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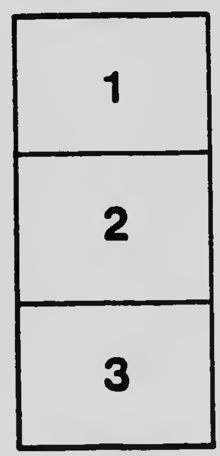
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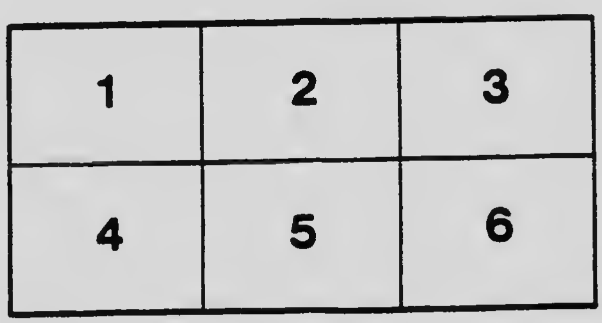
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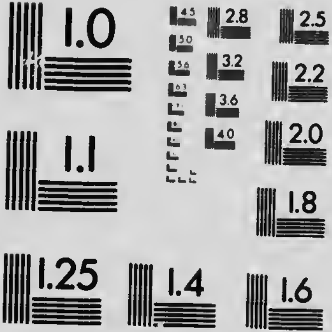

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GEOLOGICAL SURVEY
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MEMOIR 118

No. 100, GEOLOGICAL SERIES

Mineral Deposits between Lillooet and Prince George, British Columbia

BY
Leopold Reinecke

OTTAWA
THOMAS MULVEY
PRINTER TO HIS MOST EXCELLENT MAJESTY
1920

No. 1819

PLATE I

Epsomite lake at Clinton. Shed for storing salt on far shore with wooden runway for wheeling out product to shore. (Page 51).

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Illustrations.

Mineral Deposits Between Lillooet and Prince George, British Columbia.

CHAPTER I.

INTRODUCTION.

This memoir is based on information obtained during a reconnaissance of the known occurrences of mineral deposits of possible economic value lying within the area served by the Pacific Great Eastern railway between Lillooet and Prince George (Fort George), British Columbia (Figures 1 and 2). The country adjacent to this railway between Squamish and Lillooet was examined by Charles Camsell[1] in 1917. The area traversed by the railway for some 75 miles north of Lillooet was examined and geologically mapped by G. M. Dawson.[2]

In 1918 certain minerals were urgently required for war purposes. Several of these minerals were said to occur in the area in question and the writer was instructed to examine and report on them. The territory covered in 1918 extends from Lillooet to about 140 miles north. Three and one-half months were consumed in field work, and of that period six weeks were spent in examining deposits distant, by road and trail, from 16 to 60 miles from the railway line. In 1919 two and one-half months were spent in completing the exploration along the railway line as far as Prince George about 300 miles north of Lillooet, and an additional month was devoted to the area traversed in 1918.

Nearly the whole of the first season was spent within the southern portion of the field, but the time taken in visiting outlying deposits during both the first and second seasons made any attempt at areal mapping on a comprehensive scale impossible. Sketch topographic maps were made of the principal deposits reported on and as much detailed geological work as possible was done in their vicinity. A certain amount of prospecting was also done whenever time allowed.

The mineral deposits examined are unusually diversified in character and some of them are of uncommon occurrence. They include hydromagnesite, epsomite, sodium carbonate, clays, deposits of diatomaceous earth, lignite, muscovite and peridot, chromite, molybdenite, as well as occurrences of minerals carrying values in silver, lead, copper and gold, manganese, and nickel. Certain of these minerals that were quoted at high prices during the time the field investigation was made, are now scarcely saleable. There is, however, a prospect of a demand arising for them within a year or two. Others are not strictly "war minerals" and the demand for them has not been affected to so great a degree. Some of the deposits represent new and unexploited assets and will become more valuable as the country develops.

This report does not treat of any part of the Cariboo placer gold deposits which lie to the northeast, which have been the subject of special study by B. R. MacKay of this department.

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[1]Camsell, Charles, Geol. Surv., Can., Sum. Rept., 1917, pt. B, pp. 12B-23B.
[2]Dawson, G. M., "Report on the area of the Kamloops map-sheet, British Columbia." Geol. Surv., Can., Ann. Rept., 1894, vol. VII, pt. B.

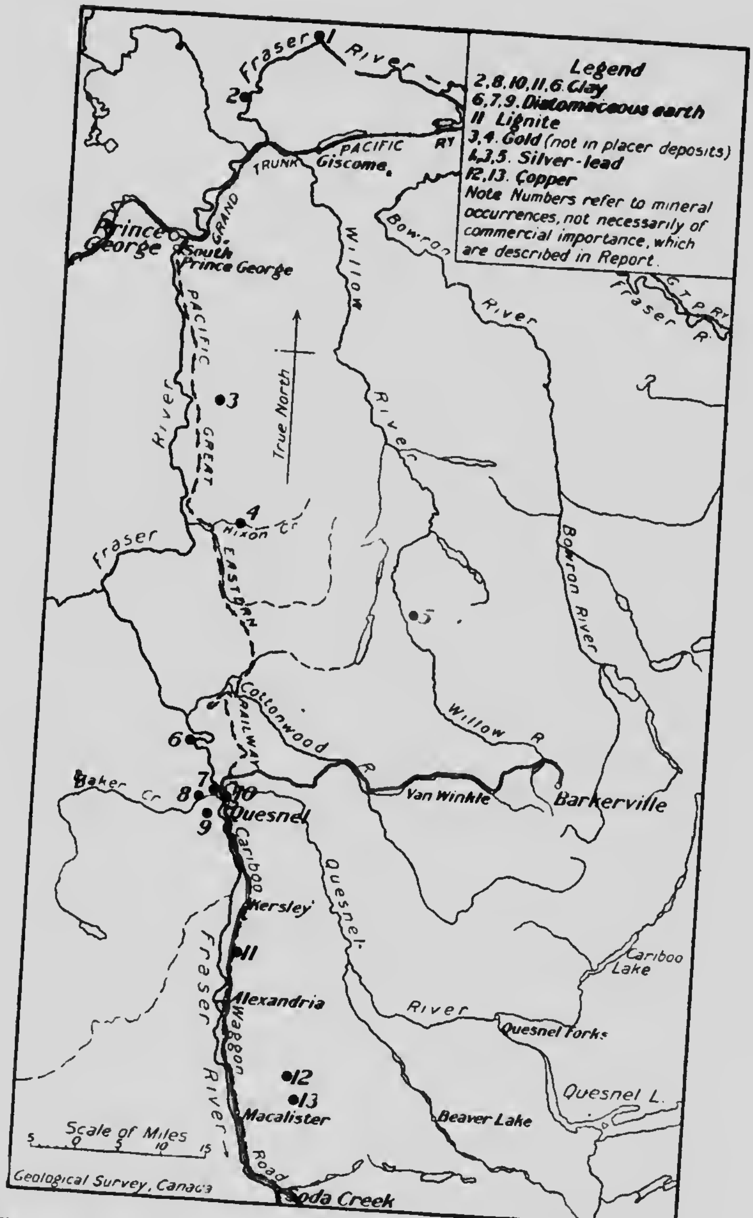

Figure 1. Mineral occurrences, Pacific Great Eastern railway, between Soda Creek and Prince George, British Columbia.

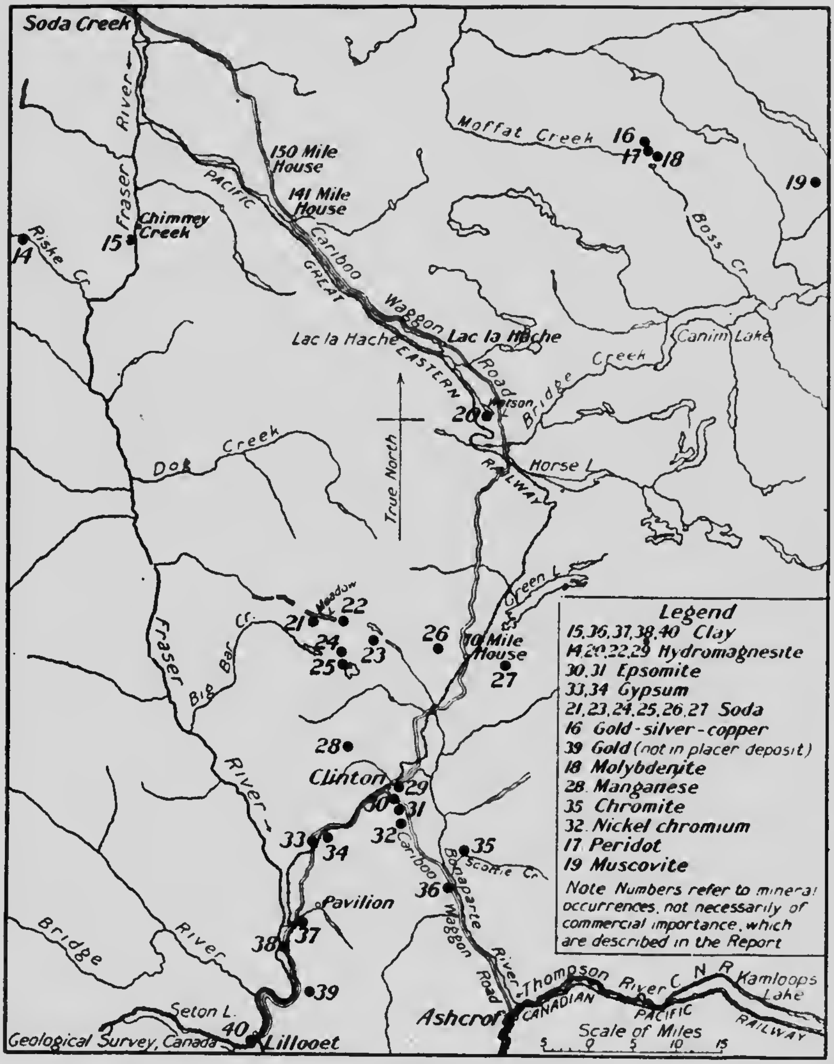

Figure 2. Mineral occurrences, Pacific Great Eastern railway, between Lillooet and Soda Creek, British Columbia.

ACKNOWLEDGMENTS.

The writer is indebted to Mr. F. Calvert of the Stewart Calvert Co., industrial chemists of Oroville, Washington, for several analyses of hydromagnesite, epsomite, and sodium carbonate, as well as for much information

concerning these deposits; to Messrs. A. E. Carew-Gibson and C. [...]wright of Vancouver, and R. M. McGusty of 150 Mile House. R. [...] and A. S. Vaughan of Quesnel, Messrs. Wm. J. Ryan of Lac la [...] H. Guthrie, and B. Gray of Cottonwood for information and assi[...] and to C. H. Colgrove and Dougald Cameron of Prince George fo[...]tality and assistance during visits paid to their claims. The topo[...] sketch maps of the deposits at Clinton, Meadow lake, and T[...] mountain were made by Harlan I. Smith, archæologist of the Geo[...] Survey, who because of the scarcity of qualified assistants in 1918, [...]teered to help in this work while carrying on his own investigations[...] writer is also indebted to him for the photographs reproduced in [...] I, IV, V, VI, VII, VIII, IX, XII, XV, and XVII. E. Norman[...] C. S. Williams acted as student assistants in 1918 and 1919 respecti[...]

LOCATION AND TRANSPORTATION.

The field work was so planned as to include the investigation [...] mineral deposits (except placers) which when exploited will afford t[...] to the Pacific Great Eastern railway. The territory examined for[...] area of irregular shape lying almost wholly on the east side of Fraser [...] between Lillooet and Prince George, in the mining districts of Lill[...] Clinton, Quesnel, and Cariboo. When the railway is completed it [...] serve as the principal artery of communication with the outside w[...] Steel had been laid on this road in September of 1919, as far as Will[...] lake, about 150 miles north of Lillooet or about 310 miles from Vancou[...] and the grade had been completed as far as Prince George on the Gr[...] Trunk Pacific railway. The district is traversed by an excellent wa[...] road that connects Ashcroft on the Canadian Pacific railway with Que[...] on the Fraser. This is a part of the route by which since the early six[...] gold seekers have reached the famous Cariboo placer fields from 15[...] 200 miles north of Lillooet. A branch of the same road diverging [...] Clinton connects via Lillooet with the Canadian Pacific at Lytton. Fr[...] Soda Creek, about 60 miles down river from Quesnel, there is steamb[...] service up the Fraser to Prince George. Before the building of the Gra[...] Trunk Pacific, Quesnel was the outfitting point for canoe trips and pa[...] trains to the Peace River district and the northern part of the provin[...] The Fraser forms a formidable barrier to transportation in an east-we[...] direction. There is a wagon bridge at Lillooet, one at Chimney cre[...] and another between these two. From Chimney creek northward the[...] is no bridge and there are only a few ferries along the stretch of appro[...]mately 175 miles to Prince George. For stretches of many miles nor[...] of Lillooet the river is impassable for boats and no swimmer could live in t[...] eddies.

TOPOGRAPHY.

The northern part of the area examined lies within the Interio[...] Plateau of British Columbia and its southwestern edge embraces mountain[...] that may be considered as subsidiary to the Coast Range system. The [...]dominating topographic feature is the canyon of Fraser river which, turn[...]ing south of Prince George, continues a little east of south in an almost straight line for about 400 miles, cutting across the Interior Plateau and well into the Coast Range system before it turns westward again to reach the Pacific ocean at Vancouver. The drainage from the southern and eastern portions of the area examined northward to the valley of Lac la Hache and northeastward from there, does not flow directly to the Fraser but south and east to the Thompson which reaches the Fraser 50 miles south of Lillooet.

From Lillooet the railway follows the canyon of the Fraser for about 29 miles north of Kelly creek, where it turns northeastward through Junction, or Cutoff valley (Plate VII) and follows that depression for some 16 miles to the village of Clinton. Thence northward it crosses the Green Timber plateau, descends slightly into the valley of Lac la Hache, or San Jose creek, and follows that depression until it again reaches Fraser canyon 116 miles in a straight line north of Lillooet. From there northward the road is within a few miles of the river as far as Prince George.

For the first 30 miles north of Lillooet the waters of the Fraser are less than 1,000 feet above sea-level, whereas to the west within a few miles the peaks of the Coast ranges rise to 6,000 and 7,500 feet above sea-level. Eastward the ridges are from 6,000 to about 7,000 feet high and their summits, which are broad, merge into those of the Interior Plateau. Farther north, however, the continuation of the same ridges, known there as Marble mountains, forms a more distinct range very sharply separated from the plateau to the east with summits rising to 6,500 and 7,500 feet above sea-level.

From Clinton to Prince George the railway traverses the Interior Plateau, a district made up of almost flat plateau areas, of rolling round-topped hills, and broad valleys. An example of an extensive flat area is that of the Green Timber plateau north of Clinton. Typically developed northwest of the railway, about 40 miles wide and from 3,800 to 4,200 feet high, it lies between Marble mountains to the southwest and the Lac la Hache depression to the northeast and is, considering its area, one of the flattest parts of British Columbia. Except along its edges the drainage is poorly developed or wanting. A large number of small saline lakes are dotted over its surface.

North of the Green Timber plateau and at some distance from the immediate canyon of the Fraser, lies a country of broad valleys and rounded hills with perhaps 300 to 500 feet difference in the elevation of valley floors and neighbouring hill tops. This type of topography, but with gradually increasing strength of relief, persists eastward as far as the front ranges of Cariboo mountains, the eastern boundary of the Interior Plateau system. Certain portions of the western ridges of Cariboo mountains, visited in the course of this work, are over 7,000 feet high and others farther east evidently attain increasing altitudes.

Fraser river flows in a gorge that lies from about 400 to 1,500 feet below the general plateau level. Near the main stream its tributaries lie in correspondingly deep gorges; between them the ridges maintain the level of the plateau to the east.

The immediate trough of the Fraser is a narrow trench about 200 to 500 feet deep. Above this there is generally a number of terraces, the upper surfaces of which are broad and slope gently to the river (Plate II). From the terraces the land slopes steeply upward to the rather flat tops of the neighbouring ridges. The level of Fraser[1] river at its confluence

[1] White, James, "Altitudes in Canada": Second edition, p. 552. Commission of Conservation, Ottawa, 1915.

with Nechako river, Prince George, is 1,848 feet above tide. About 100 miles downstream, at the mouth of Quesnel river, it is 1,563 feet, an average drop of about 3 feet to the mile, which is the average gradient for the 150 miles or so of navigable waters from Prince George down to Soda Creek. The rate of fall, however, varies somewhat and is much higher in certain short stretches such as Fort George and Cottonwood canyons. At the railway bridge near Lillooet, 200 miles or so below Quesnel, the elevation of the river is given as 619 feet above tide. From Soda Creek, the southern limit of navigation, down to Lillooet, the average rate of fall is over 5 feet to the mile. For 30 or 40 miles north of Lillooet the Fraser occupies a particularly wild and impressive canyon and for miles at a stretch the water surges along its narrow bed in a succession of eddies, whirlpools, and rolls. Boat crossings are few and many of the Indians lose their lives while fishing off the rocks for salmon.

CLIMATE AND AGRICULTURE.

The summer is dry and cool in the country near the Fraser from Williams lake south, but northward to Prince George the rainfall progressively increases and this increase is accompanied by a change in the character of the vegetation. Thus the immediate trough of the Fraser from Williams lake southward, is covered with sagebrush, with little or no timber, but back from the river douglas fir and jackpine (*Pinus contorta*) are the prevailing forest trees in the well-drained portions. Where the drainage is poor or lacking jackpine and aspen poplar prevail. There is much open grass-covered country and alkaline lakes are of frequent occurrence. Northward from Williams lake the forest becomes denser. White and black spruce as well as white cedar, with douglas fir and jackpine are found from Quesnel northward and where the forest is burned the bottoms are covered with thickets of white birch, aspen poplar, and willows.[1] An increase in the amount of rainfall, accompanied by the same increase in the density of forest growth, holds eastward toward Cariboo mountains. The winter climate is said to be very severe in parts of the plateaux.

The terraces on the Fraser banks are the sites of ranches irrigated by ditches bringing water from the side streams. Fine crops of grain, hay, and vegetables are raised in certain places up the river as far as Quesnel. Nearer Lillooet, where the elevation is lower, beans and potatoes are produced in large quantities, and at Lillooet itself a great variety of fruit is grown. The Interior Plateau on both sides of the Fraser is a cattle range, some of the ranchers owning several thousand head. Horses are also raised and small bands of wild horses are found in the mountains and are sometimes hunted down and coralled in the winter.

CHAPTER II.

GEOLOGY.

The formations observed in the district lie between, and include, the Cache Creek series of the Carboniferous (possibly in part Devonian age), and unconsolidated Recent deposits. Certain schists of unknown age

[1]The vegetation and flora along the Cariboo road from Cache Creek to Quesnel and northwest from there are described in a very interesting manner by John Macoun, in Rept. of Prog., Geol. Surv., Can., 1875-76, pp. 124-130.

occur in the northeastern part of the area. Dawson[1] described the geology of an area of 6,400 square miles whose northwestern portion includes the southern part of the district here dealt with from Lillooet to a point 75 miles northwest. North of the limits of Dawson's sheet the work of the present writer dealt only with small scattered areas of mineral deposits that are in most cases many miles apart. Such facts as were gathered relating to areal geology, are assembled in the following chapter. Time available was not sufficient to permit obtaining a comprehensive and accurate idea of the geological formations underlying the whole district. The table of formations given below is based partly on Dawson's account and is tentative. Except in the case of the Fraser River formation, thicknesses are as given by Dawson for the formations as developed in the southern part of the area.

Table of Formations.

Formation.	Age.	Character.	Maximum thickness in feet.
	Recent and Glacial.	River and talus deposits. White silts. Boulder clay, gravels, sands.	
	Early Pliocene.	Conglomerates, sandstones.	100+
	Later Miocene.	Chiefly basaltic lavas.	3,100
Fraser River formation.		Bedded gravels, sands, clays with infusorial earth, and lignite.	700+
	Earlier Miocene.	Basalts, andesites, dacites, dacitic tuffs, etc.	5,300
Coldwater group.	Oligocene.	Conglomerates, shales.	5,000
	Eocene?	Granite, quartz, diorite.	
Queen Charlotte Islands formation (in part).	Early Cretaceous.	Conglomerates, sandstones, volcanic tuffs.	7,000
	Jurassic?	Quartz diorite in large batholithic masses, dykes of pegmatite, aplite, etc.	
Cache Creek series.	Devono-Carboniferous.	Upper part—Marble Canyon formation. Limestone with some argillite, quartzite, and igneous rocks. Lower part—quartzites, argillites, altered lavas, schists, some bands of serpentine, and limestones............	3,000 6,500
	Unknown.	Mica schists, phyllites, etc.	

[1]Dawson, G. M., "Report on the area of the Kamloops map-sheet, British Columbia." Geol. Surv., Can., Ann. Rept., vol. VII, pt. B, 1895.

SCHISTS OF UNKNOWN AGE.

East of Fraser river, toward the eastern edge o' the Interior Plateau, schistose rocks were encountered whose age cannot be determined without more comprehensive areal work. Such are the mica schists at the muscovite occurrence north of Canim lake (Figure 2, locality 19), the country rock of the claims near Ahbau lake, on Willow river (Figure 1, locality 5), Hixon (Figure 1, locality 4), Government, and Stone creeks (Figure 1, locality 3) and at the silver-lead occurrence at the most northerly bend of Fraser river, northeast of Prince George (Figure 1, locality 1). The country rocks at the claim of W. Harper east of Ahbau lake, at the silver-lead occurrence on Willow river east of Ahbau lake, and on Stone creek, are schistose rocks composed mostly of quartz in rather small grains with a certain amount of colourless mica muscovite, or sericite, and may be termed quartzite, phyllite, or quartz sericite schist according as the grains of quartz are coarser or finer, or as the proportion of sericite increases. On the silver-lead property of Oscar Eden, at the north bend of Fraser river, the country rock is schist and at the tunnel is a quartz sericite schist which has been much silicified by secondary quartz. At the old workings on Hixon creek there are fine-grained quartzites or phyllites and also andesites and other much altered fine-grained igneous rocks either interbedded with or intrusive into the quartzites. The country rock in the tunnel of C. H. Colgrove, about one-half mile east of Hixon creek, is a quartz sericite schist altered to red clay. Phyllites and quartzites occur near the camp of Dougald Cameron on Government creek. The country rock at the tunnel of the Nechako River Mines, Incorporated, on Stone creek, is quartzite and phyllite, and in the creek are boulders of actinolite schist which must outcrop to the east.

The prevailing strike of these rocks is from north 20 degrees west to about northwest with steep dips to the northeast.

CACHE CREEK SERIES.

The Cache Creek series contains the chromite deposit at Scottie creek (Figure 2, locality 35), minor occurrences of gold, nickel, and manganese, and several deposits of residual clay. It is the original source also of the deposits of hydromagnesite and epsom salt. Dawson divided the series into an upper and lower portion and separately mapped these two divisions. In the southern part of the area the Lower Cache Creek outcrops in two long strips 4 to 12 miles wide. One of these strips follows the east side of Fraser valley from Elevenmile creek north of Lillooet, up the river past Kelly creek; the other runs from Clinton, south, along the bottom and the west side of the Bonaparte valley. The same strata were encountered again in the canyon of Fraser river from Chimney Creek bridge to Soda creek, and in Baker canyon west of Quesnel. The country rock containing gold on Hixon creek and silver lead on Willow river resembles the Cache Creek lithologically as do outcrops in the river between Quesnel and Fort George canyon visible from the deck of a steamer. The greater part of this lower portion of the series consists of fine quartzites, siliceous argillites or phyllites, metamorphosed lava flows, schists, and bands of serpentine and limestone, all of them apparently interbedded. The so-called quartzites and argillites have very nearly the same composition but differ in the size of their component grains. They are made up essentially of quartz and a micaceous mineral resembling muscovite. Certain of the argillites have a large carbonaceous content that gives them a black colour, and, where well foliated, a glossy lustre on the cleavage planes. The argillites are in many cases well banded with much of the micaceous mineral and are more properly called phyllites. The coarsest quartzites examined contained grains about 0·05 millimetres in diameter and the finer argillites ranged in grain down to 0·005 millimetres and smaller. All the rocks are, therefore, very fine-grained. The quartzites range in colour from white to dark grey, the argillites from grey to black. Large and small bands of dark grey limestone are developed at a number of the localities studied. An especially large band crosses Scottie creek near its mouth.

Igneous rocks, probably originally lava flows and now much metamorphosed, occur in the Cache Creek formation near Clinton, at Pavilion creek, and elsewhere. Dawson mentions the occurrence of grey-green altered diabases on Pavilion creek. A green, altered diabase was found in the hill southeast of the epsomite lake at Clinton (Figure 2, locality 30, and Figure 8, locality 9) apparently interbedded with actinolite schist. It contained labradorite, violet-tinted augite, and a great deal of secondary chlorite, actinolite, epidote, and zoisite. Metamorphosed quartz syenite porphyries and hornblende andesites were seen on the railway about 3 miles north of Pavilion.

Actinolite schists are developed east of the epsomite lake at Clinton. They are white to green fissile schists made up in some cases of actinolite, quartz, and sericite and in other cases of actinolite associated with augite and plagioclase, suggesting an igneous derivation.

The serpentines are massive, green and bluish green, soft rocks that occur with the chromite ore at Scottie creek (Figure 2, locality 35), in several places on Bonaparte river, on the railway track north of 17 Mile ranch, Fraser river, and also on the track just south of Fourmile creek above Clinton. Their petrographic character is described in the chapter dealing with the chromite deposits.

The Upper Cache Creek consists chiefly of light grey limestones. These form massive cliffs in Marble canyon in Pavilion mountains and in Marble mountains north of Cutoff valley. They crop out in a strip lying between the two areas of the Lower Cache Creek series.

In the northwestern area of the Kamloops map-sheet, the Cache Creek rocks have a general strike of about north 20 degrees to 25 degrees west and they lie in a great syncline whose trough line runs along Pavilion and Marble mountains with the lower portion of the formation dipping under the upper limestones from both the east and west sides. Certain minor folds within the syncline are overturned to the east. On the Bonaparte the Lower Cache Creek strata vary in strike from that given above to northwest. Near the epsomite lake at Clinton the beds are much twisted and are apparently close to a large fault, the strike changing from place to place. In the residual clay banks in Baker canyon and at the Chimney Creek bridge, the beds are much crumpled and in places thrown into folds. All of the Cache Creek rocks have been much metamorphosed, both by mechanical shearing and recrystallization.

GRANITIC ROCKS.

Outcrops of granitic rocks occur along the Fraser north of Lillooet and in the mountains east of it, the areas being usually narrow and elongated in the direction of the general strike of the rocks. Granitic rocks were seen on Timothy mountain (Figure 2, locality 18) and are said to occur in extensive areas between Hixon creek and Ahbau lake northeast of Quesnel. Ferrier[1] described two specimens of granitic rocks from the west side of Fountain. They are said by Dawson to cut Cretaceous strata and by Ferrier are classed as hornblende granite and biotite hornblende granite. Two miles north of Lillooet the writer found similar granitic rock within the Cretaceous area crossed by the railway. Because of the preponderance of plagioclase feldspar the rock is called quartz diorite. It consists of iron ore, hornblende, biotite, plagioclase, quartz, and some orthoclase. A hornblendite of granitic texture and composed nearly entirely of brown hornblende occurs nearby. The relation of these granitic rocks to the surrounding Cretaceous was not determined. Occurrences of minerals carrying low values in gold have been found in older rocks near these granitic intrusions.

A quartz diorite mass which occupies an area of at least several square miles forms the mass of Timothy mountain (Figure 13). It is probably part of a fairly large batholith. Ores of molybdenite and minerals carrying values in gold, silver, and copper lie in this mass. The rock is grey, even-grained, and granitoid and under the microscope was found to consist of magnetite, apatite, green hornblende, labradorite, quartz, and orthoclase. One specimen from the ridge south of the claims contained from 10 to 20 per cent of hornblende and magnetite, 60 per cent of labradorite, 20 per cent of quartz, and a small amount of orthoclase. In places the plagioclase is andesine, but labradorite is more common. Feldspar resembling orthoclase in an outcrop near the basalt occurrence on top of the mountain is probably an orthoclase approaching albite in composition. The combination of labradorite and quartz with orthoclase resembles batholithic quartz diorites described from the Boundary district, many miles to the south, and believed to be older than the Cretaceous.[2]

A large mass of granodiorite occurs at the copper claims of Chas. Foyle east of Cuisson lake and northeast of Soda creek (Figure 1, localities 12 and 13). It consists of orthoclase, plagioclase, and quartz, the plagioclase being acidic. The mass of granite that is said to lie east of Hixon creek and west of Ahbau lake was not seen. Minor intrusions of crystalline igneous rocks in the form of dykes or small stocks were observed. There is for example an augite-syenite of medium to fine grain at the junction of Government and Hixon creeks (Figure 1, locality 4). This is made up of magnetite, augite, biotite, orthoclase, plagioclase, and a little quartz. On Government creek too, below the camp of Dougald Cameron 4 miles above the last locality, a dyke of hornblende diorite intrudes into phyllites and other schists. It consists essentially of hornblende and plagioclase feldspar of intermediate composition, is much altered to epidote, chlorite, calcite, etc., and contains a great deal of secondary pyrrhotite and pyrite, scattered through it.

[1]Dawson, G. M., Op. cit., p. 396B.
[2]Geol. Surv., Can., Mem. 79, p. 42.

Pegmatite and aplite dykes were seen at the muscovite occurrence north of Canim lake; on Timothy mountain; and on the silver-lead claims on Willow river.

CRETACEOUS.

The Cretaceous as mapped by Dawson lies in a narrow strip trending north-northwest and following the Fraser from below Lytton to Fountain creek. No rocks were recognized in the course of this work as Cretaceous to the north of Fountain creek and no mineral deposits were examined in the Cretaceous. Between Lillooet and Fountain creek the Cretaceous is described by Dawson as consisting of highly indurated sandstones, argillites, and conglomerates. Specimens taken from cuts in the railway 2½ miles north of Lillooet, on the Big Bend of the Fraser above Bridge Creek mouth, and at Fountain creek, were banded, very dense, rhyolitic glassy tuffs; others resembling sandstones proved to be crystal tuffs of dacitic composition and may correspond to those described by Dawson as arkosic sandstones. The Cretaceous of Fountain ridge lies in a syncline bounded by faults and trending about north 25 degrees west.

COLDWATER GROUP.

The Coldwater group was examined in three places, in and south of the landslide at Pavilion station, and near Clinton. A sample of clay derived from the Coldwater at Pavilion was tested in the laboratory but is not of commercial value. Dawson found traces of gold in certain samples of conglomerate from this group and advised prospecting for gold in them. Near Pavilion the outcrops seen consisted of a conglomerate with boulders of Cache Creek rocks and granites, held in a grey matrix that weathers to a sticky red clay; with the conglomerates are thin, buff-coloured shales or tuffs. Dawson states that the main part of this area is occupied by slightly calcareous, arkosic sandstones. The weathering of the clay on the south side of the valley caused an immense landslide. Although the upper part is still moving this slide started at least one hundred and perhaps many hundred years ago. It is fan shaped and hummocky at the base, and its topography and composition resemble that of a glacial moraine (Plate IIIA).

Dawson mapped as Coldwater a small area near the epsomite lake at Clinton (Figure 8, localities 10 and 11). An outcrop of conglomerates, sandstones, and grey-green shale with plant remains occurs in the hill west of the lake (Figure 8, locality 11). The conglomerates carry pebbles of Cache Creek quartzites of uncertain age. Conglomerates occurring on the road directly south of the lake, and elsewhere near Clinton, are apparently of later age.

LOWER LAVAS.

Later than the Coldwater are great accumulations of lava placed by Dawson in the Miocene. He divided them into two portions separated by a period of sedimentation during which certain fine-grained tuffaceous beds were deposited. The intermediate sediments are called the Tranquille beds.

A section 700 feet thick of lavas referred by Dawson to the Low Volcanics was measured in Fraser canyon at 17 Mile ranch (Figure locality 38). It consists of beds of dark-coloured basalts and andesit with lighter coloured dacites and a nearly white dacite tuff on top (Pla XII). These beds lie in a broad syncline whose axis trends about nor 20 degrees west. The rocks are much faulted, brecciated, and alter to clay.

The following is a geologically ascending section taken across the stril from east to west. Samples of the rock from beds Nos. 2, 5, 10, 12, 1 14, 15, 16, and 21 were examined under the microscope.

	Thickness in fee
1. Just east of railway track back of first cliff, andesitic lavas strike south 28 degrees east, dip 60 degrees to the east, practically unaltered	30
2. Red basalt showing flow structure and forming a cliff, only slightly altered	50 to 100
3. Platy basalt weathering greenish brown, strike south 2 degrees west, dip 70 degrees west	6 to 10
4. Dark-coloured lava altered to a red crumbly mass; the strike of the boundary between this and the succeeding bed is south 28 degrees east	25
5. Dark grey andesites and red lavas, probably basalt cut by faults, one fault dipping west at about 20 degrees. The beds are much disturbed and in places largely changed to clay. The railway cuts through this zone. A sample of clay from beside the track was tested for its value as building brick	15
6. Hidden under the wagon road	95
7. Very basic lava weathering to a green brown clay	30
8. Much altered andesite or trachyte, altered toward top to a yellowish clay. The unaltered stone in fragments ¼ to ½ inch in size, forms about 15 per cent of the mass at the surface. Zones 7 and 8 form a 35 to 60-foot bank in places	50
9. Andesite or basalt altered to a brownish green clay. A good deal of this bed is of undecomposed rock	20
10. Red basalt weathering, in places only, to a red ochre. This bed appears to have been faulted locally. A sample of the more decomposed material was tested for its value as mineral pigment	10
11. Purplish clay	5
12. Grey-white andesite weathering to a yellowish white clay which is extremely sticky when wet. A very large proportion of the outcrop is clay. For a distance along the strike of at least 200 yards several thousand cubic yards are available. A sample of clay from this bed was tested for building brick	12 to 15
13. Grey dacite not as much decomposed as No. 12 forming cliffs which are traversed by faults	15 to 20
14. Pink-grey andesite very largely decomposed to clay, strike south 31 degrees east, dip about 75 degrees to east. This dip may be of only local significance	15
15. Red-brown andesitic agglomerate largely weathered to a purplish brown clay. Fragments resembling Cache Creek quartzite were seen in microscopic sections. The clay is not uniform in appearance. A sample was tested for its value as a mineral pigment	30
16. White volcanic ash with a band of finer texture in it. This is of the composition of dacite and weathers to a gritty clay	36
17. Dark brown basalt weathering to purplish clay	15
18. Andesite or dacite weathering white and green	(?)
19. Alternating lava or ash beds of varying composition mostly weathered to clay and more or less covered	150
20. Fresh, hard, mauve andesites or tuffs	15
Dark grey andesites or tuffs	15
Total thickness	639 to 701

From this point west the material is mostly covered except for outcrops of a few beds of comparatively unaltered lava.

21. Two or three hundred yards to the southwest, down a gully, there are nearly flat-lying outcrops of a dacitic ash of the same character and probably the same bed as No. 16. This is in the trough of the fold.

Although the Tranquille beds were not seen in this part of the area, the Upper Volcanics, consisting of nearly flat-lying basalts, occur.

From Soda Creek to a point above Quesnel, a similar succession can be observed, namely, disturbed and folded lavas overlain by a sedimentary series and this, in turn, by flat-lying basalts.

A series of volcanic flows that dip at high angles and are much brecciated in places, outcrops in Fraser canyon just north of Soda Creek, where they are apparently of great thickness. About 5 miles north of Soda Creek near the road, are platy olivine basalts striking from north 67 degrees east to north 80 degrees east with dips of 55 to 70 degrees to the north. Four miles farther up, from a cliff of much brecciated basaltic rock, large blocks have rolled from the railway cut to the road. Stringers of epidote and chalcedonic silica cut through the rock which has in places a pisolitic texture. Farther north on the east side of the road, a volcanic rock shows columnar structure. Just below the mouth of Australia creek, on the west bank of Fraser river, is an amygdaloidal basalt, much brecciated and altered to clay. Beds of clay derived from this basalt are interbedded with lignitiferous clay or sand at this place. A bed of lignite is said to outcrop nearby but was covered at the time of our visit and its relation to the basalt could not be observed. About 1½ miles below Quesnel, on the west bank of Fraser river, there is a series of augite andesites and other lavas of nearly the same composition, occurring with white, finely banded, dense, glassy lavas (Figure 12, locality 12). The rocks are much faulted and brecciated, and altered to clay, while nearby are beds of arkosic sandstone derived from them and carrying carbonaceous material. Similar lava beds outcrop on the west bank of the river about 2 miles farther down (Figure 12, locality 14) and in the road west of the river between these two localities. The very much faulted, brecciated, and altered condition of these lavas indicates that they are much older than the much less disturbed, topographically higher, strata of the Fraser River formation. This conclusion is strengthened by the finding of clay and carbonaceous beds of undoubtedly later age close to the lava outcrops.

FRASER RIVER FORMATION.

Sediments of Tertiary age were observed along Fraser river from the Big Bend 8 or 9 miles above Quesnel, to and beyond Australia creek (Figure 1). They outcrop also on the river below and above Prince George. Dawson[1] mentions occurrences on Blackwater river about 30 to 40 miles northwest of Quesnel and there are probably other occurrences of the same age near the main Fraser valley. The sediments consist of gravels, sands, and clays, and beds of lignite and diatomaceous earth.

The gravels of this formation are yellow to brownish and in many cases well cemented. Their pebbles are well rounded and composed for the most part of quartz and of metamorphosed sediments and lavas. The clays are generally grey in colour; some of them are nearly white, and

[1] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1875-76, pp. 255-256.

others, coloured by vegetable remains, vary from chocolate throug brown to black The diatomaceous earth is cream-coloured to whit very porous, and of low specific gravity. The lignites vary from brow carbonaceous clays to black lignites of good quality. The clays, lignite and diatomaceous earths are discussed further on later pages.

At the west end of the big bend of the Fraser (Figure 12, localitie 1, 2, 3), the sediments are well exposed in cliffs rising to elevations of 500 feet above the river. One section (section No. 1) measured at the soutl end of the cliffs, shows about 460 feet of cemented gravels and clays witl a few lignitic seams, the clay lying for the most part near the top of the section. The details of this section are tabulated below.

Section No. 1.

Top of section.	Thickness in feet.
Boulder clay	48
Basalt	30
Concealed	91
Alternating thin beds of clay and gravel	4¾
Red clay	3
Cemented gravel	12
Yellowish red clay	5
Firmly cemented gravel	11
Mottled clay	5
Cemented gravel	8
Reddish yellow clay with, in middle, a bed of fine-grained, cemented gravel	7
Concealed	36
Alternating bands of clay and gravel	8
Red, consolidated clay	14
Gravel with clay	3
Grey sandy clay	5
Alternating bands of chocolate and grey clay	4½
Well cemented, grey, sandy clay	3½
Fine-grained gravel	2
Grey, yellow brown clay with lignite band	4½
Fine-grained gravel	6
Sand and gravel in irregular beds	128
Sandy clay, red at top	2¾
Gravel, reddish and cemented at top with iron oxide	15
Sandy, yellow clay	10
Grey, sandy clay, with a 1-foot band of fine-grained, well cemented gravel	20
Gravel	16
Grey clay	22
Sandy, lignitic clay	4½
Gravel with one foot at top well cemented	28
Sand	2
Character not recorded	25
Sand, streaks of iron oxide	2
Gravel	27
Fraser River level. Total	613¼

(The above section was measured on the west side of Fraser river, 8 miles north of Quesnel, at west end of Big Bend, 2 miles west of section No. 2 (Figure 12, locality 4).

Farther north along the cliffs in the direction of the dip, other sections of the strata show that the higher parts of the general sedimentary section contain more clay. On top of the steep cliffs are a number of masses of diatomaceous earth and grey clay which have been affected by sliding

(Plate III B) from the higher ground so that their exact position in the section is not known. They are, however, topographically above the clays of the above tabulated section, which dip in their direction, and the lowest bed is probably at least 200 feet higher, stratigraphically. Assuming that the beds maintain a fairly uniform thickness over a distance of half a mile the sediments exposed here are from 700 to 800 feet thick. They are overlain unconformably by nearly flat-lying basalt and this in turn by boulder clay.

Another section, section No. 2 (Figure 12, locality 4), was measured on the east bank of Fraser river, 2 miles west from the locality of the above tabulated section No. 1. It contains more lignite than section No. 1 and one 3-foot seam of impure diatomaceous earth appears near its base. One gravel bed which was followed for 1,000 feet along the direction of dip increased in thickness from 10 to 15 feet in that distance.

Section No. 2.

	Thickness in feet.
Top of bluff.	
Grey boulder clay: pebbles of dense metamorphic rocks, of granodiorites, and a few of amygdaloidal basalt, in a clay matrix	65
Sand and gravel	9
Boulder clay with, amongst many other kinds, a few basaltic pebbles	6
Sand and gravel	4
Boulder clay	20
Concealed by a slide of boulders in large sections up to 100 feet by 30 feet by 20 feet and sliding today	150
Blue grey clay, floor of slide, water running over it	4
Gravel	11
Blue and grey silty clay in thin beds	9
Gravel and sand	10
Grey lignitic clay, fossil leaves, well bedded	6
Sand and gravel with a 2-inch bed of clay	50
Grey clay	2
Gravel and silt	5
Brown silty clay	3
Sand	5
Gravel. The base of the bed dips down-stream, south 16 degrees east, with an inclination of about 40 feet in 1,000 feet; thickness at north end is 10 feet, at south end, 15 feet	15
Concealed	5
Silt, brown, thin-bedded, carbonaceous	4
Fine sand	5
Coarse gravel	10
Grey clay, weathering cream, lignite at base	5½
Green clay	4
Concealed	5
Buff clay, lignite seam at base	3
Buff clay	10
Green clay	8
Silt	6
Coarse gravel	35
Silt with 2-inch gravel layer	4
Coarse gravel with 3-inch layer of ironstone containing remains of leaves.	12
Buff and grey clay	12
Cream clay with infusorial earth	3
Buff clay	3
Dark grey clay	6
Sand and gravel	12
Fraser River level. Total	527½

(The above section of the Quesnel formation was measured on the east side of Fr river, just below Big Bend at locality 4, Figure 12, 2 miles east of position of sec No. 1.)

South of Quesnel, on the east bank of Fraser river, other sections the formation are exposed. A conspicuous red bluff, just below the tov formed of burnt-out lignites and baked clays together with underlyi beds, is described by Selwyn.[1] Dawson[2] described outcrops near the villa of Quesnel. A section (No. 3), measured 2½ miles down the river fr Quesnel, opposite Baker's ranch, is given below. The proportion of cl in exposures in this neighbourhood (Figure 12, locality 13), is greater th that of gravel and there are more lignitiferous beds.

Section No. 3.

Top of bluff.

	Thickness feet.
River silt	6
River gravel	15
Grey clay with lignitic partings	10
Gravel cemented with clay	3
Grey and reddish clay	17
Gravel	30
Carbonaceous clay	15
Cemented gravel	10
Grey clay with a gravelly bed	25
Cemented sand and gravel	4
Grey clay	7
Sandy clay	3
Grey clay	12
Green clay	6
Green clay with lignitic partings	17
Sandy, green clay	3
Coarse gravel	12
Concealed	10
Total	205

Fraser River level.

A section at the Australia ranch about 18 miles south of Quesnel, taken at a tunnel opened along a seam of lignite, is given below (section No. 4). In this section there is practically no gravel, but lignite, one seam of which measures nearly 4 feet, is more plentiful than elsewhere.

Section No. 4.

Top of section.

Bed No.		Thickness in feet and inches.
1.	Poorly assorted boulder sand, probably glacial	20 0
2.	Clay with seams of sand and *lignite*	13 0
3.	Drab, carbonaceous clay with lenses of sand	2 0
4.	*Lignite*	0 3
5.	Brown grey shale	2 0
6.	*Lignite*	0 5
7.	Grey clay	1 6
8.	Brown clay with nodules of lignite	5 0
9.	Sand	1 0
10.	Drab brown clay	4 6
11.	Sand	2 0
12.	Grey clay	2 6

[1]Selwyn, Alfred, R. C., Geol. Surv., Can., Rept. of Prog. 1871-72, pp. 58-59.
[2]Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1875-76, pp. 257-260.

Top of section.

Bed No.		Thickness in feet and inches.
13.	Sand cemented by iron oxide into lenses	1 0
14.	Compact grey clay with sand lenses and seams of *lignite*	9 0
15.	Brown clay with seams, up to 1 inch thick, of *lignite*	10 0
16.	Coarse sand with clay	2 6
17.	Brown clay, with seams up to 1 inch thick, of *lignite*	4 0
18.	Grey sandy clay	1 6
19.	Sand cemented by iron oxide, into lenses	1 0
20.	Brown clay with nodules of lignite	4 6
21.	Grey clay	0 7
22.	*Lignite*	0 2
23.	Brown clay	0 6
24.	Drab clay	1 6
25.	*Lignite*	0 8
26.	Brown clay	1 0
27.	Coarse sand	6 0
28.	Sandy clay	1 6
29.	Drab clay	2 0
30.	Irregular lenses of well-cemented silt with remains of leaves	1 0
31.	Brown clay with sand lenses up to 1 foot thick, and with *lignite* partings	13 0
32.	Grey clay	2 0
33.	Brown, carbonaceous clay with seams and lenses, up to 2 inches thick, of *lignite*	7 0
34.	Sandy clay	0 3
35.	Drab clay with very little lignite	3 0
36.	Carbonaceous clay	010
37.	Grey clay free from lignite	3 0
38.	Brownish grey clay, thin seams of carbonaceous matter	2 0
39.	*Main seam, lignite* (mined)	3 9
40.	Drab grey clay	1 0
41.	*Lignite*	0 5
42.	Drab clay	011
43.	*Lignite*	1 6
44.	Brown clay, full of carbonaceous matter	7 6
45.	Concealed	15 to 20

Fraser River level.

Dawson speaks of these beds as the Lignite Group. The writer suggests the name Fraser River formation as being more definite. Dawson[1] collected a number of plants from these beds and decided that they were of Tertiary age, Miocene or older. Penhallow[2] has placed them in the Eocene. Because of their position between a series of disturbed and altered lavas corresponding to Dawson's Lower Volcanics and of younger flat-lying basalts the writer believes that they represent a period of sedimentation corresponding to that of the Tranquille formation at Kamloops. And if Dawson's Lower Volcanics are post-Oligocene these beds should be placed in the Miocene.

UPPER VOLCANICS.

The Upper Volcanics are typically developed on the Green Timber plateau. A section measured at the head of the gorge known as the "Chasm," near 59 Mile House, shows a thickness of 203 feet of flat-lying olivine basalts, in beds up to 25 feet thick, that are amygdaloidal for about 10 feet at the top, becoming denser downward with a thin layer of amygdules

[1]Dawson, G. M., Op. cit, p. 260.

[2]Penhallow, D. P., "Report on the Tertiary plants of British Columbia." Geol. Surv., Can., No. 1013, 1908 p. 111.

at the base. Chabazite, heulandite, analcite, and opal occur in the amygdules, some of them forming very beautiful specimens. Olivine basalt boulders are plentiful near the hydromagnesite deposit at Meadow lake, and on the hill at the northwest end of the lake beds of andesites and basalts several hundred feet thick overlie limestones of the Cache Creek series.

On Timothy mountain (Figure 2, locality 17, and Figure 13, locality 3) there are beds of olivine basalt with inclusions of hypersthene peridotite that carries "peridot" the green semi-precious form of olivine, a stone used in the jewellery trade (see page 81).

A series of flat-lying basalts outcrops in the edge of the Fraser valley west of Quesnel and is found farther south both on the east and west sides forming the upper rim of the valley. It was seen on the west side of Fraser river at Chimney Creek bridge and westward toward Riske creek, in each case coming to the edge of the canyon of Fraser river but not continuing down its sides. The lava is black and amygdaloidal with dense layers. At the base, in places through a thickness of 10 feet, it is disrupted, sand and clay being mixed with it in the lower foot or so. Its average thickness is about 40 feet. The basalt lies flat or nearly so on the rim of the Baker Creek canyon and is apparently flat where it occurs at Chimney Creek bridge and on a series of steeply-dipping beds near Soda creek. At two places east of Quesnel it has a strike of about north 30 degrees east and a dip to the northwest of from 15 to 25 degrees, but in both instances slipping, due to local topographic conditions, may have affected the rocks. Southwest of Quesnel it rests unconformably upon diatomaceous earth beds of the Fraser River formation and in Baker canyon and at Chimney Creek bridge it is underlain by beds of gravel and silt probably of the same formation.

PLIOCENE.

Conglomerates and sandstones are exposed at Clinton on the Clinton-Ashcroft road near the epsomite lake (Figure 8, locality 10), also west of the railway on Clinton creek and in the railway cuts north of the station. The section exposed on the road is as follows in descending order:

	Thickness in feet.
1. Fine-grained, massive sandstone, slightly iron-stained near top	23
2. Covered	17+
3. Sandstone much stained with iron and manganese	2
4. Covered	10±
5. Conglomerate with pebbles up to 1½ inches in diameter	4
6. Fine-grained, massive, firmly cemented sandstone	1½
7. Alternate beds of sandstone and fine-grained conglomerate, pebbles of pea size	4
8. Fine-grained sandstones with grains about $\frac{1}{16}$ of an inch in diameter lying in beds ½ to 2 inches thick; streaks of iron rust and black sand occur along the bedding planes	1½
9. Sandstone, grains about $\frac{1}{8}$ inch in diameter, partly covered	6
10. Conglomerate with well-rounded pebbles up to 2 inches in diameter. The pebbles consist of Cache Creek quartzites, and amygdaloidal and porphyritic basalts resembling Tertiary lavas	3 to 4

Dawson mapped these beds as Cache Creek, but the amygdaloidal basalt pebbles in No. 10 indicate that the strata are later than some of the Miocene lava extrusions. They either belong to a series corresponding to the Tranquille or are Pliocene. On the track a mile or two north of Clinton station, there are conglomerates with sandstones and shales like those at this locality, some of them slightly folded.

GLACIAL AND RECENT DEPOSITS.

More recent than the Tertiary are unconsolidated deposits of boulder clay, gravels, sands, and silts. Boulder clay or glacial till is widely distributed. Conspicuous morainal deposits are found at Big Bar lake, in the neighbourhood of Clinton, and south of 150 Mile House. A flat, irregular sheet of glacial drift lies over most of the portions of the Interior Plateau visited, including areas near the Fraser north and northeast of Quesnel. A section of boulder clay lying on the east bank of Fraser river above Quesnel, with interbedded gravels, is given in section 2, page 15. Dawson[1] records the finding of glacial striæ trending south 30 to 40 degrees east on all the higher points of the plateau lying 30 or 40 miles south and east of Green Timber plateau. The writer found glacial striæ trending true south on top of the plateau near the road between Chimney Creek bridge and Riske creek and Dawson[2] records further clear striations trending south 2 degrees east, 8 miles southwest of this place and 6 miles west of Fraser canyon at an elevation of 3,650 feet, that is on top of the plateau, well away from Fraser gorge, and he also noted striations trending a few degrees west of south on Tsawhuz mountain between Blackwater bridge and Prince George thus indicating the nearly due southward movement of a large body of ice on the plateau west of Fraser river. The records of glaciation in the northern part of this district have not been sufficiently studied to justify drawing general conclusions.

Grey, fine-grained silts occur in the immediate trough of the Fraser at intervals from Lillooet to Quesnel. They resemble the white silts of the Thompson lithologically and in their method of occurrence and are supposed to have been laid down at the end of the glacial epoch.

At Clinton and elsewhere much gravel has been laid down either by rivers on their flood-plains or by streams connected with glaciers. The following section taken at a point one mile south of the mouth of Quesnel river on the east bank of Fraser river illustrates a succession of beds from the Tertiary, Fraser River formation, up to recent river gravels, in descending order:

	Thickness. Ft.	In.
8. Soil		10
7. Gravelly sand, rusty at top	9	
6. Coarse-grained, unconsolidated gravel, with boulders up to 1 foot in diameter, mostly of dense, metamorphosed rocks, a few of granite	15	
5. Grey silt in well-defined beds	135	
4. Coarse gravel, partly concealed	15	
3. Sand with seams of lignite	7	
2. Sand with a 1-foot bed of gravel at the base	13	
1. Concealed down to level of Fraser river	20	

[1] Dawson, G. M., Geol. Surv., Can., vol. VII, 1894, pp. 253B-254B.
[2] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1875-76, pp. 261-262.

In the section above, horizons 2 and 3 at least, and possibly 4, are Tertiary age, 5 is the white silt mentioned above, 6 and 7 are recent riv deposits.

The terraces along the Fraser and its tributaries owe their level surfac to deposition of sheets of river sand and gravel during flood times.

CHAPTER III.

HYDROMAGNESITE.

Deposits of hydromagnesite were examined and mapped at Clinton Meadow lake, Watson lake, and Riske creek. The material is a cream coloured, partly consolidated earth lying on the bottoms of valley floors Although parts of the deposits contain much lime and other impurities the composition of the better grades approaches that of the mineral hydro magnesite, which is magnesium carbonate with contained water, $3MgCO$ $Mg(OH)_2+3H_2O$, and for convenience the deposits in general are referred to as being hydromagnesite.

OCCURRENCES OF HYDROMAGNESITE AND MAGNESITE IN CANADA AND ELSEWHERE.

Hydromagnesite is of common occurrence as an alteration product of serpentine, but generally was developed in quantities too small to permit of exploitation. Large deposits, however, occur in unconsolidated material near the town of Atlin, B.C., and also in and near the area dealt with in this report. Outside of a trial shipment of about 600 tons of the Atlin hydromagnesite to Vancouver in 1915, the deposits have remained practically unexploited.

Hydromagnesite is so closely related in composition to the mineral magnesite that it may reasonably be expected to yield nearly all the products obtained from the anhydrous mineral. This being so, the distribution of magnesite and the uses to which it has been put are summarized here[1].

Before the war the principal supplies of magnesite were obtained from Austria-Hungary and Greece. The production of the United States in 1913 was 9,632 tons, valued at \$77,056, and of Canada 515 tons, valued at \$3,335. The cutting off by the war of the Austrian supply and a great part of the Grecian supply, together with an increased use of magnesite products, stimulated North American production, so that in 1917 the United States[2] produced 316,838 tons, valued at \$2,899,818, and Canada[3] 58,909 (crude and calcined) tons, valued at \$728,275. The production of both countries fell off considerably in 1918 as indicated in the annexed table. Similarly, before 1915, the metal magnesium, which may be obtained from magnesite or its products, and for the production of which magnesite ore will no doubt be more extensively used in future, was not produced on a commercial scale in Canada or the United States. In 1915, however, 87,500 pounds having an average value of \$5 per pound, were produced in the United States, and in 1917 the amount had risen to 115,813 pounds but with an average value of only \$2 per pound.

[1]For a summary of the commercial products obtained from magnesite, together with an account of the world sources of magnesite, that had been developed in 1916, the reader is referred to Geol. Surv., Can., Mem. 98, by M. E. Wilson.

[2]Mineral resources of the U.S., pt. II, "Magnesite in 1917," by Chas. W. Yale and Ralph W. Stone, p. 64.

[3]McLeish, John, Ann. Rept., Mineral production of Canada for 1918, p. 57.

Table I.—Production of Magnesite, 1913 to 1918.

Country [1].	Type of occurrence.	Production in tons.					
		1913	1914	1915	1916	1917	1918
Quebec	Crystalline	515	358	14,779	54,778	64,767 [3]	57,799
British Columbia	Hydromagnesite	..		...	635 [2]	......	......
California [7]	Massive	9,632	11,293	30,499	154,259	211,663	84,077
Washington [7]	Crystalline	......	.....	....	715	105,175	147,528
Austria-Hungary	Crystalline	200,947 [4]	..	...	...	....	......
Greece	Massive [5]	98,517	136,701	159,981	199,484	..	....
		31,815	38,563	28,563	27,248	69,837	....
India	Massive [6]	16,468	1,706	7,570	17,924	....	....

[1]For a summary account of the known deposits of the world up to 1913, see U.S. Geol. Surv., Mineral resources of U.S., pt. II, 1913, p. 450, and U.S. Geol. Surv., Bull. 355, pp. 52-63.

[2]Most of it mined in 1915 and marketed in 1916

[3]Includes crude, calcined, and dead-burnt; crude making up the greatest part.

[4]No figures of production are available for Austria-Hungary. The figures given represent exports only and are for calcined magnesite. The tonnage of calcined was derived from nearly twice as much tonnage of the original crude.

[5]Crude ore.

[6]Calcined ore.

[7]Crude magnesite produced and sold or treated. This is not the same as the tonnage mined.

The principal sources of magnesite in Europe are the crystalline magnesites of Austria-Hungary and the deposits of the dense variety found in the island of Eubœa, Greece. Smaller deposits of dense magnesite exist in Norway, Silesia in Germany, in the Urals in Russia, in Macedonia, and in Italy, and minor deposits of the crystalline type occur near Tarra river in Lapland, and in Spain. Some of the Norwegian material is also crystalline.

A considerable amount of dense magnesite has been mined near Salem in Madras presidency, India, and there are deposits of the mineral in Mysore. Hydromagnesite is reported from Ceylon.

Important deposits of magnesite are said to occur near Fifield, Kennedy county, in New South Wales, and numerous smaller deposits occur elsewhere in that province, in Queensland, South Australia, and Tasmania. Some magnesite has also been shipped from the island of New Caledonia.

Dense magnesite occurs at a number of localities in the Transvaal and Rhodesia and has been mined on a small scale in the Transvaal, the product amounting to less than 1,000 tons per annum.

A deposit of magnesite occurs on the island of Margarita, Venezuela, others on the island of Santa Margarita in the gulf of California, Mexico.

All the magnesite produced in the United States up to 1916 came from California, but in that year large deposits were opened in the state of Washington. The California magnesites are of the dense variety and there is one occurrence of a sedimentary magnesite. The magnesite of Washington is of the crystalline variety and occurs about 60 miles north of Spokane. The material resembles the dolomite in which it occurs and can be distinguished from it only by chemical analyses. Although many of the California deposits are exhausted, at least several million tons of magnesite are available in the Washington deposits.

The principal Canadian deposits of magnesite[1] are situated in the hills north of the village of Grenville, Quebec. The magnesite is crystalline

[1]Wilson, M. E., "Magnesite deposits of Grenville district, Argenteuil county, Quebec", Geol. Surv., Can., Mem. 98.

and occurs in dolomites and crystalline limestones of the Grenville ser. In 1916 it was estimated[1] that close to 700,000 tons of magnesite ore car ing less than 12 per cent of CaO was in sight in this district. The magnes is sintered with about 5 per cent of magnetite iron ore in rotary kilns a the dead-burned product sold for furnace linings. It is said that mater carrying up to 15 per cent of lime has been used successfully in the proce

Smaller occurrences of both crystalline and compact magnesite ha been reported from Bolton and Sutton townships in the Eastern Tow ships of Quebec.[2] At Orangedale,[3] Inverness county, Nova Scotia, deposit of crystalline magnesite has been opened up and a small amou taken out.

Several occurrences of magnesite have been reported from the Yuk and British Columbia. Cairnes[4] found exceptionally pure magnesites few miles north of Orange creek, south of Porcupine river, on the Yuko Alaska boundary. They occur in beds from 2 to 10 feet thick, having a aggregate thickness of 100 feet or more. McConnell[5] found bands crystalline magnesite up to 50 feet thick, just below Island lake in the fir range east of Big Salmon river, a tributary of Lewes river, Yukon, an material of nearly the same character 300 miles to the northwest, 1½ mile above Indian river on the east side of Yukon river.

In British Columbia, magnesite and hydromagnesite are found nea Atlin, on the Omineca river, near Illecillewaet, in the Bridge Rive district, and in the localities described below. The surface deposits nea Atlin have been described by W. F. Robertson[6], J. C. Gwillim,[7] and G. A Young.[8] From the results of numerous tests Young concluded that abou 150,000 tons of the Atlin deposits would carry not more than 3 per cen of the following impurities: CaO, Fe_2O_3, Al_2O_3, and SiO_2, the remainder being $MgCO_3$ with about 18 to 19 per cent of water. Gwillim[9] reported impure anhydrous magnesite as occurring with diorite and serpentine at a number of localities in the same district. R. G. McConnell[10] reported bands of magnesite occurring with dolomite and serpentine on Germansen creek, a tributary of Omineca river. C. W. Drysdale[11] in 1915 and 1916 discovered magnesite of both crystalline and compact varieties, but of small extent, in the Bridge River district. Some of this material is of good quality.

USES OF MAGNESITE.

Magnesite and its products are used in the manufacture of carbon dioxide, in the digestion of wood pulp, in the manufacture of Sorel cement, as a refractory lining for basic steel and other furnaces, in the manufacture of chemicals, and in other ways. The metal magnesium forms a very useful alloy with aluminum and the powdered metal is used in the manufacture of flares, etc.

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[1]Op. cit., page 62.
[2]Logan, W. E., "Geology of Canada," Geol. Surv., Can., Rept. of Prog., 1863, p. 457.
[3]Geol. Surv., Can., Sum. Rept., 1916, pp. 277-278.
[4]Cairnes, D. D., "The Yukon Alaska International boundary between Porcupine and Yukon rivers, Alaska," Geol. Surv., Can., Mem. 67, pp. 51, 52, 113.
[5]Geol. Surv., Can., Ann. Rept., vol. XI, pp. 15R, 16R, 1898.
[6]Ann. Rept. of the Minister of Mines of British Columbia for 1904, pp. 82, 83.
[7]Geol. Surv., Can., Ann. Rept., vol. XII, 1899, pp. 47, 48B.
[8]Geol. Surv., Can., Sum. Rept., 1915, pp. 50-61.
[9]Op. cit., p. 21B.
[10]Geol. Surv., Can., Ann. Rept., vol. VII, 1894, p. 25C.
[11]Geol. Surv., Can., Sum. Rept., 1916, p. 48.

Carbon Dioxide.[1, 2]

Carbon dioxide is liberated from magnesite at a temperature about 370 degrees Centrigrade[3] lower than from limestone or calcite. Magnesite has, therefore, been used for producing carbon dioxide, but other and cheaper methods of manufacture have led to a decreased production from this source.

Sorel Cement.[4]

If magnesite be burned to a red heat a product known as "caustic, calcined magnesite" is formed, which is a mixture of magnesia and magnesite with a carbon dioxide content of less than 8 per cent of CO_2. This product, if free from certain impurities, sets into a hard cement when mixed with a solution of magnesium chloride of a certain strength. This mixture, together with fillers, such as sawdust, ground cork, ashes, china clay, asbestos, serpentine, talc, and colouring material, ochre, etc., is used in the manufacture of flooring, artificial marble, and tiles. When successfully laid, the floors are said to be smooth, resilient, and not liable to crack. They are readily coloured, take a good polish, prevent the escape of heat, and are resistant to fire. Failures in the use of this cement have been ascribed to lack of uniformity in the raw materials used, improper mixing, deterioration of the materials before construction, improper foundations, and lack of experience in the laying of the floors. Sorel cement is one of the products which eventually may be successfully produced from high grade hydromagnesites.

Refractory Materials.

When magnesite is raised to a white heat (1,700 degrees C.) and practically all the carbon dioxide is driven off, the resulting magnesia (MgO) is chemically inert and very refractory.[5] The product is known as "dead-burned magnesite" and is used either as magnesite brick or, crushed to pea size, for the lining of basic steel furnaces, copper convertors, furnaces for refining lead, electrical and other furnaces. The crushed material is employed as a lining for the bottom of open-hearth furnaces, rotary kilns in Portland cement manufacture, and in making crucibles and cupels. The foregoing comprise the principal uses of crystalline magnesite.

Digestion of Wood Pulp.

Magnesium bisulphite made from calcined magnesia, when boiled with pulp wood, dissolves the non-cellulose matter in the wood and the resulting pulp is used in the making of paper.

Manufacture of Magnesium Salts.

"Light magnesium carbonate"[6] or magnesia alba levis ($MgOH\ 3MgCO_3$) is manufactured in some instances from magnesite. It is used as a heat insulator on pipes, etc., as a fire retarding paint, as a toilet pre-

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[1] U.S. Geol. Surv., Mineral resources of the U.S. for 1913, pt. II, p. 446.
[2] Geol. Surv., Can., Mem. 98, p. 6.
[3] Chemical abstracts for 1917, p. 562.
[4] U.S. Geol. Surv., Mineral resources of the U.S., 1913, pt. II, pp. 447, 450-453.
[5] The melting point of MgO is 2,800°C., CaO, 2,572° C., Al_2O_3, 2,050°C., Cr_2O_3, 1,990°C. Jour. Franklin Inst., 1913, p. 587.

paration, and for medicinal purposes. Magnesium chloride ($MgCl_2$) be made by treating magnesite with hydrochloric acid, and magnesi sulphate by treating the same material with sulphuric acid. Magnesi chloride is used principally for making Sorel cement and in the manufact of cotton goods. Magnesium sulphate is used in the manufacture textiles, in the tanning of leather, and, in the hydrated form known epsom salt, for medicinal purposes. Epsom salt is also produced fr natural deposits at Clinton (see page 51) and elsewhere.

Magnesia (MgO) is used to some extent in glass making and in t rubber industry; crude magnesite is used with asbestos fibre as a hea resisting packing for furnaces and pipes.

Metallic Magnesium.[1]

The metal magnesium is of a silvery white colour, chemically ine tough, malleable, and ductile when heated. It has a specific gravity (1·7 or two-thirds that of aluminum, and is the lightest metal known th remains comparatively unaltered under atmospheric conditions. Magn sium is used in powdered form, in ribbons, or in sticks. Powdered magne sium is used for flash lights in photography, in fireworks, and for flare etc., in military operations. Magnesium ribbon, as well as the powder, used in testing for phosphorus and potash in chemical laboratorie Massive magnesium in sticks is used as a scavenger, that is, a deoxidizin agent of alloys. Magnesium is a powerful deoxidizing and denitrifyin agent and its oxide is more stable at high temperatures than other agent such as aluminum, silicon, and phosphorus.

The metal magnesium has been produced chiefly by electrolysis o the fused double chloride of magnesium and potassium ($MgCl_2KCl$) Other processes, some of them still in the experimental stage, are reductio of the fused magnesium chloride with soda or aluminum, reduction with carbon, reduction of magnesia (MgO) or magnesite ($MgCO_3$) to slag forming residues, and electrolysis of dissolved MgO. The double chloride of magnesium and potassium used for this purpose is the dehydrated mineral carnallite obtained from the salt deposits of Stassfurt in Germany.

A small quantity of magnesium added to steel, copper, nickel, or various alloys of these and other metals, clears up the oxides of these metals that may be present and makes for a denser and more homogeneous product. Alloys of aluminum with a small percentage of massive magnesium have proved very useful. They are lighter than aluminum and have greater tensile strength and resistance to impact. Magnalium, an alloy of aluminum, with less than 2 per cent of magnesium and with equally small percentages of calcium, nickel, tin, and lead, has been used for kitchen and domestic ware, surgical and optical instruments, military equipment, etc. Aluminum alloyed with magnesium has been used for making larger castings. Numerous other alloys of magnesium and aluminum, magnesium and copper, magnesium zinc, etc., have been made. Conditions seem promising for a more extensive use of the metal in alloys in the future. The obstacle at present to such use is the cost of producing metallic magnesium. For instance, German magnesium sold at $1.65 per pound in

[1]Grosvenor, Wm. M., Metall. and Chem. Eng., vol. 14, No. 5, Mar. 1, 1916, p. 263.
King, J. C., "Magnesium," Trans. Can. Min. Inst., vol. XX, 1917, pp 471-480.
Stone, R. W., "Magnesium in 1917," U.S. Geol. Surv., Mineral resources of the U.S., 1917, pt. I, pp. 147-151.

1913 while the raw materials sold for only a few cents per pound and under present conditions of manufacture the price of domestic magnesium will probably retain a very high ratio to that of the crude materials. If the cost of producing magnesium be reduced to a low enough point, this metal may largely replace aluminum in the making of automobile and aeroplane parts and in the many other uses to which aluminum is put at present, with a reduction in weight and increase in strength of the finished article.

PRICES.

In 1913 crude Grecian magnesite sold at from \$7 to \$8 per ton in bulk f.o.b. New York, and crude California magnesite sold at about the same price at the mine or point of shipment. Grecian material, "caustic" calcined, fine ground and packed in paper-lined barrels, sold at from \$25 to \$35 per ton in New York, and the California product prepared and packed in the same way fetched \$30 to \$35 in Los Angeles or San Francisco. The price of dead-burned, crushed, or fine-ground Austrian magnesite averaged \$16.25 to \$16.50 in New York and the same product from Norway \$22.50 in San Francisco. In 1918 the California crude sold at an average of \$9 per ton at the mines and that of Washington at a little over \$7. This represents a drop in price of about \$1 per ton from 1917. The freight from California to the east was a little over \$16 to the ton. Quebec magnesite sold at about \$9 per ton crude, caustic calcined and dead-burned averaged \$38 per ton, the dead-burned being much the higher. What prices will prevail by the time that the Cariboo deposits are being mined is a matter of speculation, but when European magnesite is again imported western magnesites and hydromagnesites will evidently be at a disadvantage in the principal magnesite markets of the eastern United States.

HYDROMAGNESITE DEPOSITS EXAMINED.

GENERAL CHARACTER.

Numerous outcrops of white or cream-coloured earths occur at Kelly lake, Clinton, Meadow lake, and Watson lake, and occurrences of the same nature are found in the neighbourhood of 141 Mile House on the Cariboo road and on Riske creek, west of Fraser river. Analyses indicate that some of these deposits are mainly hydrous carbonates of magnesia approaching hydromagnesite in composition; others contain a large proportion of lime carbonate; and others carry gypsum in excess. All these varieties closely resemble one another in general, but in places where they occur together the purer hydromagnesites can be distinguished from the earths high in lime.

The purer hydrous magnesium carbonates which for convenience will be called hydromagnesites, although they seldom have the exact composition of that mineral, are fairly coherent, white to cream white aggregates made up of extremely fine particles showing glistening faces with a beautiful silky lustre in reflected light. Scattered through these may be a few, black particles of very small size. When highly magnified the material resolves into very fine, greenish blades about 0·002 millimetres wide and 0·01 to 0·012 millimetres long, of low birefringence and parallel extinction. From the results of analyses these are thought to belong to an isomorphous series of which magnesite, hydromagnesite ($3MgCO_3\ Mg(OH)_2 + 3H_2O$), and nesquehonite ($MgCO_3\ 3H_2O$) are members (Figure 4).

Earths in which the percentage of lime and other impurities is
sidera ble are usually of a grey to cream yellow colour and are granul
in texture. An earth which from its analysis was calculated to con
36 per cent of lime carbonate and 50 per cent of anhydrous magnes
carbonate (see Table IV, analysis 6) seems to be made up nearly wh
of rounded, carbonate grains 0·002 to 0·005 millimetres in diameter,
are undoubtedly anhydrous carbonates, possibly dolomite. There are
fine, needle-shaped crystals of high birefringence, probably brucite,
a cloudy looking, very finely divided substance, the nature of which
not determined, but part of which may be amorphous silica. The c
paratively small proportion of brucite ($Mg(OH)_2$) demonstrates that n
of the magnesium exists as the anhydrous carbonate ($MgCO_3$), either
magnesite associated with calcite, or combined with calcium carbon
as the mineral dolomite[1] ($(CaMg)Co_3$).

Earths made up nearly or wholly of gypsum resemble in the ha
specimens those containing relatively large amounts of lime. Under
microscope the gypsum crystals were recognizable, but anhydrite, wh
is probably present, could not be determined because of the fineness
the material.

The white hydromagnesites are fairly dense; the earths with m
impurities are granulated. The granulated, in very many cases, show we
defined, thin beds of $\frac{1}{16}$ to $\frac{1}{12}$ inch in thickness, lying flat but with a slight
wavy outline. The same banding is observable on freshly broken surfac
of the hydromagnesites. Between the bands are flattened cavities wi
rounded and curved surfaces.[2] In places near the groundwater level t
impure earths are cemented into compact masses.

Relation of Hydromagnesites and Impure Earths.

The nearly pure hydromagnesite when present in the larger deposit
lies at the surface in a layer of from about 1 foot to 2½ feet or, in rare case
4½ feet in depth. Under it is almost invariably a layer of cream-coloure
or yellowish earth carrying a fairly large percentage of lime, silica, an
other impurities. The combined thickness of the two layers varies from
about 4 to 6 feet. The division between the two is as a rule fairly sharpl
defined by a wavy but nearly horizontal surface. Near the edges of th
larger deposits irregular, lens-shaped layers full of brown sand lie betwee
these two zones. Where, in the same deposit, both white hydromagnesite
and impure earth outcrop at the surface, the top of the white earth is at
slightly higher elevation than the neighbouring surfaces of impure material
Below the cream-coloured, impure layer is generally a dirty white earth
full of sand and clay, cemented in many cases to a hard mass, and below
this is more sand or clay. At Watson lake the succession described above
seems in places to be repeated so that a white layer underlies a yellowish
layer. In places the underlying clays contain numerous, small, freshwa er
shells.

[1] The formation of dolomite—if, indeed, this be dolomite—under the conditions in which these earths originated would be of great interest geologically. *See* K.A. Redlich in Fortschr. der Miner. Kirst und Petrog. Deutsch Miner. gesells. Band IV, pp. 9-42, "Die bildung des magnesits und seine naturliche Vorkommen." Attempts by the ordinary micro-chemical tests to discover whether dolomite or calcite was present in this earth did not succeed.

[2] The texture and structure of these beds, and especially of the calcareous tufas, pages 43 and 51, resemble the structures called stromatoliths by Kalkowsky, *see* Zeitsch der Deut. Geol. Ges. Band LX, 1908, pp. 68-125.

Shape of the Deposits.

The larger deposits are thin, flat-lying sheets of nearly uniform depth from the surface to the underlying sand or clay. The surfaces, which are from 1 to 2 feet higher than the surrounding valley floors, are broken up into nearly circular humps full of radiating cracks resembling the top of a cauliflower (Plate IV). The tops of these humps are, as a rule, from 1

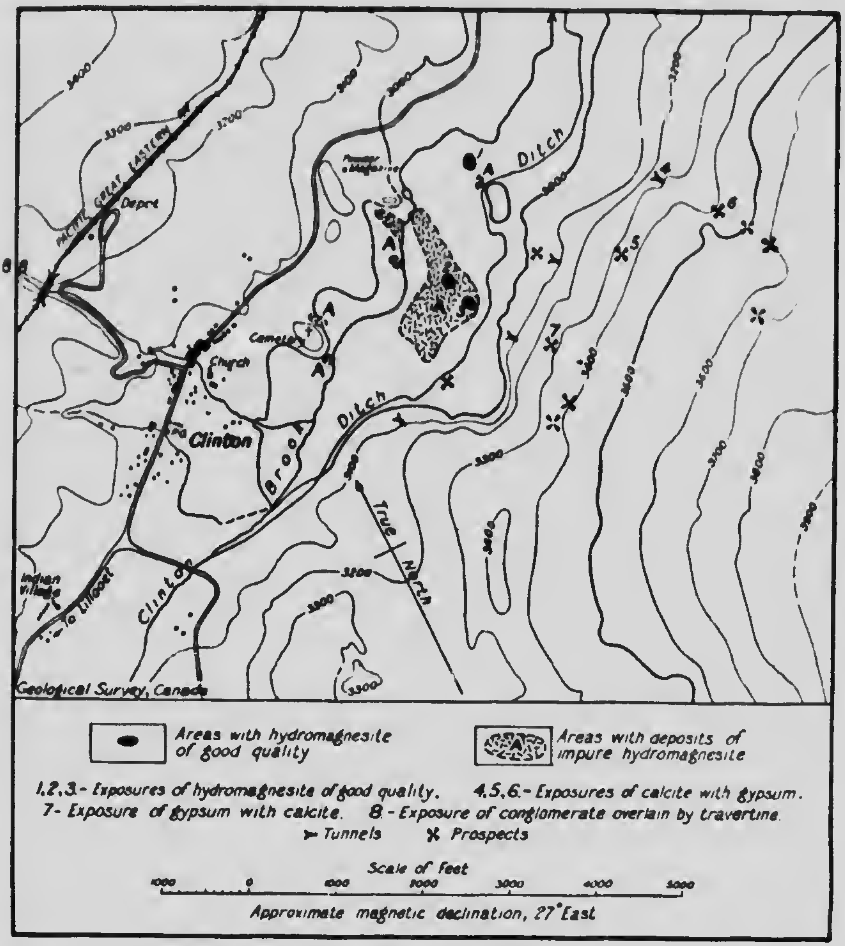

Figure 3. Hydromagnesite deposits near Clinton, Lillooet district, British Columbia.

to 2 feet higher than the ground between them. In certain places along the edges of the deposits, as at Meadow lake and elsewhere, lunar or cusp-shaped cavities filled with large basaltic boulders, but with practically no fine-grained material, lie between the cauliflower-like humps. The shapes of the cavities conform to the arrangement of the circular magnesite pat amongst which they lie. The impression gained is that the magn patches have grown upwards and sideways forcing the boulders to one and finally rising above them. That this is the true explanation is fur indicated by the presence of slight overlaps of the magnesite on indivi boulders. On the borders of large deposits outcropping at the surf there seems in places to be an overlap of soil resting on the magnesite; t is, in places, excavations made just outside of the main deposit reve foot or so of soil resting on a thin bed of hydromagnesite evidently a proj ing part of the main mass.

At Kelly lake and at Clinton near the main masses of hydromagne are occurrences of impure earths, carbonates and sulphates of magnesi and calcium, which form nodules lying at or just under the surface or occur as beds interstratified with sand or clay. One such nodule has b exposed in pit No. 7 (Figure 3), at Clinton (Plate V, and analyse and 8, Table IV). It is overlain by 6 inches of black soil and consists nearly pure gypsum and calcite along its upper border, but in depth th minerals are mixed with gradually increasing amounts of the boulder c in which the nodule lies. Under the nodule, traversing the boulder cl are fine, thread-like streaks of cream-coloured earth identical in compositi with the materials of the nodule (Plate VI). Nodular deposits of gypsu also occur on the steep hillsides at Kelly lake (Table IV, analysis Bedded deposits of calcite admixed with some gypsum and hydrous ma nesium carbonate (Table IV, analysis 2), are present in the shallow parts Kelly lake where they lie within a few inches of the surface of the wat (Plate VII) and deposits of the same character (Table IV, analysis occur interstratified with sand and clay in the flat west of Kelly lake.

COMPOSITION.

In the following table, analyses are given of the better grades hydromagnesite found at Clinton, Meadow lake, Watson lake, and Risk creek. This table represents the composition of the material in the deposits that may reasonably be expected to yield a commercial produc The yellow, granulated material under it is too high in lime as a rule to b of value. Analyses 1, 2, 4, 6, and 7 are of samples taken in such a wa that they represent an average of the full thickness of the layer sample and as stated in the table, in most instances the sampled layer represent the whole of the upper white bed. With these analyses is presented th average value of eight analyses of Atlin hydromagnesites taken from th report by G. A. Young in the Summary Report of the Geological Survey Canada, for 1915 and also the average of sixteen analyses of Californi magnesites. Analysis 5 was made in the Geological Survey laborator more than twenty years ago, on a sample which it is presumed was take from the cleanest material found near the surface of the deposit, but partic ulars as to the method of taking this sample are lacking. These results show the materials to be low in lime and other impurities. Analyses 2 and 4 reveal the presence of 4 and 4·6 per cent of silica respectively, which in all probability is derived from the fine, black specks scattered through the upper white hydromagnesite in many places. The composition of the spring waters (page 40) indicates that hydrated amorphous silica also may be present. The magnesia content runs from 41 to 43 per cent.

Table II.—Analyses of the Better Grades of Hydromagnesite.

No.	—	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	K_2O	CO_2	SO_3	Cl	H_2O above 105°C	H_2O below 105°C	Total	Calcium carbonate	Gypsum	Magnesium carbonate plus water of crystallization
1	Deposit at Clinton, Figure 3, locality 3, 0 to 24 inches from surface	2·30	0·63	0·13	.....	41·60	0·22	....	35·88	0·36	trace.	17·53	1·12	99·77	0	0·7	94·9
2	Centre main deposit at Meadow lake. Figure 5, locality 3, 0 to 15 inches from surface	4·00	1·36	0·14	0·23	41·38	1·32	0·14	37·67	...	...	12·12	1·48	99·84	2·4	.....	90·2
3	Average of five samples, 0 to 2 inches from surface, deposits 3 and 5, Meadow lake	1·22	0·67	0·18	0·63	40·56	1·26	.	35·95	.....	....	18·00	1·45	99·93	2·3	...	93·6
4	From east end of easterly deposit Watson lake, Figure 6, locality 5, 0 to 36 inches from surface	4·62	0·16	0·16	.....	43·17	1·14	.....	43·64	0·51	trace.	5·26	1·42	100·10	1·4	1·0	91·26
5	From Watson lake, exact locality unknown	1·73	0·12	0·07	.....	43·73	....	....	37·03	.....	.....	17·79	......	100·90	0	0	98·55
6	From centre of deposit, lot 178, Riske creek, 0 to 24 inches from surface	1·85	0·48	0·20	0·16	41·74	0·17	.....	40·85	0·11	none.	12·98	1·67	100·21	0·2	0·2	95·4
7	Towards southeastern end of deposit, lot 1188, Riske creek, 0 to 26 inches from surface	1·22	0·48	0·25	0·09	41·14	0·10	.....	37·70	0·08	none.	17·78	1·28	100·11	0·1	0·2	96·5
8	Atlin hydromagnesite. Average of eight analyses of pure white material	1·40	0·66	0·22	0·59	41·10	0·90	.....	35·39	.....	.....	18·36	1·38	100·00	1·6	0	94·16
9	California magnesite. Average of sixteen analyses	1·76	0·38	0·36	.....	45·38	0·99	.....	50·63	.....	.....	0·18	......	99·68	......	.....	

1 to 8. Analyses made in the laboratories of the Department of Mines, Ottawa. Analyses Nos. 1 and 4 by Frederick Baridon; Nos. 2, 6, 7 by A. Sadler; No. 5 by R. A. A. Johnston, Geol. Surv., Can., Ann. Rept., vol. XI, 1898, p. 11R. No. 8 average of eight analyses by N. L. Turner, Geol. Surv., Can., Sum. Rept., 1915, pp. 53 to 55; in these SiO_2 varied from 0·54 to 3·48, total Al_2O_3 Fe_2O_3 FeO from 0·64 to 4·22, and CaO from 0·26 to 2·04.

9. Calculated from results given in Bull. U.S.G.S. 355 by Frank La Hess, Washington, 1908. Silica ranged to 4·7 and 7·7 per cent in two analyses, lime to 5·3 in one, other variations from the given average are not important.

Variation in Composition with Depth.

In Table III certain analyses have been arranged to show the incr of lime in depth. Analyses 9 and 10 are of isolated deposits of no v that are included here for convenience. Analyses 1, 2, and 3 repre samples taken from the same section. No. 1 represents the upper w bed 15 inches thick which exists at the surface all over this deposit. N repr ents the underlying, granulated, cream-coloured bed 36 inches th and No. 3 the lower part of the deposit 15 inches thick. The lime con increases from 1·32 per cent in the upper white bed, to 6·38 in the gra lated, cream-coloured bed, and 25·55 per cent in the lower 15 inches of deposit. Samples Nos. 5 and 6 were taken from the same deposit fro pit situated a few hundred feet away from the locality of samples N 1, 2, and 3. In this case no distinction was made betw the beds, N represents the material to a depth of 39 inches and contains about 15 inc of the middle bed represented by analysis No. 2 above, and No. 6 represe the lower portion of the deposit between depths of 39 and 60 inches or alm down to the base of the deposit lying at a depth of 66 inches. By compar these analyses with analyses Nos. 1, 2, and 3, it is evident that the up half of the intermediate, cream-coloured bed is not as high in lime as t lower half. Analysis No. 4 is an average of the analyses of five samp taken from the two main deposits at Meadow lake[1].

The analyses represent the upper white layer which had an avera thickness in the five pits of about 2 feet. The average lime content the 3 to 4 feet of material underlying the upper white layer was said to 18 per cent. Analyses Nos. 7 and 8 are of samples taken at two differe places at Watson lake; No. 7 from the upper white bed, and No. 8 fro the upper bed and the upper part of the lower bed. In both these the lin content is low. The owner of the Watson Lake deposits states that th amount of lime is very small in the white earth portion of these deposit but increases to a marked extent in the cream-coloured, granulated laye that in most cases underlie the white material. The low content of lim in the white layer at Riske creek is indicated by analyses 6 and 7, Table I A sample taken from lower ground where the white layer is absent is sai to have been high in lime. The increase of lime content with depth i brought out strikingly, also, by comparing the calculated amounts of lim carbonate present in the two series of superposed beds represented by analyses 1, 2, 3, and 4, 5, and 6 respectively. The silica conten as exemplified by the analyses and by inspection of numerous test holes is erratic in its variation and does not invariably increase with depth. At Watson lake, in the easterly deposit, more siliceous impurities were visible in the upper foot of white material than in the next 3 or 4 feet of white material below, whereas in other patches the impurities seemed to increase with depth. At Meadow lake the upper layer generally appears the cleaner, but there are exceptions to this rule. In a prospect hole at the east end of deposit 3, Figure 5, for instance, numerous grains of sand occur in the upper 6 inches of an 18-inch layer of white magnesite. Analysis No. 10 is probably typical of the composition of many of the patches of grey white earth that lie near the deposits of clean hydromagnesite at Meadow lake, Clinton, and elsewhere. It is very high in siliceous impurities and also high in lime. The composition of the gypsum and calci e deposits at Kelly lake and Clinton are given in Table IV. t

[1]Analyses furnished by F. Calvert of Stewart Calvert Co., Oroville, Washington.

Table III.—Analyses to Show Variations in Depth of the Deposits.

No.		SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	K_2O	CO_2	SO_3	Cl	H_2O above 105°C.	H_2O below 105°C.	Total	Calcium carbonate ($CaCO_3$)	Gypsum ($CaSO_4 \cdot 2H_2O$)	Magnesium carbonate plus water of crystallization
1	Centre of deposit 3, Figure 5, at Mea[illegible]w lake, white earth, 0 to 15 i[illegible]s from surface.	4	[illegible]·36	0·14	0·23	41·38	1·32	0·14	37·67	none.	none.	12·12	1·48	99·84	2·4		90·2
2	Under[illegible]g No 1, granulated, crean. coloured earth, 15 to 51 inches from surface.	11·33	2·88	0·24	0·20	35·68	6·38	0·14	36·63	none.	none.	4·15	2·29	99·92	11·4	....	71·5
3	Underlying No. 2, cemented earth, base of the deposit, 51 to 66 inches from surface	7·60	...	.....	0·22	20·34	25·55	...							45·6		
4	Average of five analy es from deposits at Meadow lake, 0 to 24 inches from surface.	1·22	0·67	0·18	0·63	40·56	1·26	....	35·96	0·13	....	18·00	1·45	99·93	2·3	..	93·6
5	Near locality of No. 1, 0 to 39 inches from surface, takes in white layer and top of cream layer....	13·10	1·34	0·11	0·17	36·63	2·86	..	35·64	0·13	trace.	7·00	2·58	99·56	4·9	0·3	77·0
6	Below No. 5, 39 to 60 inches from surface. Base of deposit at about 66 inches.	10·32	1·35	0·49	..	24·32	20·12		38·64	0·14	trace.	2·93	1·45	99·76	35·8	0·3	50·1
7	Easterly deposit Watson lake. Figure 6, locality 5, white earth, 0 to 36 inches from surface.	4·62	0·16	0·16	...	43·17	1·14	....	43·64	0·51	trace.	5·26	1·42	100·10	1·4	1·0	91·3
8	Westerly deposit Watson lake. Figure 6, locality 3, includes 26 inches of white earth and part of layer of cream earth, base deposit at 85 inches.	6·36	0·20	0·12		41·06	1·62		38·04	0·08	trace.	11·25	1·32	100·05	2·8	0·2	89·10
9	Small deposit 1 mile northwest of Watson lake.	8·62	0·33	0·57	....	36·70	1·54	..	31·08	0·18	trace.	14·86	2·21	99·19[1]	....	....	
10	Grey earth northeast end Meadow lake, Figure 5, 0 to 24 inches, base deposit, 27 inches.	36·78	1·54	0·84	0·59	20·14	9·20		20·24	0·07	trace.	6·80	3·52	99·72			

[1] Including 3.1 per cent organic matter.

Table IV.—Analyses of Gypsum and Calcite Deposits.

No.	—	SiO_2	Insoluble including SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	CO_2	SO_3	H_2O above 105° C.	H_2O below 105° C.	Organic matter.	Total	Gypsum and anhydrite.	Calcite.	Magnesium carbonate and hydroxide.
1	Gypsum, just above wagon road north of and ¼ mile from west end of Kelly lake. Figure 2, locality 33	3·75	......	0·67	0·41	......	0·48	31·48	2·22	41·09	2·18	18·00	......	100·28	{ 41·6[1] 36·99[2]	5·0	
2	Calcite gathered from northeast shore Kelly lake under a few inches of water	......	9·30	0·28	0·29	......	0·66	47·70	36·76	0·24	3·72	0·53	......	99·48	0·5	83·5	0·9
3	Impure, bedded calcite interstratified with sand and clay in flat, west of Kelly lake	......	25·26	0·83	0·80	0·65	0·77	37·14	29·78	0·21	3·55	0·70	......	99·67	0·5	66·1	1·9
4	Locality 6, Figure 3, at Clinton 400 feet above the flat	......	42·00	1·75	2·25	0·26	2·49	23·04	14·64	6·29	3·73	3·62	......	100·07	13·5	33·00	3
5	Locality 4 at Clinton on hillside about 200 feet in elevation directly below locality 6	......	77·54	3·87	4·04	0·18	2·39	3·30	2·52	0·51	3·82	1·97	......	100·14	1·0	5·3	0·4
6	Locality 5 at Clinton, south of No. 4	......	60·10	2·62	2·69	0·44	3·33	13·84	10·44	1·37	3·07	1·76	......	99·66	3·1	22·9	5·6
7	Locality 7 at Clinton, 6 to 18 inches from surface (Plate V)	9·04	......	3·07	1·27	0·43	1·37	28·42	3·40	33·30	2·23	14·75	1·72	98·97	{ 42·65[1] 22·8[2]	7·7	......
8	Locality 7, 2 to 3½ feet from surface just below sample 7	......	35·86	1·16	1·64	[illegible]	1·70	19·80	2·60	23·50	3·10	10·92	......	100·57	50·5	6·00	......

[1]Gypsum.
[2]Anhydrite.

Mineral Composition.

In attempting to interpret the analyses in terms of mineral composition the writer was guided by the following considerations: (1) The sulphate radicle was combined with calcium as gypsum $CaSO_4+2H_2O$ or anhydrite $CaSO_4$, because the calcium sulphates are very much less soluble than the magnesium or ferrous sulphates, or sulphates of the alkalis. Gypsum[1] loses three-fourths of its water of crystallization when heated for some time at 100 degrees C., but retains the remainder to a much higher temperature. One-fourth of the water required to make gypsum must,

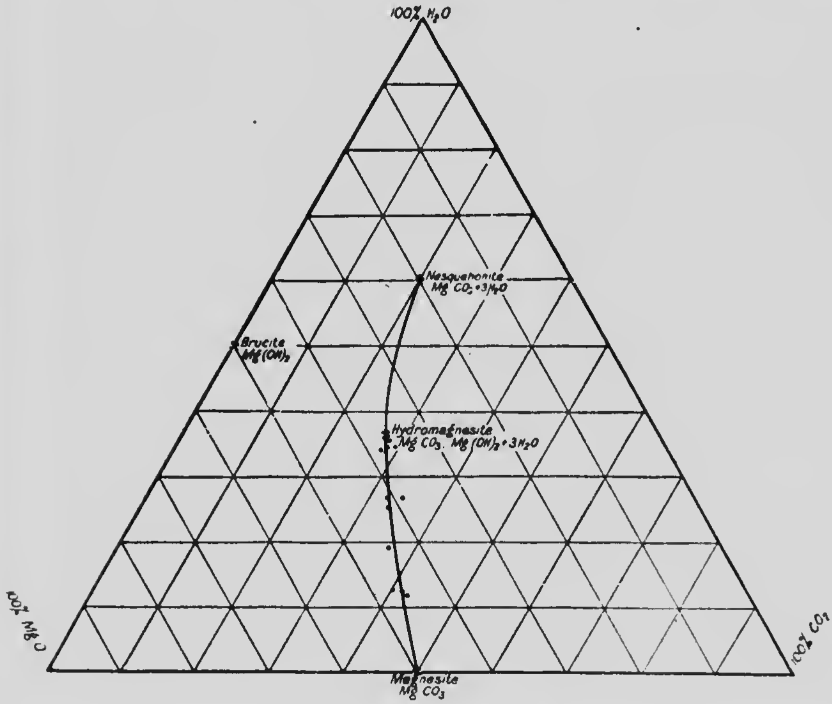

Figure 4. Chemical composition of hydrous magnesium carbonate compounds. (Plotted according to molecular proportions.)

therefore, come from the percentage given in the analysis as passing off above 105 degrees C. The maximum amount of gypsum present is, therefore, limited by the amount of water liberated above 105 degrees C. and for this reason it follows that anhydrite is present in both the earths high in gypsum represented by analyses 1 and 7, Table IV. The presence of gypsum crystals has been proved in these cases by microscopic work, but no satisfactory determinations were made of the very fine grains supposed to be anhydrite. (2) The calcium remaining after satisfying the available

[1]Thorpe, E. A., "Dictionary of applied chemistry," vol. 1, p. 611.

sulphate was calculated as calcite or calcium carbonate. Whenever t was a large percentage of calcium carbonate the presence of magnes hydroxide was assumed. This assumption was based mainly on the res contained in a very interesting paper by Johnston and the hypoth that the deposits under discussion have been formed at or very clos the surface of the ground, under temperature and pressure condit approximately that of the atmosphere (see pages 38 and 39). Altho ferrous carbonate is a very usual impurity in magnesium carbonate amount of ferrous iron in these earths is so low that it has, for the sak convenience, been omitted from the calculations. (3) Any carbon diox magnesia, and water of crystallization remaining after satisfying c ditions (1) and (2) above was assumed to exist as basic magnesi carbonate. In order to arrive at the probable compositions of th hydrous magnesium carbonates use was made of the diagram, Figure in the following way. The molecular proportions of magnesia, carl dioxide, and water of crystallization remaining were plotted in th relative proportions on the diagram. In the same diagram the miner magnesite $MgCO_3$, hydromagnesite $4MgO.3CO_2.4H_2O$, nesquehor $MgCO_3+3H_2O$, and brucite $Mg(OH)_2$ have been plotted according their respective molecular proportions. The points representing the ava able MgO, CO_2, and H_2O of the analyses lie, with very little variation, a smooth curve, the nesquehonite-hydromagnesite-magnesite curve, and lie between hydromagnesite and magnesite. The compounds who presence is thus indicated may belong to an isomorphous series of wh hydromagnesite and magnesite are end members or they may be distin compounds of compositions intermediate between hydromagnesite a magnesite.

TOPOGRAPHICAL AND GEOLOGICAL RELATIONS.

The deposits of pure hydromagnesite all lie on flat ground near t lowest part of the valleys in which they occur. The main deposit at Clint lies at the foot of a steep slope on the east side of the valley (Figure locality 3). Between it and the creek is a stretch of swamp a few feet low in elevation than the hydromagnesite. At Watson lake the deposits occu the same flat as the lake and the surface of the main deposit is about on quarter mile south of and 4 feet or so above the level of the lake (Figure 6 At Meadow lake (Figure 5) the deposits are in a valley that forms part the depression in which the lake lies and is without visible outlet. Both the deposits at Riske creek lie on the flat valley floor near the stream an a few feet above it.

At Clinton, unconsolidated sand and clay underlie the deposit. Th hill lying east of the Clinton deposit is mostly drift-covered, but such ou crops as were found were actinolite-schists and carbonaceous argillites the Cache Creek series, and rocks of the same character outcrop abo one mile to the south, and above the epsomite lake in elevation (Figure 8 In the railway cuts a mile or two to the north and several hundred fee above the flat, there are many outcrops of serpentine and other rocks Cache Creek age. These are capped by Tertiary basalts, but there is n reason to doubt that the flat under the hydromagnesites and the hil adjacent for several hundred feet above it, are underlain by Cache Cree rocks. At Meadow lake the presence of angular basalt boulders in pro fusion suggests that flat-lying beds of Tertiary basalt are not far below, but no outcrops of such rocks were seen. At the west end of Meadow lake, however, where a grey deposit at lake-level is said to contain hydromagnesite, there are outcrops of Cache Creek limestone lying several hundred feet above the lake-level. At Watson lake the deposit is underlain by green, stoneless clay at a depth of from 7 to 8 feet from the surface. This clay is yellowish or brownish at its contact with the deposit and carries freshwater shells. E. Whittaker of the Geological Survey, has made the following report on them:

"The fauna obtained from this clay consists entirely of immature and stunted forms. The following forms are represented:

Lymnaea (Galba) *tryonii* (Lea)
Planorbis cf. *binneyi* (Gould) (confirmed by Dr. F. C. Baker, University of Illinois).
Planorbis opercularis Gould
Planorbis parvus (Say)
Physa sp. very young individuals only.

"The above forms are all living at present, and all except *Planorbis parvus* are confined to the Pacific slope. They are freshwater, not land forms."

There are Tertiary lavas in the hills south of the deposits at Watson lake and basaltic ash rocks on the shores of 105-Mile lake to the north, and outcrops to the northwest down the valley appear to be older than the Tertiary. No outcrops were seen near the Riske Creek deposits.

Deposits of calcite and gypsum carrying a very small amount of hydromagnesite occur in the hill-slopes near the Clinton hydromagnesites and several hundred feet in elevation above them (Figure 3). At Kelly lake, deposits of gypsum occur in the steep hill-slope above the lake, and on fans in the lake just below the surface of the water are deposits of nearly pure calcite (Plate VII). The same material is found interbedded with sand and loam in the flat just west of the lake. About one mile east of the north end of Kelly lake, nodules of pink earth lie in boulder clay above argillites or phyllites of the Cache Creek series. They outcrop on the hill-slopes at various elevations within a few hundred feet of the valley floor.

ORIGIN OF THE DEPOSITS.

It is important from the commercial point of view to obtain a clear conception of how the hydromagnesite deposits were formed and placed where they are today, for only by so doing can the probable value and extent of such parts of the deposits as are not visible and have not been prospected be arrived at. The subject is, therefore, discussed at length.

The anhydrous magnesium carbonates, calcium carbonates, and calcium sulphates, described above, occur in this district, mixed in various proportion, and all these salts appear to have originated through the action of the same agencies. The deposit of epsomite, magnesium sulphate, at Clinton (Figure 9) occurs with sodium sulphate and hydrated magnesium carbonate and in origin is related to the others.

The hypothesis put forward to account for the Clinton deposits is as follows: The lime and magnesia which they contain were derived from rocks of the Cache Creek series; these bases were dissolved and transported to their present position as solutions in carbonated and sulphated waters of atmospheric origin, but travelling underground; the move of the underground waters, travelling in general from high to low brought these solutions to the surface at various places; the more inso calcium carbonates and sulphates were deposited first, and deposits on side hills, therefore, contain these salts in excess; the magnesium carbon stayed in solution longer and were deposited in the valley bottoms toge with the remaining part of the calcium; in the bottoms a further separa took place between the extremely soluble sulphate of magnesium (epson and the hydrous magnesium carbonates (hydromagnesite) the sulpha e b present only where the waters issuing from the ground have no n ea draining into streams. The chemistry of these solutions and precipitat is, of course, not as simple as stated. There was probably much o soluble material including sodium, potassium, and soluble silica in th waters (see analyses, page 40), the relative solubility and point of precip tion of any of the four principal salts at any given condition of temperat and pressure being affected by the relative quantities and kinds of mate in the solutions and perhaps by other factors. Finally, it is believed t these chemical activities are of very recent date and that some of th are in progress at the present time.

The evidence on which the above general hypothesis is based will discussed in connexion with the following topics and in the order indicat (1) the source of the calcium and magnesium; (2) the nature and ori of the waters by which they were transported; (3) the manner in wh they were deposited; (4) changes which have taken place since th deposition.

Origin of the Calcium and Magnesium.

There cannot be any doubt as to the derivation from Cache Cre rocks of the deposits at Kelly lake or Clinton. The Clinton area is large drift-covered, but a number of outcrops of actinolite schists and argillit of Cache Creek age occur in the hills east of the valley near the hydroma nesite and above it in elevation. The hill-slopes just east of the epsomi lake contain numerous outcrops of the same character. West of Clint the drift blanket is even thicker, but Cache Creek limestone and serpenti crop out several hundred feet above the valley for a few miles to the nort There is, therefore, no reason for believing that any but Cache Creek roc underlie the valley. The Kelly Lake gypsum-calcite material lies in a dee narrow valley with steep hills entirely underlain by Cache Creek rock The magnesium could be derived from a body of serpentine covered by th drift at Clinton (Plate X), although the actinolite schists are a very probabl source of a great part of the Clinton deposit. At Meadow lake there a no outcrops near the pure deposits, but the abundant basalt boulde point to the presence of beds of Tertiary basalt not far from the surfac That they are underlain at no great depth by Cache Creek rocks is indicate by the outcrops of Cache Creek limestone at the west end of the lake exposed up to elevations several hundred feet above the lake and above deposit of impure magnesite at lake-level. The basalt boulders show n signs of alteration such as would precede the formation of soluble magnesiu salts and it is most improbable that they are the source of any portion o the magnesium. The geology around Watson lake was not studied i detail. Most of the area around the deposits is drift-covered. Basalt-capped hills occur to the southeast and rocks resembling Cache Creek outcrop near the valley floor one mile to the northwest of the lake.

Means of Solution and Transportation.

The nature of the deposits indicates that they were derived from carbonated and sulphated waters. Surface waters percolating downward into the earth's crust contain carbon dioxide and free oxygen. If the waters traverse carbonaceous rocks such as the Cache Creek argillites, the amount of carbon dioxide is increased by oxidation of the carbon. Carbonated waters acting upon serpentine can dissolve the magnesium, yielding a solution from which magnesium carbonate and magnesium hydroxide may be precipitated according to the formula[1] $H_4Mg_3Si_2O_9$ (serpentine)$+CO_2 = MgCO_3+2Mg(OH)_2+2SiO_2+k$.

Carbon dioxide and water could react on the actinolite of the actinolite schists at Clinton to form the serpentine (bastite), together with $CaCO_3$ and water, thus $Ca(MgFe)_3Si_4O_{12}$ (actinolite)$+2H_2O+CO_2=H_4(MgFe)_3Si_2O_9$ (serpentine)$+CaCO_3+2SiO_2+k$. Further action of the carbon dioxide solutions on the serpentine would then produce solutions of magnesium carbonate and hydroxide, also iron carbonate (siderite) and hydrous silicate (opal). It is thus possible for the carbonates of magnesium and calcium to have formed from the altered Cache Creek rocks by the action of surface waters carrying carbon dioxide and oxygen. In connexion with the possible derivation of the magnesium from Tertiary basalts, it should be pointed out that serpentine and actinolite are both alteration products of original minerals of the more basic igneous rocks, and that, in general, the carbonates of magnesium and calcium seem to form more readily from certain of these alteration products than from the original minerals. Magnesite for example is more commonly derived from serpentinous rocks than from fresh olivine-bearing rocks such as the basalts.

Calcium may, of course, also be dissolved from limestones, by waters charged with carbon dioxide. Sulphated waters are a common product of the oxidation of pyrite in the rocks by surface waters. This gives rise under certain conditions to limonite and free sulphuric acid or soluble ferrous sulphate and sulphuric acid.[2] The sulphated solutions reacting on calcite or magnesite may form solutions of calcium and magnesium sulphate. After solution, the calcium and magnesium will be removed from the original source and transported elsewhere according to the direction of movement of the ground waters[3] until some point is reached where there is a change in chemical equilibrium sufficient to cause their precipitation.

The process of solution and manner of transportation have been abundantly proved in other localities. That such reactions are taking place within Cache Creek rocks in this region is shown by numerous examples.

[1]Van Hise, C. R., "A treatise on metamorphism," U.S.G.S., Mon. 47, p. 349.

[2]Van Hise, Op. cit., pp. 214, 215.

[3]Ground waters circulate downward to a zone of the crust in which the rocks are saturated. The upper limit of this zone or ground water level, is deeper on the hills and comes nearer to the surface in the valley bottoms. The waters travel along the upper part of this zone from higher to lower ground and issue as springs at favourable places on the hillsides or in the valley floors. Such as do not come to the surface will move slowly downstream close under the surface. These movements have been abundantly proved by tests, Lindgren, Op. cit., pp. 29, 30. Thus, the waters falling on high ground will percolate deeply into the rocks and take up their load of magnesium and calcium; some of them will come to the surface on the hillsides and deposit the salts that are the least soluble, the water containing the more soluble salts will flow over the surface or sink into the crust and join the main downward moving solution to be deposited in the valley bottom or carried down stream from there.

An instance of a deposit formed by the action of carbonated waters o Cache Creek rocks, is that of a brecciated rock lying near and sli higher than the epsom salt lake at Clinton. This breccia occurs amo actinolite schists and is made up of magnesite, siderite, and opal, th the products of the decomposition of actinolite by carbonated wa Near Kelly lake, crystals of gypsum with yellow oxide of iron, white nesium, and iron sulphate occur in a sheared and altered zone of car aceous argillite. The magnesium sulphate must be in process of form today, for though it is so soluble that a very light rain will wash it a yet there is an appreciable amount of it lying in partly sheltered cracks cavities in the surface. In the clay banks on Bonaparte river, descr elsewhere in this report, very strongly pyritized quartzites of the C Creek have been altered to gypsiferous clays. In an old mine tunne these clays the writer found specimens of magnesium iron sulphates l loose on the floor, not in place, but undoubtedly derived from the tun Cracks in the roof were filled with a white salt resembling magnesium phate still in process of formation, for it had dropped from the cra which was filled with the salt, to the floor and had there formed a sr ridge of salt deposited since the time that the tunnel was excavated. the Chromite mine on Chrome creek, magnesium sulphate was seen form in veinlets in serpentine and collecting in masses at the foot of serpent cliffs (Plate X). These are examples of the formation of lime and mag sium sulphates from Cache Creek rocks by sulphated waters as outli above.

Deposits of calcite, also, in fractured rocks of the Cache Creek, quite common. The Cache Creek formation, therefore, contains all materials needed to form the deposits discussed here, and in additi contains small examples of such materials near their points of origin.

Manner of Deposition.

In some instances these salts have clearly been deposited at certa focal points by waters percolating upwards through the drift. Plate illustrates the mode of occurrence of gypsum at locality 7, Figure 3, Clinton. Analysis 7, Table IV, represents the composition of the upp nodule; analysis 8 is of material below No. 7 taken from a section betwee depths of 2 and 3½ feet from the surface. By disregarding the insolub matter in the analyses it is seen that the white earth in the nodule an the white streaks in the boulder clay below are composed of gypsum an calcite in practically the same proportion of about 9 to 1. The white eart in the nodule and in the streaks is, therefore, identical. The white earth i the boulder clay gradually decreases in quantity downwards, and evidentl lies in very small fractures and capillary openings in the clay. Plate V illustrates in detail a portion of the wall pictured in Plate V and show the fineness of the threads of gypsum and the manner in which the amoun of gypsum increases upward.

The extreme sharpness of the line between the upper surface of th pure gypsum earth and the overlying black soil is remarkable. There i no mixing of soil and gypsum, no gradation upward corresponding to the gradation downward into the boulder clay. The gypsum and calcite have evidently travelled upward in solution along seams and capillary openings in the boulder clay and have been deposited close to the surface at the base of the humus line. The nodules appear to have "grown" from certain favourable foci forcing the soil sideways and upwards rather than penetrating it. The force of crystal growth is sufficient to accomplish this.

The nodule above referred to is situated on the slope of the hill at a point where a moderate slope changes below into a sharper one (Figure 3, locality 7). The main hydromagnesite deposit (No. 3) lies directly below it. At Kelly lake such nodules of gypsum with calcite are numerous and form small humps on the sides of the hills. They lie within the bedrock as well as on top of it in the drift. These nodules clearly were formed at or near the surface by upward moving waters.

The distribution of the main deposits in the flats at Clinton, Meadow lake, and Watson lake indicates deposition at certain focal points or areas in the flat land rather than as sheets covering the bottom of a lake, that is, they were formed at the points where underground waters reached the surface of the ground and spread out therefrom. The hydromagnesite patch (Figure 3, locality 3), at Clinton, for instance, lies at the foot of the hill about 4 feet above the general level of the flat to the west and 8 feet above the creek level. If it had been precipitated by the evaporation of the waters of a saline lake the deposit would originally have covered all of the flat land to an approximately equal depth and its presence now at but one point could have resulted only from the carrying away of large parts by erosion. The same may be said of the other deposits. Evidence exists to show that they have been formed since glaciation and since the glacial period there has been no erosion of any account in the Meadow Lake flat. Moreover, the hummocky portions of the surfaces of the deposits (Plate IV) do not resemble mounds left by erosion but, rather, structural forms due to growth outward from a centre. The stone craters at Meadow lake are in plan exactly like the interstices between a set of closely spaced circles. These craters contain large stones only and extend several feet in depth below the tops of the circular hydromagnesite masses alongside. Such a condition could not have arisen if the hydromagnesite had been deposited as a precipitate from lake water.

Granting that the waters carrying these salts rose as springs, the finding of shells at the base of the deposits at Meadow and Watson lakes indicates that the springs in many places reached the ground surface at the bottom of ponds, but their growth has in these cases also been around certain focal points or areas. Freshwater shells have, moreover, been found in deposits of carbonates of magnesium and calcium lying on the slopes of a hill below a mineral spring near 141 Mile House.

The action of underground waters with reference to such deposits as those in question, is illustrated by the appearance of a white efflorescence on the hill-sides below the irrigation ditch at Clinton. The water soaks downward from the ditch line, dissolves the salts disseminated through the soil and deposits them on the surface.

The following analyses of the waters of two springs and of the lime and magnesium carbonates deposited around them are given as an example of the manner in which the calcite, gypsum, and hydromagnesite are formed. The spring whose water is represented by analysis No. 1 is situated a short distance east of the railway track opposite 141 Mile House: the second spring (analysis No. 2) occurs beside the north fork of Riske creek three-quarters of a mile above the main deposit of hydromagnesite.

Table V.—Analyses of Spring Waters.

	I.
Parts of solid matter per 100,000—	
Sodium (Na)	102·35
Potassium (K)	9·95
Calcium (Ca)	2·27
Magnesium (Mg)	41·93
Iron (Fe)	9·25
Carbonic acid (CO_3)	165·91
Bicarbonic acid (HCO_3)	34·32
Chlorine (Cl)	9·82
Sulphuric acid (SO_4)	None.
Phosphoric acid (PO_4)	None
Silica (SiO_2)	4·99
Fluorine	None
Boron	None.
Total dissolved matter as found by drying at 180 degrees C.	341·71
	309·15
Specific gravity	1·005

"Reaction, as received, faintly alkaline; after evaporation to sı volume, strongly alkaline." Analysed by A. Sadler, Mines Branch. temperature of the spring water No. 1 on August 29, 1919, was 55 degrees air temperature 66 degrees F., in the shade.

Two partial analyses are given below of cream-coloured, earthy ma ials occurring near the spring at 141 Mile House and whose waters represented by analysis No. 1 above. The earthy materials are very simi in general appearance, to the large deposits already described. B analyses are of samples taken close to a stream 7 inches wide and 1 i deep, issuing at the spring. Sample "a" was taken 20 feet downstre and at the same level as the orifice of the spring. The material is coher and has formed in horizontal layers. Sample "b" was taken 100 feet dow stream and 18 feet in elevation below the spring; the material is crea coloured, and granulated, like the impure earths underlying the hyd magnesite of the main deposits.

Table VI.—Analyses of Earths Deposited by a Mineral Spring.

	a	b
SiO_2	8·78	5·2
Fe_2O_3	3·58	0·6
FeO	1·32	0·7
CaO	44·31	43·3
MgO	2·14	5·0
Na_2O	0·10	0·0
K_2O	0·58	0·36
SO_3	trace.	trace.
CO_2 estimated	36·84	35·10
H_2O loss below 105°C.	1·30	2·02
H_2O loss above 105°C.	1·80	4·04
Carbonaceous matter	None.	4·01
Totals	100·75	100·44

The material analysed above covers the slope of the hill below the spring for 100 feet or more. It is mostly calcite with magnesium carbonate and a minor amount of alkalic carbonates.

The sheets of impure magnesite such as are found at lake-level at both ends of Meadow lake, the calcite deposit on the benches in Kelly lake (Plate VII) and in the beds west of the lake, etc., prove, on the other hand, that precipitation from the waters of certain of these ponds actually has taken place. Quantitatively, this mode of origin is of minor importance, however, and the pure hydromagnesites have been formed almost solely by precipitation from ascending waters.

Order of Deposition. The separate deposition of the hydromagnesite and of the calcite and gypsum may be explained as due to the greater insolubility of the calcite and gypsum which would cause them to be precipitated before the magnesian carbonates; the relative proportion of calcite to gypsum would depend on whether sulphates or carbonates were in excess. Johnston[1] has shown that in water containing only magnesium and calcium carbonates in solution under atmospheric conditions, most of the calcium will be precipitated before the magnesium. This general rule is illustrated by the relative compositions of the earths from 141 Mile House and the spring waters from which they are derived. The waters carry a large amount of carbon dioxide in solution and carbonates form the bulk of the precipitated earths. In the spring water the molecular proportion of magnesium is in excess of calcium by about 9 to 1, whereas in the earths precipitated from this water, calcium is in excess by 2 to 1 in one case and 6 to 1 in another. Again, at Clinton, the underground waters moving from the high eastward ridge westward to the valley floor, lose some of their load of calcium at such places as localities 4, 5, 6, and 7, Figure 3, by forming through the agency of springs, nodular deposits of calcite and gypsum (Plates V and VI and analyses 7 and 8, Table IV) but a certain proportion of the calcium remains in solution until the waters reach the flat at a locality such as No. 3, Figure 3, where nearly all the ground water rises to the surface as already explained. If for the sake of simplicity it is assumed that the amount of sulphate still present is very small, the following process should take place. The checking of movement due to change of grade, the mixing with other solutions, the loss of carbon dioxide, etc., would cause the precipitation first of the available calcium as calcite, followed as the chemical equilibrium changed by the deposition of the magnesium salts. The resulting precipitate near or at the surface would be porous, with more magnesium at the top than at the base. The deposit would grow upward and as the process continued and the deposit grew thicker, more calcium would be precipitated at the base and more nearly pure hydrous magnesium carbonate would be formed on top. If the waters forming these deposits could freely drain away, the more soluble elements, such as the sulphates and chlorides of magnesium, and the sulphates, carbonates, and chlorides of the alkalis, sodium and potassium, would be almost if not completely carried away. Thus the combined amounts of the alkalis present in the spring water (Table V, analysis 1) are far in excess of calcium and magnesium, whereas only insignificant amounts of these have been precipitated near its point of issue (Table VI) analyses a and b. Where such free drainage does not take place these more soluble salts are precipitated, see pages 54-56.

[1]Johnston, John, "The solubility product constant of calcium and magnesium carbonates." Jour. Am. Chem. Soc., vol. 37, No. 9, Sept., 1915.

The recent origin of these deposits is indicated by their formatio the present time around springs such as the one at 141 Mile ranch an the finding under 7 feet of these deposits of freshwater shells of types li today in places like the Watson Lake outcrop.

Origin of Magnesite.

The magnesian carbonates of these deposits, as indicated by results of the analyses, belong to the series nesquehonite, hydromagne and magnesite, and lie between the two last in composition (Figur page 33). It is evident from a consideration of the diagram that t could be derived from nesquehonite by simple dehydration. Nesqueho is much more soluble than magnesite and can be obtained from a solu of magnesium bicarbonate and carbon dioxide in water, by removing carbon dioxide[1]. It is, therefore, possible that these carbonates v precipitated as nesquehonite and have come to their present state dehydration. It is significant that, as shown by analyses, in the dee parts of these deposits the water content is less than in the overly surface material (Table III), and microscopic work indicates tha proportion of the magnesium in the lower layers is present as anhydr magnesium carbonate, either magnesite or dolomite (see page 26). T suggestion is made that magnesite might be formed by further dehydrat of deposits of this sort. If tabular bodies of hydrous carbonates were l down and later deeply buried and consequently subjected to pressure a heat, it is rational to suppose not only that they might be entirely dehyd ted but also that they might become coarsely crystalline as in the case the metamorphism of originally fine-grained limestones. The underlyi impure beds would furnish dolomites such as are associated in so ma cases with crystalline magnesite. Not enough work has been done, eitl microscopically or chemically, to demonstrate the value of the abo general hypothesis, but at least certain occurrences of magnesite m have originated in this way and a new line of attack is indicated to th who are interested in the problem of the origin of magnesite.

Hypotheses that do not differ materially from the general theo outlined above have been put forward to account for the hydromagnesit at Atlin, B.C., as described by Gwillim[2], Robertson[3], and Young[4]. The deposits resemble those of the Clinton-Cariboo district very closely. Ho mann[5] analysed the water from a spring issuing from the centre of one these deposits and found it to contain 1·9204 parts of magnesia and 5·93 of carbon dioxide out of a total of 8·2633 parts of materials per thousar parts of water. The material from which this spring issued consisted 15 to 24 inches of hydromagnesite at the surface, underlain by somewh discoloured alternating layers high in lime with varying amounts of ma nesia and some iron and continuing to a depth of 6 feet and more since th base of the deposit was not uncovered.

Gwillim described the beds as being raised several feet above th surrounding land and both he and Hoffmann concluded that the deposit of hydromagnesite were deposited by springs whose waters were simila

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[1] Wells, Roger C., "The solubility of magnesium carbonate in natural waters." Jour. Am. Chem. Soc., vo XXXVII, No. 7, July, 1915, pp. 1704-1707.

[2] Gwillim, J. C., "Report on the Atlin district, B.C.," Geol. Surv., Can., Ann. Rept., vo. XII, 1897, pp. 47-4

[3] Robertson, W. F., "Annual Report of the Minister of Mines of British Columbia, for 1904," pp. 82-83.

[4] Young, G. A., Geol. Surv., Can., Sum. Rept., 1915, pp. 50-61.

[5] Hoffmann, G. C., Geol. Surv., Can., Ann. Rept., vol. XIII, 1900, pp. 47-51R.

to the one analysed. Robertson stated that the hydromagnesite forms hummocks in a low, swampy depression, "which are constantly rising higher and higher and now form mounds 5 to 8 feet above the swamp level." He concluded that carbonated swamp waters obtained magnesium carbonate from underlying soft magnesium rock and that the process of deposition was such as to cause the material to "grow up" from below.

Young points out that there is no evidence of magnesium bedrock directly underlying the Atlin deposits, that there may be 200 feet of unconsolidated drift between them and bedrock. He believes the earths were deposited in ponds by concentration due to evaporation, by the loss of carbon dioxide, or through some other cause. He combats the spring hypothesis vigorously, although stating that the ponds presumably receive their water by underground ways.

The writer believes that in Atlin as in the Cariboo-Clinton areas, the hydromagnesites were carried to their present sites in solution by underground waters and were not transported either mechanically or in solution by waters flowing over the surface. Precipitation occurred in ponds or on dry land according to the surface conditions existing at the place of emergence of the waters.

COMMERCIAL EXPLOITATION.

No attempt has yet been made to develop these deposits of the Cariboo-Clinton areas. The information upon tonnage given below is based for the most part on the examination of borings made with an auger by the writer in 1919. The outlines of the areas in practically all cases were measured with a steel tape. K. A. Clark of the Mines Branch determined the apparent specific gravity of the material in its natural state as 1·22. This makes the weight of a cubic yard of the hydromagnesite as it lies in the ground, including voids, 2,050 pounds. This factor was employed in calculating tonnage instead of the true specific gravity of hydromagnesite. The results of the borings made in 1919 necessitate a revision of the tonnage as estimated in 1918.[1] The final estimates of the amounts of hydromagnesite of possible commercial value are: at Clinton, 3,000 tons; Meadow lake, 114,000 tons; Watson lake, 23,000 tons; Riske creek, 13,500 tons. These estimates apply only to the upper white layer of hydromagnesite which in all cases is low in lime but varies considerably in the percentage of siliceous impurities (Table II). Austrian magnesites with total impurities ranging from 5 to about 12 per cent have been extensively used in the dead-burned form for refractory purposes and, lately, Quebec deposits high in lime have been used after treatment for the same purpose, so that it is difficult to set limits to the percentage of impurities that would condemn a hydromagnesite for commercial purposes. It is believed that the white hydromagnesite layer, and in places the top of the granulated, will prove to be of commercial value. All of the deposits are soft enough to be excavated by steam shovel, although it may be difficult to do so without including the lower more impure layers.

The Clinton and Watson Lake deposits lie from 1 to 2 miles from the railway, Meadow lake is 16 miles distant by road over easy grades, and Riske creek 35 miles over very steep grades. Clinton, Watson, and

[1] Reinecke, L., "Undeveloped mineral resources of the Clinton district," Trans. Can. Min. Inst., vol. XXII 1919, and Bull., Can. Min. Inst., Sept., 1919, p. 942.

Meadow Lake rail shipping points are about 170 to 220 miles from Sq mish and about 40 more from Vancouver. The Riske Creek deposit is far from the railway to be considered of importance at the present ti Owing to these long hauls it will be advisable to calcine the magnesite the shipping points, thus reducing the weight by more than 50 per ce It seems probable that the high freight rates across the continent will m the shipping of crude magnesite to the eastern markets unprofitable soon as rates of ocean freights fall. Refractory magnesite products w also, have to compete with the Quebec magnesites from which a sa factory high refractory is now being made. In the west, British Colum magnesites will have to compete with those of California and Washingt

Clinton.

In Clinton three areas have been mapped as commercial hydrom nesite; these are localities 1, 2, and 3, Figure 3. Area No. 1 covers square yards, the upper 3½ to 4½ feet of which is clean hydromagnesi below there is brown hydromagnesite extending to where clay commenc about 5 feet below the surface. The calculated amount of hydromagnes present is 355 tons. Area No. 2 covers 1,200 square yards with 2 feet fairly pure material on top; the estimated content is 820 tons. Area No covers 1,850 square yards. Three holes showed pure material down 2, 3, and 2 feet, respectively, with a little siliceous impurity in two cas The quality is expressed in analysis I, Table II, in which silica, iron, a lime impurities are seen to be low. The estimated amount of pure mater is 1,474 tons. The total amount of commercially valuable material Clinton in round numbers thus is 2,650 tons, but of this amount, 9 tons is of doubtful purity. In addition, as indicated in Figure 3, a relativ large area is occupied by material not of commercial value. Prospecti has been done in the hill-slopes above the hydromagnesite deposit, in search for bodies of magnesite in the bedrock, but there appears to be valid reason for believing that such bodies are present.

The Clinton deposits are about 1½ miles by road from the railw station and 275 feet in elevation below it. Clinton is 167 miles fro Squamish and about 207 from Vancouver.

Meadow Lake.

Five areas as well as some spots, of pure hydromagnesite, are present Meadow lake as shown on Figure 5. Areas Nos. 1 and 2 together cov about 16,500 square yards. They contain a grey white hydromagnesi of doubtful quality but probably fairly pure. The depth varies from 6 18 inches, below which the hydromagnesite is decidedly brown in colo and a drab clay occurs at depths from 2½ to 4½ feet. The estimated amou of hydromagnesite present is 5,640 tons.

Area No. 3 covers 154,000 square yards. In eight openings the dept of white hydromagnesite ranged from 11 to 30 inches with an avera of about 18 inches for most of the deposit. In places, very fine, blac specks are visible in the material. Analyses Nos. 2 and 3 of Table indicate the quality of the hydromagnesite and show it to be low in lim but with a variable silica content. Underlying the purer hydromagnesi is a cream-coloured material averaging 3½ feet in thickness, below whic

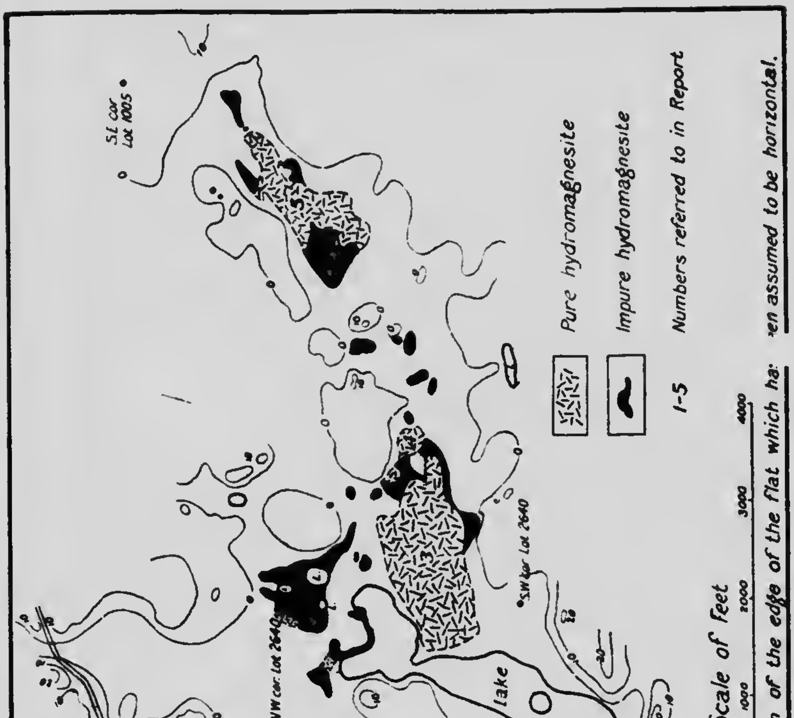


Figure 5. Hydromagnesite deposits at Meadow lake, Lillooet district, British Columbia.

there is an impure earth generally cemented to hard rock and resting sand or boulders. Analysis 2, Table III, represents the composition the cream-coloured earth and analysis 5, Table III, shows the composit of the whole of the white and the upper part of the cream-coloured la Analysis 3, Table III, is of the cemented layer at the base, and analysi Table III, of the lower part of the cream layer and the base. Ther slightly less silica and a very much greater proportion of lime in the cemen base than in the overlying cream-coloured layer. In the cream-colou layer there is more silica and lime than in the overlying hydromagnes The estimated amount of white material in area No. 3 is 78,900 tons

Area No. 4 covers 8,200 square yards. In two openings the wh layer varied from 12 to 18 inches in thickness. Beneath this was a 6-i layer of brown sand underlain by a foot or two of cream-coloured ear The estimated amount of white is 3,500 tons.

Area No. 5 covers 56,000 square yards. The depth of white mate varied from 12 to 21 inches with an average of 15 or 16 inches. T calculated amount of white is 25,920 tons. Below this is granular, crea coloured material to a depth nearly everywhere of 4 feet from the surfa under which is cemented material. In one hole the cemented mater was penetrated and in this case, grey and brown clay extended downwar from a depth of 5 feet 8 inches; the water level was reached at a depth 7 feet 1 inch. The total amount of commercial hydromagnesite in t area is estimated in round numbers at 114,000 tons. The water le lies well below the best material. These deposits are 16 miles dista over a road of good grade from Chasm station at 59 Mile House. Fro Chasm to Squamish is about 180 miles.

Watson Lake.

There are five small areas at Watson lake (Figure 6), all owned b A. E. Carew-Gibson of Vancouver. Area No. 1 lies on low ground a covers 2,250 square yards. An auger hole gave the following sectio cream-coloured, sticky hydromagnesite 2 feet thick underlain by 2½ fe of greyer to nearly white material of the same general character; und this, yellowish earth with white particles for 1½ feet resting on green cla at a depth of 5½ feet from the surface. Water stood at a level of 4½ fe below the surface and the material just above was greenish. The est mated amount of the two upper layers is 3,720 tons.

Area No. 2 covers 1,050 square yards. An 8-foot auger hole showe (*a*) white material, 18 inches thick, containing 535 tons; underlain b (*b*) 27 inches of yellowish earth; this by (*c*) 6 inches thick, browner than (*b* and full of grit near its base; (*d*) 27 inches white like (*a*) with some san particles, water present at the base; (*e*) 9 inches of browner earth; (*f*) inches of whiter earth than (*e*). At the base of (*f*), 8 feet from the surface the material was cemented hard and the hole was abandoned.

Area No. 3 covers about 7,300 square yards. According to the owne the average depth of the white, upper layer is about 23 inches. Some o this is grey or cream-coloured rather than white. Below is cream-coloure to brown material. The depth of the whole deposit varies greatly. Th owner states that he found it to be 85 inches deep in one place with 2

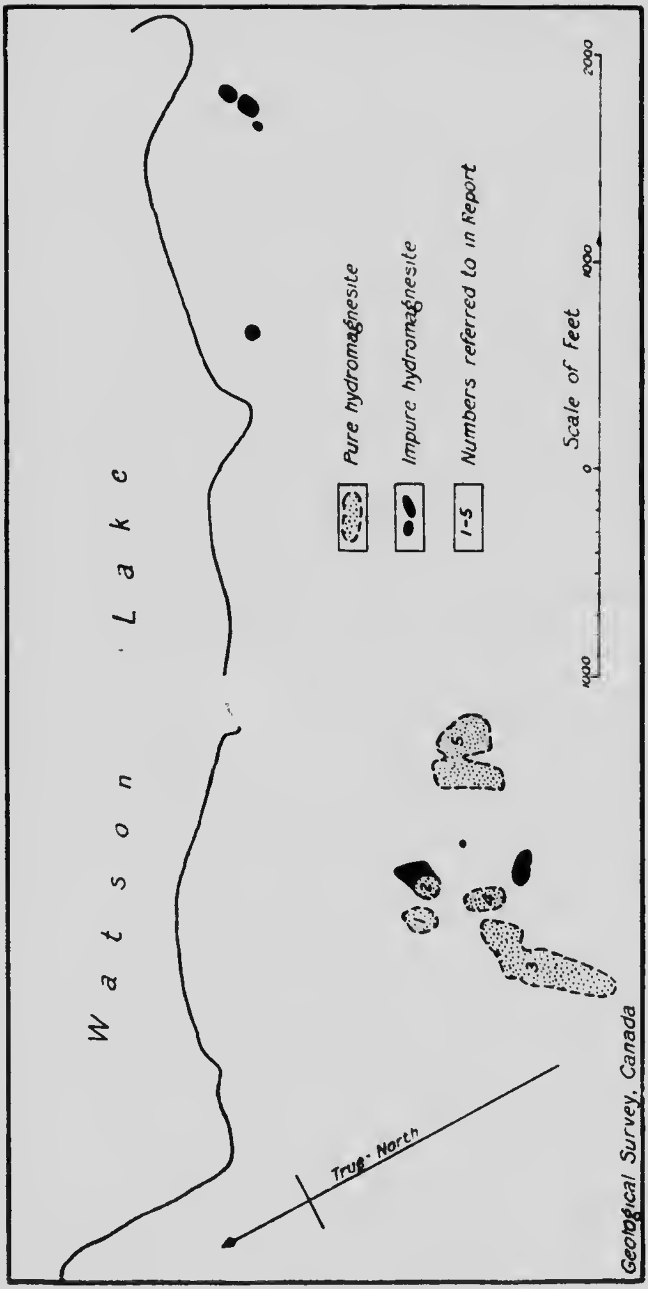


Figure 6. Hydromagnesite deposits at Watson lake, Lillooet district, British Columbia.

inches of white material on top, the base lying on dark grey mud. T
writer found the base at 54 inches toward the other end of the depos
The amount of commercial magnesite is estimated at 4,570 tons.

Area No. 4 covers about 1,500 square yards and the upper layer
pure material has an average thickness of 16·5 inches. Below this in o
hole there is 3 feet 6 inches of yellowish hydromagnesite becoming hard
and carrying more grit toward the base; the same earth but with mo
grit and brown colour continued to 8 feet 6 inches from the surface. Und
this was 6 inches of reddish earth with freshwater shells and carbonaceo
remains of roots and seeds. At the very base a plastic green clay wa
penetrated to a depth of 15 inches. There are 680 tons of the upper lay
here.

Area No. 5 covers 8,950 square yards. Three holes in the east ha
showed fairly pure material from the surface down to 60, 48, and 37 inche
respectively, with black specks showing toward the surface. In one hole
band of yellowish material separated a top layer of white from a 2-foo
band of white below. Below to the bottom of the deposit at 7 feet 3 inches
was impure brownish earth. In another of the three holes the materia
from the base of the fairly pure hydromagnesite became gradually dirtie
down to the bottom of the deposit at 7 feet 6 inches. In the third bore
hole, with 60 inches of white material, the underlying earths graduall
changed in colour from grey to pink and the bottom of the deposit was a
8 feet 10 inches. The white and pink earths overlay a green clay with
freshwater shells. In the west end of this patch a hole showed grey-whit
material with black specks to 54 inches. From there it was white, but with
much silica to 6 feet. Below this there was clayey material. The amoun
of the upper white material is calculated to be 13,232 tons.

The total quantity of commercial magnesite at Watson lake is in
round numbers 23,000 tons. The quality of the upper white layer is
expressed in analyses 4 and 5, Table II, and analysis No. 8, Table III.
It is uniformly low in lime, but the silica content varies as it does at Meadow
lake, and is high in places.

The Watson Lake deposits are about one mile from the railway grade
and below it in elevation. The shipping point would be about 225 miles
from Squamish.

Riske Creek.

The area on lot 178, Riske creek, owned by S. M. Becher, Riske Creek,
covers 10,000 square yards. One auger hole showed white to cream-tinted
hydromagnesite to a depth of 33 inches; from there down to 4 feet 2 inches
the earth became gradually browner. At that depth there was brown
clay. The estimated tonnage of the white is 6,900 tons, but this is based
on only one opening, and may be much less. An analysis of material from
the upper 2 feet in the auger hole indicates magnesite of very good quality,
Table II, analysis 6.

The deposit on lot 1188, owned by A. E. Carew-Gibson of Vancouver,
covers 26,000 square yards, of which 7,775 square yards is covered by
white hydromagnesite standing slightly higher than the remainder. Two
holes in the pure earth showed white material to depths of 2 and 3 feet,
respectively. Below this the earth became browner and dirtier looking.
The holes were not bored below 3 feet 7 inches. Analyses made from the
material from one of the holes, 0 to 26 inches from the surface, is given in

Table II, analysis No. 7. It is a high grade hydromagnesite. Analyses made on the lower lying and yellower outcrops to the west are said to have yielded results that were high in lime. The estimated amount of pure hydromagnesite is 6,600 tons and the total for the two deposits is 13,500.

The Riske Creek deposit lies west of the Fraser about 35 miles from the railway at Williams lake, and about 305 miles from Squamish.

CALCAREOUS TUFA.

In a railway cut at 42-Mile post, about 2 miles southwest of Clinton, a deposit of consolidated calcareous tufa is exposed. It was not analysed, but from qualitative tests is probably composed almost entirely of calcium carbonate. A similar deposit on Clinton creek west of the railway bridge contains iron, manganese, and other impurities as well as lime carbonate. The tufa is a bedded, firmly compacted rock unlike the unconsolidated, more or less incoherent hydromagnesite and associated deposits described above. It is white to cream-coloured and certain of the denser beds show many minute, glistening faces with a silky lustre. Under the microscope it appears to be composed of particles about 0·001 to 0·003 mm. in diameter with very high birefringence. Nearly all these particles show well-developed crystal faces and the crystals appear to be equidimensional, showing rhombs and prism faces. The material, as proved by testing with ferrous ammonium sulphate,[1] is calcite and not aragonite. The individual beds are very thin with many irregular cavities between them, lengthened in the plane of the bedding and showing small, somewhat spheroidal protuberances on their inner surfaces. In certain of the freshly opened hydromagnesite deposits very similar cavities are present, although they are on a smaller scale, perhaps because the slightly coherent state of the hydromagnesite mass would prevent the forming of larger open spaces.

The deposit is dome-shaped. It measures about 500 feet across in the railway cut, where it is exposed to a depth of 17 feet. The bedding planes are horizontal in the central part of the deposit, but outwards from there, dip downwards toward the edges, the beds being parallel to the dome-shaped upper boundary of the mass. Individual layers vary in thickness from one-quarter inch to 2 feet. The upper surfaces of certain layers are covered with wave-like corrugations resembling ripple-marks and where these occur on inclined beds the lower edge of the corrugations is steeper than the upper edge (Plate VIII).

The most remarkable feature of the deposit is a structure closely simulating folding (Plates VIII and IX). In places a series of these beds changes laterally into a bulging, pillow-like dome structure. In other places the beds, through a varying distance vertically and for spaces of 8 inches to 2 feet horizontally, appear as if closely folded into very sharp anticlinal forms, but between the steeply inclined axial planes of these fold-like structures, the beds lie almost perfectly flat. The flat-lying parts of the beds are porous, the "folded" parts are dense and traversed by radial cracks normal to the surface. In still other places, two superimposed sharply "folded" beds are separated by an absolutely flat-lying layer of travertine and soft clay. As seen in cross-section along the railway cut, the "folds" are overturned towards the outer edges of the deposit. The same layer is flat-lying and porous in one place, whereas a few inches away

[1]Rosenbusch, H., Mikroskopische mineraloque I i, p. 441.

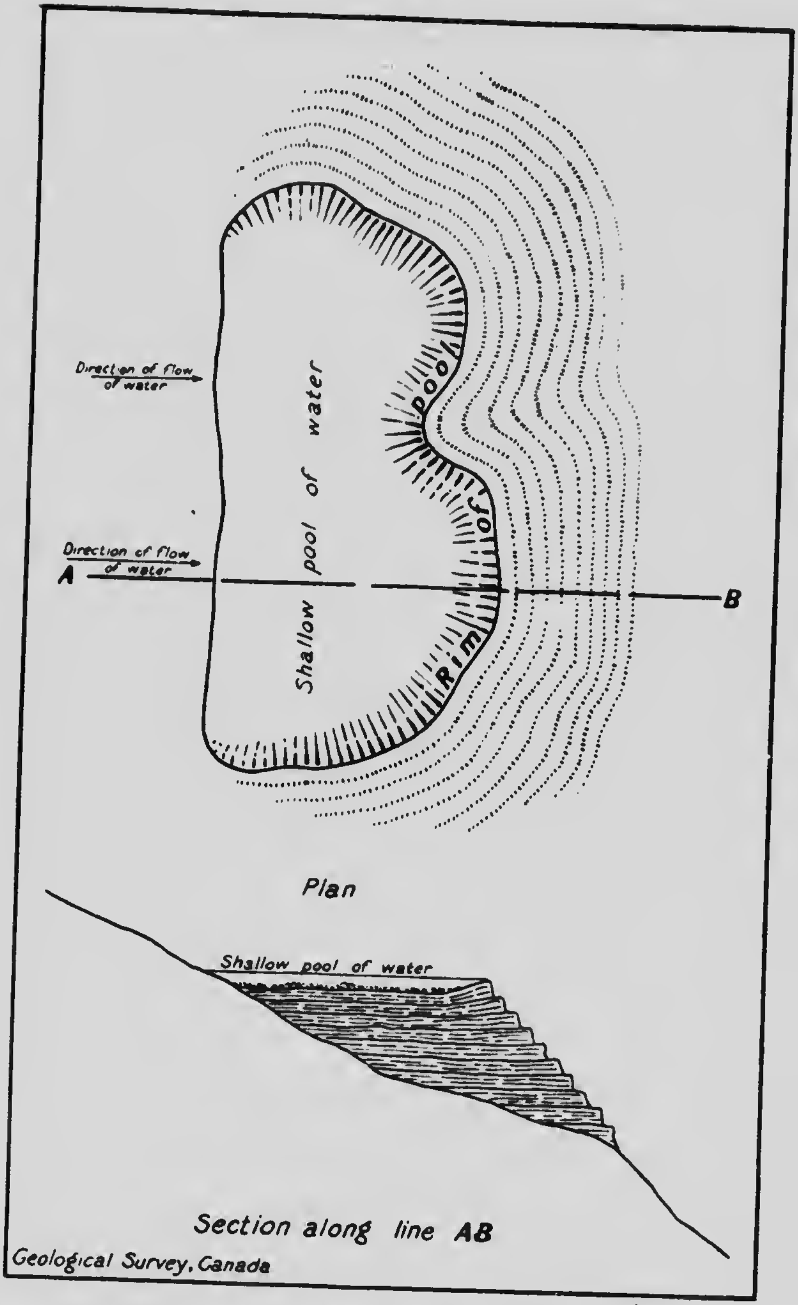


Figure 7. The mode of formation of corrugated ridges in travertine.

it is dense and appears as if sharply bent. In one place an apparent fault grades upward within 3 feet into a "fold," but within that distance the strike of the beds on one side of the fracture has changed through an angle of 90 degrees, whereas on the other side the strike shows little change. The same type of apparent folding was seen in process of formation at the soda-magnesia-lime carbonate spring at 141 Mile House. The carbonated waters (analyses page 40) have there in places dripped over logs and deposited lime and magnesium carbonates in curved beds conforming in shape to the surface of the logs. Corrugations similar to those illustrated in Plate VIII were seen forming as rims around small pools of the spring water at points where the water in its course flowed over a sudden change in slope (Figure 7).

The deposit of calcareous tufa exposed along the railway near Clinton is evidently of very recent origin. At the level of the railway rails about 16 feet from the upper surface of the travertine there is, for instance, a lens of unconsolidated boulder clay carrying pebbles of the younger Tertiary basalts of the district. The upper part of the deposit is, therefore, later than the glacial epoch. At the north end of the cutting, a great many leaf impressions were found through a vertical thickness of 13 feet. Impressions of birch boughs, up to several inches in thickness, are also present. The leaf impressions were examined by James Macoun of the Geological Survey who identified them as *Populus balsamifera*, var. *hastata* (balsam poplar) and *Alnus sinuata* (alder). Both of these species are growing in moist localities in this region today.

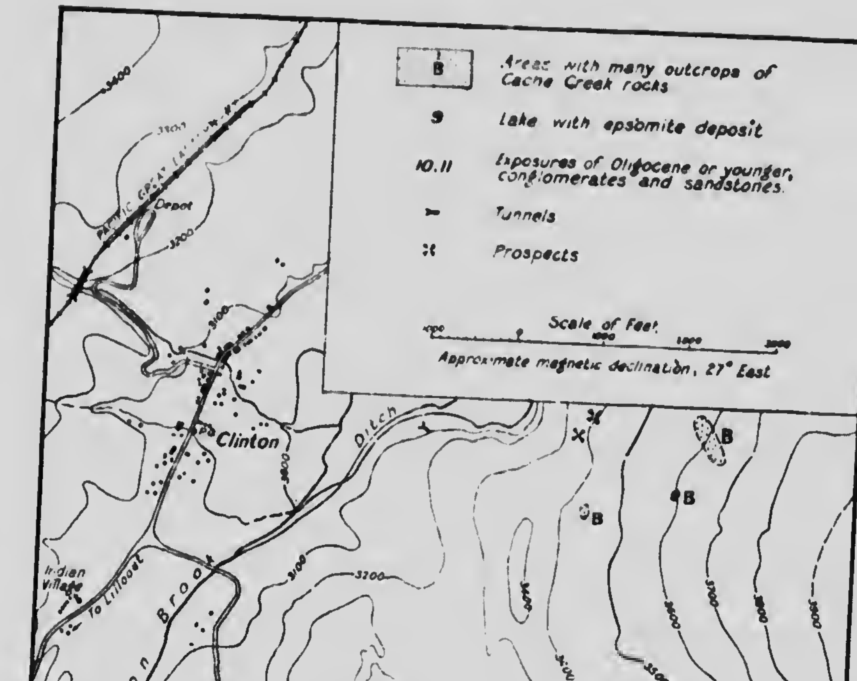
The evidence gathered shows that the apparent folds illustrated in Plates VIII and IX were formed during the deposition of the beds and are not due to later disturbance of once horizontal strata. The reasons for adopting this view of the origin of the structures in question are: (1) It was discovered that the corrugated lines in the travertine are always horizontal and thus lie as they originally formed, whereas if the fold-like structures had been produced by movements of the beds, the corrugations also would in some instances, at least, have been tilted. (2) Stresses acting on the deposit as a whole could not have folded two sets of superimposed rigid beds and left perfectly flat, soft, clay beds between. (3) The travertine is younger than the glacial till, lies on top of the ground, and is mixed to some extent with the till. Since glacial time no other rigid rock bodies have lain adjacent to the travertine in such a position as to cause the mass to be crumpled by stresses acting wholly within the travertine deposit. In other words, the curved beds have attained their shape practically under atmospheric pressure. (4) Finally, at the spring mentioned above curved beds can be seen in actual process of formation today.

CHAPTER IV.

EPSOMITE AND SODIUM CARBONATE.

EPSOMITE.

A saline lake without outlet (Plate I) lies one mile south of the village of Clinton directly east of the Ashcroft wagon road (Figure 2, locality 30, and Figure 8, locality 9). Just beneath its surface are circular deposits of nearly pure epsomite or epsom salts. Two miles farther along the



Fi[illegible] 8. Epsomite deposit near Clinton, Lillooet district, British Columbia.

Ashcroft road, and west of it, is another landlocked lake known as Three-mile lake (Figure 2, locality 31) whose water is a strong solution, 10 degrees to 18 degrees Beaumé, of magnesium sulphate, and sodium sulphate in the proportion of 4 to 1. These are the only lakes near Clinton known to contain a large quantity of the mineral. Similar deposits occur near Basque, B.C., and on Kruger mountain, B.C., near Oroville on the International Boundary.

CHARACTER.

Epsomite[1] or epsom salt is used in medicine, in tanning, and in the manufacture of textiles. The mineral is a hydrated sulphate of magnesium ($MgSO_4+7H_2O$). It is white, transparent to translucent, with vitreous to earthy lustre, hardness 2 to 2·5, specific gravity 1·751. It crystallizes in the orthorhombic system with prismatic habit giving rise to long four-sided prisms or a combination of these with pinacoids on the ends of which pyramidal faces are often developed. In the Clinton deposit, these four-sided, stick-like forms from ¼ to about 2 inches long, are characteristically developed. They are clear and translucent when first exposed, but soon become white and earthy, possibly due to a loss of contained water and alteration to kieserite ($MgSO_4$ H_2O).

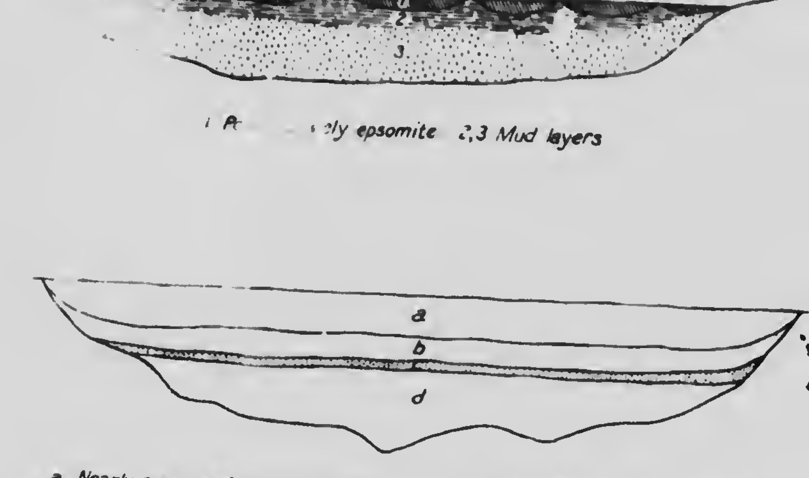
During the summer the central part of the smaller lake is generally occupied by only a few inches of water surrounded by a white rim of salt. Beneath the few inches of water are numerous, roughly circular areas 10 to 35 feet across, somewhat crowded together and white or dark according to light conditions. The upper part of each of these areas or what are known as "pools" consists of a layer of nearly pure epsomite, and epsomite mixed with dark mud occurs between the pools. The quantity of water in the lake seems to vary daily even during continued periods of rainless weather. According to the older inhabitants of Clinton, the site of this lake was at one time an irrigated hay meadow, at another period it was occupied by a lake, and the deposits of epsomite have been in evidence for the last few years only. The writer was informed by the manager of the salt works that an inch or more of epsomite crystallizes in the pools during certain seasons. Mr. F. Calvert, one of the owners, has kindly furnished the following particulars regarding the structure of the pools. The pools shown in cross-section in Figure 9 are nearly circular in plan and at the top consist of a layer of practically pure epsomite with some sodium sulphate. Below this are several layers more or less mixed with mud and a little sodium sulphate. The pools vary in thickness, the largest occur near the centre of the lake and are nearly 4 feet thick. Between the pools there is a dark mud, several feet thick and containing hydromagnesite and epsomite. No excavations have been made in the underlying materials but, presumably, beneath there is more mud carrying lime carbonate as well as hydromagnesite.

Figure 9 is an idealized cross-section of the deposit. Layer (1) represents the circular areas or pools largely of epsomite. Layer (2) represents the black mud occurring between and beneath the pools and carrying some hydromagnesite and epsomite. Layer (3) occurs at a depth of about 5 feet from the surface; it represents the upper part of a mud layer that has not as yet been penetrated but which presumably carries lime carbonate and hydromagnesite.

[1] Dana, E. D., "A system of mineralogy," 6th edition, 1909, p. 938

The lower part of Figure 9 is a cross-section of a single pool. L
"a" is composed of materials consisting of 44·3 per cent $MgSO_4$, 1·
cent $N\ \ SO_4$, the remainder water. At the very bottom of this layer
amount of sodium sulphate is, in places, 5 per cent. Layer "b" i
$MgSO$, with 4 per cent Na_2SO_4 and 8 per cent mud. Layer "c" is a
layer of black mud. Layer "d" is formed of magnesium sulphate wi
to 1 per cent Na_2SO_4 and 20 per cent mud. The crystals of epsomite
larger in layer "d" than in "a" or "b."

Hydromagnesite about 1 foot thick is said to underlie a part of
flat which, lying a foot or two above the lake, surrounds the lake
exte... some distance to the north.



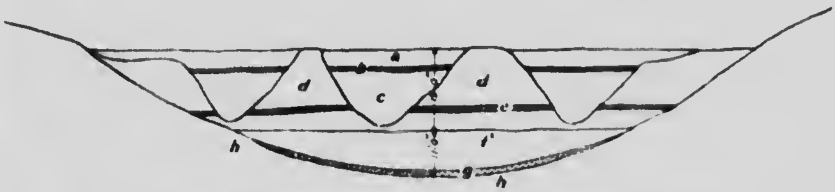
a. Nearly pure magnesium sulphate b. Impure magnesium sulphate
c Black muck d Impure magnesium sulphate

Figure 9. Idealized cross-sections of epsomite deposit near Clinton, Lillooet distric
British Columbia.

ORIGIN OF THE DEPOSITS.

The individual deposits or pools of epsomite are basin-shaped. They
contain besides epsomite, sodium sulphate and layers of mud. In the under
lying mud hydrous magnesium carbonates are present. These deposits
belong to the hydromagnesite, calcite, gypsum, series of deposits occurring
near them at Clinton (Figure 3) and elsewhere. The magnesium in the
deposits is derived, through the agency of sulphated waters, from the
magnesium rocks of the Cache Creek series such as outcrop in the hills near
the lake (Plate X) and is carried into the landlocked pond by underground
channels. The solutions diffuse into the lake, but upon condensation of
the lake water as the result of evaporation, the heavier brine collects at
the bottom on top of the mud and crystallization begins there at a number
of centres. Masses of crystals form around a centre and sink into the mud.
The process continuing, successive concentric layers with slightly larger
circumferences form on top. Successive sinking and growth cause the
formation of the basin-shaped bodies of epsomite.

The company controlling the deposits at Clinton has opened very similar deposits at Kruger mountain on the International Boundary near Oroville. These deposits were probably formed in the same manner as those at Clinton. According to Jenkins[1] there are, near Oroville, two landlocked lakes containing brines and beds of epsomite. The lakes are in rock basins without outlet; the surrounding rocks are metamorphosed pyritiferous dolomites and shales. Figure 10 is a cross-section of the lake drawn according to information furnished by F. Calvert. In this figure, layers "a" and "c" are cone-shaped bodies of epsomite with a thin layer of mud, "b." Layer "d" is of black mud carrying 25 per cent of epsomite with a layer of leaves "e." Layer "f" is a bed of epsomite with very large crystals. Layer "g" is a thin layer of gypsum underlain by a thin bed of clay resting on "h," metamorphosed dolomites and shales. The surface of the salt in "a" is lower than the top of "d."



a and c Epsomite with mud layer b, - d Mud with layer of leaves e; f Epsomite
g Gypsum over clay, h Metamorphosed dolomite, etc

Figure 10. Cross-section of Bitter lake, Kruger mountain, Washington, U.S.A.

Jenkins states that the drainage basin of the smaller lake is less than one-half a square mile in area. Sulphated waters formed by the oxidation of pyrite occurring in the surrounding rocks are presumed to have dissolved magnesium from the dolomites. Jenkins believes that the cone-shaped masses of salt in the upper part of the deposit were formed by crystallization of solutions percolating upward and that the force of the growing crystals helped to open up a space in the mud, thus forming a deposit which grew upward with increasing width until the surface was reached. Objections to this hypothesis are that a mass of salt forcing its way to the surface by crystal growth would form a body with a convex or irregular rather than flat upper surface. The flatness of the upper surfaces of the inverted cones at Kruger mountain and the fact that the materials composing the cones is comparatively free from the impurities that form small ridges all around them, suggest that the bodies were formed in the following manner.

It is well known that there are cyclic changes of climate in which conditions change from arid to moist and back to arid. It may be supposed that after the formation of the rock basin by glaciers, there was a period of aridity during which a certain amount of magnesium sulphate in solution collected in the bottom of the basin, probably mainly through underground channels. In this solution were also sodium and calcium. Evaporation and consequent concentration caused the formation of the lower bed. A succeeding cycle of greater rainfall gave rise to surface streams which

[1]Jenkins, Olaf P., "Spotted lakes of epsomite in Washington and British Columbia." Am. Jour. Sc., vol. XLVI, Nov., 1918, pp. 638-644.

flowed into the lake carrying sediment with them and forming a horizo layer of mud lying on the first formed epsomite bed and of greater thick than at present. The bed of leaves (Figure 10) is evidence of the pres of a heavier plant growth and, naturally of more rainfall, at that t than at present. This involves the accumulation of a fairly large bod water in the lake basin, both from underground and surface sources. T water naturally contained a great deal of magnesium sulphate salts, altho in very dilute solution. A final succeeding period of aridity and desiccat concentrated the brine until it began to crystallize at the bottom on of the bed of mud and sediment. Crystallization started at a great ma centres and as the crystals formed they sank into the mud. Other cryst would form on and in circular rings around the first formed. A furt sinking would result followed by the formation of crystals in another circu layer of a little larger radius on top of the first layer. The successive bui ing up of the circular layers constantly increasing in diameter, would fo a cone pointing downwards that would sink into the mud as its weig increased and if crystallization and the consequent building up process p ceeded rapidly enough the flat, upper surface of the cone would never buried entirely. If a few wet seasons intervened, the cone might supposed become covered by a layer of flocculent mud. More dry seasons wou cause further growth on top of the cone. It is to be presumed that if t underlying and surrounding mud were very fine-grained some might, places, become mixed with the salt crystals. The cross-section of a po at Clinton shown in Figure 9 suggests a mode of formation similar to th outlined above. A short season of wet weather is indicated by layer "c and general increasing aridity is indicated by the diminution of mud con tent from the bottom to the top. The tops of the pools are a little low than the surrounding mud because their weight has caused them to sin downward. This downward sinking of the cones, together with th lateral thrust[1] of the growing crystals, pushes the mud to one side and cause it to bulge upward above the pools.

EXPLOITATION.

The deposit at Clinton is owned and worked by a firm of industria chemists, the Stewart Calvert Company of Oroville, Washington. The salts are excavated with pick and shovel from beneath the few inches o covering water, wheeled on a wooden runway to the shore, sun-dried pounded with a wooden mallet, put through a $\frac{1}{4}$ inch screen, and shipped to Oroville where the more impure grades are redissolved.

Amount Available.

The epsomite lake at Clinton (Figure 8, locality 9) covers an area of about 24 acres, of which it is estimated, less than one-half is floored by the circular epsomite deposits. Though some of the pools are 4 feet thick in the middle, $2\frac{1}{2}$ feet is probably the average thickness of the middle of the pools near the centre of the lake. Towards the shore the pools are said to be shallower. Each pool is, moreover, very thin at its edges. Since the actual aggregate areal extent of the pools is not known and since only scanty

[1]Jenkins states that the force of crystallization of the epsomite crystals is such that saturated solutions passing through iron pipes split them from end to end when sudden cooling causes crystallization

data as to thickness are available, no close estimate of the tonnage can be made. If every year an inch of epsomite grows uniformly over all the present salt areas, the increase should amount to between 1,500 and 2,000 tons per annum. From the conditions obtaining at Kruger mountain it would seem possible that other epsomite layers may occur in the underlying mud.

SODIUM CARBONATE.

Between the west end of Meadow lake and a point about 5 miles east of 70 Mile House, there are a number of saline lakes with brines consisting predominantly of sodium carbonate. These lakes lie in an almost perfectly straight line trending slightly north of west. Other soda lakes occur southeast from Meadow lake toward Little White lake and also north of 70 Mile House.

VARIETIES.

Sodium carbonate is marketed[1] in the following forms: (1) soda ash, Na_2CO_3; (2) salsoda, also known as washing soda, crystal carbonate, or natron, $Na_2CO_3 . 10H_2O$; (3) bicarbonate of soda or baking soda, or saleratus, $NaHCO_3$; (4) sodium carbonate monohydrite, or thermonatrite $Na_2CO_3 . H_2O$; (5) trona or sodium sesquicarbonate, $Na_2CO_3 . NaHCO_3 . 2H_2O$.

(1) Soda ash is manufactured from sodium sulphate, limestone, and coal, by the Leblanc process; by the Solvay process it is made from a sodium chloride brine saturated with ammonia into which carbon dioxide is introduced, thereby causing the precipitation of sodium bicarbonate which is calcined to produce soda ash. Soda ash is also manufactured from the mineral cryolite and from natural deposits of sodium carbonate.

(2) Salsoda is made by dissolving soda ash and reprecipitating the salt at a temperature below 32 degrees Centigrade. It is also found in natural deposits.

(3) Baking soda or bicarbonate of soda, $NaHCO_3$, is made by the Solvay process and is a partial constituent of many natural deposits.

Table VII.—Production of Sodium Carbonate in the United States.

	1916.		1917.	
	Short tons.	Value.	Short tons.	Value.
		$		$
Sodium bicarbonate	115,177	2,303,540	174,212	5,292,374
Soda ash	1,324,208	18,283,866	1,578,889	38,374,199
Salsoda	....	....	77,939	1,698,520

[1] Wells, Roger C., "Sodium salts in 1917." Mineral resources of the United States, 1917, pt. II, pp. 305 to 341. Information regarding uses, etc., from same publication.

USES.

The use of sodium carbonate in the industries has increased ve greatly in the last thirty years and in North America the war caused further increase in production and price, as indicated in the table page 5 Sodium salts have been used in the making of munitions and as substitut for potassium compounds in the manufacture of glass, soap, matches, a cyanide in photography, medicine, and tanning. Soda ash is used ve widely in nearly all of the chemical industries, especially in making dy stuffs and explosives. It is used directly in glassmaking and as sodiu hydroxide in the wood pulp and soap industries. Sodium bicarbonate used in medicine, in cooking, and for making effervescent drinks.

OCCURRENCES IN THE DISTRICT.

The soda lakes examined during the course of this work all lie withi the Green Timber plateau, north of Clinton. The plateau is a comparativel flat tract of country covered with glacial drift in which large basalt boulder predominate. Near the edges of the plateau, as at the deep canyon know as the Chasm near 59 Mile House, the plateau surface may be seen to b underlain by several hundred feet of flat-lying basaltic flows and it i presumed that the topography of the plateau in general, is due to suc basalt beds. The soda lake basins are usually landlocked, are filled wit brines of varying strength, and their shore-lines are rimmed with a whit crust. The stronger brines have an unpleasant odour. They seem devoi of plant life, but many of them contain a small red crustacean, presumabl the alkali shrimp (*artemia gracilis*); and swarms of black flies (*Ephydra*) a little larger than the common housefly, congregate on and under the sal crust on which they seem to exist. The bottoms of these lakes are covere with soft, sticky, blue clay.

One of the lakes, the Last Chance (Plate XI), contains a brine tha is, apparently, nearly saturated and a network of salt circles was observed similar to that occurring in the spotted epsomite lakes at Clinton and Kruger mountain. The rings are from 10 to 15 feet in diameter near the edge of the lake and appear to be much wider in the middle of the lake. Between the rings are cusp-shaped spaces occupied by mud ridges rising 2 to 6 inches above the salt circles. Near the edge of the water these ridges are above water-level, and the rings, in places, are covered with several inches of water. Boulders, many of them from 6 inches to a foot in diameter, lie on these ridges. A circle of salt near the edge of the lake was found to lie on black mud. The rings of salt have the same surface appearance as those in the epsomite lake at Clinton, page 51, and the characteristic cone-shaped salt bodies may be present nearer the lake centre which was inaccessible because of the extremely soft, unstable mud bottom.

Composition.

The composition of the salts obtained from three lakes and of the brines from two is given in the following tables. The analysis of the salt dug from under the brine in Goodenough lake, Table VIII, No.2, indicates a salt composed of about 97 per cent of natron, $Na_2CO_3.10H_2O$, with less than 1 per cent of sodium bicarbonate, and some water in excess.

Analysis No. 1 gives the composition of what is probably the same material, but after it had been exposed to the weather for many years. The analysis indicates the presence of 98 per cent of $Na_2CO_3.5H_2O$, some water in excess, and less than one-fifth of 1 per cent of sodium sulphate.

Sodium carbonate[1] crystallizes from solution with 1, 2, 3, 5, 6, 7, 10, and 15 molecules of water, depending on the temperature of crystallization and free exposure to the air. Analysis No. 2 was made of a translucent, colourless salt and, therefore, the material was presumably taken from the interior of the stock pile, whereas sample 1 was collected from the surface of the pile which after exposure for a few winter months in a heated building had been converted into a fine white powder. The analysis (No. 1) probably represents the salt in an intermediate stage in the conversion from natron to a carbonate with less water, thermonatrite, $Na_2CO_3.H_2O$ and this is said to be the composition of the material existing as a white efflorescence on the shores of all the soda lakes in this area. The manufactured soda from the lake just west of 70 Mile House is of much the same composition except for the presence of a small percentage of chlorides and a proportion of crystalline water that indicates Na_2CO_3 $3H_2O$ rather than the higher hydrates. Since this salt was also freely exposed to the air before sampling, it probably represents another stage in the change from natron to thermonatrite.

The crust of salt from Last Chance lake carries 5 per cent of sodium sulphate.

An analysis of the brine from Goodenough lake, Table IX, No. 2, shows 0·7 per cent of potassium, brine from the Last Chance 3·32 per cent potash out of a total of 15·9 per cent solids in solution. The brine from Hutchinson lake, sample 1, Table IX, is a relatively pure sodium carbonate water, but of comparatively low concentration.

Table VIII.—Analyses of Salts from Soda Lakes.

———		1	2	3	4
Soda	Na_2O	31·36	21·36	......	37·83
Potash	K_2O	trace.	......	......	0·05
Magnesia	MgO	0·04	......	......	0·09
Silica	SiO_2	trace.	0·01	......	......
Alumina and iron	$Al_2O_2Fe_2O_3FeO$.	trace.	......	......	......
Carbon dioxide	CO_2	22·08	15·46	......	26·70
Sulphur trioxide	SO_3	0·11	0·08	......	0·04
Phosphorus pentoxide	P_2O_5	......	0·01	......	
Boron trioxide	BO_3	......	trace.	......	......
Chlorite	Cl	trace.	0·01	......	0·37
Water above 105°C		0·84	63·03	......	0·61
Water below 105°C		45·67	..	......	33·98
		99·90	99·96	......	99·67

[1]Chatard, Thos. M., "Natural soda, its occurrence and utilization." U.S.G.S. Bull. 60, 1890, p. 31.

Hypothetical Combinations.

Sodium carbonate	53·21	35·54	35·96	64
Sodium bicarbonate	......	1·34	......	......
Sodium sulphate	0·14	0·14	5·21	0
Sodium chloride	......	0·02	0·33	0
Potassium chloride	......	......	......	0
Magnesium chloride	......	......	......	0·
Sodium metaborate	......	trace.	......	......
Sodium hydrogen ammonium phosphate	......	0·02	......	......
Insoluble	......	......	0·02	......
Water	46·47	62·89	58·48	34·
	99·92	99·95	100·00	99·

1. From stockpile on shore of Goodenough lake near southwest end of Meadow lake, B.C. Analysed by Frederick Baridon, Mines Branch.
2. From deposit on Goodenough lake. Analysed by R.A.A. Johnston, Geol. Surv., Can. Ann. Rept., vol. XI, 1898, pp. 12, 13R.
3. From top of solid crust in Last Chance lake in northeast quarter of lot 1768, between 5 Mile House and Meadow lake. Per F. Calvert. 3·32 per cent of the solid matter derived from the brine in this lake was found to be potash, K_2O.
4. Manufactured material from soda lake in lots 1792, 1793, 3½ miles west of 70 Mile House owned by Pacific Coast Contractors, Ltd. Analysed by Frederick Baridon, Mines Branch.

Table IX.— Analyses of Brines from Soda Lakes.

	1	2
1000 grains of water contains:	Grains.	Grains.
Sodium, Na	18·3800	37·42
Potassium, K	trace.	6·890
Calcium, Ca	trace.	0·016
Magnesium, Mg	0·0261	0·037
Aluminum, Al	None.	0·083
Silica, SiO_2	......	0·041
Carbonic acid, CO_3	22·6600	42·845
Bicarbonic acid, HCO_3	3·0600	10·731
Sulphuric acid, SO_4	0·0820	7·326
Chlorine, Cl	0·8590	7·902
Boric acid	None.	trace.
Phosphoric acid	......	0·771
Total	45·0671	114·170
Percentage of total solids (dried at 103°C.)	4·53	11·14
Specific gravity at 60°F.	1·044	1·108
Equivalent to degrees Baumé	6·1	

1. Brine from lake 5 miles east of 70 Mile House, just southeast of lot 1514, owned by D. B. Hutchinson. Analysed by Frederick Baridon, Mines Branch.
2. Brine from Goodenough lake. Analysed by F. G. Wait, Geol. Surv., Can., Ann. Rept., vol. XI, 1898, pp. 48 to 50R.

Details of Lakes.

The salt deposit in Goodenough lake (Figure 2, locality 21) was worked at one time and the remains of a storage shed are still standing on the shore. A great deal of the salt has been washed away by rain, but about 16 cubic yards has been left. Analyses of this salt and of some taken directly from the lake (Table VIII) show that it is an exceedingly pure carbonate of soda. The brine examined by Wait contained 11·4 per cent of solid matter at 60 degrees F. The lake, it was stated,[1] covered 20 acres and had at the end of the dry season a deposit about 8 inches thick over the greater part of it, but thinning to about 2 inches near the sides. On this basis it was figured that 20,000 tons of solid salt was present. The present area of the lake is nearly 15 acres, and if the relative quantity of salt present be the same as before, only about 15,000 tons of salt would crystallize out during the dry season, and a small additional quantity would be present in the form of brine.

The following observations were made in September, 1919, when all the lakes had shrunk greatly in volume as compared with their condition in the previous summer of 1918. The brines were not in all cases tested, but were assumed from the appearance and character of the soils and from information received, to be mostly composed of sodium carbonate.

About three-quarters of a mile north of the road from Chasm station to Big Bar lake on lots 1759, 1760 (Figure 2, locality 24) there is a crescent-shaped lake that covered a little over 8 acres to a depth that varied on an average from about 6 inches at one end to 1 foot at the other. The specific gravity of the water at a temperature of 17 degrees C. was 1·085. On lots 1739, 1749, and 1761, just northwest of Little White lake (Figure 2, locality 25), is a lake which through continued evaporation had shrunk to two small bodies. The larger covered 15·6 acres to an apparent average depth of 10 inches. The specific gravity of the brine at a temperature of 15 degrees C. was 1·135. The smaller covered 9·5 acres to an average depth of about one foot, and the specific gravity of the brine at 15·3 degrees C. was 1·160. A large lake on lot 1768, near the road from Meadow lake to Chasm station (Figure 2, locality 23), covered from 60 to 80 acres and the water had a specific gravity of 1·070 at a water temperature of 20 degrees C. The depth of this lake is probably 2 to 4 feet in the middle. Directly east of this lake, and in the same lot is Last Chance lake, which contains brine with a specific gravity of 1·170 when the water is 21 degrees C. The lake covered nearly 40 acres and at the sides was very shallow. An analysis of the salt deposited in the lake is given in Table VIII. The water of a small lake situated west of the road leading to the two above lakes, had a specific gravity of 1·030 at a water temperature of 17 degrees C.

On lots 1792 and 1793, about 3½ miles west by north of 70 Mile House (Figure 2, locality 26) soda was manufactured in the autumn of 1918 from a lake covering about 85 acres, the waters of which were said to carry an average of about 6 per cent of solid matter in the summer. The specific gravity of the lake water, in the summer of 1919, was 1·055 at a water temperature of 15 degrees C. which indicates a slightly lower percentage of solids than stated above. The lake is owned by the Pacific Coast Contractors Limited, of Vancouver, who have installed an evaporating

[1]Geol. Surv., Can., Ann. Rept., vol. XI, 1898, p. 12R.

plant on the shore. The brine was pumped at a maximum rate o gallons per minute from the lake into an evaporating tank 43 by 14 l feet and boiled down to the proper concentration, when it was drawi and allowed to cool in a crystallizing tank where it was separated fron earthy impurities and a certain amount of "mother liquor". The proc was said to be natron $Na_2CO_3 . 10H_2O$ when it first crystallized, but evide it loses some of its water rapidly (Table VIII). The plant was intende produce the equivalent of 3 tons per day of soda ash. The comp intended to install a furnace at the lake to convert the natron into soda Wood fuel of which an abundant supply is present, was to be used in furnace. The plant which is a little over 4 miles distant by road from Pacific Great Eastern railway, was shut down during the winter of 1918-1 and was not reopened during the following summer. The lake has average depth of 3 feet in winter and 4 feet in summer and is estimated contain about 65,000 tons of sodium carbonate.

A lake of about 17 acres, and an unknown depth, belonging to D. Hutchinson and situated some 5 miles east from 70 Mile House, was fou to contain brine holding 4·5 per cent of solid material (Table IX, analy No. 1).

The specific gravity of the waters of other soda lakes was obtain A number of these lakes, some of them containing a large amount of so lie along the Cariboo road, near the railway track north of 70 Mile Hou In none of these of any size had the water a specific gravity above 1·03

Origin.

The brines from which the sodium carbonate has crystallized a contained in small lakes lying on a basaltic plateau covered with a apparently thin mantle of drift. The drainage basins of these lakes are i all cases far too small to allow of the supposition that the salts contained i them have been leached from their drift. The soda lake at 70 Mile Hous for instance, covers about 85 acres and is estimated to contain about 60,00 tons of solid hydrated sodium carbonate, but the edge of its drainage basi is not more than from 100 to 200 yards from the shore and not much mor than 10 feet in elevation above it. The lakes must, therefore, be fed b underground springs. It is significant that these brines are confine almost entirely to country underlain by Tertiary basalts. Lindgren mentions many instances of such groups of sodium carbonate brines tha are invariably found associated with areas of Tertiary volcanic activity They are presumed to be due to hot waters containing much free carbo dioxide, which act on the alkaline silicates in igneous and metamorphi rocks to form alkaline carbonates. Cold, descending waters carrying carbon dioxide generally contain much calcium and silica, that is, they produce solutions of an entirely different type from those encountered here. Amongst other criteria that distinguish waters of igneous from those of superficial origin Gauthier[2] mentions the presence of boron and phosphorus and the absence of the carbonates of calcium and magnesium. Tables VIII and IX show that the waters in these lakes have these chemical characteristics. The brines at 141 Mile lake, Table V, may be a mixture

[1]Lindgren, Waldemar, "Mineral deposits," pp. 59-61.
[2]Gauthier, Armand, "Caractères différentiels des eaux de source d'origine superficielle ou météorique." Comptes rendus, vol. 150, 1910, pp. 436-441.

of deep-seated and atmospheric waters. In this region, near the Chasm, the occurrence of hydrated sodium silicates, such as analcite and chabazite, is very common in amygdaloidal cavities in the basalts, indicating that the vapours and solutions representing the later crystallization products of volcanic activity were rich in sodium. It is, therefore, concluded that the soda in these brines was derived from hot waters ascending from below and connected with the volcanic activity that caused the extrusion of the Tertiary basalts. Their date of formation was in all probability prior to that of the hydromagnesites.

CHAPTER V.

CLAY.

Because of the comparative scarcity in Canada of developed deposits of the higher grades of clay[1], and because geological conditions in the area traversed favour the finding there of high grade clay, a special effort was made to look for and examine promising clay localities. Eight samples of clays that represented deposits containing a fair quantity of either semi-refractory or fire-clay were tested by Joseph Keele, of the Mines Branch. One deposit proved to be a No. 1 fire-clay of the kaolin type and although this deposit cannot be considered a commercial proposition at present, there is reason to hope that equally good and more favourably located clays may be found.

In order to be of assistance to those who may be interested in the finding of high grade clays in this or other parts of the country, the following short account of the properties and uses of the higher grades of clay is given, as well as a few hints on prospecting for clay.

Clays are aggregations of minute mineral particles formed by the decomposition of solid rock. Their formation in nearly all cases is due to weathering which results in the leaching away of the more soluble bases, such as lime and soda, and also a certain amount of silica, leaving behind a mass of highly oxidized and hydrous minerals. Clays that occur at their place of origin upon or within the parent rock are called residual clays. Those that have been transported by water or some other agency, from their place of origin to their present sites, are spoken of as sedimentary or transported clays. Since clays are formed from many different varieties of rock, they are very diverse in their chemical and mineralogical makeup.

All clays have the property of plasticity when wetted. "Plasticity may be defined as the property many bodies possess of changing form under pressure without rupturing, which form they retain when the pressure ceases."[2] Another important property of clays is that of changing into a hard, coherent mass upon drying. Firing generally increases the hardness and coherence of the mass. This change is accompanied by a shrinkage of the clay, the relative amount of which varies considerably with the kind of clay used, and is of great importance in the manufacture of clay products. When clays are burned they pass through a number of changes both physical and chemical. The value of a clay for certain purposes is very greatly

[1]Only one workable deposit of kaolin or china clay is known in Canada today and imports of clay products exceed the domestic production.

[2]Ries, H., "Clays, their occurrence, properties, and uses," page 94. Wiley & Son, New York, 1906. The section treating of the properties and kinds of clay is largely taken from this book.

dependent upon its refractoriness, that is, at how high a temperature it fu the higher grades of clay having, as a rule, high fusion points. A long t perature interval between the points of vitrification and fusion is als very desirable quality in a clay that is to be used in the manufacture vitrified ware.

The more important varieties of clay that are recognized in the c industry are mentioned below. Their suitability for use in the manufact of certain wares is determined by the degree in which they possess properties mentioned above, that is, their plasticity, resistance to fusi colour upon burning, and so forth. It must be understood that there many clays with properties intermediate between these groups.

KAOLIN.

Kaolins are white burning, residual clays that contain mostly sili alumina, and combined water with few fluxing impurities. When tes they usually show low plasticity, low air shrinkage, low tensile streng burn white, and are highly refractory, that is, they fuse at a high tempe ture above cone 30 (1730 degrees C.). Kaolin mixed with quartz, feldsp and bone ash, is used in the manufacture of high grade porcelains. Kao is used also for making semi-porcelain whiteware, for floor and wall til as a filler in paper manufacture, etc. Kaolins are washed to free th from the silica and unaltered rock that is present in all residual clay deposi The kaolin deposit at St. Remi, north of Grenville, Que., is the only one commercial size that has been opened up in Canada. It occurs in P cambrian quartzites.

BALL CLAY.

Ball clays are a variety of white burning clays that are very plast They are used as a binding medium in the manufacture of whiteware semi-porcelain. There are very few known occurrences in the Unit States. A clay occurring at Willows in southern Saskatchewan m be considered a ball clay.[1]

REFRACTORY OR FIRE-CLAY.

Fire-clays are those clays that can withstand high temperatures wit out fusing. This means that they are low in fluxing impurities such iron, lime, magnesia, and alkalis, and that the amount of free silica is al low.[2] The better grades of fire-clay fuse at temperatures above cone 2 (1,650 degrees C.). Those that fuse at temperatures between cones 26 an 30, inclusive (1,650 degrees and 1,730 degrees C.) are classed as No. between cones 30 and 33 (1,730 degrees and 1,790 degrees C.) as No. and above cone 33 as No. 1 grade fire-clays. They vary in plasticity tensile strength, and other properties. Most fire-clays are white or yellow ish white and burn to a light colour. There are instances of fire-clay however, that are black or even yellowish red in the raw state. Fire-clay are used in the manufacture of firebricks, retorts, furnace linings, and fo other purposes where resistance to heat after manufacture is of importance They are used also in the manufacture of floor tile, terra-cotta, pavin bricks, and so forth.

[1]Davis, N. B., "Report on the clay resources of southern Saskatchewan." Mines Branch, Pub. No. 468, 191 pp. 14.

[2]Ries, H., Op. cit., p. 174.

SEMI-REFRACTORY CLAY.

Clays that deform above cone 10 and below cone 26 (1330 degrees to 1,650 degrees C.) may be considered semi-refractory.[1] They are used in the manufacture of stoneware, art pottery, terra-cotta, sewer-pipe, paving brick, and face brick. Stoneware clay should be sufficiently plastic and tough to allow of its being turned on the potter's wheel, should have low fire shrinkage, and should vitrify at a fairly low temperature, but with a sufficient range between vitrification and fusion to allow the ware to hold its shape when burning. In making terra-cotta and sewer-pipe, more easily vitrified clays are often mixed with semi-refractory clay in order to give a dense body at fairly low temperatures. Low shrinkage and freedom from warping are desirable qualities in terra-cotta clays. High percentages of soluble salts are objectionable. Paving brick is made from impure shales as well as from semi-refractory clays. The raw material should be fairly plastic and show a range of at least 140 degrees C. between the beginning of vitrification and fusion. The known occurrences of refractory and semi-refractory clays in Canada are summarized by J. Keele.[2]

BRICK CLAYS.

Clays used for common building-bricks vary in their characteristics. The requisites are that they mould easily and burn hard at a low temperature without cracking or warping. Most of them burn red. Pressed brick, face brick, and hollow brick call for somewhat higher grades of clay. None of them need be highly refractory, but their plasticity, shrinkage, and colour after burning are usually important. Although the better grades of brick are in many cases transported for long distances they are comparatively low-priced products, and the clays used in their manufacture are in general of commercial importance only when they occur in fairly thickly populated areas. Clays suitable for the manufacture of common brick occur rather widespread in the Thompson and Fraser River valleys. These are glacial, stoneless, stratified silts. The white silts are mentioned on page 19.

PROSPECTING FOR CLAY.

In a sparsely settled district like the one being dealt with, only fairly large deposits of kaolin or high grade fire-clay may be considered commercially workable. The kaolins and high-grade fire-clays are usually white, or white tinged with yellow or pink. Other earthy deposits, namely, white infusorial earth and volcanic ash, both of which occur extensively in places in this district, might be mistaken for clay, but for their lack of plasticity, that is, if wetted and kneaded, they do not mould into a coherent mass, but break. Infusorial earth and white volcanic ash are in most cases also much lighter than an equal volume of white clay. White talc is distinguished by its relative hardness, non-slaking properties, and lack of plasticity. If the clay deposit be residual it is important to note the percentage of unaltered rock present with the clay. The profitable exploita-

[1] Davis, N. B., Op. cit., p. 16.
[2] Keele, J., "Refractory materials in Canada." Dept. of Mines, Mines Branch, Sum. Rept., 1916, pp. 112-114.

tion of clay deposit depends also on the amount of overburden that h
be removed before excavating can commence; the facilities for wash
whether the clay be residual; the size of the deposit—10,000 cubic yar
probably a minimum—and above all on the cost of transportation to
nearest market. Before expenses are incurred in developing a prospe
clay deposit it should be thoroughly sampled. The samples shoul
forwarded to the Mines Branch, Department of Mines, Ottawa, for test
If two or more large portions of the deposit apparently vary in chara
they should be sampled separately. Each sample should weigh from
10 pounds, and should be taken at equal intervals across the part of
deposit that it is intended to represent.

Table X.—Value of the Production[1] *and Imports of Clay and Clay Prod in Canada.*

—	1915.		1916.		1917.		1918.	
	Production.	Imports.	Production.	Imports.	Production.	Imports.	Production.	Impo
Kaolin	$ 13,000	$ 124,658	$ 17,500	$ 114,110	$ 9,594	$ 97,856	$ 19,299	$ 116
Fire-clay and fire-clay products[2]	110,693	87,267	234,562	187,124	326,511	283,746	397,458	401
Total for all clay products...	3,914,488	2,998,463	4,120,805	4,554,167	4,779,038	6,610,837	4,583,489	6,734

[1] McLeish, John, "Mineral production of Canada in 1916," "Preliminary report of the min production of Canada for 1917 and 1918", respectively.

[2] The value of *imports* under this heading covers *only* fire-clay, ground or unground, and c not include firebrick or other refractory brick such as magnesite or silica brick, the values of imports of which were: 1915—$813,071; 1916—$1,657,792; 1917—$3,156,591; 1918—$3,712,677.

The *production* figures do not include production from imported materials. Production fr this source in 1915 was $28,807; in 1916—$22,484; 1917—$61,317; 1918—$84,018.

Average Prices of Clays and Clay Products.

	1915.	1916.	1917.	1918.
Kaolin, crude per ton	$ 10 00	$ 10 00	$ 18 00	$ 22 00
Fire-clay per ton	2 00	3 50	6 00	4 00-10 (
Common brick, per thousand	7 48	7 71	9 49	11 14 (Pre
Pressed or front brick, per thousand	9 89	10 95	14 07	16 35 (Pre

CLAY LOCALITIES EXAMINED.

REFRACTORY AND SEMI-REFRACTORY CLAYS.

Clays of this type were examined at Chimney Creek bridge (Figure 2, locality 15), at Baker Creek canyon opposite Quesnel (Figure 1, localities 7 and 8), at a point 8 miles north of Quesnel (Figure 1, locality 6), and at another place 30 miles above Prince George (Figure 1, locality 2). All these localities lie close to the west bank of Fraser river.

Chimney Creek Bridge.

Samples 1 to 4 were taken from a point 1,400 feet in elevation above Chimney Creek bridge, west of Fraser river and within sight of the bridge (Figure 2, locality 15). The bridge is about 26 miles by road from 150 Mile House and 15 to 16 miles over a high grade from the railway at Williams lake. The clays occur as residual masses produced by the alteration of a series of Cache Creek fine-grained quartzites and argillites. The clay-bearing zone is much crumpled and faulted, whereas the undisturbed beds below and to the side are hard, fresh, and free from clay. Figure 11 shows the mode of occurrence. Over the clay there are silts and basalts of Tertiary age.

A section from the top down is as follows (Figure 11).

	Thickness in feet.
(a) Black basalt nearly flat-lying and forming the summit of the slope. The lower 15 feet is broken up and consists of broken basalt fragments mixed with clay . . .	40
(b) Fine silt, unconsolidated and well-bedded, probably of Tertiary age	10
(c) Fine-grained argillite or quartzite, yellowish white, partly altered to clay . . .	30
(d) Bluish, fine-grained quartzite, the bed much crumpled and apparently wholly changed to clay, although the sample carried 50 per cent of non-slaking material. Sample tested . . .	2 to 4
(e) Silty argillite or quartzite changed to yellowish white clay, 15 to 20 per cent of fresh rock present. Sample tested . . .	25
(f) Seam of white clay with pinkish streaks, showing in places only, in a much crumpled and faulted bed. This is the best clay in the bank. Sample tested . . .	2 to 3
(g) Resembles (e) with seams of white clay through it, percentage of fresh rock about the same as in (e). Sample tested . . .	25
(h) Alternate bands of silty argillite or quartzite varying slightly in texture and colour, largely altered to clay but with more fresh rock present than in (d), (e), (f), (g) . . .	85
(j) Black, carbonaceous argillite somewhat altered to clay	
(k) Alternations of argillite and quartzite exposed for 800 feet down the slope. These beds are not changed to clay.	

The beds from (k) downward strike along the slope and are practically undisturbed; those from (e) to (g) are very much crumpled, twisted, and appear in all attitudes, and the bed from (h) is less disturbed. The alteration to clay of beds (e) to (g) is very pronounced; (h) is partly altered to clay and from (k) down the beds are quite fresh. Beds (e) to (k) belong to the Lower Cache Creek series.

Samples 1, 2, 3, and 4 correspond to beds (d), (e), (f), (g), in the above section.

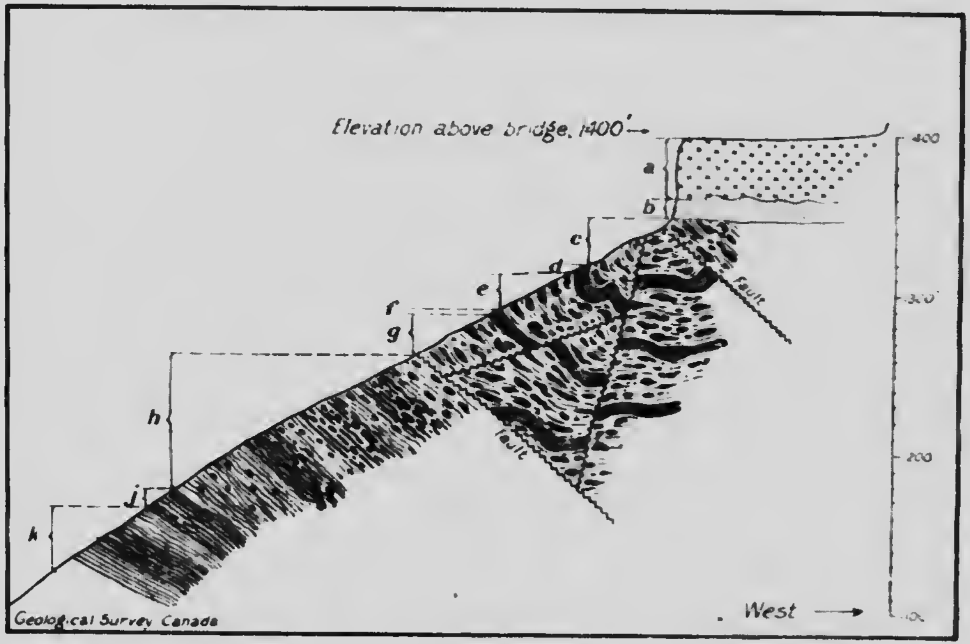


Figure 11. Idealized cross-section of residual clay deposit near Chimney Creek bridge, west of Fraser river, Lillooet district, British Columbia.

Sample 1. Semi-refractory. A white, residual clay. Washing and screening through 80-mesh sieve yields 50 per cent of plastic clay resembling stoneware clay. This burns to a light grey, hard body. The crude clay, ground to pass a 16-mesh screen, has low plasticity but is easily moulded, burns to a dark grey, hard body at cone 5 (1230 degrees C.). Total shrinkage at cone 5, 8 per cent, absorption at same temperature 6 per cent. Washed clay fuses at cone 15 (1430 degrees C.) and crude clay at cone 18 (1490 degrees C.).

Sample 2. A No. 3 fire-clay. A white and pink residual clay. Plasticity low. Burns to a hard, buff body at cone 5 with total shrinkage 11 per cent and absorption 11 per cent. Twenty-five per cent of the crude is clay.

Sample 3. No. 1 fire-clay or kaolin. White and pink residual clay. Ground to pass 16-mesh sieve. Plasticity low. All particles do not slake, hence granular when wetted. Burns to a cream-coloured body at cone 5 with total shrinkage 15 and absorption 17 per cent. Portion ground to pass an 80-mesh sieve; plasticity good, clay smooth when wetted. Floor tile burnt to cone 5 slightly off white colour and not vitrified. Clay makes a good casting slip when poured into plaster moulds, but needs addition of potter's flint because of high shrinkage. Clay not affected when heated to cone 30 (1730 degrees C.), hence highly refractory.

Sample 4. Semi-refractory clay. Light buff, residual clay. Ground to pass 150-mesh screen; plasticity fair but short in texture. Burns to drab grey vitrified body at cone 5 with total shrinkage of 14 per cent. Fuses to slag at cone 17. Resembles No. 2.

Mr. Keele remarks on the results as follows: "These tests show that the deposit is uneven in quality, that the clay-forming processes are not completed, as plasticity is generally low and fluxing impurities are rather high in certain portions. The clays of this deposit as a whole might be worked for the manufacture of a low grade of firebrick, or as a mixture with a more plastic clay for making sewer-pipe. If the material was crushed and washed it would yield a certain amount of fine clay which could be used in the manufacture of stoneware goods, but the yield of washed clay would probably be too small to repay that operation. As the material is not fine-grained and is not white either in the raw or burned state it cannot be classed as a commercial kaolin or china clay."

There is another deposit about one-half mile or so along the slope to the south, which the writer was unable to visit.

Baker Creek Canyon.

Samples 5 and 6 are from Baker Creek canyon opposite the village of Quesnel. Sample 5 is from the base of a number of rock pillars on the north side of Baker Creek canyon about $3\frac{1}{2}$ miles above its mouth (Figure 12, locality 8). These pillars are partly changed to clay. The rocks are grey to buff quartzites and argillites of Cache Creek age, with occasional beds of black argillites. All of these rocks are exceedingly fine-grained and quartzose. They have been much crumpled and folded. They are accompanied in varying amount by grey and cream-coloured clays that have been formed by alteration of the hard rocks. A number of pillars on the steep sides of the canyon, some of them over 100 feet in height, extend for a distance of 400 or 500 feet. The upper clay masses are about 300 feet in

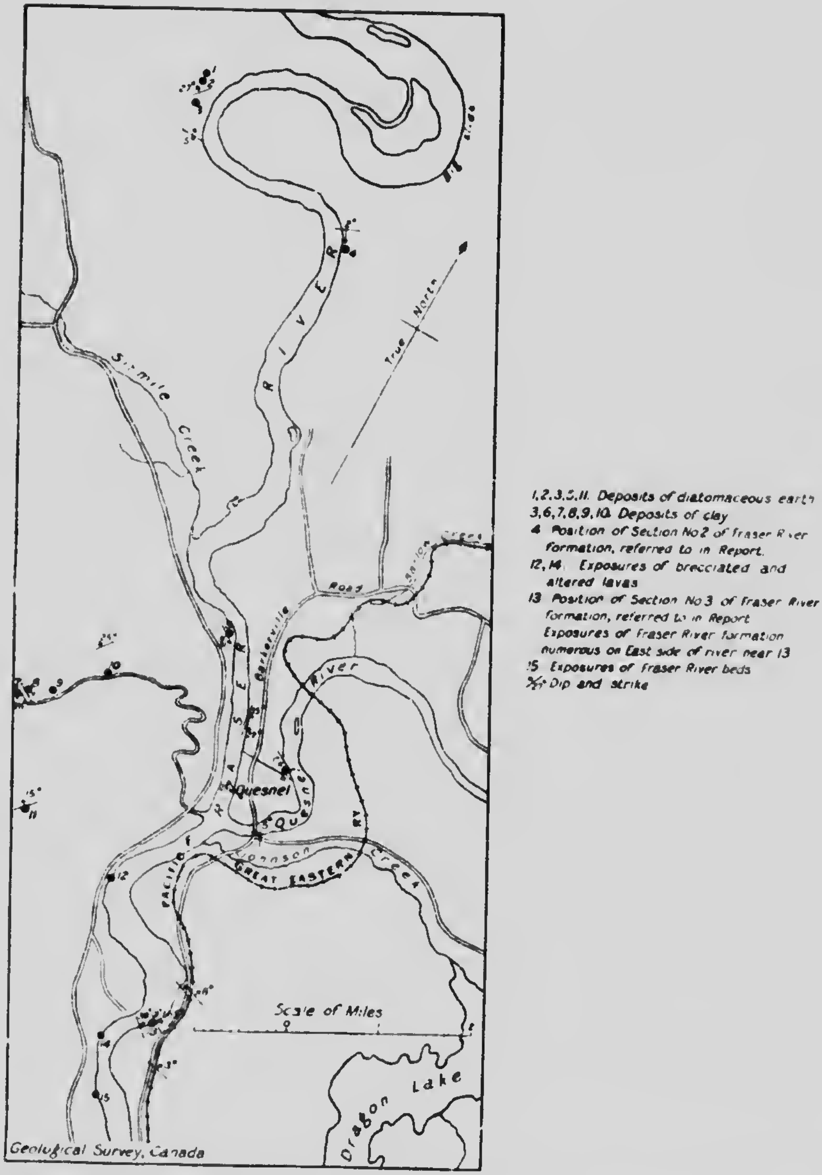


Figure 12. Clay and diatomaceous earth deposits near Quesnel, Cariboo district, British Columbia.

elevation above the lower masses and perhaps 400 to 500 feet above the creek bed. Probably less than 30 per cent of their aggregate mass would be clay, although there are parts which contain more clay. An accurate estimate of this character is most difficult to make, however.

Sample 6 is from an outcrop that lies one mile down the canyon on the west bank of the creek near the southeast corner of lot 8654 (Figure 12, locality 10). The outcrop which is of the same character as No. 5 is 80 by 120 by 40 feet in extent and is overlain by a red ochre clay that stains the white clay.

Sample 5. Semi-refractory. Grey-white, residual clay; only 40 per cent washes through a 150-mesh screen. Washed product has no plasticity, burns to a buff vitrified body at cone 7 (1290 degrees C.), softens and deforms at cone 15 (1430 degrees C.). Needs addition of 20 to 30 per cent of a clay like sample 7.

Sample 6. Semi-refractory. Crude clay, low plasticity, difficult to mould, burns to a hard, grey body at cone 7 (1290 degrees C.) and fuses at cone 18 (1490 degrees C.). Portion washed and 70 per cent of the washing passed through a 200-mesh sieve. The washed material had low plasticity and was difficult to mould. Burnt to a porous, white body at cone 7. Clay white enough for paper filler, but lacks cohesiveness. It needs addition of plastic clay as in the case of sample 5.

The deposits from which sample 5 was taken lie on the steep slope of the canyon in a position not easily accessible and where they would be difficult to work. A road could, however, be built without much difficulty to the flat on which the lower outcrop (sample 6) lies. This would be about 2½ miles from steamboat transportation. A few other outcrops on the south side of the canyon may yield workable clay.

North of Quesnel.

Eight miles above Quesnel, on top of a series of steep bluffs from 400 to 600 feet high, are outcrops of beds of clay and infusorial earth (Figure 12. locality 3) that have been subjected to sliding, and lie in detached masses. Outcrops are not plentiful except near the cliff edges, and the beds have not been traced to their original location. They belong to the Fraser River formation of Tertiary age and their horizontal extent is in all probability quite limited.

Sample 7 was taken from a bed 20 feet thick and 50 feet long (Figure 12, locality 3). Undoubtedly more clay of the same quality is present, and another 20-foot bed overlain by 20 feet of infusorial earth occurs nearby. The location of the original bed should be sought for back from the cliff faces to the west.

Sample 7. Stoneware clay. A grey-white, bedded clay. Plasticity and working qualities good. Dries well and has low air and fire shrinkage. Burns to a white, porous, strong body at temperatures up to cone 7 (1290 degrees C.) and a strong dense body at cone 7. It softens and deforms at cone 17 (1470 degrees C.). This is a clay suitable for stoneware manufacture, the first recorded from British Columbia. Mixed with the clays from Baker canyon, it could be used to advantage in making semi-refractory clay products.

There is an overburden of soil 2 feet thick on the outcrop. In other places there is from 5 to 7 feet of soil and large trees.

North of Prince George.

Sample 8 was taken from a series of beds, probably of Tertiary ag outcropping for 750 to 1,000 feet on the immediate west bank of Fras river, in lot 3991, 30 miles above Prince George (Figure 1, locality 2 The following section was measured from the river level up.

(a) Covered with talus 7 feet.
(b) Bluish-grey clay 3 feet.
(c) Sandy, white-grey clay 2 feet.
(d) Very plastic, white clay 2 to 6 feet.
(e) River gravel and boulders 4 to 8 feet.

Sample 8. Fire-clay. Grey-white, bedded clay. Good working an drying properties. Sandy in texture. Burns to white, porous bodies u to cone 7 at which it is cream-coloured, hard, and porous with total shrin age of 6 per cent. It is intact at cone 20 (1,530 degrees C.) and wou probably stand up high enough to be classed as fire-clay. On accou of its good working and drying qualities, low shrinkage, and refractorine this material would make firebrick and stove linings.

The outcrops are over 700 feet in length, but how far the beds exte back under the flat terrace that forms the top of the gravel is not kn w A wagon road $1\frac{1}{2}$ miles long would connect the deposit with the Prin George-Giscome portage road at a point about 22 miles from Prince Georg The most feasible method of transportation is by scow down the river Prince George. There is a steamer channel all the way. Although t overburden that will have to be moved is thick in places there should enough material to pay for exploitation. Care should be taken to separa the different beds, for the lower beds recorded above are not in a probability, of equally good quality. This clay cannot at the prese railway freight rates be shipped to eastern Canada at a profit, but it m become a decided asset if a market can be found for it in northern Briti Columbia.

BRICK CLAYS.

Ten samples of clays that were not of refractory grade were teste Of these the white silts at Lillooet (Figure 2, locality 40) and grey, bedd clays at Quesnel (Figure 1, locality 10 and Figure 12, locality 6) gave t most satisfactory results. Both are suitable for the making of comm building brick and the Quesnel clay can in addition be used for makin drain tile. Very large amounts of the white silts similar to those at L looet are found at intervals in the immediate neighbourhood of Fras river from Lillooet to Quesnel. The Quesnel clays are not of very gre extent. The clays tested at Australia creek might be used for makin building brick if no better material were available. None of the oth clays tested are of commercial value.

Sample 1. One mile from Lillooet on road to Seton lake (Figure locality 40). Green-grey, bedded silt of White Silt formation of Glaci age. Eighteen feet of 40-foot bank sampled, with coarser layer omitte Clay is short in texture when wetted, burns to light red porous bod Shrinkage air dried, 5 per cent, burnt at cone 03 (1,090 degrees C.) 7 p cent. Absorption, cone 010, 18 per cent, cone 03, 17 per cent. Mak good common brick by soft mud process; not plastic enough for wir cut brick or drain tile. Bank is 40 by 400 feet in outcrop. Many large deposits at intervals along Fraser canyon as far as Quesnel, see section on page 19. Silt from near Kersley yielded similar results.

Sample 2. In railway-cut just north of 17 Mile ranch, Fraser canyon (Figure 2, locality 38). Dark grey, residual clay in 15-foot bed of andesite. This is bed No. 5 of section in Lower Volcanics (see page 12). Good plasticity, but stony. Burns to porous, red body of low strength. Not refractory and not of commercial value because of its stone content.

Sample 3. West of sample 2. Yellow white or drab, residual clay in 12-foot bed of white andesite. This is bed No. 12 of section in Lower Volcanics (see page 12). Extremely stiff, soapy, and hard to work. Cracks badly on drying and cannot be used in plastic state. Worked by dry process, yields sound, dark red bricks suitable for face brick. Not refractory and not of commercial value because of stone content.

Sample 4. West of sample 2. Green-grey, residual clay in 35-foot bed of dacitic ash. This is bed 21 of section referred to in Nos. 2 and 3. Its properties resemble No. 3.

Sample 5. From base of slide opposite Pavilion station (Figure 2, locality 37). Red, stony clay derived from Coldwater formation. The clay content has good plasticity, burns red, but brick develops cracks in firing. Shrinkage air dried 9·5, burnt to cone 03, 13 per cent. The clay content would make common brick, but it would not pay to separate the rock from it for that purpose.

Sample 6. Just west of and above Cariboo road, 17 miles north of Ashcroft, in Bonaparte valley (Figure 2, locality 36 and Plate XIII). Green and yellow, residual clay in an 80-foot bed of grey quartzite of the Cache Creek series. The beds are faulted, mineralized, and much altered; 75 per cent of mass is clay. The clay part separated by washing, burnt to tiles dark red at 1,000 degrees C.

Not refractory and not of commercial value because of stone content.

Sample 7. Overlying sample 6. Yellowish clay in a 40-foot bed of white, coarse quartzite of the Cache Creek series. Same properties as sample 6.

Sample 8. Just below [illegible] seam of lignite 20 feet from mouth of tunnel on Australia creek (Figure 1, locality 11). Drab-grey clay in 1-foot bed in the Fraser River formation. Another seam of same kind and thickness 5 [illegible] below. Fairly plastic. Burns to deep buff. Shrinkage air dried 6 per cent, at cone 06 (1,[illegible] degrees C.) 12 per cent. The shrinkage is high and sand should be [illegible] brickmaking. A rapid rise of temperature [illegible] will [illegible]. A fair grade of common brick.

Sample 9. [illegible] lignite seam, same location as sample 8. Several beds of brownish clay, [illegible] thickness 5 feet. [illegible] and crumbling [illegible] when wet. Burns to light red, [illegible] body at 900 degrees C., red [illegible] and vitrified at 1,[illegible] degrees C. [illegible] bloats at higher temperatures. A poor grade of common building brick.

Sample 10. [illegible] brick yard [illegible] bank [illegible] village (Figure 1, locality 10, and Figure 12, locality 6). [illegible] bed of grey to drab clay of Fraser River Tertiary formation [illegible] with beds carrying [illegible] concretions, 17 feet [illegible] 3 feet of carbonaceous clay and [illegible] of silt and [illegible] working qualities good, requires [illegible] per cent of water [illegible] after moulding, but shrinkage rather high. Burns to pale red, hard bod at 900 degrees C., and dark brown vitrified body at 1,100 degrees C Flows smoothly through a die and is suitable for making field drain til as well as for bricks. Will require admixtures 20 to 30 per cent of san because of the high shrinkage. It is not a fire-clay. Outcrops for at leas 200 feet along river where the 5 to 7 feet of overburden could be dumpe into swift current. Flat terrace 120 feet wide with an old brick-yar clay mill, and covering racks still standing.

MINERAL PIGMENTS.

Samples of clay from 17 Mile ranch and from Baker canyon opposit Quesnel were tested by H. Frechette of the Mines Branch to determin their values as mineral pigment.

Samples 1 and 2, west of railway cut north of 17 Mile ranch, Frase canyon (Figure 2, locality 38).

Sample 1. Red clay from a 10-foot bed of basalt (No. 10, page 12)

Sample 2. Purplish, brown clay from a 30-foot bed of red-brow andesitic agglomerate (No. 15, page 12). These belong to the Low Volcanics (see section on page 12). The beds are only partly turned t clay.

Samples 1 and 2 when ground in raw oil produce a chocolate brow and when burnt and ground in oil a light brown-red colour. The colou lacked the brilliancy of commercial ochre. The large amount of grit i these clays makes them of no value in the manufacture of pigments. Clay from this bank, burnt and mixed with salmon grease, have been used fo generations by the Indians of Pavilion for tracing the tribal history i pictographs on the rocks. These old drawings retain their colour for a lon time.

Sample 3. From Baker canyon 2½ miles from Fraser river, opposit Quesnel (Figure 1, locality 7, and Figure 12, locality 10). Overlies a be of refractory, white clay, No. 6, page 12. It is derived from rocks of th Cache Creek series. There is a thickness of 10 feet of the parent roc on top of a cliff 80 by 120 feet in horizontal extent, and the clay forms onl a part of this. Three hundred feet north a 3-foot bed of red clay overli steel grey clay and conglomerate. This bed has evidently been washe from the cliff. The clay is not suitable for brickmaking, but may be o use as a pigment. When ground in raw oil it produces a brown pain somewhat similar to Peruvian ochre, but not so dark or rich in tone. Burn and ground in oil it produces a brick red paint with the tone of Englis Venetian red and lighter in colour than standard Canadian red oxid Both raw and calcined materials have good covering and staining powe and would possibly produce a marketable pigment. This material wa used with very satisfactory results in painting a house in Quesnel.

ORIGIN OF THE RESIDUAL CLAYS.

Two possible modes of origin of the residual clays present themselve They could have been formed at the surface by weathering of the paren rocks through the agency of atmospheric waters, or they were formed b the introduction of the clay substances from the outside; in this case b means of hot solutions rising from below. The second process seems t have taken place in this case; the reasons for which are as follows:

The original rocks in the Cache Creek series could not by simple weathering have been turned to clay, since the clay contains elements which have been added to them presumably by hot ascending solutions. The residual clays in the Lower Cache Creek series occur in rocks composed essentially of quartz in very fine grains, in some cases 005 millimetres and less, with a small percentage of muscovite or hydromica. Where the rocks have disintegrated to clay the change appears to have consisted solely in an increase in the amount of hydromica or in other cases of hydromica with kaolin and other clay-forming substances. The residual clays in the Lower Tertiary Volcanics lie in lavas and ash rocks that have glassy or very fine groundmasses, and the change to clay has produced what looks like hydromica, kaolin, iron oxide, carbonate, etc. In this instance the rock itself possibly could have furnished the elements for its alteration products. In residual clays in Cache Creek rocks, however, the fresh rock is made up essentially of quartz which cannot, by the agency of atmospheric waters, be turned to clay-forming elements, nor is there enough hydromica in the parent rock to account for the clay by simple alteration of that mineral to kaolinite. The increase of hydromica and the actual replacement of quartz by it can be accomplished only by the agency of hot ascending solutions. In places like the Bonaparte clay belt, the widespread occurrence of pyrite in the parent rock shows that there has been mineral deposition through the agency of ascending solutions. The presence of gypsum in these clay banks shows, on the other hand, that oxygenated atmospheric waters have also had an effect, forming sulphate waters from the pyrite after its deposition, and from these gypsum, $CaSO_4+2H_2O$, has been precipitated.

The zone of decomposition is related to fracture zones rather than to a land surface or zone of weathering. In all cases where residual clays were examined the rocks in which they occur have been much disturbed, that is, either closely folded or faulted and brecciated, or both crumpled and faulted. Figure 11 illustrates the close relationship at Chimney Creek bridge between a zone of faulting and the extent of the residual clay. At 17 Mile ranch, the Lower Volcanics are lying in a syncline and it is along the upturned beds on the edge of the syncline, where a great deal of faulting has taken place, that the clay banks lie (Plate XII). On the Bonaparte (Plate XIII) the Cache Creek beds are also much disturbed and similar beds in Baker canyon have been much crumpled. In all these places it is possible to find beds of the original, unaltered rock lying at the same level as the altered material. At Chimney Creek for example, fresh rock not only underlies the clay belt but is found at the same level to the north of it. At Baker canyon there is fresh rock over the clay.

Age of Formation.

The absolutely unaltered character of the Miocene basalt lying directly over Cache Creek clay in Baker canyon, proves that the clay-forming processes had ceased to act in the late Miocene. In Baker Creek canyon, near the occurrence of residual clays in the Lower Cache Creek rocks, masses of the same residual clay occur as boulders in a gravel carrying plant remains and underlying the upper Miocene basalts. This gravel belongs to the Fraser River formation and the clays were, therefore, formed in the Cache Creek rocks before the Fraser River beds were laid down. The Lower Volcanics of Miocene age that underlie the Fraser River formation at Quesnel, were first faulted and brecciated and afterwards turned to clay, so that the clay-forming processes were active after the extrusion of the Lower Volcanics. The evidence, therefore, indicates that the period of clay formation, if it be assumed there was only one such period, antedated upper Miocene time and post-dated a period of faulting. This period of faulting must have followed soon after the extrusion of the Lower Volcanics, and, therefore, the formation of the clays can be ascribed to heated solutions and vapours derived from the same source as the lava and rising to the surface after the lava eruption.

CHAPTER VI.

DIATOMACEOUS EARTH, LIGNITE, PERIDOT, AND MUSCOVITE.

DIATOMACEOUS EARTH.

Deposits of diatomaceous earth were examined in the vicinity of Quesnel. Diatomaceous earth is the name given to deposits that are usually white or cream-coloured, and consist wholly or in part of the siliceous tests of low forms of plant life known as diatoms. These tests or shells are very minute, the largest smaller than a pin head, the average visible only under a high-power microscope. They are composed wholly of hydrous silica and contain a great many small pores arranged in intricate patterns. The chemical composition, minute size, hardness, and porosity of the tests, have made the earths composed of them useful in a number of ways. The coherent earth, reduced in a manner which will not destroy the tests themselves and separated into powders of varying fineness, is used largely as an abrasive and polishing agent in metal polishes, soaps, metal powders, match heads, etc. The purer products are used in the manufacture of siliceous glazes and waterglass or silicate of soda. The large amount of pore space within the tests prevents the passage of heat through the loosely packed earth or through blocks and bricks made of it. This property, combined with the ability to stand great heat without fusion, makes the earth of great use as insulating linings for furnaces, ovens, safes, as well as in the walls of cold storage receptacles. It has also been used as an absorbent for corrosive liquids, liquid manures, and nitroglycerine, and for many other purposes.[1] [2].

OCCURRENCES AT QUESNEL.

Deposits of diatomaceous earth occur in a cliff-face 2 miles southwest of Quesnel (Figure 12, locality 11, and Plate XIV), also 2 miles farther up Fraser river (Figure 12, locality 5), and a number of deposits occur on top of the river-cut cliffs on the big bend of the Fraser 8 miles north of the village (Figure 12, localities 1, 2, 3). All these localities are west of Fraser river. A small lens of the earth is exposed in the brick-yard at Quesnel and there are a few other unimportant occurrences near the river (Figure 1, localities 6, 7, and 9).

[1] Boeck, Percy A., "The Kieselguhr industry," Metall. and Chem. Eng., vol. XII, No. 2, Feb., 1914, pp. 109-113.

[2] Frechette, Howells, "Report on the non-metallic minerals used in the Canadian manufacturing industries, Mines Branch, Department of Mines, Ottawa, 1914, pp. 105, 107.

Character.

The material is exceedingly fine-grained, quite coherent, grey-white to cream-coloured, and of exceptionally light weight. Seven samples from the two main deposits examined under the microscope were found to be composed almost wholly of cylindrical tests varying from about 0·003 to 0·03 millimetres in length and about one-fourth as wide as long. In one slide, diameters up to 0·04 millimetres were seen. Some samples contained minute impurities that are probably clay, others contained quartz grains, and in one was a piece of woody substance.

Structure.

On a steep hill-slope 800 feet above Fraser river and 2 miles southwest of Quesnel, near the southwest corner of lot 906 (Figure 12, locality 11), about 48 feet of infusorial earth is exposed in thick beds (Plate XIV), between which are three layers of silty or sandy beds having a total thickness of 14 inches. Unconformably over this is a thick bed of basalt with broken basalt and clayey gravel at the base. The beds of infusorial earth strike north 3 degrees east and dip west, and the strike of the basalt is northeast with a dip of 15 degrees to the west. The structure is somewhat obscured by faulting that may be due to local slipping of the beds down the steep hillside.

About 8 miles from Quesnel, on the right bank of the Fraser, at the west end of a big "S" curve of the river and at an elevation of 500 feet or so above the river (Figure 12, localities 1, 2, 3), masses of diatomaceous earth are found on top of a series of river-cut cliffs. The cliffs below are composed of bedded gravels, sands, and clays, which at the south end of the cliff faces strike north 75 degrees east and dip northwest about 5 degrees. Six detached masses of the earth were located near the edge of the cliffs opposite the middle of the bend. Three of them strike approximately north 33 degrees east and dip northwest, others lie nearly at right angles to this direction. Some are interbedded with grey and whitish-grey clay. Outcrops were seen at intervals for 600 feet to the west of the cliff in the neighbourhood of a small gulch, and the whole area for that distance back of the cliff faces has been disturbed by sliding that has taken place in the direction of the river.

Two miles up the Fraser from the village, on lot 1120 (Figure 12, locality 5) a few hundred feet from the west bank, 4 to 5 feet of infusorial earth outcrops on both sides of a small gully. The average strike of the beds is south 55 degrees east with a dip of 33 degrees to the west. They are underlain by bedded sands and clays.

Just north of the old brick-yard at Quesnel, is a lens of infusorial earth 10 feet long and 1½ feet thick at its thickest point. It contains lenses of silt, clay, and iron oxide, and is overlain by 2 feet of boulders, sands, and clays, probably recent river deposits.

Quality of the Earths.

Table XI shows three analyses of samples of diatomaceous earth from the 44 feet exposed in the 48-foot section occurring 2 miles southwest of Quesnel (Figure 12, locality 11). No. 1 is from the top bed 11 feet thick

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composed of white, thin-bedded earth with a few leaf remains. No. 2 is from the middle bed 12 to 15 feet thick, apparently carrying some clay also plant remains, and a few pebbles. Between these two beds is 2 feet o earth similar to that in No. 1 and 3 inches of impure material. No. 3 i from a 15-foot bed at the base, resembling the middle bed but with more impurities, and is separated from the middle bed by 8 inches of sandstone and from a 3-foot bed of diatomaceous earth below, by 3 inches of silt Included with these analyses, which were made by F. W. Baridon, Mines Branch, Ottawa, have been placed for comparison an analysis, No. 4, of a pure commercial diatomaceous earth from California[1], and two partia analyses of commercial earths, Nos. 5 and 6, from Nova Scotia.[2]"

Table XI. Analyses of Diatomaceous Earth.

	1	2	3	4	5	6
SiO_2	70·20	79·81	76·52	88·78	72·10	81·[illegible]
Al_2O_3	12·60	7·60	8·63	2·68		
Fe_2O_3	1·56	2·82	3·92			
FeO	0·81	0·51	0·09	trace.	0·51	0·3[illegible]
TiO_2				0·10		
CaO	0·85	0·50	0·53	1·61		
MgO	1·70	1·00	1·12	1·30		
Na_2O / K_2O	0·60	0·27	0·20			
MnO	trace.	trace.	trace.			
H_2O above 105°C	7·66	6·22	6·56	5·51	10·70	9·3[illegible]
Carbonaceous matter	1·06	1·01	1·20		6·30	0·[illegible]
	100·04	99·77	99·37	100·01		
Loss on drying at 105°C	7·97	6·52	6·80		6·10	5·1[illegible]

From the analyses it appears that the middle bed is the purest of the three. It carries more silica and a smaller percentage of impurities than the top and bottom beds; the top bed is the poorest. The large percentage o iron would cause the material, not any of which is pure white in the un burned state, to burn reddish. The composition of the beds at the b bend to the north may show a somewhat higher percentage of silica, a indicated by the tests for absorption.

The results of tests of the fineness and absorption of the material are given in Table XII. Here Nos. 1, 2, 3 represent three beds referre to in Table XI. Nos. 4, 5, 6, and 7 refer to deposits occurring along th top of the cliffs at the big bend (Figure 12, localities 1, 2, 5). These deposit lie near together and are numbered from south to north as they occur alo the top of the cliff. Number 4 lies at locality 3 in Figure 12 south of a sma canyon in the face of the cliff (Figure 12, localities 1 and 2). Nos. 5, 6 and 7 lie north of this canyon.

[1] Beck, Op. cit., p. 109.
[2] [illegible], C., "Mineral production of Canada for 1914," p. 173.

Table XII.—Fineness and Absorption of Diatomaceous Earths.

Total percentage retained on sieves.	1	2	3	4	5	6	7
100 mesh....	7	1	4	12	2	12	9
150 mesh....	11	5	11	28	4	34	20
200 mesh....	38	47	68	70	34	65	50
Passing 200 mesh....	62	53	32	30	66	35	50
Absorption. Cubic centimetres absorbed by 100 grams of earth.	113	130	113	127	141	133	128

Howells Frechette, Mines Branch, reports as follows in regard to methods employed by him in making these tests.

"The crude material was firmly coherent and difficult to break down without at the same time breaking the integral grains. Great care was taken during the crushing not to overgrind the material, therefore it is altogether likely that the percentages shown retained on the larger screens do not represent coarse grains but rather uncrushed particles of the original aggregate. Due to the angularity of the particles and their light weight, the material fluffs and forms small pellets on the screens, which are difficult to overcome. Therefore, the percentages of the material passing through the 150-mesh and retained on the 200-mesh screens are higher than they should be. In other words, it is probable that the percentages shown of material passing through the 200-mesh screens are lower than they should be in all cases.

"The following method was used to obtain figures to represent the capacity of the several samples for absorbing liquids. On the addition of water to the powdered material it was readily absorbed and a sample first became roughly coherent though crumbly. As the water content increased, the sample suddenly lost its "shortness" and became slightly plastic and could be considerably deformed with a spatula without showing cracks. Check tests showed that the amount of water necessary to attain this condition was practically the same for any one sample. The amount of cubic centimetres of water absorbed by 100 grains of the material when at this condition was used as a measure of the absorption."

High absorption probably indicates large percentage of diatoms relative to that of clay and other impurities in the earths. Sample No. 2, for instance, which is higher in silica and lower in impurities than samples 1 and 3, has also a higher absorption. If this conclusion be correct the material on the bluffs (Figure 12, localities 1, 2, and 3), is of somewhat higher grade than that at locality 11, Figure 12.

Commercial Development.

The deposit southwest of Quesnel (Figure 12, locality 11) lies near the summit of an east-facing hill at an altitude of 300 feet above the level of the Fraser. The outcrop, about 100 feet in length and 40 feet high (Plate XIV), is covered by debris in both directions along the strike. In the direction of dip it is overlain by 3 feet of gravel and 7 feet of basalt, and farther in this direction the hill rises for 35 feet, partly slide material and partly solid basalt. The nature and thickness of the overburden ar such that it cannot be profitably stripped off for more than a few yard inwardly from the present outcrop, and further excavation would have t be by underground methods. It is possible that stripping along the hill sides in the direction of the strike will reveal more deposits of the earth although a traverse of about one mile in that direction did not reveal an further outcrops. A wagon road of slightly more than 2 miles in lengt would be required to transport the material to the ferry-landing opposit Quesnel.

On top of the bluffs at the big loop (Figure 12, localities 1, " 3), th deposits lie mostly near the edge of the cliffs at elevations of from 430 t 550 feet above the river. They lie in detached masses and the amoun of diatomaceous earth in sight at each of these is small, the aggregate of si being about 7,000 cubic yards. Other masses, probably undisturbed b slipping, should be looked for west of the cliff edges toward the east line o lot 8643 and beyond. Near river level is a suitable site for loading bins and a small wharf. The earth would have to be taken down the cliff b aerial tramway or some other economical method.

The deposit 2 miles up the river from Quesnel (locality 5) is of smal extent and the lens at the brick-yard is not important.

Preparation of the material for the market would have to take plac at a central point like Quesnel, convenient to both the railway and river.

LIGNITE.

Lignite beds were seen at Quesnel and there are a number of outcrop on the Fraser south of that village, but the only known bed of commercia size occurs on Australia creek about 1½ miles east of the river (Figure 1 locality 11). A seam varying from 3 feet 6 inches to 3 feet 10 inches i thickness outcrops about 20 feet over the level of the creek on the nort side. Below the seam 1 foot of drab clay is underlain by 5 inches of lignit under which is 11 inches of clay succeeded by 1½ feet of lignite, makin about 2 feet of clay and 2 feet of lignite in addition to the main seam. detailed section of the beds is given on page 4. The strike of the coal sean is north 44 degrees east with a dip of 20 degrees to the northwest. A slop has been run down the main seam into the hill for about 50 feet in a directio approximately at right angles to the strike. The lignite maintains a fairl uniform thickness in the tunnel, although thin seams of clay appear an peter out. An analysis of the lignite, made by Edgar Stansfield of th Mines Branch, is given below. The sample was taken across 3 feet 1 inches of the main seam on the west side of the tunnel at its face.

Table XIII.—Analyses of Lignite from Australia Creek.

—	R	D
Moisture	11·5 per cent.	
Ash	29·4	33 2 per cent.
Volatile matter	30 6 "	34 6 "
Fixed carbon (by difference)	28 5 "	32 2 "
Carbon hydrogen ratio	0·93 The lignite is non-coking	

Column R refers to analysis of sample as received, column D to sample dried at 10 degrees C.

The high ash content of the Australia Creek lignite condemns it for industrial purposes. The ash content undoubtedly varies from point to point and could be reduced considerably by careful sorting out of the shale. The lignite should eventually prove useful as a local source of fuel. Two seams of lignite 2 feet and 7 inches thick with 15 inches of clay between, crop out 200 feet down the creek from the tunnel. They correspond stratigraphically with beds Nos. 25 and 22 in the section, page 17, which are 8 inches and 2 inches thick, respectively. Other seams, said to have been exposed a hundred feet or so up the creek, were covered by debris at the time of visit. Outcrops of lignites were reported on the east bank of Fraser river 1 mile south and nearly 4 miles north of Australia creek, but a search for these proved unsuccessful, owing perhaps to a combination of slides and high water. No other outcrops of lignite are known in this vicinity and no basis exists for believing that the outcrops mentioned on the Fraser and that at the tunnel represent parts of a continuous bed of lignite. The 3-foot 9-inch seam exposed in the tunnel probably underlies an area of several acres, but its extent can become known only by development work.

PERIDOT.

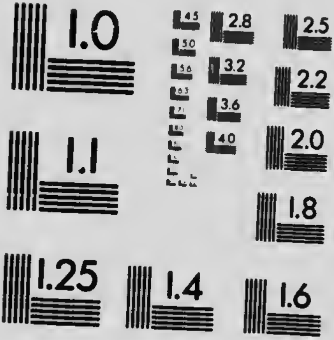
Peridots occur in a series of basalts on the summit of Timothy mountain (Figure 2, locality 17, and Figure 13, locality 3, see also Plate XV).

Peridot is another name for the common, rock-forming mineral olivine, Mg (Fe) SiO_4. A dark green variety of this mineral is very much in vogue as a cheap form of jewellery. According to one of the leading jewellers in Canada peridot stones are used to give pleasing effects in combination with other and more precious forms of jewellery and to harmonize with many colours of wearing apparel. Although olivine is a common rock mineral, the dark green variety is rarely found in such form and quantity that it can be profitably mined for commercial purposes. The stones are commonly cut in round, square, and oval shapes varying in size from 3 to 6 millimetres ($\frac{1}{8}$ to $\frac{1}{4}$ inch). Cut stones of these sizes are sold at from 40 cents to $1.50, unmounted.

The basalts on Timothy mountain occur in two cone-shaped hills rising for about 220 feet over the plateau-like floor of quartz diorite that forms the summit of the mountain. Most of the peridot occurrences are on the north-east and steepest side of the hills. The peridots occur in irregularly shaped masses of red, brown, and green crystalline rock known as hypersthene peridotite. These lie in a reddish-brown groundmass. The peridotite masses generally have rounded corners, although there are many angular fragments scattered through the basalt and one had the form of a brick with banded layers. They vary in size from about $\frac{1}{4}$ inch to boulders 18 inches across. There are also boulders of grey quartz diorite in the basalt. The masses are coarsely crystalline and are made up of olivine with a lesser amount of pyroxene. The olivines are translucent, pale yellowish green through dark green to black. In certain masses they are stained red by iron oxide and this forms veinlets in the masses in places radiating out into the basalt. The olivines vary in size from $\frac{1}{50}$-inch to $\frac{1}{4}$-inch and over and have a conchoidal fracture and vitreous or glassy lustre. In the same

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



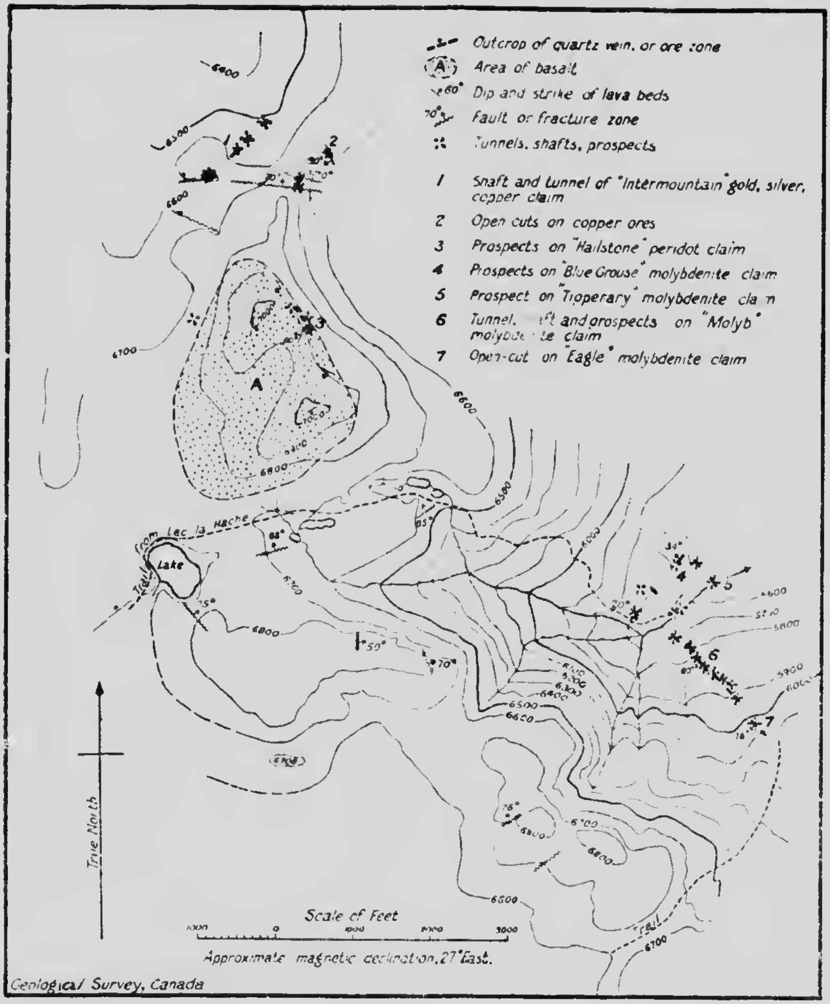


Figure 13. Molybdenite, peridot, and copper ore occurrences on Timothy mountain, Cariboo district, British Columbia.

masses are pyroxenes of a rich green colour with well-marked parallel striations. These are hard to distinguish from the olivines when small, but in many cases occur in large crystals up to $1\frac{1}{2}$ inches across. The olivines have the appearance of broken green bottle glass, whereas the pyroxenes are not translucent.

Under the microscope some masses of this material were seen to consist nearly entirely of olivine, others carry up to 30 per cent of hypersthene. Feldspar also occurs. Rare constituents of these masses are individuals of biotite, magnetite, and green spinel. The olivines are in most places clear and colourless; in others they are shot through with iron oxide in thread-like films. The hypersthenes are green and pleochroic in tones of green and golden yellow in thick sections; they are colourless in others. Two cleavages intersect nearly at right angles, but in many sections cleavage is poorly developed and the mineral is traversed by irregular cracks. They are negative in optical character with extinction angles up to 28 degrees. In certain cases twinning has taken place in narrow strips along one of the cleavage planes. Walker and Collins[1] have described hypersthenes of this character from the Hill Tracts, Vizagapatam district of India. A feldspar was determined as basic labradorite, $Ab_{30}\ An_{70}$, in one instance.

The basalt is dark brown, fine-grained, and holocrystalline, with pilotaxitic texture and amygdaloidal cavities. It is made up of iron ore, augite, olivine, and plagioclase. Quartz is present in one or two cases. The magnetite forms 15 to 20 per cent of the slides. The augite is of a reddish violet colour, in some cases colourless. So many fragments of olivine scattered through the matrix are clearly derived from the hypersthene peridotite that it is difficult to distinguish those that crystallized as a part of the basalt. These are small, of higher birefringence than other minerals present, and are stained brown by iron oxide. The plagioclases are andesines or labradorites in the few cases tested.

Certain fragments of hypersthene peridotite lying in the basalt have been fused along the edges and sometimes the whole fragment has been changed. In some places the outer edge of the altered mass is a ring of violet-coloured augites, in others it has been altered to a highly birefringent aggregate of small particles. Larger masses are not affected to so great an extent and in some instances there is no sign of fusion at the contact.

On the northeast and steeper side of the hills (Figure 13, locality 3) the actual contact between granite and lava is exposed at the foot of the hill, where it strikes north 10 degrees east and dips 60 degrees to the west. The granite is shattered and oxidized and the lava is dense at the contact. It has the appearance of a part of a fissure from which the lava was extruded. The immediately adjacent cliff which does not show bedding, but an irregular structure dense toward contact and porous away from it, may be the side of a lava dyke from which the quartz diorite has been removed. Across the basalt area 1,500 feet west from this place, an olivine basalt dyke cuts the quartz diorite striking south 35 degrees east and dipping 60 degrees west. It is 4 feet thick and trends away from the basalt area to the north, and to the south successive lava flows can be distinguished lying one over the other. In places there are pillow-shaped masses with layers like the skin of an onion. Ropy and amygdaloidal lavas are common, but no true ash beds were observed.

[1]Walker, T. L., and Collins, W. H., "Petrological study of some rocks from the hills of Vizagapatam district, Madras Presidency." Records, Geol. Surv., India, vol. XXXVI, pt. 1, 1907, pp. 14, 15.

The main occurrence of peridotite is in the cliff immediately west of the contact. It has been opened at a point 45 feet above where the contact was exposed and 100 feet southwest of it. There the masses lie in a zone that is 2 feet wide and trends north 29 degrees west and can be followed to the top of the cliff 75 feet above and 300 feet to the north.

The basalts appear to have come up for the most part quietly as flows of molten rock, with little or no accompanying explosive action. In their passage upward they have picked up and carried to the surface masses of peridotite and quartz diorite. As the lava was extruded its internal pressure was suddenly diminished through the escape of contained gases and there was a gradual loss of heat. It is probable that the diminished internal pressure caused the load of foreign material, peridotite and quartz diorite, to sink to the bottom of the molten layers and to remain near the point of extrusion while the main basaltic flow solidified farther on. This may account for nearly all the larger peridotite masses being in the cliff near the contact mentioned above.

COMMERCIAL POSSIBILITIES.

A few, small prospect holes have been opened on top and on the sides of the dyke-like cliff. A large percentage of the masses does not contain peridot of the proper size or colour for commercial purposes, and a fairly high proportion of waste must be looked for in mining. Further development work should be done in the face of this cliff and possibly later by sinking along the granite contact. Most of the waste rock will have to be eliminated at the mine, so as to save freight charges. Since there is no market for uncut stones in Canada nor in the United States, arrangements will have to be made for cutting the stones before their exploitation can be commercially successful.

MUSCOVITE.[1]

Mica is marketed in sheet, splittings, and ground form. The non-inflammable and non-conducting properties of sheet mica render it particularly suitable for the electrical industry and in place of glass in furnaces, stoves, and so forth. It takes the place of glass in windows subjected to shock and vibration, such as shields in aeroplanes, and windows in the conning towers of warships. Ground mica is used for lubrication, for annealing steel, as a filler in various compounds, in paints, wall-papers, and for other purposes. Sheets for condensors should yield a rectangle at least $1\frac{1}{2}$ by 2 inches in diameter. Prices per pound vary according to size of sheets, colour, and freedom from stains. It is estimated that the percentage of marketable sheet mica produced by Canadian mines averages above 5 per cent of the run of mine and rarely exceeds 10 per cent. In 1917 split and trimmed Canadian amber mica (phlogopite) sold in the United States at prices ranging from 11 cents per pound for 1 by 1-inch sheets, $1 per pound for 3 by 3-inch sheets, $3 per pound for 6 by 6-inch sheets, to $5.50 per pound for 8 by 10-inch sheets. White mica, from the

[1]de Schmid, Hugh S., "Mica, its occurrence, exploitation, and uses." Mines Branch, Department of Mines, 2nd edition, 1912, pp. 302-313.
Schaller, Waldemar, T., "Mica in 1917." U.S.G.S., Mineral resources, 1917, pt. II.

southern states, sold for 30 to 40 cents per pound for $1\frac{1}{2}$ by 2-inch sheets, for \$1.30 to \$1.55 for 3 by 3-inch sheets, \$3 to \$3.80 for 6 by 6-inch sheets, and \$5.65 to \$7.50 per pound for 8 by 10-inch sheets. The price varied according to whether the mica was spotted or clear. Slightly stained Indian muscovite sold at about the average price of the United States product.

A hasty visit was made to an occurrence of muscovite mica situated in the Clearwater (or Cariboo) mountain (Figure 2, locality 19). This property, owned by F. D. Foster, lies on one of the western ridges of the range between Clearwater and Crooked lakes, about 15 to 20 miles from the east end of Canim lake, in a direction north 2 degrees west, magnetic (approximately north 26 degrees east true azimuth). The location as given on the index map with this report may be in error as much as several miles. The elevation as determined by aneroid in unsettled weather, is 6,450 feet above sea-level. The claims were reached by two and a half days of hard riding from the west end of Canim lake over an Indian hunting trail. From the east end the trip would occupy one and a half days.

The mica occurs in a series of parallel pegmatite dykes lying in mica schist. The easterly dyke strikes east 53 degrees south, dips 54 degrees to the northeast, and is from 10 to 20 feet wide; its outcrop could be traced for about 500 feet. Other dykes lying parallel to and within a few hundred feet of each other are from 5 to 25 feet wide and form a belt that was traced a distance of about three-quarters of a mile. One opening is 20 by 15 by 8 to 10 feet deep. The mica crystals occur in bands in the pegmatite, the bands being up to a foot in width. The individual crystals seen varied from 6 inches to 12 inches in greatest dimension, through a distance of about 100 feet along the length of the easterly dyke. An outcrop of one of the dykes contained crystals 6 inches in diameter, but the diameter in general was rarely more than 3 inches and the greater part of the outcrop was barren. The thickness of the crystals was as a rule about one-third of the greatest dimension of the leaves. The crystals are in many cases wedge-shaped, books of leaves overlapping and "feathering out." A considerable amount of so-called "A" mica occurs, in which only a small part of the sheets is of any commercial value. The best crystals were perhaps removed from the open-cut before the writer's visit. The mica seen was white or nearly colourless with a greenish to amber tint. A great many crystals are stained yellowish by surface weathering.

The condition of the mica crystals at the surface, indicating that they have been subjected to pressure and contortion after their formation, is to be expected throughout the deposit, but the yellow stain on the mineral is likely to disappear in depth.

The dykes cross a nearly flat-topped ridge about half a mile wide, from both sides of which the land slopes steeply for several hundred feet. The dykes were not followed down the sides of the ridge for any great distance. If development is ever undertaken both depth and drainage could be obtained by a tunnel driven from the southeast slope of the ridge. The outcrops are above timber-line, but mine timber can be obtained within a short distance.

An expenditure of \$600 to \$800 would be necessary to construct a first class pack trail from the property to the east end of Canim lake. This trail could be travelled by heavily loaded pack trains during August and September, but shipments in June and July would necessitate bridging two large streams, namely, Spanish and Deception creeks. A heavily laden pack train could make a round trip every three days. The freight charges from the end of the trail, 20 miles by boat and about 35 by wagon to the railway grade, would cost from $20 to $25 per ton.

CHAPTER VII.

CHROMITE, MOLYBDENITE, MANGANESE, AND NICKEL.

CHROMITE.

Chromite ores lie on Chrome creek (Figure 14) one-quarter to half a mile above its entrance into Scottie creek, 4 miles by road from the point where Scottie creek enters Bonaparte river, and a farther 19 miles by wagon road with an easy grade to Ashcroft on the Canadian Pacific railway (Figure 2, locality 35). The deposit was discovered by Mike Ahearn in 1901, but was not developed until the first half of 1918 when the price of chrome and an anticipated shortage stimulated the search for new ore-bodies. Chrome creek flows between steep banks and has a broad, flat bottom of easy gradient, but the lower part of Scottie creek lies in a rather rugged gorge. The hills back of the creek courses are flat-topped and mostly drift-covered.

The ore mineral at Chrome creek occurs in serpentine rocks and consists of chromite, or more properly chrompicotite. It is associated with some magnetite and carbonates, probably of magnesium and calcium, and, occasionally with opaline silica, white magnesium sulphates, and chrome-bearing chlorites and garnets, but the garnets are not commercially important. Chromite is composed principally of the oxides of chromium and ferrous iron ($FeOCr_2O_3$), with varying amounts of magnesium, aluminum, and ferric iron chemically combined. The mineral rarely contains 60 per cent and sometimes contains only 10 per cent of chromium oxide. In this connexion it is important to bear in mind that no system of mechanical concentration of chromite ore can raise the percentage of chromic oxide above that contained in chemical combination in the mineral. A sample of chromite from this locality, Scottie creek, was forwarded to the Geological Survey in 1901 and examined and analysed by R. A. A. Johnston[1] with the following results: chromium sesquioxide, 55·90 per cent; alumina, 13·83 per cent; ferrous oxide, 14·64 per cent; magnesia, 15·01 per cent; silica, 0·60 per cent; total 99·98 per cent. Colour, velvet black, opaque; in very thin sections, however, translucent, and brownish-red by transmitted light: streak, grey to black-brown, fracture uneven, specific gravity 4·2. Its hardness is about 5·5, it is non-magnetic and it crystallizes in the isometric system, usually in octahedra.

Magnetite which occurs with chromite here and elsewhere has approximately the same colour, lustre, and shape of crystals. It can be distinguished from chromite by its streak, which is black, whereas chromite when scratched yields a brown powder. Magnetite is in all cases strongly magnetic, but chromite is rarely magnetic.

[1]Geol. Surv., Can., Ann. Rept., vol. XIII, 1900, pp. 11-12R. The location is incorrectly stated in this report because of a mistake by the person who forwarded the sample to Ottawa.

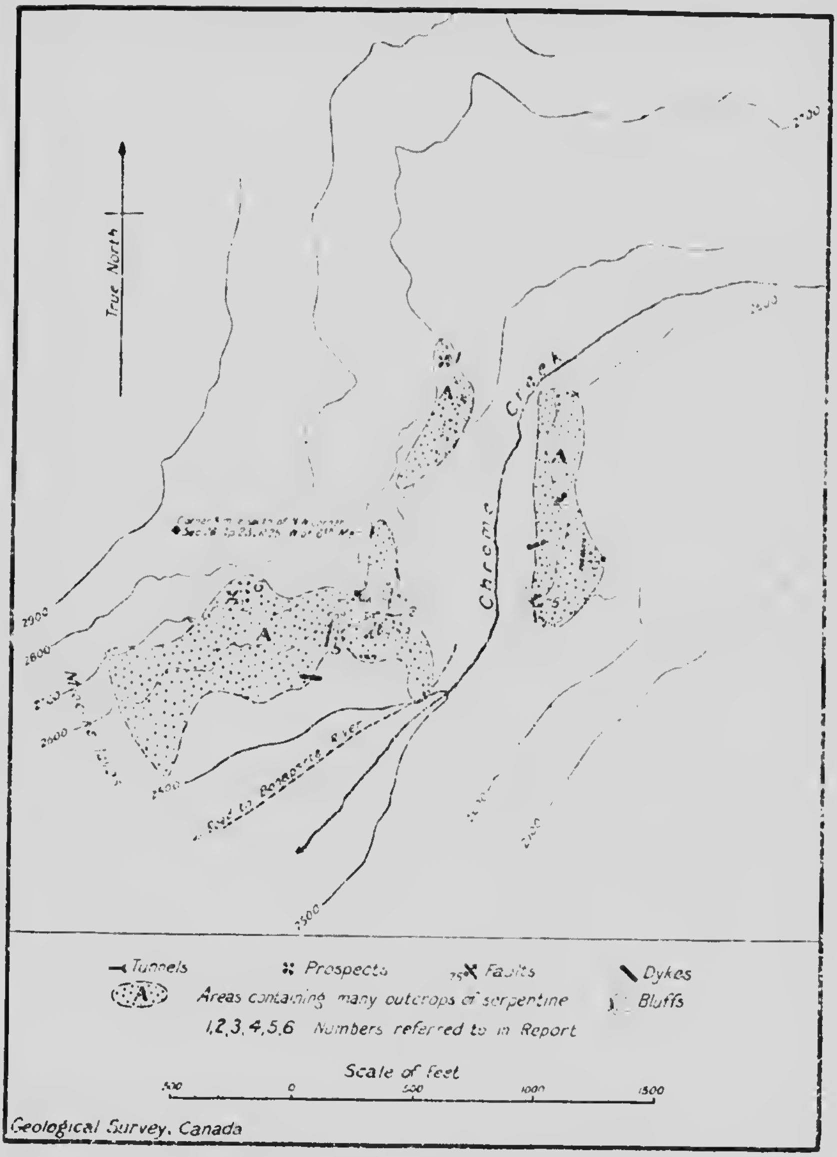


Figure 14. Chromite occurrence near Chrome creek, Kamloops district, British Columbia.

Very minute diamonds were discovered by R. A. A. Johnston[1] in the laboratory tests to be associated with the Scottie Creek chrompicotite but owing to their small size they are of mineralogical interest only.

Eugene Poitevin of the Geological Survey, Canada, collected samples of pinkish chromiferous chlorite and emerald green chromiferous garnet uvarovite from this locality, in the summer of 1918.

The serpentine in which the chromite occurs, outcrops on both sides of Chrome creek, (Figure 14). At the southwest extremity of this area are outcrops of Miocene basalts and augite andesites. The lavas outcrop also in the bottom of Scottie creek one-quarter to half a mile to the south-east and southwest. To the north and east, the country for long distances is covered with glacial drift. The serpentine in places is a greenish black, dense rock; in other places, light yellow green, much sheared, with films of white in the shear-planes; and in others it has a red colour. In the field these three varieties of serpentine are in most places sharply differentiated from each other by fracture planes, although in one or two exposures they were seen to grade into each other. The dense serpentine has an irregular almost conchoidal fracture and within it are forms with a well-defined, platy cleavage which may be serpentine, pseudomorphous after pyroxene, but of the original mineral matter from which the serpentine was derived nothing was seen. Through the serpentine mass are scattered black minerals with metallic lustre, which are secondary magnetite and, in the case of the larger individuals, chromite. Under the microscope the rock is seen to be made up practically wholly of serpentine and iron ore. There are larger individuals of the ore that are chromite, and smaller crystals of secondary magnetite lying parallel to the serpentine fibres in small veins in the rock. The yellow-green variety of serpentine is seen under the microscope to consist of iron ore, serpentine, and a carbonate. The serpentine has a fibrous appearance, the fibres being at right angles to central lines, giving them a feathery appearance. The carbonate lies in veins along these lines which are often roughly parallel over a small area, and from the main carbonate veins little arms project into the serpentine and into adjacent cracks, so that the carbonate is evidently of later origin. The red variety of serpentine found in certain places owes its colour to the oxidation of the iron ore crystals that lie scattered through the rock which consists of serpentine, iron ore, and carbonate, or areas that are a mosaic of fine secondary quartz, carbonate, and iron ore partly altered. The red variety apparently represents a further stage in the alteration of the serpentine.

Intruded into the serpentine are dykes of diallage pyroxenite and quartz diorite; one dyke of an acid, much altered rock was also noted.

Major fault planes were observed in the cliffs at the tunnel (Figure 14, locality 2), in prospect holes just to the west of this, and in the cliffs east of the valley. All these fault planes trend within 15 degrees of true north, most of them slightly to the east of north. Some well-defined fault planes in the serpentine occur farther west and trend northeast and northwest. In most exposures of the serpentine, the whole mass is very much fractured in an irregular manner into rounded, lens-shaped, and angular masses, some only a few feet across. Figure 15, in which a section of the wall of tunnel No. 2 is shown, illustrates the irregularity of the fracturing. The best-defined fault plane ((A) in this figure) is warped and has a northerly

[1]Geol. Surv., Can., Sum. Rept., 1911, p 360.

strike and low dip to the west; numerous other   at planes do not appear to follow any systematic plan. The dense serpentine outcropping in the hills on both sides of the creek at the tunnel lies in bands trending just west of north and dipping for the most part steeply to the west. South of the tunnel, in the cliff east of the creek, the dense bands swing around to the west and east. If these bands represent structural zones in the original igneous rock, if, for instance, they were the dense edges of flows or intrusions, they here indicate a system of close folds trending west of north, pitching southerly, and partly overturned to the east. The main faults, some of which are of the overthrust type, presumably, would have accompanied this folding. There is no proof, however, that the various bands do represent such structural zones. The serpentine is similar to the serpentines in the adjacent Bonaparte valley, classed by Dawson[1] in the Cache Creek series of Carboniferous age.

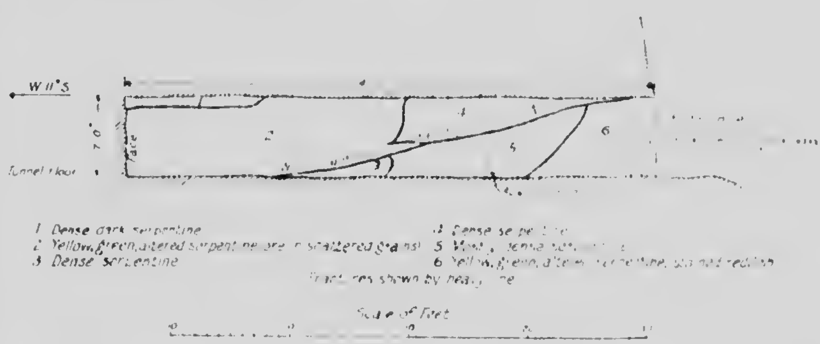


Figure 15. Fracturing of serpentine at north wall of tunnel, chromite occurrence near Scottie creek (Figure 14, locality 2), Kamloops district, British Columbia.

The mineral chromite appears to be extremely resistant to secondary alteration, the processes of serpentinization, and the further change of serpentine to carbonate and quartz, leaving the chromite unaltered. In some places, however, veinlets and scattered spots of green, chromiferous ...ts and pink, chromiferous chlorites, traverse the ore-bodies, proving ...ght, secondary alterations of the original chromite have taken place. ...chlorites and garnets, together with veinlets of opaline silica, are ...ntly related to the intrusion of quartz diorite and aplitic dykes that ...ar nearby cutting the serpentine body. The alteration is not related to surface weathering. Veinlets of magnesium sulphate found in the serpentine are probably the products of descending sulphated waters acting on the serpentine (Plate X).

The chromite is believed to have been formed during the cooling and crystallization of the original igneous rock from which the serpentine was derived, the richer ore-bodies forming by the collection of chromite crystals (segregation) during the cooling. This is proved by the association of chromite with diamonds at this place, page 88. Diamonds are formed under conditions of great heat and pressure and must have been one of the original minerals of the rock body. Moreover, the ore lies within

[1]Dawson, G. M., "Report on the area of the Kamloops map-sheet." Geol. Surv., Can., vol. VI, pt. B, p. 86B.

the serpentine in bunches of irregular form or in grains scattered through the serpentine body with no apparent connexion with later intrusions or fissure veins. The relation of the chromite to the rock is that of an original mineral, therefore, and not of a later accession.

MINING DEVELOPMENT.

A number of claims have been staked. The Iron King and Iron Queen are owned by Stewart Calvert Company, of Oroville, Washington. On these two claims there is an open-cut (Figure 14, locality 1) and, east of Chrome creek, outcrops of serpentine. Claims owned by Mr. Bryson of Pavilion and leased by Stewart Calvert Company, lie west of the above-mentioned two claims. Workings on these leased claims include a tunnel 46 feet long (Figure 14, locality 2), and four prospect pits (Figure 14, localities 3, 4, 5, and 6). At the end of July, 1918, the total amount of excavation represented by the four prospect pits or open-cuts amounted to about 700 cubic yards, and about 75 yards had been taken from the tunnel. There had also been prospecting work in other places. At the date mentioned, about 200 tons of ore averaging about 40 per cent of chromic oxide and 40 or 50 tons of lower grade, had been produced, and there were a few hundred tons in sight. Later on another 100 tons was excavated, mostly from the westerly opening (Figure 14, locality 6). No ore had been shipped up to the summer of 1919, but a wagon road had been constructed to connect the property with the Ashcroft-Clinton road. Mr. E. Calvert of the Stewart Calvert Company supplies the following assay results of the chrome ore: average assay from open-cut No. 1 and an open-cut on cliff top just south of No. 1 on the Iron King claim, 42·6 per cent Cr[illegible] average of ore from near tunnel and from open-cuts Nos. 5 and 6 [illegible] per cent Cr_2O_3. Float on the Iron Queen claim, across the creek [illegible] the tunnel, 41·2 per cent Cr_2O_3.

Ore-bodies.

The ore occurs in nodules, lenses, and tabular sheets, some of them with quite definite borders, and is also disseminated through the serpentine. Areas of disseminated ore are not necessarily connected with a core of rich ore. The ore lies in either dense black or yellow-green, altered serpentine with no apparent relation to any determinable structure. The trend of two of the ore-bodies seems to have been northeast by east; [illegible] trends east. Faults trending east of north have offset the ore in at least two places. The ore-bodies vary in size and all those so far uncovered have been small. At open-cut No. 1, a rich ore-body 15 feet long, 8 to 10 feet wide, and about 8 inches in thickness was uncovered. The open-cut No. 3, about 80 feet long with an average depth of about 5 feet, followed a small ore-body for most of the length. About 150 tons of ore were excavated. The ore pinched and swelled, its thickness being measurable in inches more often than in feet. About 100 tons of ore were taken from the most westerly opening, No. 6.

Ore Available.

The chrome ore is an essential part of the rock mass in which it occurs. Because of the isolation of the serpentine from outcrops of other rocks the structure, shape, and size of the serpentine mass could not be determined and any estimate of the possible amount of chrome ore present is, in such circumstances, simply speculative. The serpentines of the district in general occur in bands or sheets that are as a rule not very wide: a bed on the Bonaparte 2 miles above Loon creek, is, for instance, only 100 feet wide[1]; others may be nearly 200 feet in width. The serpentine body on Chrome creek may be a mass of irregular shape, but it is probably a narrow, closely folded band of no great thickness. The total area over which outcrops of serpentine are found is about 800 yards by 300 yards or less than 50 acres. Serpentine cliffs 60 feet high occur in this area (Plate XVI) and the greatest difference in the elevation of the outcrops is just over 200 feet (Figure 14).

MOLYBDENITE.

Molybdenite is the sulphide of molybdenum (MoS_2), carrying 59·95 per cent of molybdenum and 40·05 per cent of sulphur. It is an opaque mineral with metallic lustre and greasy feel; colour lead-grey, streak bluish to greenish grey; hardness 1 to 1·5 so that it will rub off on the fingers when handled; specific gravity 4·7 to 4·8; and it crystallizes in the hexagonal system with perfect basal cleavage, yielding thin, flexible, but not elastic plates. It resembles graphite, but its specific gravity is much greater.

Ores of molybdenite occur on Timothy mountain in Cariboo district (Figure 2, locality 18); the peridot and gold-copper ores are found nearby. Timothy mountain lies at the western foot of Cariboo mountains, 16 to 20 miles in a straight line north of Canim lake, and 30 to 35 miles northeast of Lac la Hache. Its location and the positions of the surrounding lakes are not accurately known and, therefore, the position (locality 18) as given in the accompanying map (Figure 2) may be in error by several miles. From Lac la Hache post office on the Cariboo road, about a mile from the new railway grade, a wagon road leads north to Horsefly river. Seven miles from the lake, a new road branches off which in 1918 had been cut nearly to the 52nd parallel survey, east of Sprout creek. From the end of this road a very excellent pack-trail follows eastward round the south end of Murphy lake and thence northeastward to Timothy mountain. The total distance by road and trail from the railway grade at Lac la Hache to Timothy mountain, is about 35 miles of which over 20 miles is trail, most of which could easily be converted into a wagon road. The grades are easy except on the last 2 miles. For the greater part of the distance the road and trail lead through the rolling hill country of the Interior Plateau with numerous lakes and with ridges covered with jackpine, rising 300 or 400 feet above the valleys. From this rolling country, Timothy mountain rises in the form of a crescent-shaped ridge, to elevations (as determined by barometer) of from 6,500 to 7,000 feet above sea-level. A topographical sketch of the top and northeast flank is given in Figure 13. The top of the ridge is above timber-line. On its eastern flank is a heavy growth of spruce and balsam, but on the western slopes the trees are less plentiful and in places there are great grassy swamps and shallow lakes. Several deep creeks and high ridges separate the mountain from the main Cariboo range to the east.

[1]Dawson, Op. cit., p. 86B

The molybdenite ores occur as a series of parallel quartz veins cutting quartz diorite. The veins outcrop near the head of a ravine on the northeast side of the mountain at elevations of from 750 to 1,200 feet below the summit of the ridge (Figure 13). The gold-copper ores occur in veins in the same country rock on the summit of the ridge and near its north end.

The minerals occurring in the molybdenite ores are molybdenite, molybdite in a gangue of pyrite, orthoclase, quartz, sericite, biotite, epidote, and the original minerals of the country rock.

Molybdenite is the only valuable ore mineral on this property. It occurs in crystals up to one-half inch in diameter in some of the fissures.

Molybdite[1] is a hydrous ferric molybdate ($Fe_2O_3 \cdot 3MoO_3 \cdot 7\frac{1}{2}H_2O$), carrying about 40 per cent of molybdenum. It is fibrous, forming radiating groups; yellow with silky lustre; its specific gravity is 2·99.

The country rock in which the ores occur is a grey, even-grained, quartz diorite (see page 10) made up for the most part of dark hornblende and white plagioclase feldspars, with some quartz. Under the microscope, magnetite, apatite, green hornblende, labradorite, orthoclase feldspar, and quartz were determined.

A number of dark green to black, fine-grained dykes or inclusions found within the quartz diorite near the ore occurrences (Plate XVII) are made up almost wholly of hornblende and biotite with less than 5 per cent of white mineral, most of which is quartz.

Dykes of pegmatite occur at a number of places on the mountain. They consist of feldspar, quartz, and coarse crystals of mica, but the composition varies. In one place they may consist almost wholly of feldspar and in another, entirely of quartz. In places the feldspar and quartz are fine-grained and the dyke resembles aplite more than pegmatite. West of the creek on the Blue Grouse claim, molybdenite and quartz lie within a pegmatite dyke.

The molybdenite occurs in a number of nearly parallel quartz fissure veins that vary in width from 1 inch to 3 feet, and strike in directions varying from south 52 degrees east to south 38 degrees east with dips to the southwest of from 20 degrees to vertical. Vegetation and debris conceal the rocks to a great extent, but the main belt of veins clearly runs in a direction south 37 degrees east on the southeast side of the creek (Figure 13, locality 6). This belt has been opened up at intervals along the strike for a distance of 1,900 feet from near the creek level to 450 feet above it. The greatest proved width of the belt, that is, the distance between veins across the strike, is about 75 feet. Northwest of the creek in the direction of the trend of the main belt, two outcrops have been opened up at a distance of 500 feet from the creek and about 50 feet above it. Down the creek, 800 feet to the northeast of the belt, there is in the creek bottom an outcrop of much shattered quartz diorite with an irregular network of quartz veins and ore forming what may be spoken of as a "stockwork" about 40 feet wide (Figure 13, locality 5). Two hundred and fifty feet to the northwest of this outcrop, in a direction exactly parallel to the main belt, is another outcrop of the same character. These two outcrops may indicate a shattered zone impregnated with ore, lying parallel to the main belt, but the cover is heavy and there are no other rock outcrops to prove or disprove this supposition. Between the "stockwork" and the vein belt, molybdenum showings are said to have been found in numerous places.

[1]Schaller, Waldemar T., U.S.G.S., Bull. 490, pp. 84-92, 1911. Hordin, F. W., Op. cit., pp. 11, 12.

In the main belt, the veins have, as a rule, well-defined walls of quartz diorite and are composed of parallel bands of quartz and molybdenite occasionally associated with orthoclase and pyrite. In many places well-formed quartz crystals project into cavities in the veins. In the country rock immediately adjacent to closely spaced veins, are minute veins of quartz, sericite, biotite, epidote, and pyrite, and from these veinlets small, irregular areas of the same minerals project into and replace the minerals of the country rock. The replacement does not seem to extend more than an inch or so in the case of some of the well-marked fissures. Away from the fissures molybdenite is present very sparingly, if at all, and most of the pyrite lies in the country rock adjacent to, rather than in, the fissure.

In many of the openings, quartz veins lie alongside black dyke rocks; in others they cut across them at a low angle. The veins also occur associated with pegmatite and cut across an aplite dyke. The fractures occupied by the veins evidently were formed after the intrusion of the dykes.

In studying the arrangement of the bands of mineral in the veins it was found that the orthoclase when present lies on the outside. This is followed toward the centre by bands of molybdenite and these by bands of quartz, proving that the minerals formed in the order, orthoclase, molybdenite, and quartz. The relative order of deposition of the pyrite is not so clearly indicated, but the mineral when present seems to lie near the outside of the vein, so that quite possibly it is earlier than the molybdenite. From the examination of one thin section of the altered quartz diorite occurring near the ore, it was concluded that pyrite was later than the other secondary minerals in the replaced rock. As far as could be discovered then, the order of deposition of ore and gangue minerals was as follows: quartz, sericite,, biotite, and epidote formed first and replaced the country rock near the fissures. These were followed by pyrite. Before the replacement by pyrite ceased the main fissures were being filled by molybdenite and quartz, these two crystallizing in the order named. Calcite was seen in one place only, where it was evidently one of the latest minerals. In the outcrop in the creek bottom northeast of the main belt an exposure (Figure 13, locality 5) about 30 by 40 feet consists of very much fractured quartz diorite traversed by numerous, irregular quartz veins, most of them under one inch in thickness and trending in all directions, but with a general direction nearly at right angles to that of the fissure vein described above. The manner of arrangement of the minerals in each of the individual veins and in the adjoining country rock is the same as in the case of the main belt.

In the upper few feet of many of the ore-bodies, the quartz is stained brown with limonite, and yellow powdery molybdite is found coating the molybdenite crystals and lying in seams in the quartz. The molybdite and limonite are evidently the results of the alteration by surface waters of molybdenite and pyrite. The alteration was observed to extend to 4 feet below the surface. Since the yellow oxide carries only 40 per cent of molybdenum as against 60 per cent in the sulphide, there has been considerable impoverishment of the ore by weathering. Underground work is necessary to prove whether this has given rise to secondary enrichment below.

The persistence in the trend of the outcrops of the main belt of veins indicates that no large displacements of the ore veins by faulting have taken place. In the second tunnel east of the creek on the Molyb claim is a fault striking north 23 degrees east and displacing the upper part of the quartz vein southwest for a few inches. In the shaft on the same claim a flat fault offsets the upper part of the vein about 4 feet to the northeast. In the gully southeast of the shaft a number of evident faults occur and some of these have offset the veins slightly. One of them strikes north 38 degrees east and dips southeast 80 degrees.

ORIGIN OF THE MOLYBDENITE AND NEIGHBOURING GOLD-COPPER ORES.

Timothy mountain is made up of a huge mass or batholith of quartz diorite. Through this mass are a number of fracture zones in which are found dark green, basic dykes, light-coloured pegmatites, and quartz veins. The pegmatites are accompanied by tourmaline, magnetite, epidote, and quartz veins, proving the presence of hot magmatic vapours during their crystallization and indicating the presence close below of molten magma. The dark, basic dykes are probably earlier than the pegmatites. Both are fractured and traversed by quartz veins carrying molybdenite. The molybdenite veins are accompanied by replacement of the country rock by sericite, biotite, epidote, quartz, and pyrite; and since all of these minerals can form under great heat and pressure, and molybdenite is generally so formed, it is probable that the molybdenite veins were formed near the hot intrusive body immediately after the pegmatites and perhaps simultaneously with some of them, that is, while their parent magma was still hot. The presence of galena and zinc blende among the minerals occurring in the gold-silver-copper ores 1½ miles to the northwest indicates that they crystallized under lesser heat and pressure than the molybdenite, either nearer the surface or farther from the intrusive body. Their structure and geological relations are so similar in character to those of the molybdenite that it seems probable they were derived from the same source and at the same time. The geological age of the ores cannot be proved, but is probably post-Jurassic and pre-Miocene.

ORE VALUES.

With no underground workings to speak of, there is very little to indicate whether the ore varies in value, either laterally or in depth. It is evident from an inspection of the veins, however, that in a great many of the outcrops weathering has impoverished the ores for the first 2 to 4 feet from the surface. In an open-cut on the Eagle claim, the most easterly and highest of the workings, the writer sampled an ore-body consisting of two quartz veins with altered country rock and vein matter between (Plate XVII). The sample included everything within the vein zone for a width of 30 inches, 4 feet from the surface. The assay by F. W. Baridon of the Mines Branch yielded 0·86 per cent molybdenum (that is, 1·43 per cent molybdenite) and no copper. No further assays are available, but from the quantities of ore prepared for shipment and from rough estimates of the cubical content of vein matter involved, it is concluded that in a number of places at least, the assay results approximate the values below the zone of weathering, that is, from a depth of 4 feet downward.

Considerable variation occurs along the veins, but the present development does not indicate what the factors are that control these variations. No marked differences appear between the outcrops near the creek bottom and those on the hill, 400 feet or so above. In one case richer values were found on a flat vein crossing several vertical ones, and in further development it would be well to keep in mind that good ore is apt to be found at the intersection of fissures.

MANGANESE.

In the summer of 1918 the writer visited a manganese claim situated some 10 miles northeast of Clinton. The deposit occurs on one of the foothills of Marble mountains about 2 miles north of Clinton creek and may be reached by an old trail from Clinton. The owner is W. Murray of New Westminster, B.C. The ores were seen in an open-cut 38 feet long by 4 feet wide and from 5 to 7 feet deep, situated on the east slope of a hill, some 100 feet below its summit. For several hundred yards on all sides of the open-cut, the rock is drift-covered. The ore occurs in argillites and quartzites of the Cache Creek series. The following ascending section was seen in the open-cut: (a) thin-bedded, siliceous argillite $\frac{1}{4}$ to $\frac{3}{4}$-inch beds, 12 feet; (b) bluish-grey, dense quartzite cut by quartz stringers and impregnated in an irregular manner with black manganese, 20 feet; (c) greenish-white beds of quartzite 1 to 2 inches thick, 4 to 5 feet. The general strike of the beds is north 55 degrees west, dip 40 degrees to 70 degrees to the southwest.

The ore minerals are psilomelane, manganite, and pyrolusite. A fault occurs between zones (a) and (b), accompanied by much alteration of the rock to clay, in which the best ore seems to lie. Stringers of quartz cut across the bluish-grey quartzite of zone (b) and they are accompanied by nodules and irregular masses of the black ore. The ore is also concentrated near fracture planes where the rock is in many places altered to clay. A few stringers of ore occur in zone (c), but most of the ore is in the lower 15 feet of zone (b).

The ore seems to have been introduced into the quartzite with the quartz veins and to have impregnated the country rock in an irregular manner. It has been enriched in places by leaching away of the country rock by surface waters.

The writer took a sample representing the first 4 feet of the wall from the floor of the open-cut upwards, and across the lower 15 feet of zone (b). The result of an assay of this sample by F. W. Baridon is as follows:

Manganese	7·57	per cent.
Silica	82·57	"
Phosphorus	0·018	"

The high percentage of silica is due as much to the country rock included in the sample as to quartz gangue. The ore is too low in manganese and much too high in silica to be of commercial value[1].

[1] Allen, M. A., and Butler, G. M., "Manganese," Univ. of Arizona, Bull. No. 91, pp. 20-23.

NICKEL.

About 4½ miles south of Clinton, one-half mile west of the Ashcroft road, and 500 feet above it, an outcrop of a calcareous quartz rock carries the green, nickeliferous silicate, garnierite. The rock is foliated and the green mineral, which is of later origin than the parent rock, lies in parallel bands through it. The outcrop is 25 feet by 10 feet in extent and may be an immense boulder. Two hundred feet south is an outcrop of quartz. There are a number of boulders along the side hill for one-half mile north, but no other outcrops have been discovered. An assay made by H. V. Ellsworth of the Geological Survey, of a sample taken at intervals across the 25-foot outcrop, yielded 0·11 per cent nickel and 0·17 per cent chromium oxide, Cr_2O_3.

CHAPTER VIII.

GOLD, SILVER, COPPER, LEAD.

In this chapter are described a number of mineral occurrences that carry values in gold, silver, copper, or lead. All of these are prospects as yet and except in two cases, no underground development work has been done. Deposits of placer gold are not dealt with in this report. The occurrences include prospects in Fraser canyon; on Timothy mountain; north of Soda creek; on Willow river; on Hixon and Stone creeks; and on the North Bend of Fraser river above Prince George (Figures 1 and 2).

FRASER CANYON.

The railway between Pavilion and Kelly lake cuts through many outcrops of argillites and quartzites of the Cache Creek formation. In places these have been sheared and the rock near the shear zones altered to a soft mass of carbonaceous material accompanied by deposits of brown and yellow hydrated iron, many crystals of gypsum, and a white powder consisting mostly of hydrated magnesium sulphate, with some gypsum and less sodium sulphate. Just east of the tunnel at the 28·5 mileage on the railway there is a section exposed showing this alteration for a distance of 130 feet along the track, portions 30 feet wide by 30 feet high being extremely altered. At the base of the escarpment north of Elevenmile creek and east of Fraser river, about 2,300 feet above the railway grade and 2 miles from it (Figure 2, locality 39), is an occurrence of the same character in which two or three shear zones traverse argillites and dense quartzites of the Cache Creek in a direction north 16 degrees west. Two of the zones are from 10 to 12 feet wide. The material within them is soft and contains much carbon which often shows glistening faces with the appearance of graphite. The amount of carbonaceous material is greater along the fractures than when a foot or so from them. The white salts and yellow iron stain are also in evidence. The altered zones run up the face of the cliff, but appear to end 20 to 30 feet from the top. Mr. H. Donaghey, owner of the 11 Mile ranch, sampled a portion of the shear zone material and had it assayed. The results were 6·8 per cent carbon, $3.20 in gold per ton, and some silver. The writer sampled across 4 feet of one of the carbonaceous shear zones and the assay results gave 7·42 per cent of carbon.

no gold, and no silver. Messrs. F. and W. Dillon of McKinnon post office own claims situated nearby, on which it is said are veins of quartz containing pyrite and chalcopyrite and carrying values in gold, silver, and copper.

At the Big Slide mine[1], situated on the banks of the Fraser at the mouth of Kelly creek, are quartz veins carrying pyrite and chalcopyrite. A ten-stamp mill with chlorinating furnace was erected here in 1886 and considerable underground work was done. A sample taken by Dawson in 1887 of the concentrates, assayed 0·408 ounce of gold and 0·933 ounce of silver to the ton. The mine, which was in operation for only a few months, is situated at the bottom of the canyon and is most difficult of access.

Two of the occurrences described, and probably the McKinnon claims, lie in the neighbourhood of granite intrusives that crop out in narrow strips parallel to the strike of the formations in Fraser canyon.

The gold values found should encourage prospecting in the Cache Creek rocks near this contact. The carbonaceous matter near Elevenmile creek looks like graphite, but tests show that it is not.

TIMOTHY MOUNTAIN.

On the flat summit of Timothy Mountain ridge, about 2 miles by trail northwest of the molybdenite claims, values in gold, silver, copper, lead, and zinc occur in sheared country rock of quartz diorite (Figure 2, locality 16, and Figure 13, localities 1 and 2). The ore minerals are chalcopyrite, bornite, pyrite, galena, and sphalerite lying in a gangue of quartz. The country rock is quartz diorite of the same character as that on the molybdenite claims and near the ores are occurrences of dark green augite andesite dykes and light-coloured pegmatites. Tourmaline and epidote occur with and near the pegmatites.

Ores of the same general character and occurrence were found along the northeastern rim of the ridge and in the gulch below. On the summit are a number of parallel and branching veins about 6 inches thick, striking north 42 degrees east, dipping steeply eastward, some of them apparently running together in depth. They have been opened up ina belt of sheared quartz diorite at intervals for a horizontal distance of about 700 feet. The width of this sheared zone is from 25 to 30 feet. A few hundred feet south of the main outcrops, openings showing galena and pyrite have been made in a shear zone crossing the prolongation of the vein zone described, with a general trend of east 80 degrees south. The ore occurs as fissure filling in the veins and disseminated through broken quartz diorite. On the northeast rim of the ridge are a number of shear zones from 5 to 50 feet wide, striking down the slope. Bornite and chalcopyrite occur disseminated in dark green dykes in these zones or are found in connexion with quartz and altered quartz diorite.

The copper claims on the summit are the Intermountain, owned by W. J. Ryan, and the Highland Mary. On the Intermountain there are a shaft 25 feet deep, a short tunnel, and a great deal of trenching both along and across the veins. Numerous prospect holes have been dug in the occurrences to the east. The values of assays from different localities have been given by Mr. Ryan as follows: (1) picked sample of galena ore

[1]Dawson, G. M., "Report on the Kamloops map-sheet, British Columbia." Geol. Surv., Can., Ann. Rept. vol. VII, 1894, pp. 339-340B.

from the shaft (Figure 13, locality 1), gold $7, silver 20 ounces per ton, copper 2 per cent, lead 25 per cent, and zinc 20 per cent; (2) bornite ore from the middle vein north of the shaft, gold $44, and silver 30 ounces per ton, copper 22 per cent; (3) chalcopyrite, pyrite in quartz gangue, from prospect hole 50 feet north of shaft, gold $17, and silver 28 ounces per ton, copper 18½ per cent; (4) at locality 2, Figure 13, ore composed of bornite and chalcopyrite is disseminated in a basic dyke, gold $10, and silver 7 to 8 ounces per ton, copper about 5 per cent; (5) in a gulch about 500 yards east and 900 feet in elevation below locality No. 2 there is a shear zone 4 feet wide with pyrite in a quartz gangue. Two assays from this place yielded gold $5 and 2 ounces of silver to the ton, and gold $10 and 4 ounces of silver to the ton.

Galloway[1] took samples of the mineralized zones on these claims, across widths of 3 and 6 feet, in order to determine the gold and silver values, but found only traces of gold and silver.

NORTH OF SODA CREEK.

Bodies of quartz carrying copper minerals occur in the hills about 10 to 13 miles in a direct line due north of Soda Creek and 7 miles east of Fraser river (Figure 1, localities 12 and 13). The northerly outcrops (locality 12) are 2 miles northeast of the north end of Cuisson lake from where there is a wagon road leading to the Cariboo road along the Fraser. The owners are Chas. Foyle and J. Briand of Soda Creek. The elevation by barometer is about 3,350 feet.

At this locality quartz carrying chalcopyrite occurs in sheared granodiorite. The shear planes and the edges of the large quartz bodies trend on an average north 11 degrees east, and dip in some cases to the east at angles up to 35 degrees. The sheared zone is about 60 feet wide with a 17-foot ledge of quartz on its west side and lenses of quartz through the remainder. On the eastern side is unsheared granodiorite. The eastern edge of the shear zone outcrops in places for a length of 150 feet and carries bodies of quartz a few feet wide. No other outcrops were seen either north or west. A shallow shaft, full of water at the time of visit, sunk on the thick quartz body on the west edge of the zone, is said to have passed through a foot-wall of solid granodiorite dipping east. The amount of chalcopyrite in samples of quartz on the dump and in the outcrop is very small.

One-quarter mile south by east from this shaft is an area of sheared granodiorite, about 80 feet wide in a northeast-southwest direction, in which are a number of bodies of quartz. Copper-bearing minerals occur in the sheared country rock as well as in the quartz. The ore minerals and quartz occur in a zone which is irregular in outline and whose probable trend under the surrounding cover could not be determined. A small open-cut and shallow shaft are the only developments. The ore minerals seen on the dump were chalcopyrite, chrysocolla, azurite, and chalcocite.

Galloway[2] reports assay results of 5 to 6·3 per cent of copper from selected ore specimens from either or both of these places, and traces of gold and silver from a number of samples.

[1]Galloway, John D., Report of the Minister of Mines of British Columbia for 1917, Northeastern district, p. 135
[2]Op. cit., p. 133.

Another claim (Figure 1, locality 13) at an elevation of 3,450 feet, lies about 2 miles northeast of the south end of Cuisson lake and 3 miles south of those described above. Here 9 feet of quartz carrying chalcopyrite lies between well-defined walls of granodiorite trending south 60 degrees east and dipping north 35 degrees. The quartz body has been exposed for only 15 feet. The rest of the country is covered. The amount of chalcopyrite in the quartz is small. Chas. Foyle is one of the owners.

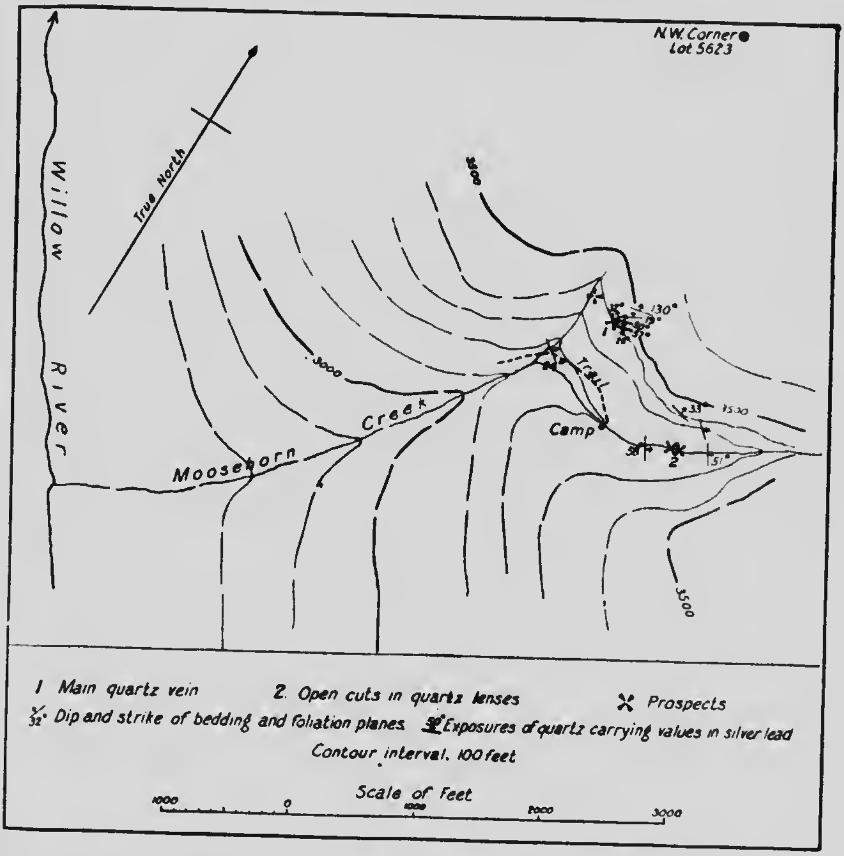


Figure 16. Silver-lead claims, 5 miles east of Ahbau lake and near Willow river, Cariboo district, British Columbia.

WILLOW RIVER.

Five miles east of the head of Ahbau lake and somewhat more than 30 miles in a straight line northeast of Quesnel village, occurrences of quartz carrying values in silver, lead, and zinc (Figure 1, locality 5) were discovered and staked by H. Guthrie and B. Gray in 1918; they lie on lot 5623 on a small creek called Moosehorn, less than a mile from Willow river which the creek enters from the east (Figure 16). Ahbau lake is 6 miles long and from its southern end a good pack-trail runs 18 miles south to Cottonwood ranch, 20 miles from Quesnel on the Barkerville road. Guthrie and Gray bonded the property to Oscar W. Alston and associates of New Westminster, in the autumn of 1919.

The ore-bearing veins consist of galena (lead sulphide), zinc blende (zinc sulphide), and pyrite (iron sulphide) in a gangue that is almost entirely quartz with films of sericite. The sulphides lie in masses and veinlets within the quartz, and where pyrite occurs with galena or zinc blende it lies in many cases on the outside of these masses, next to the quartz. Sericite, greenish white and micaceous, lies in cracks in the quartz. Pyrite is found in the wall rock, apparently formed after the rock had been metamorphosed to schist. The probable order of formation is, therefore, quartz, then pyrite, and afterwards galena, zinc blende, and sericite. The country rocks consist of blue-grey quartzite of very fine grain, and phyllite or argillite of which certain beds are carbonaceous. The argillites and quartzites are nearly of the same composition, that is, they consist mostly of quartz with minor amounts of muscovite mica, but the argillites are of finer grain than the quartzites. Both types of rocks are foliated or schistose, that is, they split easily along closely spaced parting planes. Two dykes occur close to the main quartz vein, intruding the country rocks. One is an aplite, the other a feldspathic porphyry, probably andesite,

Ore has been found in two places (Figure 16). On the north side of the creek, about 300 feet above its bed, a quartz vein carrying galena and pyrite crops out in a cliff on the side hill. This vein is from 3½ to 4½ feet wide, strikes north 78 degrees east and dips 50 degrees to the west. At the time of visit it had been proved over a horizontal distance of about 150 and a vertical distance of 80 feet; since then it is said to have been encountered in a tunnel below, increasing the proved dimensions both horizontally and vertically. Two nearly parallel quartz veins lie 25 and 100 feet north and up the hill from the main vein. They are 1½ and 2 feet wide, respectively. Other small stringers were seen, one of which lies close to and south of the main vein and trends away from it at a low angle. About 1,000 feet to the southwest in the creek bottom are lenses of quartz and galena 15 to 20 feet apart, that lie along the planes of schistosity of the rock. The largest is 4 feet at its widest point; it is exposed for about 13 feet on one side of the creek and may continue across the stream. It strikes south 50 degrees east and dips 45 degrees to the northeast. A series of parallel lenses occurs, apparently, in this place, for galena float has been found 60 feet to the east up the creek, but here, and on top of the hill, the drift cover is an impediment to prospecting. The general strike of the planes of schistosity in the rocks and of such true bedding planes as were observed is to the northwest, with dips of from 24 degrees to 55 degrees to the northeast (Figure 16). At the upper quartz occurrence there is a cross anticlinal fold with a northeast trending axis. The series of nearly parallel ore-bearing quartz veins cross the crest of this fold at an angle.

Two short tunnels had been run near the main quartz vein in July, 1919, the longest following the vein for 15 feet. Two open-cuts had been made on the lenses of quartz in the creek bottom and about 40 cubic yards of rock had been moved. The writer sampled across 4 feet of the ore-body in the face of the larger tunnel and across $2\frac{1}{2}$ feet of the larger lens in the creek. The results of assays of these samples at the Mines Branch laboratories are as follows:

Tunnel	Gold	Trace.
	Silver	1·13 ozs. per ton.
	Lead	3·15 per cent.
Lens	Gold	Trace
	Silver	2·25 ozs. per ton.
	Lead	5·52 per cent.

The results of assays upon samples taken by the present owners in a tunnel driven since that time at a point lower on the hill yielded: gold 0·01 ounce, silver 16·35 ounces, lead 44·15 per cent, zinc 5·10 per cent, total value $75.84 per ton. The results of assays on samples taken by the writer are low, but he believes that higher grade ores will be found in these deposits. Surface prospecting should be done, first, by cross trenches through the heavy drift cover at points lying in the direction of the strike of the system of parallel fissure veins, and also in the neighbourhood of the exposed lenses in the creek. If the results are satisfactory the occurrences on top of the hill can be developed by a tunnel starting south and down hill to crosscut them (Figure 16). Waterpower for a small concentrating plant can be obtained from the creek.

If the Pacific Great Eastern railway be built along the route as originally planned, about 25 miles of wagon road would connect the railway with these deposits, the most feasible route being probably from the south end of Ahbau lake down the North Fork of Cottonwood river. The connecting of Barkerville to this railway would shorten the haul which would otherwise be very expensive.

About 2 miles northeast of the south end of Ahbau lake quartz claims have been staked by W. Harper and others. The prevailing country rock is quartz sericite schist. An outcrop of quartz 2 feet wide and 30 feet long trends south 41 degrees west with quartz float extending farther southwest along the strike for perhaps 100 feet (Figure 17). A tunnel 90 feet long has been driven to a point immediately under the northeast end of the outcrop (Figure 17). The tunnel follows an anticlinal arch in the schist for 50 feet, after which a 2- to 3-foot vein of quartz, broken by a north-south fault, is encountered. The quartz is cut off to the south by another fault striking north 50 degrees west. The 2-foot quartz vein in the tunnel is probably identical with the vein on the surface. About 30 feet north by east of the mouth of the tunnel a 2-foot vein of quartz crops out on the hillside. There is a little galena and pyrites in this outcrop and a few stringers of galena were seen at the point indicated in the tunnel; otherwise the writer was unable to find occurrences of ore-bearing minerals in either the tunnel or outcrops. The claims lie 1,000 feet above Ahbau lake.

HIXON CREEK.

On Hixon creek 4 miles east of its junction with Canyon creek and $3\frac{1}{2}$ miles from the proposed route of the railway (Figure 1, locality 4), are a number of old workings that mark the site of a gold mine operated more than forty years ago. A wagon road from the mine to the flats of

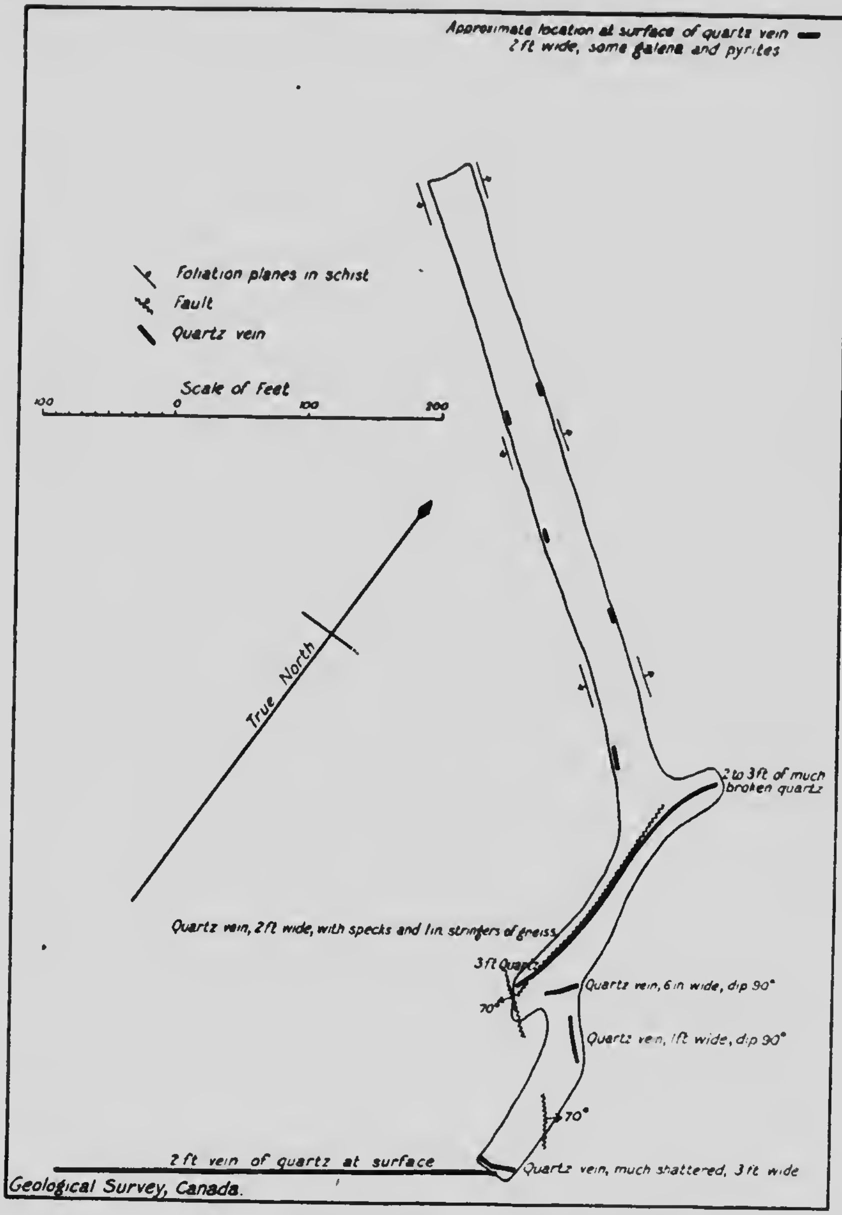


Figure 17. Quartz veins and tunnel, 2 miles northeast of south end of Ahbau lake, Cariboo district, British Columbia.

Canyon Creek valley joins the new provincial highway and crosses the grade of the proposed railway, from where it is about 10 miles by road to White and 8 miles to Woodpecker steamboat landings on Fraser river. Three old shafts were seen that had evidently penetrated to bedrock. Three tunnels are said to have been driven, but only two are now open. The shafts were filled with water nearly to the surface and the observations recorded here were the result of an examination of the dumps and of the two tunnels.

Rock outcrops occur in the creek bottom in a few places and for a short distance up the side of the valley, behind the main cabins. The remainder of the north side of the valley is covered with unconsolidated material, mostly gravel, and at elevations of about 130, 200, and 275 feet above the creek bottom are well-defined gravel terraces (Figure 18). Pyrite which is presumably the auriferous mineral was found in the old workings lying in a gangue of quartz accompanied in places by calcite.

Quartz from the dump of the shaft in the old mill building south of the creek carries some chalcopyrite and minute veins of a grey mineral that may be galena. Galloway[1] reports free gold, native silver, and hematite from the quartz samples on this dump. The country rocks are grey quartzites, phyllites, quartz sericite schists, and greenstones, the greenstones apparently interbedded with the sediments. A specimen of greenstone proved to be a fine-grained and very much altered igneous rock originally perhaps an andesite or basalt. These rocks are in nearly all cases much altered to red clay. The planes of foliation of the schists strike from south 31 degrees east to south 49 degrees east with an average of about south 40 degrees east, and with steep dips, in places northeast, in others vertical or slightly southwest.

Two miles west, near the junction with Government creek, is an outcrop of augite syenite, a medium-grained, unfoliated and unaltered and, therefore, much later rock than the schists. The rock near the workings has been faulted and quartz veins traverse the schists in an irregular way. Bowman[2] shows a number of parallel quartz veins striking north 46 degrees west at the easterly shafts and dipping 70 degrees northeast, crossed by others striking north 34 degrees east and dipping vertically. Most of the veins are small stringers from a few inches to one foot thick. Wider veins are reported, but the writer did not see any. Pyrite is found in the quartz veins and disseminated through the country rock. From the meagre evidence at hand it seems probable that, if the pyrite carries the gold values, the ore-bodies are of the nature of irregular stockworks fading into the country rock without well-defined boundaries. Bowman states that the cross veins striking northeast carry pyrite, tetrahedrite, and free gold assaying from \$28 to \$274 per ton, averaging \$70 to the ton. These cross stringers are said to have been of small extent. Three shafts and several tunnels have been driven on this property and there are the ruins of a five-stamp mill, an old arrastra, bunkhouses, etc. (Figure 18). In 1918 an attempt was made to unwater and examine the property but without success. Surface values are low and the higher grade ore which is said to have occurred in the deeper workings was not reached. A small shipment of gold is said to have been made from this property in 1880. Part of this property is now owned by the Quesnelle Quartz Mining Company, of which H. E. C. Carry, Vancouver, is president.

[1] Galloway, John D., "Hixon creek," Rept. of Minister of Mines, B.C., 1918, p. K128.
[2] Bowman, Amos, "Report on the geology of the mining district of Cariboo, B.C.," Geol. Surv., Can., Ann. Rept., vol. III, pt. 1, 1887-1888, p. 48C, with map

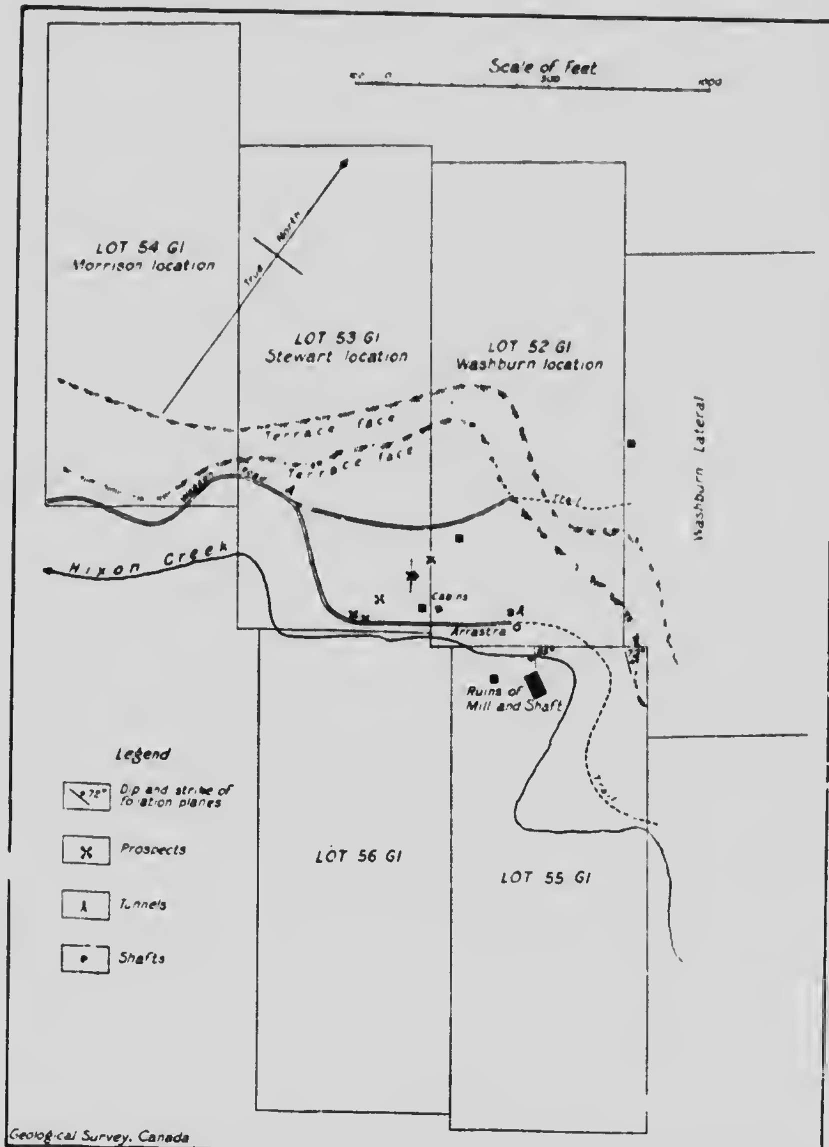


Figure 18. Old workings on gold claims, Hixon creek, Cariboo district, British Columbia.

About 2,000 feet east of where the east boundary of lot 55 crosses the creek, Messrs. C. H. Colgrove, A. McLarty, and S. A. Gillis have driven a tunnel into quartz sericite schist on the south side of the creek. The rock here is very much altered to red clay and the tunnel had fallen in and was inaccessible upon our visit. It is 150 feet long with two short crosscuts and encountered one vein 2 to 4 feet wide and many small stringers. Values are said, by Mr. C. H. Colgrove, to be from 40 cents to $14 in the schist and $40 in a 6-inch vein. Galloway[1] found a trace of gold in a sample of schist collected by him from the dump and 0·2 ounce of gold in a 6-inch stringer.

Just below the camp of Dougald Cameron, on Government creek, 4 miles from its junction with Hixon creek, are black clay schists and grey schists striking north 39 degrees west, intruded by a dyke of hornblende diorite. The dyke forks at the creek, one branch being 100 feet and the other 40 to 50 feet wide, with black slate lying between. The strike of the dyke is approximately north 60 degrees west with dips of 70 degrees and more to the northeast. It is foliated, the planes of schistosity striking north 67 degrees west and dipping 40 degrees to 50 degrees to the north. Quartz stringers occur in the clay schists at and near the contact. Pyrrhotite and some pyrite are disseminated through the diorite, and altered zones of black material, apparently manganese oxides, trend with the foliation planes. According to Mr. Cameron values in gold and silver have been obtained from samples taken across the face of a part of the dyke and picked samples have run as much as $17.20 in gold.

STONE CREEK.

A property owned by the Nechako River Mines, Incorporated, and managed by W. West, Prince George, was examined on Stone creek. The claims lie on lot 4618 about 5 miles by trail up Stone creek which enters Fraser river from the east 20 to 35 miles south of Prince George (Figure 1, locality 3). Two tunnels have been driven, one 95 feet long on the south side of the creek, the other 55 feet long on the north side. The country rock which is much broken consists of white to grey quartzites, phyllites, and black clay schists. A brecciated quartzose phyllite called "porphyry" at the mine carries pyrite in quartz stringers and disseminated in the country rock. Two faults striking west 12 degrees north and northwest and dipping south and southwest 20 degrees and 70 degrees were seen in the northern tunnel. A vertical brecciated contact between black clay schist to the north and brecciated quartzite had a strike of north 2 degrees east and a vertical dip. Mr. West stated that gold values up to $1.50 per ton, 4 ounces in silver, and 14 per cent of lead, had been found in samples from the southern tunnel and that a sample across a 6-foot face in the northern tunnel assayed $2 in gold, 4 ounces of silver, and a trace of copper to the ton. The writer sampled across the roof of the northern tunnel in a spot thought to be favourable by Mr. West. The result of an assay in the Mines Branch showed no traces of gold, copper, or silver. About half a mile east of the tunnels on the north bank of Stone creek are outcrops of much crumpled, black clay schist striking west 36 degrees east and dipping 73 degrees east. A zone 12 feet wide across the strike carries quartz and calcite with pyrite and chalcopyrite lying in the quartz and disseminated in the country rock.

[1]Galloway, Ibid, p. 128.

NORTH BEND OF FRASER RIVER.

A prospect owned by Oscar Eden, of Prince George, and others, situated just north of the most northerly bend of Fraser river (Figure 1, locality 1), carries values in silver, lead, and gold. The property is connected by steamer channel up the Fraser with Hudson Spur near Hansard about 24 miles east, on the Grand Trunk Pacific railway, and to Prince George about 50 miles down the river to the southwest. The route to Hudson Spur is in quiet water all the way, but there are several long rapids down the river toward Prince George. Developments on this property include a tunnel and shallow shaft. The tunnel, within 100 feet of the north bank of the river, is about 95 feet long trending about north 40 degrees west. The country rock is a quartz muscovite chlorite schist carrying some carbonate. A sheared zone about 3 feet wide and dipping east, carries quartz with pyrite. In places in the tunnel it lies between fairly solid walls, the easterly wall being apparently more schistose, but otherwise of the same character as the wall on the west side. There has been much faulting and silicification of the country rock. The shaft lies 300 feet in elevation over the river, about 1,800 feet north of it, and about 750 feet east by south of the northeast corner of Eden's homestead lot. Galena occurs in quartz that is from 5 to 6 feet in width lying between well-defined walls of schist. The walls strike 285 degrees magnetic north (46 degrees true north) and dip 60 degrees to 65 degrees to the northeast. Faulting on the foot-wall is represented by 8 inches of black and red gouge. About 20 feet of the length of the ore-body has been exposed. If the strike of the ore zone be followed in an easterly direction for 550 feet along the side hill a gulch is crossed running south 67 degrees west toward the Fraser. Two hundred feet down the gulch from where the strike of the ore zone would cross the gulch are boulders of quartz, some of them 2 feet across, with much galena. They must have moved downhill from their outcrop and are a very excellent indication that the ore zone has a length of from 500 to 600 feet at least.

Samples taken from various places in the tunnel and in the foot-wall of the ore zone at the shaft are said to have carried radium. The writer took samples from the gouge in the shaft and from points in the tunnel, as near as possible to the points from which the original samples are said to have come from, but a test on these samples by H. V. Ellsworth of the Geological Survey, did not indicate any trace of radium. According to Mr. Eden samples taken by him across the outcrop near the top of the shaft gave 13 ounces of silver and 15 per cent of lead to the ton, whereas a sample across the ore at the bottom of the shaft yielded 25·8 ounces of silver, 42 per cent of lead, and a trace of gold. The writer did not sample this ore-body, but galena is plentiful through the quartz.

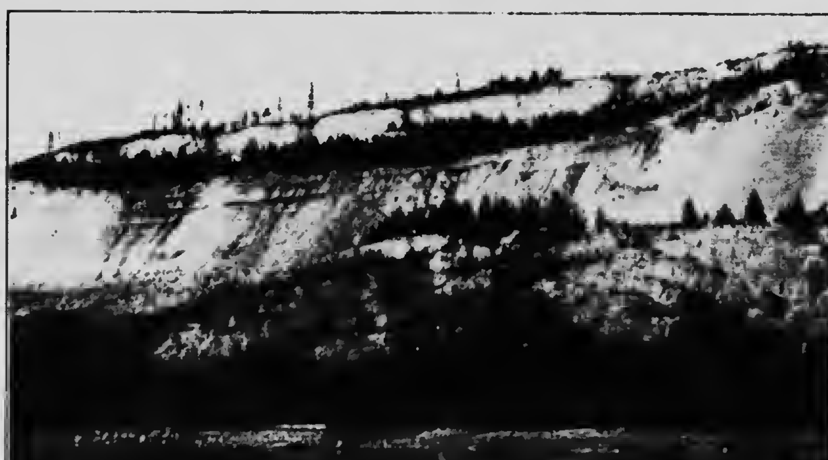
Assays made from samples 30 feet and 60 feet from the mouth of the tunnel are said to have yielded respectively 3 ounces silver, 50 cents in gold, with some lead; and $4.80 in gold.

A company known as the North Point Mining Company, of which Oscar Eden is president, has been formed to develop this property. Surface trenching should be done to prove the outcrop over as long a distance as possible so as to determine its dip and strike and whether it has been faulted. With this information it should be possible to drive a crosscut to meet the lead from a point on the steep side hill south of and below its outcrop. This would give adequate drainage. There are plenty of good landing places for scows along the north bank of the river. The company owns a large motor boat and the ore can be conveniently transported to the railway at Hudson Spur. This is the most promising looking of the prospects dealt with in this chapter.

PLATE II.

Fraser river at Soda Creek showing terraces and the comparatively flat horizon line of the hill tops which are part of the Interior Plateau. (Page 5.)

A. Huge slide of the Coldwater formation at Pavilion. Indian village in foreground. (Page 11.)

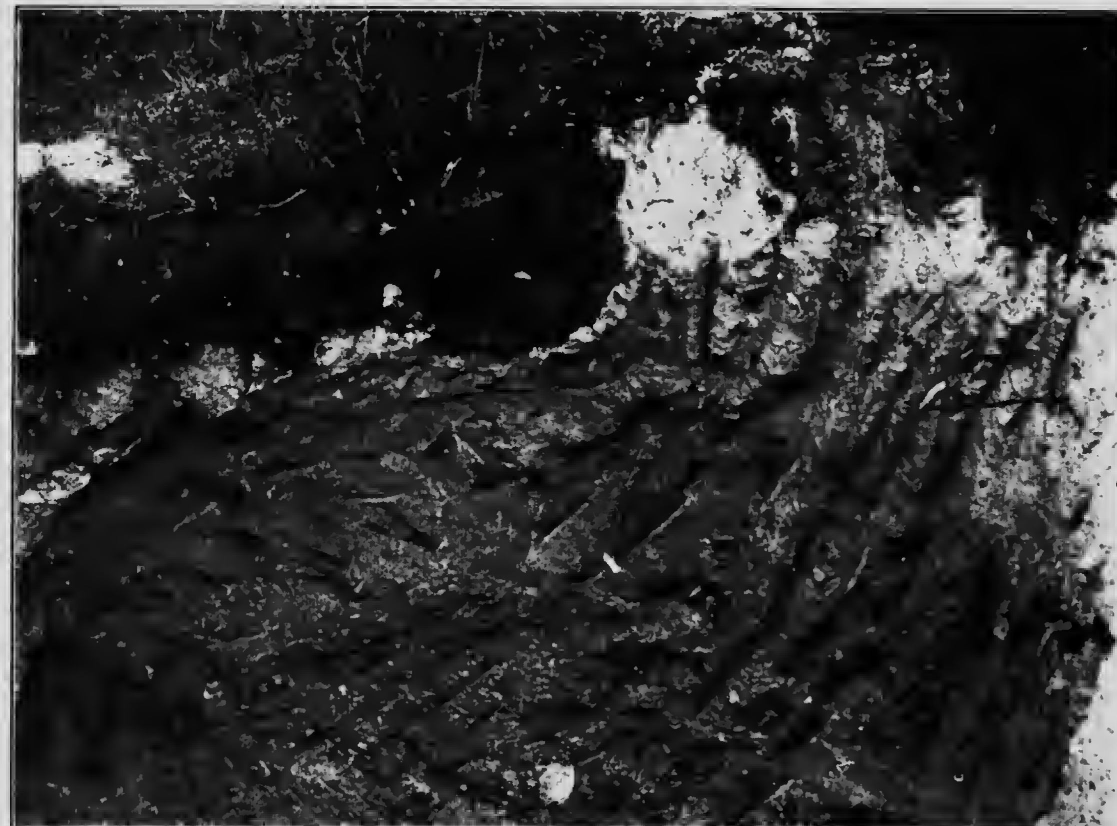


B. Nearly horizontal gravel, sand, and clay beds of Fraser River formation, overlain by boulder clay. The boulder clay has slid over the wet Fraser River beds and down the cliff to the river. From the river to the top of the banks the difference in elevation is 176 feet. (Page 14.)

PLATE IV.

Portion of main hydromagnesite deposit at Meadow lake (Figure 5, locality 3), cauliflower-like hummocks showing along edges. (Page 39.)

PLATE V.



Nodular deposit of gypsum and calcite in boulder clay above the hydromagnesite at Clinton (Figure 5, locality 7, and analyses 7 and 8, Table IV). (Pages 32, 38, 41.)

Nodular deposit of gypsum and calcite in boulder clay above the hydromagnesite at Clinton (Figure 3, locality 7, and analyses 7 and 8, Table IV). (Pages 32, 38, 41.)

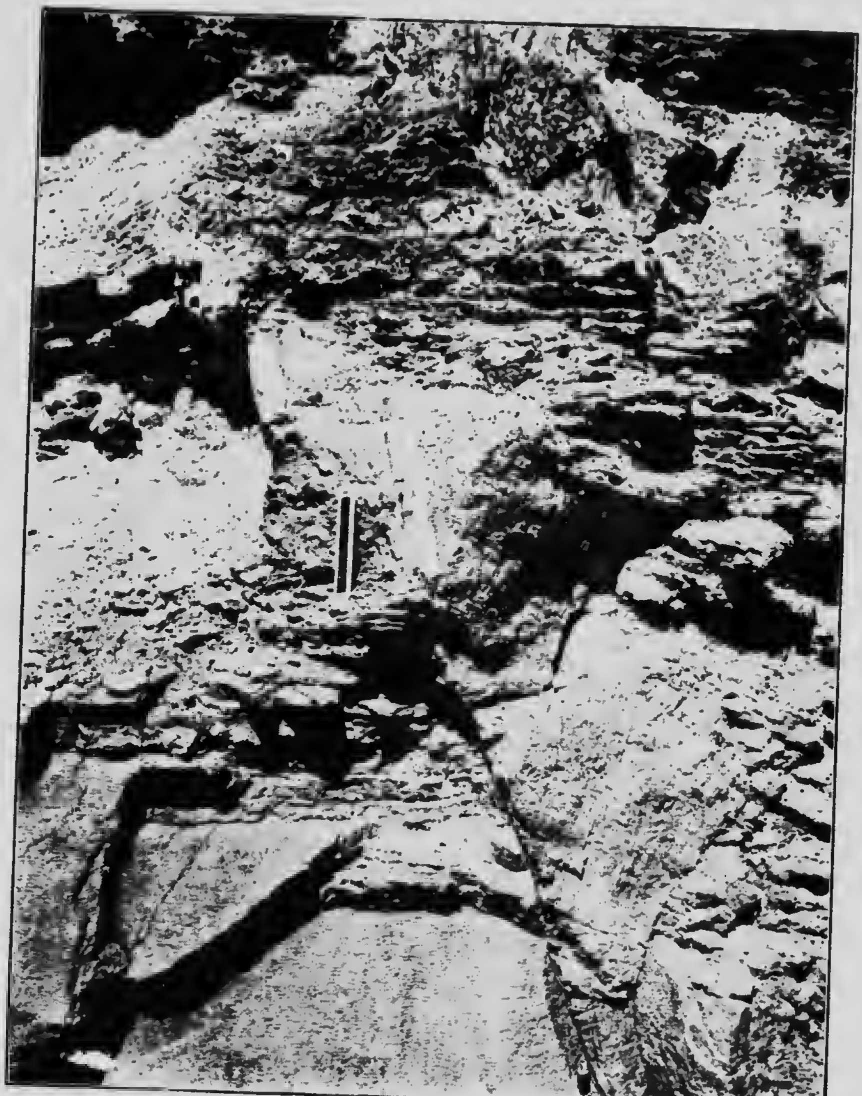
PLATE VI.

Detail of a portion of Plate V to show the streaks of gypsum and calcite in boulder clay below the nodule and the increase of white material upward. (Pages 38 41.)

PLATE VII.

East end of Kelly lake in Cutoff or Junction valley, 11 miles southwest of Clinton. In the left foreground calcium carbonate (Table IV, analysis 2) can be seen deposited a few inches under water on a tree trunk and on an alluvial fan at the edge of the lake. Gypsum and calcite nodules occur on the steep hillsides in Lower Cache Creek argillites. Hills in the distance are underlain by Upper Cache Creek limestones. (Pages 5, 28, 35, 41.)

PLATE VIII.



Calcareous tufa or travertine on railway 2 miles southwest of Clinton showing horizontal corrugations on curved beds apparently folded and faulted. (Pages 49, 51.)

PLATE IX.

Same locality as Plate VIII. Illustrates the structure of the curved beds, due to original deposition but simulating folded strata. (Pages 49, 51.)

PLATE X.

Veinlets of magnesium sulphate in serpentine of Cache Creek series at the chromite occurrence on Scottie creek. (Pages 36, 38, 54, 89.)

Plate XI.

Rings or pools of sodium carbonate with intervening ridges of black mud and stones in Last Chance lake (Figure 2, locality 23). (Page 58.)

PLATE XII.

Banks of residual clay in lavas of the Lower Volcanics at 17 Mile ranch, Fraser canyon. (Pages 12, 75.)

PLATE XIII.

Banks of residual clay in quartzites and argillites of the Lower Cache Creek series on west side of Bonaparte river, 17 miles north of Ashcroft. (Pages 73, 75.)

PLATE XIV.

Forty-foot bank of diatomaceous earth overlain by basalt, 2 miles southwest of Quesnel, B.C. (Figure 12, locality 11). (Pages 76, 77, 79.)

PLATE XV

Cone-shaped hills of basalt on Timothy mountain, quartz diorite outcrops in foreground. Peridot occurs on north-east side. (Page 81.)

PLATE XVI.

Northerly outcrops of serpentine at chromite occurrence near Chrome creek (south of locality 1, Figure 14). Cliff is 60 feet high. (Page 91.)

PLATE XVII.

Open-cut at the molybdenite occurrence on Timothy mountain showing two parallel quartz molybdenite veins (white) in quartz diorite. The scale is 6½ inches long. (Pages 92, 94.)

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