is, wherever noted, finely granular in structure. The malachite occurs in the seams, cracks, and dissolution-spaces in the ore-material.

Assay Values.—The samples of these ores that have been assayed show them to contain from traces to $2 per ton in gold. With the exception of this metal, the copper minerals are the only ones of economic importance, and in the best places at the surface or in the bottom of the trench the copper will not exceed one per cent.

Oxidation, Leaching, and Enrichment.—The iron minerals at the actual surface have been to some extent oxidized to limonite, which gives the ores a reddish appearance; this alteration-product does not extend far below the surface, however, and at a depth of 4 feet the iron oxides are but slightly altered, and even the pyrite has been only to a limited extent oxidized. The copper minerals have been more affected than the iron oxides, and, at the surface, have been oxidized and entirely leached out; but at a depth of 3 or 4 feet some chalcopyrite exists, and the copper carbonates, malachite, and azurite are quite plentiful. The copper in the sulphide and its oxidized products in the bottom of the central portion of the trench, above mentioned, constitutes about one per cent of the ore-material.

Since the deposits outcrop on a steep sidehill, it is probable that the greater portion of the copper that has been leached out has been removed by surface waters, and so lost, as far as these ores are concerned. However, the remainder of the copper must have been carried down and been precipitated in the deeper portions of the deposits. It is thus apparent that an enrichment in the copper content of these deposits may occur just above the zone of unoxidized materials, or at the depth of the permanent water-surface. Since the surface ores do not show, by the evidence of porosity or otherwise, that any great amount of copper has been removed, and as considerable of this amount is lost due to the surface-waters, while the chalcopyrite is already coming in at a depth of 4 feet, indicating that the oxidized zone is shallow, it is not probable that any considerable secondary enrichment will be encountered.

The two chief causes that have apparently been influential in preventing oxidation and leaching from being more effective, are the cold, northern climate, and the character of the topography. At this northern latitude the ground is, in most places, permanently frozen to considerable depths, and so all chemical activity is much retarded. Also these deposits are situated on a steep mountain-side, which results in a rapid run-off of the surface waters that thus have little opportunity to attack the ore-deposits. These points have been discussed more fully above, in considering other types of ore-deposits in Wheaton district.

Genesis and Age.—In studying the genesis of these deposits a number of striking and definite points have been noted. In the first place, as mentioned above, the minerals constituting the ore-material are chiefly magnetite, specularite, chalcopyrite, pyrite, epidote, actinolite, chlorite, and yellow garnet which is either grossularite or andradite. This combination of specularite and magnetite with sulphides is very characteristic of contact--metamorphic deposits, and is practically unknown in fissure-veins. Further, when these minerals occur with actinolite, garnet, chlorite, and epidote, an association is produced which is generally diagnostic of contact-metamorphism. These same individual minerals may occur in regional-metamorphic ores, but it is highly improbable that a deposit of this class should include at one time, and within a few feet, all these minerals, which are so characteristic of contact-metamorphic deposits, and should, in addition, contain no other minerals.

Also, in regional-metamorphic deposits the materials cannot have travelled far, and a very gradual change from unreplaced country-rock to ore is prevailingly found. On the Fleming claim, although there is a transition from ore to country-rock, nevertheless almost solid iron and copper minerals can be seen within 2 or 3 feet of unaltered gneiss.

Further, these ore-materials occur near intrusive granitic rocks, and at other points in Yukon territory[1] deposits almost identical in composition have been found occurring in similar rocks, and are always in the immediate vicinity of granitic intrusives. The gneissoid formation in which these ores occur is of wide-spread distribution, but only adjoining the deep-seated igneous materials have the ore-deposits been produced.

The ores on the Fleming claim also occur replacing gneiss-bands that are particularly rich in lime. This seems only to be accounted for by the fact that the deposits are of contact-metamorphic origin.

The gneisses in which the ore-materials occur consist almost entirely of plagioclase, quartz, and hornblende, with accessory magnetite. The ores are mainly oxides of iron, pyrite, chalcopyrite, and copper carbonates. It is, therefore, evident that a considerable portion of these deposits was derived from sources outside the gneisses which contain very little iron and practically no copper and sulphur. There thus appears to be little or no doubt, but that these ore-deposits have been caused by the adjoining and underlying granitic intrusives, and that the mineralizers have travelled along the lamination-planes of the country-rock, which are the planes of easiest circulation.

As to the cause of contact-metamorphism,[2] petrographers agree that this is due to the heat of the molten magma, combined with the action of the water which it contains. In many cases, no perceptible accessions of substance from the magma have taken place, while in perhaps as many others, important additions have been received. The amount of material that is derived from the intrusive body appears to be due mainly to two circumstances, the amount of water-gas in the molten igneous body, and the susceptibility of the invaded rock. In many intrusives there may be present only a very small amount of water-gas, and thus the accession of material to the invaded formation may be slight and the contact-phenomena mostly due to

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[1]Cairnes, D. D.—"The Giltana Lake claims": in "Report on the Lewes and Nordenskiöld Rivers coal area": Geol. Surv. Branch, Dept. of Mines, Canada, 1910.

[2]Lindgren, Waldemar—"The character and genesis of certain contact deposits": T. A. I. M. E., Vol. 31.

Barrell, Joseph—"Physical effects of contact metamorphism": Amer. Jour. Sci., Vol. 13.

the heat of the rock; if, however, the water-vapour is abundant, the amount of material given off may be very great. Magmatic waters also vary widely; some contain large amounts of boron, fluorine, chlorine, etc., while others have none of these, and possess chiefly sulphur, copper, iron, and related minerals. Thus a wonderful variety of contact-metamorphic deposits are formed.

The ore-materials on the Fleming claim, therefore, appear to be due to magmatic vapours, rich in iron, copper, and sulphur, which were derived from the granitic intrusive body.

If this be true, the deposits were formed during the cooling period of the granitic batholith, which, as explained under 'General Geology,' was in Jurassic, and probably late Jurassic, time.

MINING PROPERTIES.

The Fleming Claim.—This claim is owned by Messrs. W. J. Fleming and H. E. Porter, and was located in July, 1909, by Mr. Porter. As mentioned above, the only regional-metamorphic deposits known to exist in Wheaton district are found on this property; thus the discussion of their occurrence, which has just been given, is in reality a description of the mineral deposits on the Fleming claim, so that nothing further can here be added.

COAL.

Discovery.—During the summer of 1906, the writer noted Tantalus conglomerates outcropping on the ridge to the north of Idaho hill, and between it and Mt. Bush. Search was at once made for coal which so frequently occurs in these rocks, and what appeared to be the outcrops of two or three seams were found on the top of the ridge. This discovery was made public,[1] and several prospectors attempted to find the coal, but being unaccustomed to look for mineral-fuels, were unsuccessful.

The writer again visited this locality in July, 1909, and with the help of two assistants uncovered three seams of coal, and found what appeared to be the outcrops of others. However, as the seams are deeply covered with superficial materials which were frozen, digging was slow and laborious, and only three seams were stripped, and these not for their entire widths.

[1]Cairnes, D. D.—"A portion of Conrad and Whitehorse mining districts, Yukon": Geol. Surv. Branch, Dept. of Mines, 1908, p. 32.

Descriptions.—These coal seams have been actually exposed to view only in one place, which is situated about one mile west of the Union mines and on the top of the ridge joining Idaho hill and Mt. Bush. Since the coal was discovered just east of Mt. Bush, the belt in which the coal-bearing formation occurs has been named the 'Mt. Bush coal area,' which is about 2 miles long and one-third of a mile wide at the widest point.

The coal occurs in the Jura-Cretaceous Tantalus conglomerates, in, or immediately below, which has been found all the valuable coals so far discovered in southern Yukon. This conglomerate formation

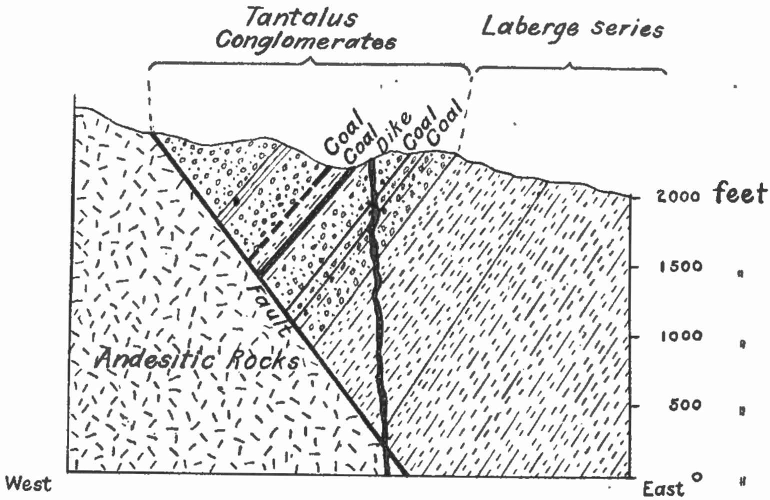

Fig. 10. Diagrammatic east and west section through the coal measures.

is composed chiefly of massive conglomerate beds, the component pebbles of which consist entirely of chert, quartz, or slate, but also includes some intercalated shales, sandstones, and the coal seams.

At Discovery, in the Mt. Bush area, one 18 inch seam, and one at least 6 feet thick, were uncovered; but since the surface materials overlying the coal were several feet thick, the hanging-wall of the larger seam was not definitely found, and so the coal may be thicker than the 6 feet, as measured. A portion, 3 feet thick, of another seam was also stripped and the hanging-wall appeared to be still 2 to 4 feet distant. Indications of other seams were also noted.

The formation containing the coal is considerably distorted and disturbed, but strikes in a general northerly direction, and is inclined at 60° to 80° to the west. A fine-grained, dark greenish andesite dyke, about 15 feet wide, cuts these measures and adds to their other irregularities.

The Tantalus conglomerates extend down to near the creek bottoms on both sides of the ridge on which the coal was found, and also appear to the south, across Schnabel creek, on Mt. Follé. An easterly-dipping, normal fault, having a displacement of at least 5,000 feet, however, occurs to the west of the coal-outcrops, so that if the coal seams persist downward sufficiently far, they will encounter this break and be cut off, at a depth, measured along the seams, of 1,500 to 2,000 feet from discovery. The strike of the coal-measures is also approximately parallel to the trend of the fault.

No evidence of coal was found in the Tantalus conglomerates on Mt. Follé.

An outcrop sample taken from the 6 foot seam was analysed by the Mines Branch of the Department of Mines at Ottawa. The following is the result of the analysis:—

Moisture..	4·78	per cent.
Volatile matter..	8·62	"
Fixed carbon..	56·50	"
Ash..	30·10	"
	100·00	"

This shows that the coal is a semi-anthracite. The high ash is probably partly due to the fact that the sample was derived from the frozen outcrop of the seam, and contained a certain percentage of sand and other materials.

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GEOLOGICAL SURVEY BRANCH

Hon. Robert Rogers, Minister; A. P. Low, Deputy Minister;
R. W. Brock, Director.

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572	" "	1893-4	*928	" "	1904
602	" "	1895.	971	" "	1905
625	" "	1896.			

Mineral Production of Canada:—

No. *414.	Year 1886.	No. *422.	Year 1893.	No. 719.	Year 1900.
*415	" 1887.	*555	" 1894.	719a	" 1901.
*416	" 1888.	*577	" 1895.	813	" 1902.
*417	" 1889.	*612	" 1896.	861	" 1903.
*418	" 1890.	*623	" 1886-96.	896	" 1904.
*419	" 1891.	*640	" 1897.	924	" 1905.
*420	" 1886-91.	*671	" 1898.	981	" 1906.
*421	" 1892.	*686	" 1899.		

Mineral Resources Bulletin:—

No. *818.	Platinum.	No. 860.	Zinc.	No. 881.	Phosphate.
851.	Coal.	869.	Mica.	882.	Copper.
*854.	Asbestos.	872.	Molybdenum and Tungsten.	913.	Mineral Pigments.
857.	Infusorial Earth.	*877.	Graphite.	953.	Barytes.
858.	Manganese.	880.	Peat.	984.	Mineral Pigments (French).
859.	Salt.				

Report of the Section of Chemistry and Mineralogy:—

No. *102.	Year 1874-5.	No. *169.	Year 1882-3-4.	No. 580.	Year 1894.
*110	" 1875-6.	222	" 1885.	616	" 1895.
*119	" 1876-7.	246	" 1886.	651	" 1896.
*126	" 1877-8.	273	" 1887-8.	695	" 1898.
*138	" 1878-9.	299	" 1888-9.	724	" 1899.
*148	" 1879-80.	333	" 1890-1.	821	" 1900.
*156	" 1880-1-2.	359	" 1892-3.	*958	" 1906.

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* Publications marked thus are out of print.

REPORTS.

GENERAL.

745. Altitudes of Canada, by J. White. 1899.
*972. Descriptive Catalogue of Minerals and Rocks, by R. A. A. Johnston and G. A. Young.
1073. Catalogue of Publications: Reports and Maps (1843-1909).
1085. Descriptive Sketch of the Geology and Economic Minerals of Canada, by G. A. Young, and Introductory by R. W. Brock. Maps No. 1084; No. 1042 (second edition), scale 100 m. = 1 in.
1086. French translation of Descriptive Sketch of the Geology and Economic Minerals of Canada, by G. A. Young, and Introductory by R. W. Brock. Maps No. 1084; No. 1042 (second edition), scale 100 m. = 1 in.
1107. Part II. Geological position and character of the oil-shale deposits of Canada, by R. W. Ells.
1146. Notes on Canada, by R. W. Brock.

YUKON.

*260. Yukon district, by G. M. Dawson. 1887. Maps No. 274, scale 60 m. = 1 in.; Nos. 275 and 277, scale 8 m. = 1 in.
*295. Yukon and Mackenzie basins, by R. G. McConnell. 1889. Map No. 304, scale 48 m. = 1 in.
687. Klondike gold fields (preliminary), by R. G. McConnell. 1900. Map No. 688, scale 2 m. = 1 in.
884. Klondike gold fields, by R. G. McConnell. 1901. Map No. 772, scale 2 m. = 1 in.
*909. Windy Arm, Tagish lake, by R. G. McConnell. 1906. Map No. 916, scale 2 m. = 1 in.
943. Upper Stewart river, by J. Keele. Map No. 938, scale 8 m. = 1 in. } Bound together.
951. Peel and Wind rivers, by Chas. Camsell. Map No. 942, scale 8 m. = 1 in. } Bound together.
979. Klondike gravels, by R. G. McConnell. Map No. 1011, scale 40 ch. = 1 in.
982. Conrad and Whitehorse mining districts, by D. D. Cairnes. 1901. Map No. 990, scale 2 m. = 1 in.
1016. Klondike Creek and Hill gravels, by R. G. McConnell. (French.) Map No. 1011, scale 40 ch. = 1 in.
1050. Whitehorse Copper Belt, by R. G. McConnell. Maps Nos. 1,026, 1,041, 1,044-1,049.
1097. Reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon, and North West Territories, by Joseph Keele. Map No. 1099, scale 8 m. = 1 in.
1011. Memoir No. 5 (Preliminary): on the Lewes and Nordenskiöld Rivers coal-field, Yukon, by D. D. Cairnes. Maps Nos. 1103 and 1104, scale 2 m. = 1 in.
1228. Memoir No. 31: Wheaton district, by D. D. Cairnes.

BRITISH COLUMBIA.

212. The Rocky mountains (between latitudes 49° and 51° 30′), by G. M. Dawson. 1885. Map No. 223, scale 6 m. = 1 in. Map No. 224, scale 1½ m. = 1 in.
*235. Vancouver island, by G. M. Dawson. 1886. Map No. 247, scale 8 m. = 1 in.
236. The Rocky mountains, geological structure, by R. G. McConnell. 1886. Map No. 248, scale 2 m. = 1 in.
263. Cariboo mining district, by A. Bowman. 1887. Maps Nos. 278-281.
*271. Mineral wealth, by G. M. Dawson.

* Publications marked thus are out of print.

*294. West Kootenay district, by G. M. Dawson. 1888-9. Map No. 303, scale 8 m. = 1 in.
*573. Kamloops district, by G. M. Dawson. 1894. Maps Nos. 556 and 557, scale 4 m. = 1 in.
574. Finlay and Omineca rivers, by R. G. McConnell. 1894. Map No. 567, scale 8 m. = 1 in.
743. Atlin Lake mining division, by J. C. Gwillim. 1899. Map No. 742, scale 4 m. = 1 in.
939. Rossland district, by R. W. Brock. Map No. 941, scale 1,600 ft. =1 in.
940. Graham island, by R. W. Ells. 1905. Maps No. 921, scale 4 m. = 1 in.; No. 922, scale 1 m. = 1 in. (Reprint).
986. Similkameen district, by Chas. Camsell. Map No. 987, scale 400 ch. = 1 in.
988. Telkwa river and vicinity, by W. W. Leach. Map No. 989, scale 2 m. = 1 in.
996. Nanaimo and New Westminster districts, by O. E. LeRoy. 1907. Map No. 997, scale 4 m. = 1 in.
1035. Coal-fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, by D. B. Dowling.
1093. Geology, and Ore Deposits of Hedley Mining district, British Columbia, by Charles Camsell. Maps Nos. 1095 and 1096, scale 1,000 ft. = 1 in.; No. 1105, scale 600 ft. = 1 in.; No. 1106, scale 800 ft. = 1 in.; No. 1125, scale 1,000 ft. = 1 in.
1121. Memoir No. 13: Southern Vancouver island, by Charles H. Clapp. Map No. 1123—17 A, scale 4 m. = 1 in.
1175. Memoir No. 21: Geology and ore deposits of Phoenix, Boundary district, by O. E. LeRoy. Maps Nos. 1135 and 1136, scale 400 ft. = 1 in.
1204. Memoir No. 24–E: Preliminary Report on the Clay and Shale Deposits of the Western Provinces, by Heinrich Ries and Joseph Keele. Map No. 1201—51 A, scale 35 m. = 1 in.

ALBERTA.

*237. Central portion, by J. B. Tyrrell. 1886. Maps Nos. 249 and 250, scale 8 m. = 1 in.
324. Peace and Athabaska Rivers district, by R. G. McConnell. 1890-1. Map No. 336, scale 48 m. = 1 in.
703. Yellowhead Pass route, by J. McEvoy. 1898. Map No. 676, scale 8 m. = 1 in.
*949. Cascade coal-fields, by D. B. Dowling. Maps (8 sheets) Nos. 929-936, scale 1 m. = 1 in.
968. Moose Mountain district, by D. D. Cairnes. Maps No. 963, scale 2 m. = 1 in.; No. 966, scale 1 m. = 1 in.
1035. Coal-fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, by D. B. Dowling. Map No. 1010, scale 35 m. = 1 in.
1035a. French translation of coal-fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, by D. B. Dowling. Map No. 1010, scale 35 m. = 1 in.
1115. Memoir No. 8-E: Edmonton coal-field, by D. B. Dowling. Maps Nos. 1117–5 A and 1118–6 A, scale 2640 ft. = 1 in.
1130. Memoir No. 9–E: Bighorn coal basin, Alta., by G. S. Malloch. Map No. 1132, scale 2 m. = 1 in.
1204. Memoir No. 24–E: Preliminary Report on the Clay and Shale Deposits of the Western Provinces, by Heinrich Ries and Joseph Keele. Map No. 1201—51 A, scale 35 m. = 1 in.

SASKATCHEWAN.

213. Cypress hills and Wood mountain, by R. G. McConnell. 1885. Maps Nos. 225 and 226, scale 8 m. = 1 in.
601. Country between Athabaska lake and Churchill river, by J. B. Tyrrell and D. B. Dowling. 1895. Map No. 957, scale 25 m. = 1 in.

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* Publications marked thus are out of print.

868. Souris river coal-field, by D. B. Dowling. 1902.
1035. Coal-fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, by D. B. Dowling. Map No. 1010, scale 35 m. = 1 in.
1204. Memoir No. 24-E: Preliminary Report on the Clay and Shale Deposits of the Western Provinces, by Heinrich Ries and Joseph Keele. Map No. 1201-51 A, scale 35 m. = 1 in.

MANITOBA.

264. Duck and Riding mountains, by J. B. Tyrrell. 1887-8. Map No. 282, scale 8 m. = 1 in.
296. Glacial Lake Agassiz, by W. Upham. 1889. Maps Nos. 314, 315, 316.
325. Northwestern portion, by J. B. Tyrrell. 1890-1. Maps Nos. 339 and 350, scale 8 m. = 1 in.
704. Lake Winnipeg (west shore), by D. B. Dowling. 1898. Map No. 664, scale 8 m. = 1 in. } Bound together.
705. Lake Winnipeg (east shore), by J. B. Tyrrell. 1898. Map No. 664, scale 8 m. = 1 in. }
1035. Coal-fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, by D. B. Dowling. Map No. 1010, scale 35 m. = 1 in.
1204. Memoir No. 24-E: Preliminary Report on the Clay and Shale Deposits of the Western Provinces, by Heinrich Ries and Joseph Keele. Map No. 1201-51 A, scale 35 m. = 1 in.

NORTH WEST TERRITORIES.

217. Hudson bay and strait, by R. Bell. 1885. Map No. 229, scale 4 m. =1 in.
238. Hudson bay, south of, by A. P. Low. 1886.
239. Attawapiskat and Albany rivers, by R. Bell. 1886.
244. Northern portion of the Dominion, by G. M. Dawson. 1886. Map No. 255, scale 200 m. = 1 in.
267. James bay and country east of Hudson bay, by A. P. Low.
578. Red lake and part of Berens river, by D. B. Dowling. 1894. Map No. 576, scale 8 m. = 1 in.
*584. Labrador peninsula, by A. P. Low. 1895. Maps Nos. 585-588, scale 25 m. = 1 in.
618. Dubawnt, Kazan, and Ferguson rivers, by J. B. Tyrrell. 1896. Map No. 603, scale 25 m. = 1 in.
657. Northern portion of the Labrador peninsula, by A. P. Low.
680. South Shore Hudson strait and Ungava bay, by A. P. Low. Map No. 699, scale 25 m. = 1 in. } Bound together.
713. North Shore Hudson strait and Ungava bay, by R. Bell. Map No. 699, scale 25 m. = 1 in. }
725. Great Bear lake to Great Slave lake, by J. M. Bell. 1900.
778. East coast Hudson bay, by A. P. Low. 1900. Maps Nos. 779, 780, 781, scale 8 m. = 1 in.
786-787. Grass River region, by J. B. Tyrrell and D. B. Dowling. 1900.
815. Ekwan river and Sutton lakes, by D. B. Dowling. 1901. Map No. 751, scale 50 m. = 1 in.
819. Nastapoka islands, Hudson bay, by A. P. Low. 1900.
905. The Cruise of the *Neptune*, by A. P. Low. 1905.
1006. Report of a Traverse through the Southern Part of the North West Territories, from Lac Seul to Cat lake, 1902, by A. W. G. Wilson. } Bound together.
1080. Report on a Part of the North West Territories, drained by the Winisk and Upper Attawapiskat rivers, by W. McInnes. Map No. 1089, scale 8 m. = 1 in. }
1069. French translation: Report on an exploration of the East coast of Hudson bay, from Cape Wolstenholme to the south end of James bay, by A. P. Low. Maps Nos. 779, 780, 781, scale 8 m. = 1 in.; No. 785, scale 50 m. = 1 in.

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* Publications marked thus are out of print.

1097. Reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon, and North West Territories, by Joseph Keele. Map No. 1099, scale 8 m. = 1 in.

ONTARIO.

215. Lake of the Woods region, by A. C. Lawson. 1885. Map No. 227, scale 2 m. = 1 in.
*265. Rainy Lake region, by A. C. Lawson. 1887. Map No. 283, scale 4 m. = 1 in.
266. Lake Superior, mines and mining, by E. D. Ingall. 1888. Maps No. 285, scale 4 m. = 1 in.; No. 286, scale 20 ch. = 1 in.
326. Sudbury mining district, by R. Bell. 1890-1. Map No. 343, scale 4 m. = 1 in.
327. Hunter island, by W. H. C. Smith. 1890-1. Map No. 342, scale 4 m. = 1 in.
332. Natural Gas and Petroleum, by H. P. H. Brumell. 1890-1. Maps Nos. 344-349.
357. Victoria, Peterborough, and Hastings counties, by F. D. Adams. 1892-3.
627. On the French River sheet, by R. Bell. 1896. Map No. 570, scale 4 m. = 1 in.
678. Seine river and Lake Shebandowan map-sheets, by W. McInnes. 1897. Maps Nos. 589 and 560, scale 4 m. = 1 in.
723. Iron deposits along the Kingston and Pembroke railway, by E. D. Ingall. 1900. Map No. 626, scale 2 m. = 1 in.; and plans of 13 mines.
*739. Carleton, Russell, and Prescott counties, by R. W. Ells. 1899. (*See* No. 739, Quebec.)
741. Ottawa and vicinity, by R. W. Ells. 1900.
790. Perth sheet, by R. W. Ells. 1900. Map No. 789, scale 4 m. = 1 in.
961. Sudbury Nickel and Copper deposits, by A. E. Barlow. (Reprint). Maps Nos. 775, 820, scale 1 m. = 1 in.; Nos. 824, 825, 864, scale 400 ft. = 1 in.
962. Nipissing and Timiskaming map-sheets, by A. E. Barlow. (Reprint). Maps Nos. 599, 606, scale 4 m. = 1 in.; No. 944, scale 1 m. = 1 in.
965. Sudbury Nickel and Copper deposits, by A. E. Barlow. (French).
970. Report on Niagara Falls, by J. W. Spencer. Maps Nos. 926, 967.
977. Report on Pembroke sheet, by R. W. Ells. Map No. 660, scale 4 m. = 1 in.
980. Geological reconnaissance of a portion of Algoma and Thunder Bay district, Ont., by W. J. Wilson. Map No. 964, scale 8 m. = 1 in.
1081. On the region lying north of Lake Superior, between the Pic and Nipigon rivers, Ont., by W. H. Collins. Map No. 964, scale 8 m. = 1 in.
(980 and 1081: Bound together.)
992. Report on Northwestern Ontario, traversed by National Transcontinental railway, between Lake Nipigon and Sturgeon lake, by W. H. Collins. Map No. 993, scale 4 m. = 1 in.
998. Report on Pembroke sheet, by R. W. Ells. (French). Map No. 660, scale 4 m. = 1 in.
999. French translation Gowganda Mining Division, by W. H. Collins. Map No. 1076, scale 1 m. = 1 in.
1038. French translation report on the Transcontinental Railway location between Lake Nipigon and Sturgeon lake, by W. H. Collins. Map No. 993, scale 4 m. = 1 in.
1059. Geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont., by W. H. Collins. Map No. 993, scale 4 m. = 1 in.
1075. Gowganda Mining Division, by W. H. Collins. Map No. 1076, scale 1 m. = 1 in.

* Publications marked thus are out of print.

1082. Memoir No. 6: Geology of the Haliburton and Bancroft areas, Ont., by Frank D. Adams and Alfred E. Barlow. Maps No. 708, scale 4 m. = 1 in.; No. 770, scale 2 m. = 1 in.
1091. Memoir No. 1: On the Geology of the Nipigon basin, Ont., by A. W. G. Wilson. Map No. 1090, scale 4 m. = 1 in.
1114. French translation: Geological reconnaissance of a portion of Algoma and Thunder Bay district, Ont., by W. J. Wilson. Map No. 964, scale 8 m. = 1 in.
1119. French translation: On the region lying north of Lake Superior, between the Pic and Nipigon rivers, Ont., by W. H. Collins. Map No. 964, scale 8 m. = 1 in.

(1114 and 1119: Bound together.)

QUEBEC.

216. Mistassini expedition, by A. P. Low. 1884-5. Map No. 228, scale 8 m. = 1 in.
240. Compton, Stanstead, Beauce, Richmond, and Wolfe counties, by R. W. Ells. 1886. Map No. 251 (Sherbrooke sheet), scale 4 m.= 1 in.
268. Megantic, Beauce, Dorchester, Lévis, Bellechasse, and Montmagny counties, by R. W. Ells. 1887-8. Map No. 287, scale 40 ch. = 1 in.
297. Mineral resources, by R. W. Ells. 1889.
328. Portneuf, Quebec, and Montmagny counties, by A. P. Low. 1890-1.
579. Eastern Townships, Montreal sheet, by R. W. Ells and F. D. Adams, 1894. Map No. 571, scale 4 m. = 1 in.
591. Laurentian area north of the Island of Montreal, by F. D. Adams. 1895. Map No. 590, scale 4 m. = 1 in.
670. Auriferous deposits, southeastern portion, by R. Chalmers. 1895. Map No. 667, scale 8 m. = 1 in.
707. Eastern Townships, Three Rivers sheet, by R. W. Ells. 1898.
*739. Argenteuil, Ottawa, and Pontiac counties, by R. W. Ells. 1899. (*See* No. 739, Ontario).
788. Nottaway basin, by R. Bell. 1900. *Map No. 702, scale 10 m.=1 in.
863. Wells on Island of Montreal, by F. D. Adams. 1901. Maps Nos. 874, 875, 876.
923. Chibougamau region, by A. P. Low. 1905.
962. Timiskaming map-sheet, by A. E. Barlow. (Reprint). Maps Nos. 599, 606, scale 4 m. = 1 in.; No. 944, scale 1 m.=1 in.
974. Report on Copper-bearing rocks of Eastern Townships, by J. A. Dresser. Map No. 976, scale 8 m.=1 in.
975. Report on Copper-bearing rocks of Eastern Townships, by J. A. Dresser. (French).
998. Report on the Pembroke sheet, by R. W. Ells. (French).
1028. Report on a Recent Discovery of Gold near Lake Megantic, Que., by J. A. Dresser. Map No. 1029, scale 2 m.=1 in.
1032. Report on a Recent Discovery of Gold near Lake Megantic, Que., by J. A. Dresser. (French). Map No. 1029, scale 2 m.=1 in.
1052. French translation report on Artesian wells in the Island of Montreal, by Frank D. Adams and O. E. LeRoy. Maps No. 874, scale 4 m.=1 in.; No. 375, scale 3,000 ft.=1 in.; No. 876.
1064. Geology of an Area adjoining the East Side of Lake Timiskaming, Que., by Morley E. Wilson. Map No. 1066, scale 1 m.=1 in.
1110. Memoir No. 4: Geological Reconnaissance along the line of the National Transcontinental railway in Western Quebec, by W. J. Wilson. Map No. 1112, scale 4 m.=1 in.
1144. Reprint of Summary Report on the Serpentine Belt of Southern Quebec, by J. A. Dresser.

NEW BRUNSWICK.

218. Western New Brunswick and Eastern Nova Scotia, by R. W. Ells. 1885. Map No. 230, scale 4 m.=1 in.

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* Publications marked thus are out of print.

219. Carleton and Victoria counties, by L. W. Bailey. 1885. Map No. 231, scale 4 m.=1 in.
242. Victoria, Restigouche, and Northumberland counties, N.B., by L. W. Bailey and W. McInnes. 1886. Map No. 254, scale 4 m. = 1 in.
269. Northern portion and adjacent areas, by L. W. Bailey and W. McInnes. 1887-8. Map No. 290, scale 4 m.= 1 in.
330. Temiscouata and Rimouski counties, by L. W. Bailey and W. McInnes. 1890-1. Map No. 350, scale 4 m.=1 in.
661. Mineral resources, by L. W. Bailey. 1897. Map No. 675, scale 10 m. = 1 in. New Brunswick geology, by R. W. Ells. 1887.
799. Carboniferous system, by L. W. Bailey. 1900. } Bound together.
803. Coal prospects in, by H. S. Poole. 1900. }
983. Mineral resources, by R. W. Ells. Map No. 969, scale 16 m.=1 in.
1034. Mineral resources, by R. W. Ells. (French). Map No. 969, scale 16 m.=1 in.
1113. Memoir No. 16-E: The Clay and Shale deposits of Nova Scotia and portions of New Brunswick, by H. Ries and J. Keele. Map No. 1153, scale 12 m.=1 in.

NOVA SCOTIA.

243. Guysborough, Antigonish, Pictou, Colchester, and Halifax counties, by Hugh Fletcher and E. R. Faribault. 1886.
331. Pictou and Colchester counties, by H. Fletcher. 1890-1.
358. Southwestern Nova Scotia (preliminary), by. L. W. Bailey. 1892-3. Map No. 362, scale 8 m.=1 in.
628. Southwestern Nova Scotia, by L. W. Bailey. 1896. Map No. 641, scale 8 m. = 1 in.
685. Sydney coal-field, by H. Fletcher. Maps Nos. 652, 653, 654, scale 1 m. = 1 in.
797. Cambrian rocks of Cape Breton, by G. F. Matthew. 1900.
871. Pictou coal-field, by H. S. Poole. 1302. Map No. 833, scale 25 ch.= 1 in.
1113. Memoir No. 16-E: The Clay and Shale deposits of Nova Scotia and portions of New Brunswick, by H. Ries and J. Keele. Map No. 1153, scale 12 m. = 1 in.

MAPS.

1042. Dominion of Canada. Minerals. Scale 100 m. = 1 in.

YUKON.

*805. Explorations on Macmillan, Upper Pelly, and Stewart rivers, scale 8 m. = 1 in.
891. Portion of Duncan Creek Mining district, scale 6 m. = 1 in.
894. Sketch Map Kluane Mining district, scale 6 m. = 1 in.
*916. Windy Arm Mining district, Sketch Geological Map, scale 2 m. = 1 in.
990. Conrad and Whitehorse Mining districts, scale 2 m.=1 in.
991. Tantalus and Five Fingers coal mines, scale 1 m. = 1 in.
1011. Bonanza and Hunker creeks. Auriferous gravels. Scale 40 chains =1 in.
1033. Lower Lake Laberge and vicinity, scale 1 m.=1 in.
1041. Whitehorse Copper belt, scale 1 m. = 1 in.
1026. 1044-1049. Whitehorse Copper belt. Details.
1099. Pelly, Ross, and Gravel rivers, Yukon and North West Territories. Scale 8 m. = 1 in.
1103. Tantalus Coal area, Yukon. Scale 2 m. = 1 in.
1104. Braeburn-Kynocks Coal area, Yukon. Scale 2 m. = 1 in.

* Publications marked thus are out of print.

BRITISH COLUMBIA.

278. Cariboo Mining district, scale 2 m. = 1 in.
604. Shuswap Geological sheet, scale 4 m. = 1 in.
*771. Preliminary Edition, East Kootenay, scale 4 m. = 1 in.
767. Geological Map of Crowsnest coal-fields, scale 2 m. = 1 in.
*791. West Kootenay Minerals and Striæ, scale 4 m. = 1 in.
*792. West Kootenay Geological sheet, scale 4 m. = 1 in.
828. Boundary Creek Mining district, scale 1 m. = 1 in.
890. Nicola coal basin, scale 1 m. = 1 in.
941. Preliminary Geological Map of Rossland and vicinity, scale 1,600 ft. = 1 in.
987. Princeton coal basin and Copper Mountain Mining camp, scale 40 ch. = 1 in.
989. Telkwa river and vicinity, scale 2 m. = 1 in.
997. Nanaimo and New Westminster Mining division, scale 4 m. = 1 in.
1001. Special Map of Rossland. Topographical sheet. Scale 400 ft. = 1 in
1002. Special Map of Rossland. Geological sheet. Scale 400 ft. = 1 in.
1003. Rossland Mining camp. Topographical sheet. Scale 1,200 ft. = 1 in
1004. Rossland Mining camp. Geological sheet. Scale 1,200 ft. = 1 in.
1068. Sheep Creek Mining camp. Geological sheet. Scale 1 m. = 1 in.
1074. Sheep Creek Mining camp. Topographical sheet. Scale 1 m. = 1 in.
1095. 1A—Hedley Mining district. Topographical sheet. Scale 1,000 ft. = 1in.
1096. 2A—Hedley Mining district. Geological sheet. Scale 1,000 ft. = 1 in.
1105. 4A—Golden Zone Mining camp. Scale 600 ft. = 1 in.
1106. 3A—Mineral Claims on Henry creek. Scale 800 ft. = 1 in.
1123. 17A—Reconnaissance geological map of southern Vancouver island Scale 4 m. = 1 in.
1125. Hedley Mining district: Structure Sections. Scale 1,000 ft. = 1 in.
Deadwood Mining camp. Scale 400 ft. = 1 in. (Advance sheet.)
1135 15A—Phoenix, Boundary district. Topographical sheet. Scale 400. ft. = 1 in.
1136. 16A—Phoenix, Boundary district. Geological sheet. Scale 400 ft. = 1 in.
1164. 28A—Portland Canal Mining district, scale 2 m. = 1 in.
Beaverdell sheet, Yale district, scale 1 m. = 1 in. (Advance sheet.)
Tulameen sheet, scale 1 m. = 1 in. (Advance sheet.)

ALBERTA.

594–596. Peace and Athabaska rivers, scale 10 m. = 1 in.
*808. Blairmore-Frank coal-fields, scale 180 ch. = 1 in.
892. Costigan coal basin, scale 40 ch. = 1 in.
929–936. Cascade coal basin. Scale 1 m. = 1 in.
963–966. Moose Mountain region. Coal Areas. Scale 2 m. = 1 in.
1010. Alberta, Saskatchewan, and Manitoba. Coal Areas. Scale 35 m. = 1 in.
1117. 5A—Edmonton. (Topography). Scale ½ m. = 1 in.
1118. 6A—Edmonton. (Clover Bar Coal Seam). Scale ½ m. = 1 in.
Portion of Jasper Park, scale 1 m. = 1 in. (Advance sheet.)
1132. 7A—Bighorn coal-field. Scale 2 m. = 1 in.
1201. 51A—Geological map of portions of Alberta, Saskatchewan, and Manitoba. Scale, 35 m. = 1 in.

SASKATCHEWAN.

1010. Alberta, Saskatchewan, and Manitoba. Coal Areas. Scale 35 m. = 1 in.
1201. 51A—Geological map of portions of Alberta, Saskatchewan, and Manitoba. Scale, 35 m. = 1 in.

MANITOBA.

804. Part of Turtle mountain showing coal areas. Scale 1¼ m. = 1 in.
1010. Alberta, Saskatchewan, and Manitoba. Coal Areas. Scale 35 m. = 1 in.

* Publications marked thus are out of print.

1201. 51A—Geological map of portions of Alberta, Saskatchewan, and Manitoba. Scale, 35 m. = 1 in.

NORTH WEST TERRITORIES.

1089. Explored routes on Albany, Severn, and Winisk rivers. Scale 8 m. = 1 in.
1099. Pelly, Ross, and Gravel rivers, Yukon and North West Territories Scale 8 m. = 1 in.

ONTARIO.

227. Lake of the Woods sheet, scale 2 m. = 1 in.
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