CANADA
DEPARTMENT OF MINES
MINES BRANCH

Hon. W. Templeman, Minister; A. P. Low, LL.D., Deputy Minister;
Eugene Haanel, Ph.D., Director.

REPORT

ON THE

TUNGSTEN ORES OF CANADA

BY

T. L. WALKER, M.A., Ph.D.

OTTAWA
PRINTED BY C. H. PARMELEE, PRINTER TO THE KING'S MOST
EXCELLENT MAJESTY
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No. 25.

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UNIVERSITY OF TORONTO,

TORONTO, ONT., December 31, 1908.

DR. EUGENE HAANEL,

Director of Mines,

Mines Branch, Ottawa, Ont.

SIR,—In accordance with your instructions, I have examined the chief occurrences in Canada of ores of tungsten. In the report herewith submitted I have attempted to indicate the chief uses to which this metal is put at the present time, the geological occurrence of tungsten ores in general, the production of the various countries, the prices realized for such ores, and especially the distribution and character of these ores in Canada.

My thanks are especially due to many mining men throughout the country who have rendered ready assistance in this work. I trust that the information contained in this report may be useful to those interested in the tungsten industry.

I have the honour to be, sir,

Your very obedient servant,

T. L. WALKER.

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REPORT

ON THE

TUNGSTEN ORES OF CANADA

BY

T. L. Walker, M.A., Ph.D.

GENERAL STATEMENT.

The Metal and its Uses.

Tungsten is one of those rare metals which have become generally useful during the last few years. Formerly it was of interest chiefly because it was one of the rare chemical elements. Of late it has become an article of commerce and industry, and has attracted much attention on the part of iron masters, dyers, silk workers, electricians, and especially of those connected with the mining industry. During the middle ages one of its commonest ores was well known to the tin miners of Saxony and Cornwall. This mineral, which is now called wolframite, was named *lupis spuma* by Agricola in his master work on minerals, mining, and metallurgy, in the early part of the sixteenth century. In 1781, Scheele—a Swedish chemist—discovered the metal tungsten, which from that date was long known as Scheele's earth. Finally, Cronstedt called this metal tungsten: a name which in Swedish means heavy stone, in reference to the heaviness of all the minerals containing tungsten. Tungsten is one of the very heavy metals, being nearly as heavy as gold—having a specific gravity of 16. It is very hard, and much heavier than lead, hence has been suggested for use as bullets, and would doubtless be employed for special bullets were it not for the difficulty of fusing and forming it. The melting point has been recently determined by Dr. C. W. Waidner, and Dr. G. K. Burgess of the Bureau of Standards, Washington, D.C., to be 3080° C. Being one of the most infusible metals known it has been recently employed in the manufacture of incandescent electric lamps. The tungsten filament has

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the advantage over the ordinary carbon filament of yielding a much whiter light. When carbon filaments are heated to a brilliant white, a black smoky deposit of volatilized carbon forms upon the interior of the bulb so that much of the light efficiency is lost; while the tungsten lamp will stand this white incandescent condition without any appreciable deterioration. Apart from this advantage, the manufacturers of the tungsten bulbs claim for their product a greater light efficiency for the electric energy consumed, even when compared with new, undimmed carbon bulbs. Considerable quantities of tungsten are consumed in the manufacture of tungstates, which are used as a mordant in dyeing, in giving weight to silk goods, and in rendering cotton fabrics fireproof. The chief demand for tungsten, however, is for the production of tungsten steel, which is also called wolfram steel. The addition of a small percentage of this metal increases the elastic limit and tensile strength. Tungsten steel is self-hardening, so that no special skill is required on the part of the blacksmith in the sharpening of tools made from it. Tools which have been heated are found to be well tempered as soon as they cool. These properties make this alloy very desirable for high speed tool steel. Similar effects are produced by adding molybdenum to steel

The Chief Tungsten Ores.

Wolframite.—This ore has been known since the middle ages to the tin miners of Cornwall and Saxony. It is black, or brownish black in colour, yields a red-brown powder, is very heavy, having a specific gravity of over 7. It frequently forms crystals almost metallic in lustre, which cleave easily in one direction, giving rise to thin flat plates. In some cases, as for example some of the wolframite ores of Boulder county, Colorado, the mineral is almost massive, resembling very fine grained, compact magnetite. Chemically it is an iron manganese tungstate, having the formula $(Fe,Mn)WO_4$. Wolframite fuses easily, and is only partially decomposed by the common acids. In Canada it is found in boulders, near Lake Simcoe; at the Kootenay Belle mine near Salmo, B.C.; and in small amount at Hardscrabble creek, Barkerville, B.C.

Hübnerite is closely related to wolframite in the shapes of its crystals, hardness, and specific gravity. The chief difference lies in its being a tungstate of manganese, containing very little iron in its reddish-brown colour, and in yielding when finely pulverized, a yellowish-brown powder. It is found near Northeast Margaree in Cape Breton; Atlin, B.C.; and near Ward, Boulder county, Colorado.

Scheelite.—Next to wolframite, scheelite is the chief ore of tungsten. This mineral is white, cream, yellowish, or brownish in colour. It can be readily scratched by a knife. Its specific gravity is 6. At first sight scheelite suggests calcite or orthoclase; it is, however, far less easily cleaved and is more than twice as heavy as these minerals. More frequently it is confused with barite or heavy spar. In general its most characteristic property is its high density; none of the minerals resembling scheelite are as heavy. Its chemical composition is calcium tungstate, $CaWO_4$. Scheelite is found in Canada near Moose River mines, N.S.; Victoria mines, Ontario; Granite, near Nelson, B.C.; and near Barkerville, B.C.

Tungstite.—This mineral usually occurs as soft, earthy decomposition products of scheelite, or wolframite. The iron or lime of these minerals is leached out by water circulating in the rock mass, leaving a hydrated tungstic acid WO_3H_2O. It bears the same relationship to these minerals as bog iron ore or limonite bears to pyrite or pyrrhotite. It is, therefore, always a secondary mineral. The most striking property of tungstite is the fine canary or golden yellow colour of the mineral, and particularly of its powder.

Tungstite has hardly attained the prominence of an ore as yet; but in certain deposits near Salmo, B.C., at the Kootenay Belle mine, the possibility of its occurring in economic quantities is indicated. Other Canadian localities are, Moose River mines, N.S.; with scheelite near Barkerville, B.C.

General Chemical Tests for all Tungsten Ores.

(1) To the finely pulverized mineral add strong hydrochloric acid—part of the tungsten will pass into the solution. To this solution add metallic zinc, then boil. A fine azure blue indicates the presence of tungsten.

(2) When any tungsten ore is fused with sodic carbonate, leached out with hot water and filtered, the tungsten passes into the filtrate and may be precipitated from this by adding hydrochloric acid and evaporating to dryness. This precipitate is a fine yellow colour, and is insoluble in acids, but dissolves readily in ammonia.

(3) This yellow precipitate of tungstic acid may be tested further: to a bead of salt of phosphorus add a little of the yellow powder, treat

in a reducing flame using a blow-pipe. A fine blue bead is characteristic for tungsten.

Signs for the Prospector.

Regions characterized by the occurrence of ores of tin, or of gold quartz veins, occasionally bear tungsten minerals as well. While tin ores are of very rare occurrence in Canada, it is interesting to remember that, in several of them tungsten minerals occur also. This is the case in Lunenburg county, N.S.; in the vicinity of Victoria Mines, Sudbury district; and, in some of the creeks in the Yukon, where cassiterite or tinstone and scheelite are found in the heavy sand and gravel.

It will accordingly be profitable to examine quartz veins in gold quartz districts. As a rule the veins rich in gold are poor in tungsten, while quite near gold quartz mines the veins may be valuable for tungsten, but practically free from gold. An assay of concentrates from a stamp mill may reveal the presence of ores of tungsten. Occasionally when concentrating with Wilfley tables, a band of white scheelite, or a canary yellow band of tungstite may be observed. These minerals are so heavy that this band is always somewhere between the bands of galena and pyrite.

In quartz veins scheelite might easily be overlooked, or mistaken for feldspar or calcite, but its great weight would be a sufficient characteristic if pieces of fair size were obtainable. When exposed to the atmosphere, or to the action of circulating waters, it is chemically changed to the canary yellow tungstite. Generally it shows a decided preference for the vein margins.

Hübnerite and wolframite are similarly found in quartz veins. Their dark colour, easy cleavage into plates, and high density are very characteristic. In some regions the cracks in the quartz are spotted by thin black secondary deposits, possibly of some manganese compound. These thin, dark discolourations are sometimes dendriform or tree-like in shape. This type of quartz is in some regions characteristic of tungsten bearing veins.

In placer mining the presence of scheelite is readily detected by the occurrence of more or less rounded grains and pebbles, almost white in colour, and so heavy as to concentrate with the gold. Seldom is there in the gravel sufficient scheelite to be of economic importance, but this information is a valuable indication of the possibility of finding scheelite bearing quartz veins or stringers in the neighbourhood.

General Geological Occurrence of Tungsten Ores.

Ores of tungsten, as indicated above, are generally confined to tin regions, or where auriferous quartz veins abound. Where intrusive granite comes in contact with slates and schists, quartz or pegmatite veins frequently intersect both the intrusive and the overlying slate-schist series. It is now generally agreed that in many instances the cooling and solidifying granite mass contracted, and in the last stages became fissured; the fissures being filled by constituents of the igneous mass which had not yet solidified. This mother liquor filled in the rifts in the rock mass, and on cooling and solidifying gave rise to very coarse granite known as pegmatite. In other instances the granite mass, and the overlying slate series as well, contain irregular veins rich in minerals, containing fluorine, boron, lithium, tin, and tungsten. These are tin ore veins, and at times carry considerable tungsten, in addition. Fissures in the slate-schist series appear to have become quartz veins, at times carrying gold or tungsten. Where the mantle of slate or schist overlying the granite mass is not very thick these veins may occur at considerable distance from known outcrops of granite, while the granite may be at no great distance below them. The evidence, therefore, suggests that tungsten deposits found in proximity to granite masses are derived from these constituents of the igneous mass which are expelled towards the close, (either as mother liquor or as gases), and find their way into pegmatite masses, irregular tin-wolfram-quartz veins in the granite or quartz veins, carrying occasionally gold, or tungsten, or both.

Deposits of slightly different type occur near Trumbull, Connecticut, and near the famous Homestake gold mine in the Northern Black hills in South Dakota. In the former locality tungsten ores have been known for nearly a century; but not until 1898 were the deposits worked for tungsten. In the latter locality a heavy black 'iron' had been observed for many years, associated with some of the refractory siliceous gold ores. Not until 1899 was this ore recognized—by a local mineralogist—to be wolframite. Since this discovery South Dakota has been a continuous, if fluctuating, producer of ores of tungsten.

In the latter case the tungsten ore seems to have been deposited by replacement of fractured limestone or dolomite, the waters being derived through prominent fracture lines in the rock mass. Some of the tungsten ores of this region contain a little gold, but as a rule it is insignificant. This region has been described by J. D. Irving,[1] from whose excellent report the following paragraphs, descriptive of the ore bodies, have been taken:—

'As stated above, the wolframite is found in much the same relations as the refractory siliceous ores already described.

'It occurs in flat, horizontal, but rather irregular masses up to 2 feet in thickness. They frequently cover considerable areas, of which perhaps the largest so far discovered may have an extent of 20 to 30 square feet; but they are so extremely irregular that it is difficult to form an exact estimate of their lateral extent. These masses lie upon or near the basal quartzite of the Cambrian, or, where that is absent, upon the conglomerate that separates the upper members of the series from the rocks of the Algonkian. The beds in which it lies are an impure dolomite, sometimes so full of sand grains as to grade into quartzite—a fact that has not infrequently given rise to the erroneous opinion that the ores are mineralized quartzite.

'Above the dolomitic beds generally occur layers of shale, which become much more argillaceous, and often contain considerable glauconite, as one passes vertically upward. Above these shales, both in the vicinity of Lead and Yellow creeks, are found remnants of a rhyolite sheet, showing in many cases a well-developed columnar structure.

'The wolframite is to be considered more in the nature of a basic phase of the refractory siliceous ores than as a separate and distinct deposit; for it occurs always in intimate association with them. At times it forms a rim around the outer edge of the siliceous ore shoots, often extending inward and upward so as to form a thin capping to that ore. It thus appears as a sort of envelope to the siliceous ore mass, which it encloses, or nearly encloses, on all except the lower side. Margins of this kind are often from 2 to 2½ feet thick; but the capping portion is generally thinner. At other times the wolframite occurs in irregular masses, scattered through the siliceous ore, or in stringers and thin, contorted layers in the partially silicified dolomite. In the Wasp No. 2 mine, in Yellow creek, it was observed in lenticular or kidney-shaped masses in the shaly dolomite. An excellent instance of the first or envelope type of occurrence is to be seen in the Harrison mine, near Lead. In the Two Strike mine in the Yellow Creek area it was seen in thin, irregular

[1] Irving, J. D., Professional Paper No. 26, United States Geological Survey, "Economic Resources of the Northern Black Hills," pp. 164, 165 and 169.

layers replacing the uppermost and more calcareous portion of the basal Cambrian quartzite.

'In general the ore is separated from the non-mineralized rock by a fairly sharp line of demarcation; but in not a few cases it grades off so that the ore becomes leaner and passes by scarcely perceptible transitions into the country rock. In almost all cases considerable silicification has extended beyond the wolframite deposition, so that, without the aid of the microscope, it is difficult to distinguish the original rock from quartzite.

'It will at once appear that neither of these two classes of deposits[1] bears any resemblance to those under discussion, and it is evident from the manner in which the ore occurs that it is to be ascribed to the same mineralizing agencies as the deposition of the siliceous ores. The association of the latter with fractures, the occurrence in an easily replaced rock, and the manner in which original structures have been preserved in the ore have been shown to prove that they are due to the replacement of carbonates by siliceous material. In the case of the wolframite there seems no reason to doubt that the same series of events has taken place, although a partial replacement of quartz may have occurred at the same time. First there was a fracturing of the country rock, then the replacing action of mineralizing waters which gained access to the replaceable strata by means of the fractures, and finally a gradual interchange of carbonate (and possibly of some quartz) for wolframite, molecule by molecule.'

This type of tungsten deposit does not seem to have been recognized in Canada up to the present time.

In addition to deposits of the four types above mentioned, tungsten ores, being very heavy and not easily disintegrated, collect in some measure in sand and gravel beds as placer deposits, along with gold or tinstone.

The Concentration of Tungsten Ores.

Tungsten ores as mined usually require milling and concentrating in order to save cost of transportation, and especially to bring the ore up to the standard required by purchasers, and by those who use it in the industries. The tungsten contained in ores carrying less than 60 per cent tungstic acid is less valuable than the same amount of tungsten would be in an ore containing 60 per cent or

[1] The author had just referred to tungsten bearing quartz veins and tungsten bearing pegmatite veins.

over. When orés fall far short of 60 per cent tungstic acid it is difficult to secure ready purchasers, even at much lower prices.

The following table (1) shows the amount of tungstic acid contained in each of the four common minerals, while (2) indicates the amount of each of these minerals which is present in an ore sample, together with the gangue when the ore contains the standard 60 per cent of tungstic acid:—

	(1)	(2)
Wolframite..	76·3	78·6
Hübnerite...	76·6	78·3
Scheelite..	80·6	74·4
Tungstite..	92·8	64·6

It is the practice in some tungsten regions to hand pick the ore, and to ship without milling all ore containing 30 per cent tungstic acid, or over. In this way the cost of milling, and what is more important, the loss of from 15 to 30 per cent of the ore values in the tailings is avoided. These advantages seem to be sufficient to outweigh the penalty inflicted by the purchasers on account of the ore falling short of the 60 per cent standard.

The method of concentration varies in different regions, and depends upon the nature of the tungsten ores and of the associated gangue minerals. In general it may be said that up to the present time neither chemical nor furnace methods have been introduced. The concentration usually consists in crushing the ore, washing away the lighter rock minerals, and occasionally passing the concentrate over a magnetic separator, to separate the tungsten minerals from the base materials. Wolframite is slightly magnetic, and in that case the magnetic process might be used to select it from the gangue minerals. With the other ores of tungsten, which are not attracted by the electro magnet, the base materials might be picked out by this process.

Since Canada has not yet become a producer of tungsten ores, one must look abroad for information regarding tungsten milling and concentration.

In Cornwall, where wolframite occurs in the tin mines, together with tinstone or cassiterite, experiments have been made in the magnetic separation of these two minerals. It is said that the wolframite can be picked out from the cassiterite by an electro magnet, and a fairly good separation made, especially after roasting.

In considering the wet concentration of tungsten ores it is necessary to remember that scheelite, wolframite, hübnerite, and tungstite, are relatively soft minerals, and that they are prone to grind to a very fine powder, and, as a result, great loss is likely to ensue from the floating away in the water of fine ore particles. The great problem in tungsten concentration appears to be to reduce as far as possible this high loss of slimes.

In California, near Randsburg, where scheelite occurs with a quartz gangue, the ore is crushed in a Blake crusher, ground in a 6 foot Huntingdon mill to a certain fineness, and then passed over 6 foot Frue vanners. It has been found that less loss in slimes results by this method of crushing than when the ore is crushed in a stamp mill. No attempt is made to recover the fine particles which wash away with the tailings. The operators report that, with this treatment the loss in milling and concentrating amounts to about 30 per cent of the tungsten values.

One of the oldest American localities where tungsten minerals occur—scheelite, wolframite, and tungstite—is near Trumbull, Connecticut. The deposits were worked for silver long before the tungsten

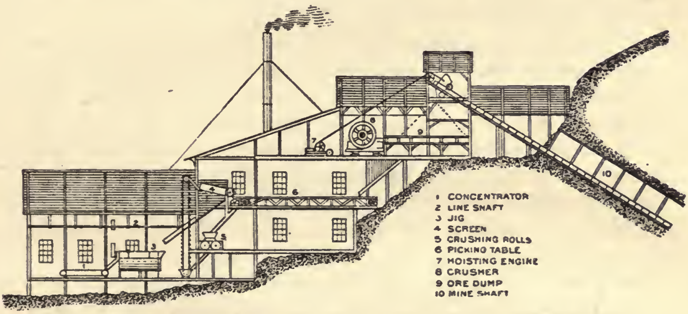


FIG. 1.—Diagram showing sectional elevation of mill (after Hobbs).

contents had become important; and it was not until 1898 that serious note was taken of these unusual ores. Unfortunately the undertaking was found unprofitable, hence after several years of mining for tungsten, the work was suspended.

Professor W. H. Hobbs[1] has described these deposits, and from his description of the milling and concentrating plant the following account is copied:—

'The machinery installed consists of a Blake crusher (15 by 24 inches) with a capacity of 10 tons per hour. The crusher, which with

[1] Hobbs, W. H., Twenty-second Annual Report of the United States Geological Survey, 1900-1.

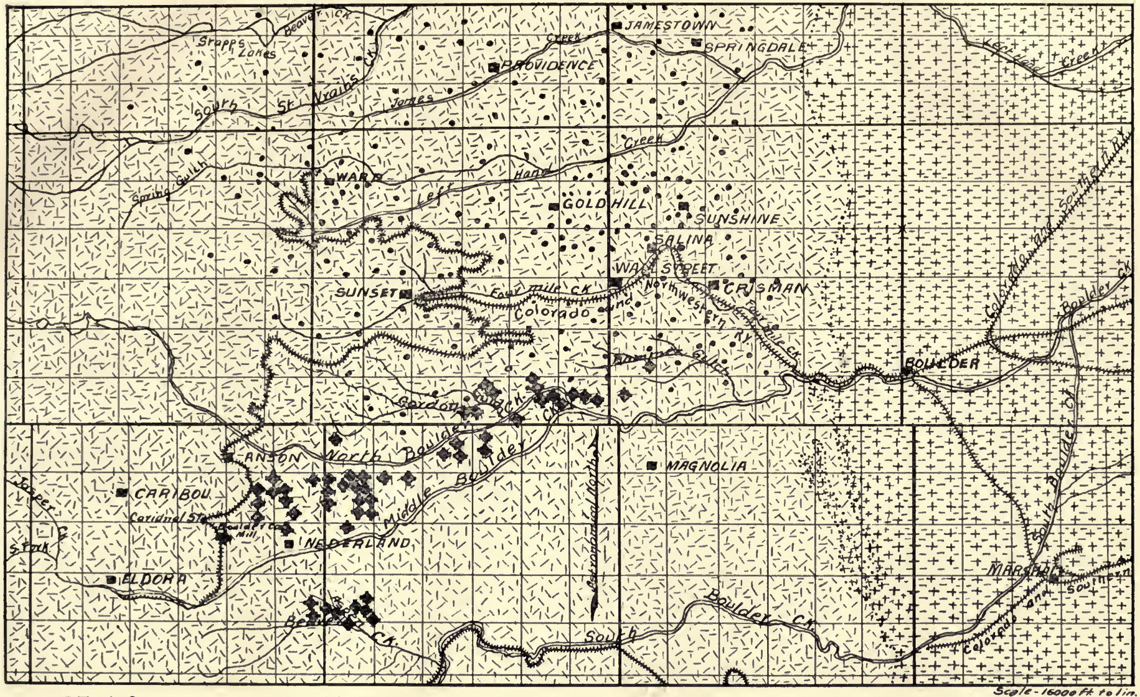
the other pulverizing machinery is actuated by a high-speed, 200 h. p. engine, discharges its product on the end of the picking table, an endless rubber belt 3 feet in width acting as carrier and feeder to two small crushers on the floor below.

'These crushers deliver their product to two corresponding sets of Cornish rolls running one-fourth inch apart and having a 22-inch diameter and 16-inch face. These rolls discharge the material to an endless-belt elevator, which carries it to the top of the mill and delivers it to a pair of revolving screens 36 inches in diameter and 8 feet in length. These screens have wire meshes ⅛ inch square, and hence refuse most of the pulp. A considerable portion of the dust is here drawn out by a current of air which passes under the screens. The portions of the material refused by these screens are carried by gravity to a pair of belted high-speed rolls of 30-inch diameter and 18-inch face, running one-eighth inch apart, and are from them returned to the elevator and again passed through the screens. After this second screening the material passes to a pair of Wolf gyrating screens of three sizes (meshes 40, 60 and 90).

'Concentration is effected by a dry process in what is known as the Hooper pneumatic concentrating machine, which delivers the concentrates clean, and leaves little scheelite in the tailings. Each machine is said to be capable of treating approximately 10 tons of pulp per day, and the yield of pure concentrates is reported to average 5 per cent by weight of pure scheelite. The scheelite as it comes from the mill is contaminated with a small percentage of pyrite, which must be removed by roasting. No attempt is made at the mining plant to separate the lime so as to change the mineral to tungstic oxide, in which form it is usually quoted in the market. Indeed, no appreciable quantity of the product appears to have been placed upon the market. The concentrating machinery is operated by a separate engine from that which runs the crushing machine.'

The best developed tungsten region in America is in Boulder county, Colorado, where there are about twenty properties developed so that they may be spoken of as mines. The ore is wolframite, with a quartz feldspar gangue. Several mills have been erected to concentrate the ores. Some are customs mills which purchase the ores delivered to them by small operators.

The Wolf Tongue mill is largely occupied in this type of work. The ore as received is crushed in a Blake crusher and sampled. It then passes through a twenty stamp mill from which the amalgama-



GEOLOGICAL SKETCH MAP., BOULDER COUNTY TUNGSTEN AREA.

Gneissoid Granite — Sedimentary Rocks. — Tungsten Prospects or Mines — Gold Mines

ting plates have been removed. A twenty mesh screen is used. After classifying, the pulp is treated on five Wilfley tables, and five Wilfley slimers. The tailings are retained by a small dam, so that they may be available for further treatment in case a method suited to the recovery of the tungsten should be devised later.

The following three analyses indicate (1) the type of ore milled, (2) the composition of the coarse concentrates, (3) the composition of the slimes:—

	(1)	(2)	(3)
WO_3	24·60	53·70	56·80
MoO	.....	0·24	0·16
FeO	.....	29·82	28·37

The Cardinal mill treats ores from mines owned and operated by the same company. Very little custom work is undertaken. Most of their ore comes from the Conger and the Lone Tree mines, which are situated nearby. The ore is hauled in wagons from the mines to the mill.

The treatment at the Cardinal mill involves the following steps in the order indicated:—

(1) Crushing in stamp mill,
(2) Concentration on two Wilfley tables,
(3) Hydraulic classifier,
(4) Several large Frue vanners, (1st set),
(5) Huntingdon mill,
(6) Several large Frue vanners, (2nd set),
(7) Five 6 foot California canvas tables,
(8) Long series of settling tanks.

As will be readily understood by those acquainted with concentrating appliances, the wolframite is recovered in four different types of concentrate in the above process.

(1) Coarse, from Wilfley tables,
(2) Intermediate, from first treatment of Frue vanners,
(3) Fine, from second treatment of Frue vanners,
(4) Slime, in settling tanks from treatment on California canvas tables.

While no exact data are available for the Cardinal mill as to the percentage of values lost in the tailings, it may be assumed that the loss is relatively low for tungsten concentration. This will seem to be unusually complete, and its savings are at least as high as any in the district.

Some of the wolframite ores in Boulder county, Colorado, are very difficult to bring up to the 60 per cent standard by mechanical concentration, owing to the very fine state in which the wolframite exists along with chalcedonic quartz. This is particularly true of some of the ore obtained in the Rogers tract. This type of ore would become more valuable if some method of chemical concentration were devised.

In May, 1907, some of the customs mills at Nederland, Boulder county, Colorado, charged $4 a ton for crushing and concentrating ores, and offered to purchase the concentrate obtained, at $9.50 per unit for 60 per cent ore, and $8.50 per unit for 50-60 per cent ore. It was then profitable to concentrate ore containing 2 per cent of tungstic acid. Ores of lower grade could be concentrated profitably when the mill and mine belonged to the same proprietors.[1]

Tungsten Producing Countries, Production and Prices.

It is only within the last twenty-five years that tungsten has become an important element in the mineral industry. Prior to that time but little was required by the industries; and since sufficient was forthcoming as a by-product from the tin mines of Cornwall and Saxony, there was no incentive to prospect for tungsten deposits, or even to carefully save tungsten ores when they were met with in mining for other metals. This has been changed by the discovery of the advantages of tungsten steel. So great was the demand for tungsten ores for steel making that, the prices advanced very rapidly, and even with the higher prices consumers often found it necessary to make contracts ahead in order to ensure a supply adequate for their requirements.

The present annual production of tungsten ores for the world is estimated at about 4,000 tons. Exact statistics are not obtainable in many cases, so that these figures are only approximate.

A general view of the prices of tungsten ore, the quantities produced, and the chief tungsten producing countries, may be obtained from the following tables:—

[1] Greenawalt, Wm. E., Engineering and Mining Journal, May 18, 1907.

*World's production of Tungsten Ores in 1905; with a partial statement for 1906.**

Country.	1906.		1905.	
	Short Tons.	Value.	Short Tons.	Value.
		$		$
Great Britain	....	....	193	55,271
New South Wales	271	81,349	251	85,090
Queensland	892	322,400	1,582	487,688
South Australia	....	....	71	16,446
Tasmania	22	7,130	36	11,540
Northern Australia	95	33,977	....	....
New Zealand	....	....	64	22,400
Rhodesia	17	7,399	....	....
Austria	....	....	65	20,418
Bolivia	....	....	75	26,250
France	....	....	28	11,448
Germany	....	....	42	16,184
Saxony	....	....	37	12,437
Portugal	....	....	320	99,413
Spain	....	....	413	32,111
United States	928	348,867	803	268,676
Other countries	....	....	20	7,000
Total	....	....	4,000	1,172,372

* Mineral resources of the United States, 1906.

*Tungsten production of the United States from 1900–1906 in tons of 2,000 pounds.**

Year.	Tons.	Value.	Value per Ton.
		$	$
1900	46	11,040	240
1901	179	27,720	155
1902	184	33,112	180
1903	292	43,639	149
1904	740	184,000	249
1905	834	257,436	308
1906	1,096	443,150	404

* The Mineral Industry, 1906—p. 744.

From these statistics it is apparent that, during the last few years the production of ores of tungsten has advanced very rapidly. The accelerated demand seems to have had considerable influence on the price as shown by the increasing average price per ton of the ore. For 1907 complete data are not yet available, but we believe there is a considerable advance in the tonnage as well as in the average price per ton.

The standard for concentration for tungsten ores is 60 per cent of tungstic acid, and the price in purchasing such ores is so much per unit—that is, for each per cent of tungstic acid present. When such ores are quoted at $6 per unit, 60 per cent ore is worth $360 a ton, and 75 per cent ore is worth $450 a ton.

The following table from Mr. Greenawalt's paper[1] indicates the value of ores of various grades at Nederland, Boulder county, Colorado, for May, 1907, when the price per unit was $9.50 for 60 per cent concentrates.

Basis for Purchasing Tungsten Ore.

WO_3 %.	Value per ton.	WO_3 %.	Value per ton.
	$		$
3	10	20	100
4	15	30	180
5	21	40	280
10	46	50	400
15	71	60	570

The highest price recorded for tungsten ores was touched during 1907, when the price for 60 per cent ore was $11 per unit. Shortly after this, owing to the depression in the steel industry, the demand for tungsten ores weakened, and a year later the price had fallen to about $5.50 per unit for the same grade of ore.

Producing Regions in the United States.

Boulder county, Colorado.[2]—The wolframite mines of this region have developed rapidly in the last five years, making this the greatest tungsten producing region in the United States. There are within a radius of a few miles at least twenty mines, and four large mills for crushing and concentrating the ore. (Plates 2 and 3.) Some of the mines have reached a depth of 400 feet. It is reported that the ore

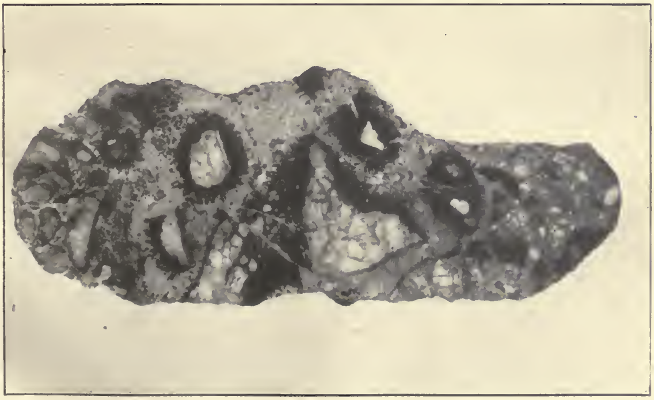
[1] Engineering and Mining Journal, p. 952, May 18, 1907.

[2] Much of the information regarding the production of Boulder county is derived from:—

Lingren, W., "Gold and Tungsten Deposits of Colorado," Economic county is derived from:—

Greenawalt, Wm. E., "The Tungsten Deposits of Boulder County, Colorado," Engineering and Mining Journal, May 18, 1907.

Tungsten Mines, Boulder County, Colorado.



Brecciated Tungsten Ore.

Wolf Tongue Mill, Nederland, Colorado.

Reservoir for Tailings, Wolf Tongue Mill.

bodies are as well marked at these lower levels as in the upper workings.

The geological relationships of this region are indicated in the accompanying sketch map (Plate 1). Boulder city is situated within the area of sedimentary rocks which occupies the eastern portion of the map. To the west of a line passing north and south through Boulder, the rock formation changes and the country is characterized by a gneissoid granite, marked by pegmatite in the form of dikes and irregular masses. The ore bodies seem to have formed in late fissures and shattered zones, especially of the pegmatite masses.

Hayden's geological map of this region indicates certain areas of gneissoid granite as auriferous. Within some of these gold areas, in recent years, valuable tungsten deposits have been discovered and worked.

The output of these mines is indicated by the following table:—

Year.	Tons.	Value.
1905	721	$350,000
1906	820	———
1907	982	375,000

This does not represent the full production for 1907, but only the ore sold. Owing to a fall in the demand toward the end of 1907, much of the ore produced was stored.

The deposits consist of a series of stringers occurring along fractured zones of pegmatite, which is associated with granite. The ore is wolframite, which often forms a cement holding together angular fragments of broken pegmatite, and giving rise to a breccia. Ground fault rock seems to be the chief filling in these so called veins. This structure is admirably shown in the illustration of a polished specimen of ore from the Conger mine. The black radiating mineral is the wolframite. (*See* Plate 2.) The ore bodies, while fairly continuous, must not be regarded as well defined veins. As a rule the ore stringers are quite narrow—½″ to 2″ wide. In some exceptional cases they may expand so as to include wolframite masses 6″ across. The ore is usually very fine-grained, or massive, seldom very drusy. The massive ore resembles, in a degree, very fine-grained magnetite. Other tungsten minerals are not frequent.

The geological relationships, and the extent of this tungsten area may be gathered from the accompanying sketch map (Plate 1). The topographical detail of this map is from Drumm's map of Boulder county—the geological outline is according to Hayden's Geological Atlas of Colorado. The tungsten mines are indicated according to a sketch prepared by Professor R. D. George, State Geologist for Colorado. (Plate 1.)

Randsburg, California.[1]—This tungsten field was discovered only a few years ago, but has already taken the second place in this branch of mining in the United States. The ore is scheelite, occurring in the quartz veins in granite. The scheelite is granular, and almost white in colour—very fresh, and unusually free from intermingled gangue minerals. The ore is said to occur in 'kidneys,' which at times attain 200 pounds in weight. These mines are situated quite conveniently near railway transportation. The area over which the good deposits are distributed is said to be comparatively small. The chief towns for thtis region are Johannesburg and Randsburg. According to a communication from the Atolia Mining Company, they produced 500 tons of scheelite concentrate between July, 1906, and July, 1908. After the decline in the tungsten industry, due to the congestion of the steel market, in September, 1907, the mines of this Company were closed temporarily.

Snake Range, Eastern Nevada.[1]—Geologically this tungsten region is marked by the occurrence, in a large boss of granite, of quartz veins carrying hübnerite, scattered irregularly through the quartz mass. Occasionally there is a tendency for the hübnerite to become more prominent toward the border. The granite mass is surrounded by metamorphosed sediments, but the ore veins do not extend into this series. Scheelite occurs sparingly along with the hübnerite, but wolframite is not known in these deposits.

Other tungsten producing States are:—Arizona, Alaska, Connecticut, Idaho, Montana, New Mexico, Oregon, South Dakota, and Washington. At present, these States supply only a relatively small portion of the total production of the United States.

Tungsten Development in India.

Recently, an agent of the Carnegie Steel Company, exploring for ores of manganese in Nagpur district, Central Provinces, India, obtained from some prospecting pits samples which were determined in the laboratories of the Geological Survey of India to be wolfra-

[1] For much of this information the writer is indebted to Mr. DeGolia of the firm DeGolia and Atkins, San Francisco, California.

[2] F. B. Weeks, "Tungsten Deposits in Snake Range, White Pine County, Eastern Nevada," Bull. 340, United States Geological Survey, 1908.

mite. This is a new location for the occurrence of wolframite in situ in peninsular, only one such place being previously on record. These deposits seem to be quartz veins carrying much tourmaline and very coarsely crystallized wolframite.

From a preliminary description by Mr. L. Leigh Fermor,[1] of the Geological Survey of India, the following extracts are made:—

'The wolfram deposit lies within the boundaries of Agargaon village area or mauza, in the Umrer tahsil. This village lies on the south bank of the Kagan river at a point about seven miles south-east of Maunda (nine miles by bullock-cart road). Maunda is twenty miles east of Nagpur on the main road from Nagpur to Raipur. The pit where the wolfram was first found lies about three-quarters of a mile south by a little west of the village, on a low ridge of mica-schists striking N. 65° E.

'The rocks seen in this section consist of micaceous schists, frequently containing abundance of tourmaline; with some layers of fine-grained tourmaline schist; some of the less crystalline form of schist known as phyllite, and some of fine-grained quartzites. The quartzites, which occur towards the south end of the section, are of subordinate importance as compared with the mica-schists, and there is every gradation between the quartzite, through micaceous or sericitic quartzite, to the mica-schist. Interbedded with these schists there are several lenticular masses of quartz varying up to eight inches thick. The mica of these schists is chiefly a white mica.

'In the portion in which the existence of wolfram has been proved four trenches have been put across the strike of the ridge. None of these have been carried to a greater depth than eight feet, because the Deputy Commissioner of the district has fixed this as the maximum depth to which the surface of the land may be turned up under an exploring licence.

'Each trench also shows several quartz veins interbedded in the schists and varying in thickness from a small fraction of an inch to as much as eighteen inches, though this thickness is exceptional. In some cases the quartz veins are in the mica-schists, but they tend to be more closely associated with the tourmaline-schists. When in the latter the quartz sometimes takes the form of a series of numerous small veins close together, and often joined up by small cross stringers.

---

[1] Records, Geological Survey of India, Vol. XXXVI, p. 301, Calcutta, 1908.

'The third trench from the watercourse section was 133 feet long. It showed several quartz veins of thicknesses of three and four inches, with one expanding to as much as eighteen inches in one place. There were also a large number of very thin veins wherever the tourmaline-schists appeared. As in the second trench, these tourmaline-schists were brecciated by thin veinlets of mica-schists with the schistosity parallel to that of the tourmaline-schist.

'In size the wolfram individuals vary from very small up to as much as four to five inches across; between one-half and two inches seems to be the most usual size.

'Besides occurring in the quartz the mineral sometimes occurs in the mica-schist close to the quartz; but the mica-schist is then extra rich in quartz.

'Subsequent to the original find of wolfram in situ in the quartz veins several small pockets of weathered out nuggets have been found at the surface. These nuggets are sometimes one to three inches in diameter, and often consist practically entirely of wolfram.

'The wolfram occurs in quartz veins, intercalated in a series of mica-schists and tourmaline-schists, and tending to be more closely associated with the tourmaline-schists.

'The schists are a part of the Dharwar series.[1]

'The quartz veins have been granulitized and in places squeezed into lenticles; the enclosed wolfram has often been brecciated; whilst portions of the tourmaline-schist have been enclosed in the quartz, and the neighbouring tourmaline-schist also brecciated.

'The close association of the tourmaline and the wolfram suggests that these two minerals are genetically connected.

'Should these veins be found to continue in depth as rich as they have proved at the surface I believe it is Mr. Kellerschon's intention to erect a concentration plant on the spot. Should the other concessionaires on the strike of the wolfram-bearing belt of schists find wolfram in their claims, they will probably arrange for the Carnegie Company's mill to treat their ores as custom-ore.

'An analysis of some broken crystals and fragments of wolfram sent by Mr. Kellerschon to the Carnegie Steel Company in America gave the following result:—

---

[1] The gold formation of peninsular India. This series includes non-fossiliferous much metamorphosed rock overlying the gneisses. Apparently somewhat similar to the Canadian Huronian.

Tungsten	51·59
Iron	14·50
Manganese	2·94
Silica	3·40
Phosphorus	0·018.'

This occurrence closely resembles the Moose River tungsten deposits in the following points:—

(*a*) Interbedded veins,

(*b*) in the gold formation of the region,

(*c*) much pinched into lenses, and

(*d*) the association of tourmaline, and tungsten ores.

In the Nova Scotian deposits, tourmaline is quite subordinate—occasional needles.

CANADIAN TUNGSTEN OCCURRENCES.

Nova Scotia.

Cape Breton.

In the spring of 1898 a tungsten bearing deposit was discovered in Inverness county, Cape Breton, near Northeast Margaree on Tom Murphys brook, which is a tributary of Big brook, flowing westward into it, midway between Pine and Coady brooks.

An ore sample from this prospect was assayed by Mr. F. H. Mason, who concluded that the mineral was manganese wolframite, a name well in accord with his analysis[1]:—

Tungstic acid..	66·32
Silica..	6·25
Manganese..	12·02
Iron..	0·12

It thus appears that, the mineral contains very little iron, is high in manganese and that it is very typical hübnerite.

In the Mineral Industry for 1900 (p. 658) we read of a discovery of wolframite in Inverness county, C.B. The analysis seems to be Mason's, but with a mistake in the decimal point for the iron value. This new form for Mason's analysis is:—

WO_3..	66·32
SiO_2..	6·25
Mn..	12·02
Fe..	12·00

It is almost certain that 0·12% has been entered as 12%. With such a high iron value the mineral would be called wolframite, and so we read in several instances of *wolframite from Northeast Margaree, C.B.*

The occurrence of hübnerite near Emerald, Inverness county, C.B., is also recorded. The writer is of the opinion that there is only one discovery—Emerald and Northeast Margaree being rural post-offices, more or less close to the tungsten discovery, and that no wolframite has been found. Published records sometimes give the

[1] Ross, A. C., Journal of the Mining Society of Nova Scotia, Vol. V, part 1, p. 33.

impression that wolframite occurs at Northeast Margaree and hübnerite at Emerald.[1]

This mineral has been carefully analysed by Mr. Johnston, of the Geological Survey, with the following result:—

WO_3	74·28
MoO_3	trace
MnO	22·73
FeO3	0·47
CaO	0·02
MgO	0·86
SiO_2	1·33
Total	99·69
Specific gravity	6·975

The hübnerite occurs in crystals and crystal clusters scattered through a milky quartz mass. Associated with the hübnerite is a small amount of chalcopyrite, and also a soft, black, earthy substance, probably an oxide of manganese resulting from the decomposition of the hübnerite. Near Murphys brook a block of quartz hübnerite ore was discovered, and this, when broken up, yielded about half a ton of ore with the analysis first quoted above. (66·32% WO_3). The weight of the block was about one and a half tons. Those in charge, after breaking up the mass, proceeded to sink a small shaft and drift both ways into the steep hillsides on both sides of the brook near which the block had been found. Their general conclusion was that they were dealing with a lenticular mass which pinched out.

On visiting this prospect in May, 1908, the writer concluded that the ore quartz mass had been a loose block which had rolled from the hillside to the south of Murphys brook. The rock in which the work has been done is a reddish biotite granite, containing little orthoclase and much plagioclase. The biotite is much decomposed. This granite forms part of a boss which is overlaid by old Palæozoic slates and shales. Just near the contact the slate is altered to a hard greenish lime silicate. The microscope shows that the rock is made up almost entirely of secondary green acicular hornblende, yellowish epidote, and secondary quartz. This fact means that the granite is intrusive into the slates, and that it has metamorphosed it to the green type above mentioned. The mine where the hübnerite

[1] Johnston, R. A. A., "Molybdenum and Tungsten," p. 13.

boulder was found, is situated near the boundary between the slate and granite, but on the granite side of the line. The wooded granite hill slope, south of the brook, is marked by the occurrence of many large quartz masses, probably derived from quartz veins in granite, hidden by the vegetation and humus. This valley seems to be very promising ground for prospecting—searching for quartz veins and float—and carefully examining the quartz for hübnerite or wolframite. The situation is ideal for the occurrence of tungsten bearing quartz veins in the granite or altered slate. In such prospecting an examination should be made for tin as well as for tungsten. Panning and assaying the stream gravels might give valuable information.

An average analysis of the quartz hübnerite fragments collected when the prospect was visited gave the following asays:—

WO_3	9·74%
FeO	5·67%

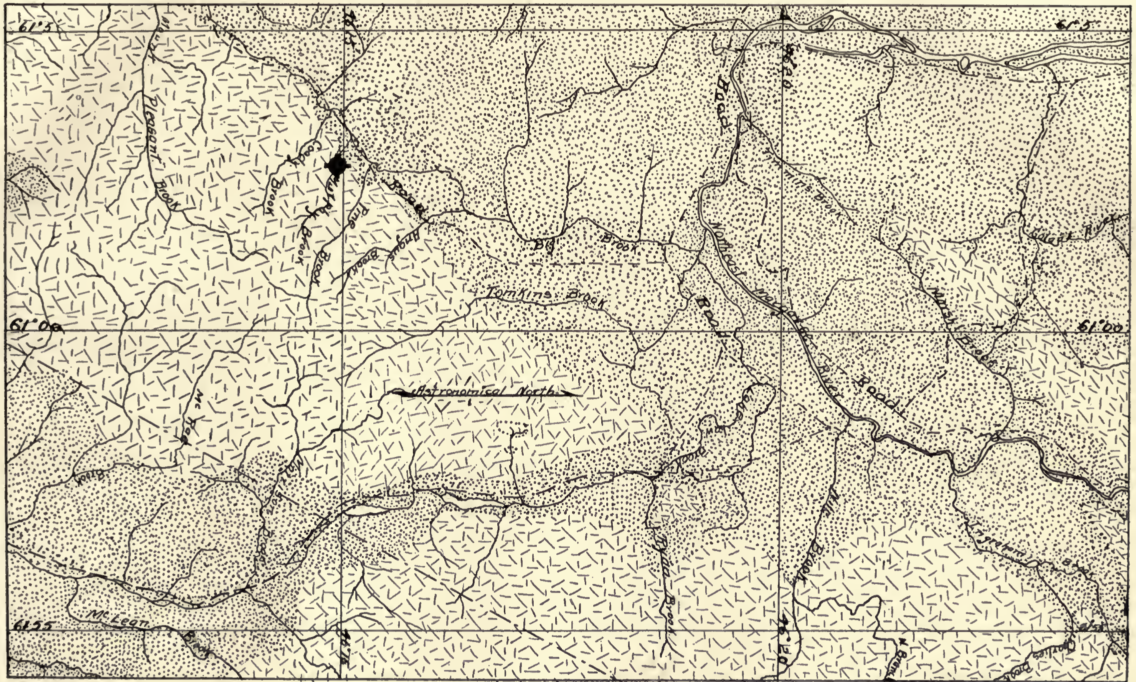
Some of the sand and gravel from the stream bed was washed, and the resulting concentrate on analysis yielded the following:—

WO_3	0·47%

The accompanying sketch map illustrates the geological and topographical relationships mentioned. This map is based on the maps prepared by H. Fletcher for the Geological Survey of Canada. None of the maps contained in this report attempt more detail than is necessary to an understanding of the outline of the geological relationships and topography of the region. These sketch maps have been drawn by George Wright, Esq., B.A.Sc., of the University of Toronto. (Plate 4.)

Moose River, Halifax County.

Several years ago a trapper brought to the Cariboo mines a heavy white stone which he had picked up about ten miles from Cariboo in the direction of Moose river. The high density of the piece was its chief characteristic. For some time it remained undetermined, when finally one of the men on leaving this camp to proceed to California, broke off a fragment and took it with him. It was there recognized as scheelite, and the bearer was engaged to return to Nova Scotia and search, with a view to discovering the mother lode from which the mass had been derived. The search in Nova Scotia was fruitless. This information was obtained by the writer from Professor Wood-



GEOLOGICAL SKETCH MAP PART OF CAPE BRETON ISLAND TUNGSTEN AREA

Granite   Lower Cambrian.   Tungsten Prospects or Mines.

man of Dalhousie College and from Mr. Getschel of the Cariboo mines.

On visiting the Moose River gold mines, special inquiry was made as to the occurrence of minerals of tungsten. Mr. A. L. McCallum, assayer of the mines at the time, had in his possession a specimen of white quartz containing a canary yellow mineral which was at once recognized as tungstite. This specimen had been broken off a quartz boulder some two miles west of the mines, a short time before by Messrs. Currie and Reynolds while out hunting. On learning the nature and value of the yellow mineral the three gentlemen above mentioned searched the region very carefully for the parent deposit with very satisfactory results.

More recently, after my first visit to this field and possibly in some measure resulting from it, several very promising deposits of scheelite were found in the vicinity of Moose River gold mines.

The three gentlemen, Messrs. McCallum, Reynolds, and Currie, followed up the discovery, and made determination of tungsten in quartz drift by very systematic examination of drift and croppings of quartz veins in the neighbourhood. By examining the exposures in the river beds, and by trenching, they had, by the end of September, located at least six veins of quartz bearing scheelite. It is now generally agreed that the trapper's scheelite samples were collected from these same deposits near Stillwater brook.

Geological Relationships.—The gold bearing slate-whin series in the region is here folded into a great anticline, with an east and west strike. On the north flank of this great fold about two miles west of Moose River settlement, and one hundred yards north of the crest of the anticline, in the vicinity of Stillwater brook, the slate-whin gold series is cut by several interbedded veins of white scheelite bearing quartz. This group of veins is indicated very accurately on Mr. Faribault's geological map of the region, but not until recently was it known that they carried any constituent of value. The largest of these veins reaches a maximum of 22″ as exposed in the bed of Stillwater brook, all the others being relatively smaller. In some cases the quartz vein is represented by a series of lenses from 2″ to 6″ across and 6″ to 15″ long. These disconnected lenticular veins are relatively richer in scheelite than the large, sharply walled, continuous veins where the scheelite occurs only along the selvage, at the most penetrating only an inch or two into the quartz mass. In contrast to this, the scheelite in the lenticular masses frequently makes up a third or a quarter of the whole quartz scheelite aggregate.

The slate when fresh is very cleavable, greyish in colour, and well impregnated with arsenopyrite in the vicinity of the veins. Where altered by the oxidation of the arsenopyrite it is rusty, and crumbles readily. The veins follow the rock formation—strike east and west, dip about 80° north. In some instances, as shown by the big vein in the bed of the brook (Plate 5), well defined stringers penetrate the country rock. Several instances of dislocation by northwest, southeast faulting, were observed. This region is entirely free from igneous rock of any kind, the nearest being bosses of granite, about six miles to the southeast.

These veins are approximately parallel, and are all contained in a belt of not more than one hundred yards wide. In some cases they are so close together—5 or 6 feet apart—as to make it possible to profitably mine two or more together. West of Stillwater brook I am informed that their extension is indicated by quartz drift. East of this brook for a quarter of a mile their constancy has been proved by trenching. The geological relationships are indicated in the accompanying sketch map which is based on the map by Mr. Faribault of the Geological Survey. (Plate 6.)

Mineralogical Association.

The quartz is white and glassy—not the type that carries good gold values—and, it has been said, constitutes the largest part of the well defined veins. In some instances the central parts are drusy, showy quartz crystals. In the smaller veins the quartz is relatively much less abundant, free from druses and rather milky.

Second in quantity in these veins comes the scheelite, which in the selvage of the larger veins penetrates the quartz irregularly, forming masses up to two or three cubic inches in volume. In the lenses of the smaller veins, the scheelite frequently seems to form the core of the mass, is slightly reddish brown in colour, cleaves fairly well, and sometimes suggests that these large cores of scheelite are really deformed crystals (simple pyramids). Sometimes the surfaces are curved from deformation, and blades and strings of quartz penetrate the scheelite.

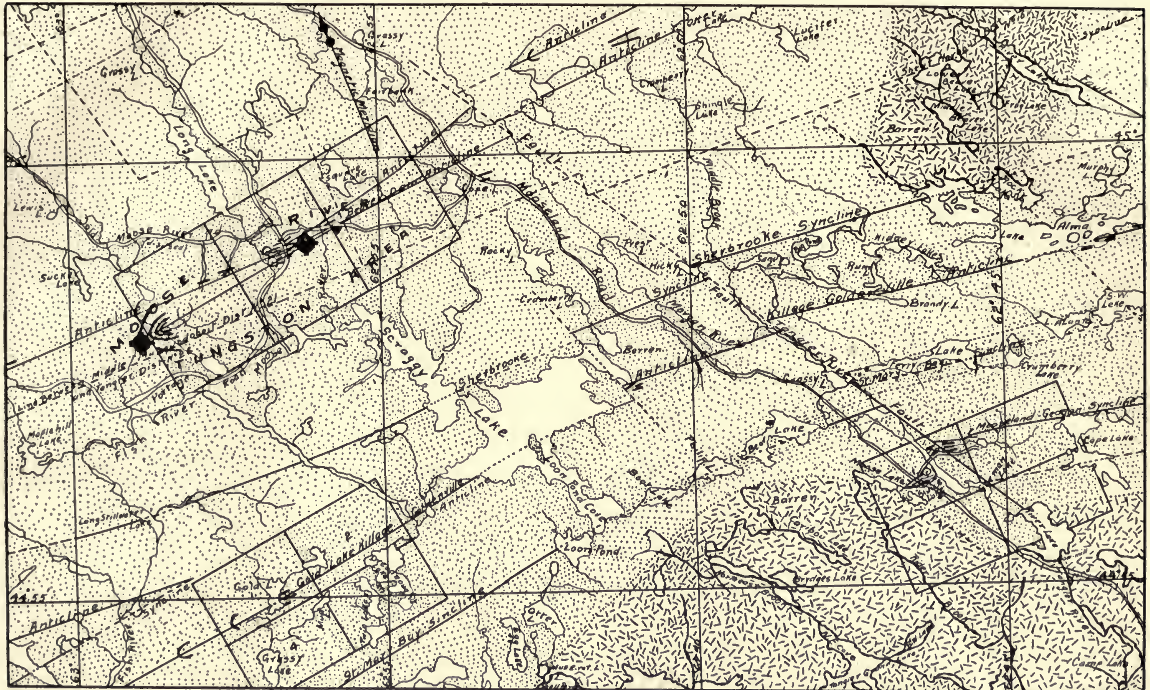
An analysis of the scheelite by Mr. D. E. Beynon gave the following result:—

WO_3	76·02%
MoO_3	1·34%
CaO	19·58%

Faulted Quartz Veins, Stillwater Brook.

Part of a Lense of Ore, Moose River Tungsten Mines. Black Slate, Dark Grey Arsenopyrite. Clear White Quartz. The dull white forming the upper part of the picture is Scheelite.

12804—p. 26 (a)



GEOLOGICAL SKETCH MAP MOOSE RIVER TUNGSTEN AREA

Granite. Gold Bearing Series. — Quartz Veins. Tungsten Prospects or Mines.

Third in importance among the minerals contained in these veins comes arsenopyrite. It is extremely abundant in the adjoining slate (single embedded crystals from ⅛″ to ¼″ long), making up at times 10% of the slate mass. In the vein proper it seems to form the selvage on some of the lenses, making up masses an inch or two thick, and twice as long. This arsenopyrite is quite fine grained and massive. So abundant is it that, in concentrating the scheelite by Wilfley tables or Frue vanners, I should expect that the arsenopyrite of the slate and vein together would make at least half the percentage of the scheelite. It would probably be necessary in any method of concentration to provide for the removal of the arsenopyrite by means of an electro-magnet. On plate No. 5 a cross-section through one of the lenses is shown, and the association of the three chief minerals—quartz, scheelite, and arsenopyrite—is well illustrated. The clear white mineral is quartz, the rough white, at times somewhat buff, is scheelite. In the scheelite there are many veinlets of quartz: the latest of the minerals to be deposited.

These three minerals constitute practically the whole of the vein matter. Slender, black, tourmaline needles are sometimes observed penetrating the quartz.

No pyrite, pyrrhotite, or other sulphide—except the arsenopyrite—has been observed. This is very remarkable, since these minerals are very abundant in the gold mines two miles to the east. No native gold has been seen, and according to assays made by Mr. McCallum, no economic amount of gold or silver has been found in the arsenopyrite. Equally remarkable is the absence of wolframite and hübnerite. Some yellowish stains on fractures in the scheelite suggest slight alteration into tungstite.

Since the discovery of these deposits, scheelite has been found in the workings of the Moose River mines—two miles to the east—and I am informed that a mass weighing several pounds was picked up on the dump of the Tuquois gold mine, about one and three-quarter miles east of Stillwater brook. This seems to indicate the possible extension of the scheelite zone east and west for a distance of two miles. At the time of writing we have very little information to assist in indicating the limits of the scheelite area.

The Ore.—Incidental to the prospecting and the work on the shaft started on one of the veins, a small quantity of scheelite ore—possibly two tons in all at the end of September—had been produced.

Mr. McCallum[1] informs us that an assay of a sample, representing approximately the whole, resulted as follows:—

WO_3	44·10
CaO	12·70
SiO_2	29·29
Arsenic	3·43
Sulphur	1·46
Oxides of Fe and Al	7·70

An analysis by McCallum of the pure scheelite gave the following result:—

WO_3	79·84%
CaO	20·11%

The specific gravity was found to be 6·10.

By December some of the exploration pits on the scheelite claims had reached a depth of twenty-five feet. (Plate 7.)

It is of interest to learn that concentrates collected at the Cariboo mines a few miles north of Moose river were found on chemical examination to contain 0·22% of tungstic acid. A sample collected in June, 1908, at the Moose River mill contains 0·52% tungstic acid.

Molega Mines.

These gold quartz mines, which are situated in the northern part of Queens county, were operated on a large scale for several years, but have been long closed, and most of the machinery has either been removed or rusted, hence is now valueless. Several large companies operated here nearly twenty years ago, and even yet there are about twenty families occupying the cottages built for the miners. The gold was mostly free milling; concentration and cyaniding were not practised. From the Ballou, Minneapolis, and Molega mines, concentrates were collected for assays. In the case of the first two the material was obtained from the flumes through which the tailings from the stamp mills flowed away. At the Molega mines a small concentrator had been established to work over the tailings, but it was only an experiment. From these old concentrates I secured a sample. There were other large mines which I did not visit.

The chemical analysis of these concentrates failed to show even a trace of tungsten. This is surprising, when we remember that, in at least one of these mines, scheelite had been observed when the mines were in operation.

[1] McCallum, A. L., Canadian Mining Journal, 1908, p. 456

Moose River, Tungsten Mines, Initial Stage, September, 1908.

Reynolds Bros., the operators of Moose River Tungsten Mines, September, 1908.

The gold quartz is in most cases highly mineralized, and very prominent among these heavy minerals is arsenopyrite, so that to-day the concentrates might possess an additional value for the arsenic content. The geological formations here are of the common Nova Scotian gold bearing type—alternating bands of slate, and slaty quartzite locally called whin—and in this series occur bands of quartz, looking like veins as they appear on the surface. I am informed that they are frequently rather of the nature of great bedded veins now folded with the containing rock into great anticlines.

In the Ballou mines many years ago Mr. W. H. Prest[1] observed, in some of the smaller cross stringers, the occurrence of scheelite. In 1894, Dr. Hoffmann—then chemist to the Geological Survey of Canada—describes the mineral as follows[2]:—

'A light smoke grey, sub-translucent, massive mineral with a vitreous lustre . . . . associated with a little arsenopyrite and pyrite in a quartz lead intersecting the main auriferous vein.'

Specimens of this mineral analysed by Mr. R. A. A. Johnston[3] give the following result:—

WO_3	79·01%
CaO	19·80%
CO_2	·71%
Insoluble	·11%
Total	99·63%

The mineral thus appears to be remarkably pure. Its specific gravity was found to be 6·002.

The scheelite does not seem to have been prominent, nor has it been reported from any of the other mines of this camp. At the time of my visit I examined several of the dumps, but without observing any trace of tungsten bearing minerals. As these mines are not being worked at present, the best evidence available is that to be derived from the chemical examination of the concentrates collected. Unfortunately no data are to hand as to the proportions of concentrates to tailings. At several of these mines great quantities of tailings could be concentrated at a very low cost.

[1] Report of the Geological Survey of Canada, Vol. IX, 1896, p. 93 A.

[2] Hoffmann, G. C., Report of the Geological Survey of Canada, Vol. VII, 1894, p. 14 R.

[3] Report of the Geological Survey of Canada, Vol. VIII, 1895, p. 9 R.

New Ross.

For some years past there have been rumours of the discovery of tin ore in the vicinity of Lake Ramsay in Lunenburg county, N.S. Two years ago, while sinking a pit on decomposed pegmatite, Messrs. Reeves and Keddy came across a little cassiterite as part of the rock mass.[1] The specimens were examined and determined by the mineralogists of the Geological Survey; also by Mr. Piers of the Provincial Museum of Halifax, so that there is no longer any doubt as to the existence of tin ore in Nova Scotia.

This pit proved to be a regular storehouse for rare minerals, and several previously not known to occur in Canada were found. Mr. R. A. A. Johnston has determined most of these minerals. The result of his work is indicated by the following paragraph:—

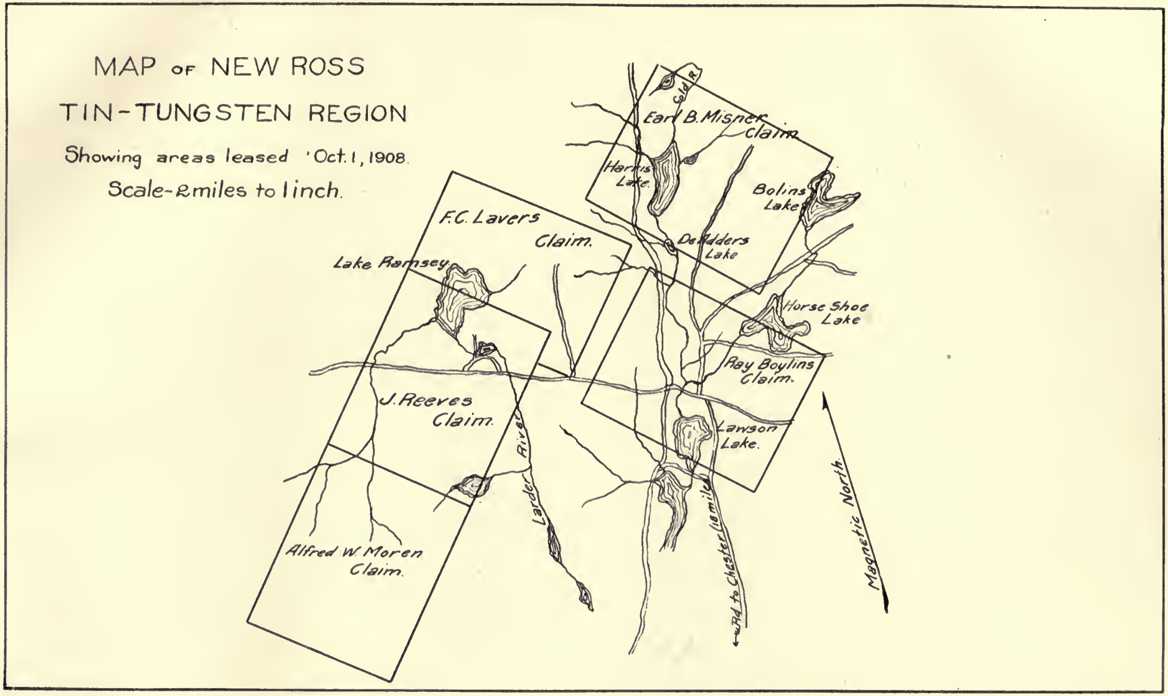
'From the results of Mr. Johnston's determination up to date, the following minerals have been found to occur in the granites at New Ross: cassiterite, menazite, one of the columbite minerals, durangite, amblygonite, a lithium mica probably lepidolite, wolframite, scheelite, hübnerite, molybdenite, zinc blende, beryl, apatite, tourmaline, fluorite, pyrolusite, manganite, limonite, hematite, magnetite, siderite, bismuthinite, argentiferous galena, copper, iron and arsenical pyrites, kaolin and fire-clay, crystals of black smoky quartz, large crystals of white, smoky quartz, some of which measured twenty-seven inches long by ten inches thick.'

The discovery of tungsten minerals in the specimens from New Ross, N.S., led the writer to visit that locality. The prospects were not being operated at the time, and only a few of the commonest minerals were observed.

The common rock of the region is biotite granite: intersected by veins of quartz, also by pegmatite masses, and in some places is more or less cavernous, and rich in purple fluor-spar. The region around Lake Ramsay seems to have been subjected to considerable fracturing of the rock mass, and into these fissures the pegmatite, quartz, and fluorite have made their way. The geological conditions are, therefore, on the whole, very favourable for the occurrence of ores of tin and tungsten; but very little was to be seen of ores of these metals at the time of my visit.

This region lies to the southwest of Halifax, and is best reached from Chester Basin station, which lies about eighteen miles south of New Ross. Good climate, adequate supply of timber, and cheap

[1] Summary Report of the Geological Survey, 1907, p. 81-82.


MAP OF NEW ROSS
TIN-TUNGSTEN REGION
Showing areas leased 'Oct. 1, 1908.
Scale-2 miles to 1 inch.
F.C. Lavers Claim.
Lake Ramsey
J. Reeves Claim.
Alfred W. Moren Claim.
Larder River
Earl B. Misner claim
Harris Lake.
De Adders Lake
Bolins Lake
Horse Shoe Lake
Ray Boylins Claim.
Lawson Lake.
Rd to Chester (12 miles)
Magnetic North.

labour, are all favourable to the commercial development of the region; if it should be found—either on the prospects now held, or on others which may be taken up later—that tin ores and tungsten minerals are present in such richness as attracts attention in other parts of the world.

The accompanying sketch map indicates the areas taken up for tungsten, and tin, up to the first of October, 1908. The claims of Reeves, Lavers, and Boylin, are those which have produced the tungsten minerals. In addition to the minerals listed by Mr. Johnston, the writer has observed tungstic ochre—impure tungstite—as a constituent of certain small quartz veins carrying cassiterite, to the north of the Reeves claim. (Plate 8.)

QUEBEC.

Beauce County.

In the early eighties, numerous quartz veins were discovered in the townships of Risborough and Marlow, in Beauce county, Quebec. For some years a little development was carried on for argentiferous galena. In addition to the galena these veins carried zinc blende, copper pyrites, pyrrhotite, and a little gold. The country rock here is Cambrian slate and indurated sandstone, the former much crumpled. The veins are said to vary in size from 3″ to 18″. They strike about N. 75° E. and dip at from 70-80° to the south.

In 1890, Mr. W. F. Ferrier—then petrographer to the Geological Survey of Canada—was examining some specimens collected from these veins in 1879, when they were first operated for silver, and made the interesting discovery of the occurrence, along with these ores, of scheelite and meymacite, or hydrated tungstic oxide.

Dr. Selwyn,[1] then Director of the Geological Survey of Canada, gives the following account of Mr. Ferrier's work:—

"In the spring, while examining the rocks collected by Mr. Webster in 1879, Mr. Ferrier had recognized in a specimen from lot 1, range VII of Marlow, a small fragment of scheelite or tungstate of lime. He, therefore, also visited this locality and succeeded in finding it in some quantity in quartz veins, cutting Cambrian slates, and accompanied by its decomposition product tungstite or tungstic acid. Galena, copper and iron pyrites, blende and other minerals were also found in the veins.

[1] Selwyn, A. R. C., Report of the Geological Survey of Canada, Vol. V, p. 74 AA, 1893.

'On the 10th of August he returned to Ottawa and was occupied chiefly in microscopical work until the 30th of September, when he again visited the locality, remaining there until the 8th of October. The tungsten minerals were found in nearly all the veins examined, but in some only in small quantity.

'The best locality, apparently, is that from which the original specimen came, where they are rather abundant in the vein. Though little more than a foot wide at its outcrop, further development might reveal the tungsten ore in quantities sufficient to justify mining on this vein.'

This was the second indication of the occurrence of tungsten minerals in Canada, the only previous record being the discovery of wolframite in boulders, on Lake Couchiching, by the late Professor E. J. Chapman.

The scheelite was found to possess a specific gravity of 6·059, and on analysis by Mr. R. A. A. Johnston gave the following result[1]:—

Tungstic acid	79·90
Lime	19·37
Ferric oxide	0·70
Silica	0·29
Total	100·26

The scheelite occurs largely in crystals yellowish in colour. Occasionally, the crystal surfaces, and the cracks in the vein matter are coated with a thin yellowish deposit of tungstite. Some of this latter material was analysed by Mr. R. A. A. Johnston, and although a complete analysis had not been published, he reached the conclusion that, the mineral was meymacite or hydrated tungstic acid. At the time, the name tungstite was reserved for the anhydrous tungstic acid, and all specimens found on analysis to be hydrated tungstic acids, were referred to as meymacite. More recently[2] it has been suggested that, since anhydrous tungstic acid is not known to occur as a mineral, the name tungstite should be applied to the hydrated minerals. The Marlow mineral is, therefore, impure tungstite.

At the time of my visit to this region—June, 1908—little was to be seen as to the mode of occurrence of the tungsten ores in Marlow. Many old trenches and rock dumps were discovered, but the rank

[1] Johnston, R. A. A., Report of the Geological Survey of Canada, Vol. VII, p. 14 R.

[2] Walker, T. L., American Journal of Science, Vol. XXV. 1908.

vegetation of the past few years concealed much that must have been plain when the prospecting was being done. This region never passed the prospecting stage. The relatively higher prices now available for tungsten ores might make it profitable to open up some of the best of the veins. On the other hand, the price of silver has fallen so much in twenty-five years, as to go a long way to balance the increased revenue which would be derived to-day from the tungsten by-product.

This region is best reached at present from St. George de Beauce, on the Quebec Central railway. From this station there is a good road to St. Rufine, about thirty miles from St. George de Beauce. The silver-tungsten prospects lie three miles to the east in the forest, and can not be reached during the summer except on foot. Winter roads are available quite up to the silver-tungsten region.

It will be remembered that this tungsten region is only a few miles south of the Chaudière alluvial gold region. It is another example of the close proximity of gold and tungsten ores. A good geological map of this region, together with an account of the geology and mineral resources, has beeen prepared by Dr. R. W. Ells.[1]

Ontario.

Victoria Mines.

In 1904, at the Victoria mines of the Mond Nickel Company, Mr. T. M. Paris, assayer to the Company, presented to me a few small fragments which he had determined as scheelite. The specimen had been picked up on the rock dump, so that nothing is known as to the mode of occurrence. As far as I am aware, this is the only place in the Sudbury district where any tungsten mineral has been found. The general studies of the genesis of the Sudbury ore deposits do not lead us to anticipate the occurrence of such minerals as scheelite.

The mineral is quite white, and of very vitreous lustre, with a specific gravity of 6·167. On the fragments in my possession no crystal surfaces are visible; but from the continuous cleavage surfaces it is probable that they are crystal fragments.

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[1] Report of the Geological Survey of Canada, Vol. II, 1886, Section J.

A chemical analysis showed that the mineral was exceedingly pure (Analysis by T. L. Walker):—

WO_3	79·36%
CaO	19·96%
Total	99·32%[1]

During the past summer the Sudbury district was visited, and inquiry was made at the various mines, but no additional information as to new discoveries was elicited.

Lake Couchiching.

Besides the occurrence of scheelite in situ at Victoria Mines, we have indications that there are somewhere in northern Ontario, hidden in the forests, deposits of wolframite. This statement is based on the discovery, by the late Professor E. J. Chapman of the University of Toronto, a little more than fifty years ago, of a boulder containing crystallized wolframite on the west side of Chief island, Lake Couchiching, Ontario. We do not know, up to the present, the mother rock from which this boulder was derived; but a study of the direction of the glacial striation and the associated boulders to be found around Chief island might give valuable suggestions as to the location of this still undiscovered tungsten deposit.

The mineral was described crystallographically and physically by Professor Chapman,[2] and later it was examined chemically by Dr. T. Sterry Hunt.[3] From their published accounts the following extracts are taken:—

'The accompanying figure represents a crystallized specimen of wolfram—(FeO, MnO) WO_3—discovered by the writer in a boulder on the west shore of Chief island, Lake Couchiching, Canada west. The mass of the boulder consisted of gneiss, traversed by a vein of coarse granite, with red orthoclase, in which the specimen was found. Magnetic oxide of iron, in small granular pieces, was also present in the boulder.

'Briethaupt subdivides wolfram into two species: mangano-wolframit and ferro-wolframit. The first has a reddish-brown streak, with G–6·98–7·17, and the formula shows: 2(FeO,WO_3) 3(MnO,

1 Walker, T. L., Transactions of the Canadian Mining Institute, Vol. XI, March, 1908. "The Occurrence of Tungsten Ores in Canada."

2 Chapman, E. J., Canadian Journal, 2nd Series, Vol. I, p. 308. "Wolfram."

3 Hunt, T. Sterry, F.R.S., Canadian Journal, Vol. V, p. 303, "An Analysis of Canadian Wolfram."

WO_3). The second exhibits a blackish-brown streak, with stronger metallic lustre, and G–7·3–7·5. Its formula shows : $4(FeO,WO_3)$ $MnO.WO_3$. Our speciment is of the first kind.

'Our specimen exhibits the following blowpipe reactions: *Per se,* it fuses easily, and without intumescence or bubbling, into a dull iron-grey globule, the surface of which is scoriaceous rather than crystalline. The globule is not attractable by the magnet.

'It dissolves readily in borax, producing before the oxidizing flame a dark amethystine glass. Quickly cooled, after exposure to the reducing flame, the glass is yellow. With a sufficient quantity of the assay, the surface of the bead may be enamelled (or rendered mild-white) by the flaming process.

'It dissolves also readily in salt of phosphorus. A very small quantity renders the bead opaque, but no effect is produced by flaming.

'With carbonate of soda, effervescence takes place, but a very small portion of the assay dissolves, so that no striking manganese reaction is produced. If, however, a minute quantity of borax be added, the greenish-blue enamel is at once obtained. On cooling, the fused mass shoots into crystals.' (Chapman.)

'A chemical examination of a portion of this specimen has yielded the following results:—

'The specific gravity of the mineral was found to be 6·938. Two grammes of it were finely levigated, and decomposed by prolonged digestion with aqua regia; after which, the solution was evaporated to dryness, and the residue being heated with water and hydrochloric acid, the insoluble yellow portion was separated, washed with spirit of wine, and finally digested with ammonia. The ammoniacal solution left by evaporation and ignition—1·469 grm. of tungstic acid. The residue, insoluble in ammonia, weighed 0·048 grm. It was heated in a platinum crucible with fluorid of potassium, and an excess of sulphuric acid to drive off any silica which might be present, and then fused with the resulting bisulphate of potash. The fused mass was transparent, but on adding water white flakes separated—0·039 grm., and the solution contained 0·005 of oxide of iron and manganese. The loss, equal to 0·004 grm., was supposed to be silica, and the white matter, which was grey after ignition, and insoluble in a solution of potash, was regarded as niobic acid.

'The iron was separated as peroxide from the hydrochloric solution by carbonate of baryta, and equalled 0·181 of protoxide. The manganese, being lost by an accident, was calculated from the difference. We have thus, for 100 parts of this specimen of wolfram, the following composition:—

Tungstic acid	73·45
Niobic acid (?)	1·95
Protoxide of iron	9·05
Protoxide of manganese	15·35
Silica	·20
Total	100·00

'These results lead to the general formula $2(FeO,WO_3)\ 3(MnO,WO_3)$; the specimen belonging to the mangano-wolframit of Briethaupt, as stated in the mineralogical description referred to above.' (Hunt.)

From the above analysis, in which the proportion of oxide of manganese is much higher than that of ferrous oxide, we would be inclined, according to the present custom, to speak of this Lake Couchiching mineral as hübnerite rather than wolframite.

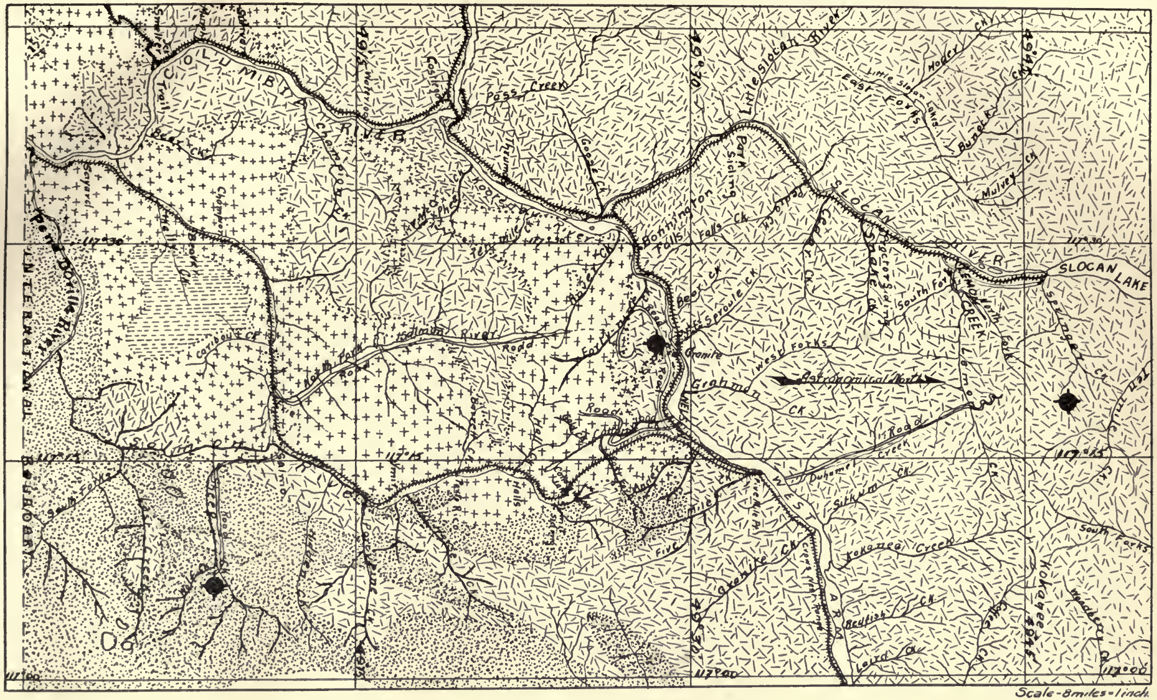
Up to the present time no prospecting has been done with a view to the discovery of the original deposit. The glacial striation is such as to indicate that, the ice came from the north-northeast, and it is in this direction that one would expect the parent deposit to occur. Such a course from Couchiching would lead past Mattawa and towards Grand Lake Victoria, near the headwaters of the Ottawa river, in the Province of Quebec. It is well to remember, however, that the flow of the glacial sheet was not continuously in the direction indicated by the striation, and that the direction mentioned is only approximate and must not be regarded as an infallible guide leading to the main ore body.

British Columbia.

Kootenay District.

General Geological Associations.

The tungsten ores of the Kootenay district occur in association with gold in quartz veins, which occur either in granite, or related igneous intrusive rocks, or in old Palæozoic rock, much altered, and probably underlaid by acid igneous rocks. In a few instances the silver contents of the ores have been more valuable than the gold;



GEOLOGICAL SKETCH MAP WEST KOOTENAY TUNGSTEN AREA

Granite. Rossland Volcanic. Beaver Mts. Volcanic. Old Palaeozoic. Tungsten Prospects.

but usually the tungsten is confined to well defined gold quartz deposits. Up to the present time the tungsten has not been separated, or turned to any commercial purpose, though it is hoped that in some instances the saving of tungsten ores as by-products may be profitable, and may cause some properties—too low in gold to be worked as regular gold mines—to be worked as gold-tungsten mines, or even as tungsten mines.

The accompanying sketch map shows the geology and topography of the district. It is an outline of Professor Brock's map published by the Geological Survey of Canada. (Plate 9.)

Kootenay Belle Mine.

This mine is situated near Sheep creek, about ten miles southeast of Salmo. The quartz veins are contained in more or less slaty quartzite, grey or buff in colour. On this property there are several quartz veins, but in only two of them has tungsten been reported. In the smaller of these veins the quantity of tungsten ore in some parts is promising. This vein varies from 6″ to 18″ in width, and, when worked some years ago, produced ore which was at times fairly rich in tungsten minerals.

The chief mineral is the heavy yellow tungstite, which occurs in the form of kidneys within the vein. In addition to this mineral black wolframite and light brown or buff scheelite were also observed, though in much smaller proportions. The ore of this mine is very free from sulphides in the higher workings, and the presence of much tungstite and little scheelite and wolframite is taken to mean the alteration of these latter into the former; just as pyrite and galena give rise to characteristic secondary minerals of iron and lead in the upper workings of so many mines in the Kootenay district. If this reasoning is correct, we may expect the tungstite to give place to wolframite and scheelite when this vein is followed to greater depth.

Mr. John Bell of Salmo, who operated the Kootenay Belle when the best tungsten ores were obtained, informs me that on one occasion fully half a car of high grade tungstite ore was shipped to the smelter. In this ore free gold occurs in the tungstite as well as in the quartz. Only gold values were obtained, the tungsten apparently going to waste as its value was not known at the time.

The following analyses are from material obtained from Kootenay Belle mine. (*a*) Picked sample of tungstite-scheelite ore, (*b*) wolframite, (*c*) concentrate from small tungstite bearing vein, (*d*) concentrates from ore from other veins on the same property (analyses (*a*) and (*b*) by T. L. Walker):—

	(*a*)	(*b*)	(*c*)	(*d*)
WO_3	86·20	74·90	0·66	0·55
FeO	1·20	17·75		
Fe_2O_3	4·14	——		
MnO	——	2·75		
CaO	0·54	1·52		
MgO	——	2·66		
SO_2	——	1·02		
H_2O	7·72	——		

At the confluence of Sheep and Wolf creeks, near the Kootenay Belle, lies the Queen mine. This mine is now operating about 200 feet beneath the level of the tram line. At present the ore is very rich in sulphides, and little altered. I have been told that in the earlier history of the Queen, when much oxidized ore from near the surface was being mined and milled, the presence of tungstite was very plainly seen on the Wilfley tables, where, owing to its high density, it formed a well marked golden yellow band. Samples of concentrates collected from the Wilfley tables in July, 1908, at the mill where this ore was being treated were found to be free from tungsten.

The Porto Rico mine, a few miles north of Ymir, on the Great Northern railway, when operated some years ago was said to have shown considerable quantities of tungstite on the concentrating tables. Unfortunately as the mine is not now operating I have not been able to confirm this report.

Granite-Poorman Mine.

The Granite-Poorman claims have been worked for a number of years for gold, and are now being operated as one mine. They are situated about five miles west of Nelson, on the south side of the Kootenay river. The mines, which are a short distance to the south, deliver the ore to a mill located on the bank of the river. The ore is largely free milling. When treating ores from certain parts of the mine, a white band of heavy scheelite is occasionally seen on the Wilfley tables. This has been known for many years, and was first communicated to me by Mr. S. S. Fowler, M.E., of Nelson, who was at one time associated with those operating the Granite.

The quartz veins are said to occur in granite, or related igneous rock. Some of the ore which I obtained at the mill showed scheelite disseminated in small grains and stringers through the quartz. The scheelite is light grey in colour, and very fresh. The associated sulphides are chiefly pyrite, pyrrhotite, and a little copper pyrites, the whole making up only a relatively small proportion of concentrates. From information given me by Mr. Gough and his associates there seems to be occasionally on the tables enough scheelite to be worth separating and selling as tungsten ore.

A sample of concentrates collected from the Granite-Poorman mill in August, 1908—when Poorman ore was being milled—was found on analysis to contain 0·46 per cent of tungstic acid. Assays of 0·26 and 0·40 per cent tungstic acid were obtained from Granite concentrates.

From information obtained from prospectors and others it seems probable that some of the claims on Cottonwood and Fivemile creeks, near Nelson, carry scheelite or tungstite, but unfortunately I was not able to visit these to make personal observations.

Springer Creek—Meteor Mine.

The Meteor mine is located near Springer creek about nine miles east of Slocan. It has been worked as a silver mine with subordinate quantities of gold. The country rock is a very coarse porphyritic biotite granite in which occur quartz veins carrying silver, gold, and scheelite. In 1904, after the nature of the heavy mineral had been determined, it is said that 500 pounds of nearly pure scheelite was saved. The scheelite was found in lenses from 1 to 3 feet in length, and up to 3″ in thickness. Specimens of the scheelite shown me were coarsely crystalline, buff to pink in colour, and, apart from the high density, resembled, in many respects, calcite, or coarse marble. At the time of my visit—August, 1908—the mine being closed down I had no opportunity of examining the underground workings, or the scheelite in place. So far as I am aware no analyses of this ore have been made.

St. Mary Creek—Fort Steele Mining Division.

Mr. E. W. Widdowson, assayer of Nelson, B.C., has in his possession a very fine specimen of coarsely crystalline wolframite which was brought in by a prospector from a claim on the upper waters of St. Mary creek, west of Marysville. The exact location of this claim—if indeed it had been staked—could not be ascertained, and as the prospector in question is no longer in the country it may be some time before further information is available.

Cariboo District, Barkerville.

This region became famous as a placer gold field in 1860, from which date it has continued to be operated, and has already produced about $50,000,000 worth of gold. The highest annual return was in 1863, when about $4,000,000 was obtained. In recent years the amount has not exceeded half a million dollars. Through more or less metamorphosed slate or schist of Lower Palæozoic age—the so-called Cariboo series—auriferous quartz stringers, sometimes fairly well defined veins, extend, and the gold mined in the creeks is supposed to be derived from natural concentration of the ruins of these old slates. In the vicinity of Barkerville the slates strike approximately northwest and dip to the northeast, being overladen by the more massive Upper Palæozoic Bear Lake beds.[1]

These quartz stringers usually follow the strike of the slate. Several attempts to mine and mill the auriferous quartz have been made, but up to the present all such attempts have ended in failure; due possibly to the high cost of operating in a region distant nearly three hundred miles from the most accessible railway communication.[2]

The quartz is well mineralized with pyrite, and, to a less degree, galena. The adjoining slates are often impregnated with pyrite in the form of cubes. A general view of the various heavy minerals is readily obtained by examining the heavy gravel and black sands which occur in the sluices of the hydraulic mines now being operated. To the south of the gold region in the mines at Bullion the platinum minerals are present in subordinate proportions.

In 1904, Mr. W. C. Fry—while mining a placer claim on Hardscrabble creek, a tributary of Willow river, about ten miles northwest of Barkerville—had great difficulty owing to the appearance in the sluices of a heavy white mineral which some had called barite or

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1 See A. Bowman, "Mining District of Cariboo, B.C.," Geological Survey, Annual Report 1887.

2 Barkerville is about 280 miles from Ashcroft; all freight carried from the railway to Barkerville costs $120 a ton.

heavy spar. It was so heavy that a current sufficient to wash it away carried the gold off also. Mr. Austin J. R. Atkin[1] was the first to recognize this mineral as scheelite.[2] Later, in drifting in connexion with placer mining, a shoulder of the bed-rock was cut and the mineral was discovered in place. Knowing the value of the scheelite, the ground was staked as a mineral claim (carrying rights to operate in the hard bed-rock). At the time of my visit—August, 1908—the mine was idle, but from those interested I learned that a shaft had been sunk about 30 feet in the rock, and, drifting along the scheelite zone, had been carried about 50 or 60 feet.

The deposit as revealed by the underground working, appears to constitute a zone from 3 to 8 feet wide, following the northwest-southeast strike of the country rock, which is here much metamorphosed to a mica schist. Mr. Angus Macpherson who had charge of the underground work informs me that masses of practically pure scheelite were found, at times 50 pounds in weight.

The scheelite is coarsely crystalline, pink to brown, where fresh, but buff to cream in colour where weathered on the surface as found in the gravels. Along with the scheelite I observed, on examining the ore pile, small quantities of canary yellow tungstite, and from some of the operators I learned that wolframite had been reported. Besides these tungsten ores and the two main gangue minerals—quartz and ferruginous calcite—pyrite and galena occur in small proportions.

It would be very difficult to form a correct estimate of the proportion of scheelite contained in the zone of tungsten bearing rock. Mr. Macpherson as a result of assays made considers that the whole belt carries about eight per cent of tungstic acid. The two or three tons of ore which I saw were probably much richer, but as far as I am aware, no satisfactory assay sample has been taken with a view to determining the richness of the belt as a whole, and since no ore has been milled or concentrated, such estimates may be very far from assays based on systematic sampling or concentrating.

The results of an analysis of a sample of practically pure scheelite from Hardscrabble are as follows:—

WO_3	73·68%
MoO_3	0·66%
CaO	20·00%

[1] Report of the Minister of Mines for British Columbia, 1904.
[2] Geological Magazine 1905—pp. 116-117.

This mine is easily accessible, being reached by a good bridle trail and winter road. The mine is but little above the level of Willow river. Hardscrabble creek flows within a few hundred feet of the shaft house, and would probably supply water sufficient for hoisting and milling. The high value of scheelite concentrate should make it possible to ship to Ashcroft even with the present long haul and high freight. (Plate 10.)

In addition to the scheelite deposits described above, there are numerous placer mines in the region where this mineral occurs; and this is very noticeable in cleaning up after washing the ground. I have observed scheelite at Nugget gulch on Antler creek, where it occurs in grains and pebbles up to 1″ in diameter, and at the Lowhee and China Creek claims. In some of these claims the scheelite is accompanied by a little barite or heavy spar, which is lighter in colour and in weight.

Analyses of scheelite from Nugget gulch:—

WO_3	76·79%
CaO	18·90%
MoO	1·06%

It is, therefore, reasonable to conclude that, the presence of scheelite in these placer mines indicates the proximity of scheelite bearing ledges or zones similar to that occurring at Hardscrabble, and consequently the possibility of reward for those who prospect in the Cariboo district for tungsten ores.

It is interesting to note that the tungsten ores in the Cariboo district are not known to have any immediate connexion with igneous granite masses, as is generally the case with the tungsten ores in the Kootenay district. No igneous intrusions occur within a radius of many miles of any of the tungsten occurrences recorded in the Cariboo.

Atlin District.

In 1904, on visiting the provincial museum in Victoria, Mr. Carmichael presented me with a small sample of a black mineral forming blades in quartz. It was said to be from Atlin district. Recently it has been determined to be hübnerite. No information is available as to the mode of occurrence, quantity available or exact locality.

Hardscrabble Tungsten Mine, August, 1908.

Means of Transportation to and from Hardscrabble Mine.

Yukon Territory.

It has been already stated that, in many of the regions where placers are worked for gold, subordinate quantities of tungsten minerals are also found among the heavy sands which remain behind with the native gold.

A few years ago Mr. Joseph Keele of the Geological Survey brought from the Yukon several samples of the heavy minerals which collect in the heavy sands, along with the gold. These sands on being examined by Mr. R. A. A. Johnston showed the presence of scheelite and cassiterite or tinstone. The following extract is from Mr. Johnston's report[1]:—

'Some very noteworthy observations have been made, in the course of examining material obtained by Mr. Keele, from the riffles of sluice-boxes, in the course of placer gold-mining on Highet creek, a remote tributary of the Stewart, and at Dublin gulch, on Haggart creek, a tributary of the McQuesten, which also flows into the Stewart, Yukon Territory. The material from the first mentioned locality was found to contain small irregular-shaped fragments of native bismuth with, in some instances, a little attached native gold, and small water-worn nodules of an association of scheelite (calcium tungstate) with a little quartz; whilst that from Dublin gulch consisted very largely of more or less rounded grains of scheelite with a few intermixed particles of quartz and of hematite and a little native gold. Again, in a sample of gold-washings from the Lippy claim, Eldorado creek, in the Yukon district, which was sent for examination, aggregations of native gold with embedded particles of native lead were found.'

Up to the present no analysis of this scheelite has been made, but from its general appearance it seems to be of first quality.

The writer did not visit the Yukon, as the distance and time required did not seem to justify the effort. The quantity found with the heavy sands is too small to be of serious commercial value, but such occurrences indicate the possibility of discovering valuable deposits in the region, and the advisability of prospectors and others remembering the tungsten minerals in their explorations.

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[1] Johnston, R. A. A., Report of the Geological Survey of Canada, 1904, (New Series), Vol. XVI, p. 340 A.

Chemical Analysis of Concentrates.

Remembering the high specific gravity of all the minerals of tungsten, one would expect to find these minerals concentrated in the products from Frue vanners, Wilfley tables, and other concentrating appliances used especially in treating ores of gold and silver.

Acting under this impression, many samples of such concentrates were collected from various parts of Canada, with a view to examining them in the chemical laboratory for tungsten. Some of the samples were collected personally, while others were obtained from mine operators. A very valuable series of concentrates and pulp samples—mostly from the Kootenay district—was furnished by Mr. E. W. Widdowson, assayer and chemist of Nelson, B.C. The cooperation of those engaged in the mining industry was hearty, and to their cordial assistance the value of this work is largely due.

The qualitative testing of these samples was carried out in the laboratories of the Department of Mineralogy, University of Toronto, by Mr. B. Neilly, B.A.Sc. The quantitative work throughout this report—unless specially credited to someone else—was carried out by Mr. D. E. Beynon, B.A.Sc., in the same laboratories.

The general positive result of the qualitative work is the discovery of appreciable quantities of tungstic acid in concentrates from the following mines:—

(1) Cariboo mines, Halifax county, N.S.
(2) Moose River mines, Halifax county, N.S.
(3) Granite mine, near Nelson, B.C.
(4) Poorman mine, near Nelson, B.C.
(5) Kootenay Belle mine, Salmo, B. C.
(6) Ymir mine, Ymir, B.C.

The presence of ores of tungsten at the Kootenay Belle mine had been reported by the writer a few months earlier.[1] From Mr. S. S. Fowler, M.E., of Nelson, B.C., it was learned that scheelite had been observed at the Granite mine years before. The Poorman is adjacent to the Granite, and on visiting the Granite mill it was learned that the same type of ore occurred in the Poorman. In the other three mines tungsten had not been detected. Since the concentrate samples were collected at the Moose River mill, scheelite has been found in the vicinity, and even in some of the eastern workings of the mine itself.

[1] Walker, T. L., Transactions of the Canadian Mining Institute, Vol. XI, 1908.

It may be observed that, the occurrence of tungsten in certain mines is quite local, and is sometimes shown by certain samples from a particular mine, while the other samples from the same mine are quite free from this metal. It seems remarkable that none of the samples from Molega mines, Queens county, N.S., contain tungsten, in view of the fact that Prest obtained specimens of the scheelite from the old Bain mine many years ago, when these mines were operating.

The results of this work as shown in the following tabular statement should encourage mine operators and assayers to examine concentrates from time to time for tungsten. The qualitative test is extremely simple, and consumes very little time.

Result of Examination of Concentrates from Gold and Silver Mills for Tungsten.

No.	Name of Mine.	Location.	Origin of Sample.	Date.	WO_3 %.
1	Middle River gold mine.	Cape Breton.......... ..	Collected by T. L. Walker.	June, 1908..	None.
2	Doliver Mountain gold mine.	Goldboro, N.S....	" ..	May, 1908..	"
3	Seal Harbour mine.	"	" ..	" 1908..	"
4	Boston Richardson mine.	"	" ..	" 1908..	"
5	Modstock mine.	Forest Hill, N.S	" ..	" 1908..	"
6	Mic-Mac Gold mine.	Lunenburg co., N.S.....	Forwarded by operators.	....	"
7	Regina mine..	Lake of the Woods..	" ..	....	"
8	Cariboo mine......	Nova Scotia	Collected by T. L. Walker.	June, 1908..	0·22
9	Stewart's mine..	Chester Basin, N.S.	" ..	" 1908..	None
10	Moose River mine ..	Moose River, N.S.......	" ..	" 1908..	0·52
11	Balu mine	Molega Mines, N.S......	" ..	Old concentrate.	None.
12	Minneapolis mine ..	Molega Mines, N.S......	" ..	" ..	"
13	Molega Mines Co...	Brookfield, N.S.........	" ..	" ..	"
14	Brookfield mines ...	"	" ..	" ..	"
15	King mine....	"	" ..	June, 1908..	"
16	Mikado mine.	Lake of the Woods......	Forwarded by operators.	Old concentrate.	"
17	Summit mine	Kootenay district........	From E. W. Widdowson, Esq.	....	"
18	Empress mine..	Bear lake, Kootenay district.	" ..	....	"
19	Nevada mine.	Granite Siding, Kootenay district.	" ..	. .. .	"
20	Granite mine.	" " .	" ..	Oct. 1907...	0.26

Result of Examination of Concentrates for Tungsten—Con.

No.	Name of Mine.	Location.	Origin of Sample.	Date.	WO_3%.
21	Granite mine..	Granite Siding, Kootenay district.	From E. W. Widdowson, Esq.	May, 1907..	None.
22	"	" " ..	" ..	" 1907..	"
23	"	" " ..	" ..	Mar. 1907.	0·40
24	Eva mine	" " ..	" ..	....	None.
25	"	" " ..	" ..	....	"
26	Kootenay Belle mine	" " ..	" ..	Dec. 6, '07	0·44
27	Second Relief mine .	Erie, B.C., Kootenay district.	" ..	....	None.
28	Mother Lode mine..	Sheep creek, Kootenay district.	" ..	....	"
			" ..	....	"
29	Queen mine	" " ..	" ..	....	"
30	"	" " ..	" ..	....	"
31	"	" " ..	" ..	....	"
32	Nugget mine	" " ..	" ..	....	"
33	"	" " ..	" ..	....	"
34	"	" " ..	" ..	....	"
35	Silver Cup mine	Ferguson, B. C..	" ..	....	"
36	Emerald mine	Salmo, B.C.	" ..	....	"
37	Yankee Girl mine .	Bear creek, B.C....	" ..	Dec. 14, '03	"
38	Ymir mine	Ymir, B.C.....	From the operators.	" 26, '03	"
39	"	"			
40	"	"	" ..	Feb. 3, '03	"
41	"	"	" ..	" 5, '03	"
42	"	"	" ..	Jan. 20, '03	Trace.
43	"	"	" ..	Dec. 10, '03	None.
44	"	"	" ..	Jan. 24, '03	"
45	"	"	" ..	" 5, '04	"
46	"	"	" ..	Feb. 6, '03	"
47	Poorman mine.....	Granite Siding, Kootenay district.	Collected by T. L. Walker.	Aug. 1, '08	0·46
48	Kootenay Belle mine (small vein).	Sheep creek, Kootenay district.	" ..	Aug., 1908..	0·66
49	Kootenay Belle mine (big vein).	" " ..	" ..	" 1908..	0·55
50	Queen mine (coarse concentrates).	" " ..	" ..	" 1908..	None.
51	Queen mine (middle concentrates).	" " ..	" ..	" 1908..	"
52	Queen mine (fine concentrates).	" " ..	" ..	" 1908..	"
53	McKinley-Darragh mine.	Cobalt, Ont.	" ..	July, 1908..	"
54	Cobalt Central mine	"	" ..	" 1908..	"
55	Coniagas (deister concentrates).	"	" ..	" 1908..	"
56	Buffalo mine (middle concentrates).	"	" ..	" 1908..	"
57	Buffalo mine (fine concentrates).	"	" ..	" 1908..	"
58	Buffalo mine (coarse concentrates).	"	" ..	" 1908..	"

GENERAL CONCLUSIONS.

The investigation of material for this report has rendered it possible to make a complete statement of the distribution of tungsten ores in Canada. Since beginning the work, information has been obtained from mining engineers, assayers, and others, regarding occurrences of these ores which were not known except in the immediate vicinity of the mines where the ores had been found. From the chemical examination of concentrates many new sources of tungsten have been revealed. In most instances the quantity of ore available is insignificant, in others the grade is very low. Such discoveries have their importance, however, since they indicate the probability of the discovery of richer or larger deposits in the vicinity. During the past summer, scheelite deposits of a very promising character were discovered in Halifax county, N.S. This discovery may in some measure be regarded as one of the indirect results of this investigation. Within very modest space in the preceding pages is brought together practically all the available information as to the occurrence and value of Canadian tungsten ores.

It is hoped that the general sections of this report dealing with the occurrence of tungsten ores in other countries, prices, production, uses and methods of concentration may be useful to those who have no previous special information, and desire a general introduction to the subject.

It cannot be claimed that there are in Canada any well developed and established tungsten ore mines. On the other hand there are numerous districts where these ores occur, and there are many claims well worth developing. Hitherto no tungsten production has been credited to Canada in our mineral statistics. It would seem very strange, if, from the known tungsten claims and tungsten regions, some regular mines should not result from exploration.

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APPENDIX.

Additional Occurrences of Ores of Tungsten.

Since the completion of the foregoing report, ores of tungsten have been reported from several new localities. Brief references to these are contained in the following paragraphs:—

I. *Halifax County, Nova Scotia.*—The discovery of scheelite near Moose River by McCallum, Reynolds, and Currie, was soon followed by the location of another deposit of scheelite in the same county. Mr. A. L. McCallum having distributed numerous pieces of scheelite with a view of encouraging prospectors and others to pay attention to this ore, was approached by some men who remembered having seen ore of this type many years ago when prospecting for gold near Waverley. On investigating, a scheelite bearing quartz vein was discovered about a mile north-northwest of the Waverley gold mine.

The country rock here is the quartz-slate gold bearing series so prominent in Nova Scotia. On the whole the occurrence is very much like that at Moose River—already described in considerable detail. The chief vein strikes nearly east and west (magnetic), dips to the north at about 80 degrees, and varies from 6″ to ½″ in thickness. The veins follow the dip and strike of the country rock, and are prone to occur in the slaty parts of the series. The vein has been stripped for about 200 feet, and shows scheelite for a distance of 110 feet. There are two prominent parallel quartz veins: one, 60 feet to the north, and the other 40 feet to the south. Several small prospect pits were made on these years ago, when the country was being explored for gold. In the vein matter thrown out of these pits scheelite is said to have been found. Only on the one main vein has any work been done since the discovery of the scheelite.

The scheelite is yellowish brown to reddish brown in colour. The vein has not been pinched into a series of lenses, as was the case in the Moose River deposits. There is possibly a tendency for the scheelite to be more abundant toward the foot-wall; but the exploration is too scanty to permit such a generalization. Apart from the scheelite and quartz the chief minerals are arsenopyrite and chlorite.

This new scheelite area seems to lie more or less in line with the strike of the rocks from Moose River, and it is not improbable that the intervening region may, when prospected, give encouraging results. The distance between the two scheelite regions is about forty miles. The new deposits may be easily reached, being not more than two miles from Windsor Junction.

II. *Another Discovery in New Ross, Lunenburg Co., N. S.*—Mr. E. R. Faribault of the Geological Survey Branch, has visited this area and describes it as follows:—

> 'E. Turner has also opened a vein in the granite, on the west side of the Wallaback stream, halfway between Camp and Harris lakes, carrying tin tungsten ores, in the form of cassiterite and scheelite, associated with copper pyrites and zinc blende. Several dikes of quartz porphyry, aplite and quartz have been located in this vicinity, some of which show molybdenite, chalcopyrite, etc. Several blocks of quartz carrying molybdenite in fair quantity have been observed three miles east of New Ross on the south side of the new Windsor road, on Harden Russell's farm and also on the southeast side of Whalen lake.'

III. *Hübnerite from Yale District, B.C.*—A small specimen of hübnerite from Cathedral Mountain, near the head of Ashnola river, Yale district, B.C., has been brought in by Mr. Charles Camsell, Geological Survey.[2]

IV. *Hübnerite, Atlin District, B. C.*—Several years ago a specimen of quartz bearing red brown needles and blades of hübnerite was presented to me by Mr. Herbert Carmichael of the Department of Mines, British Columbia. Later, after determining that the dark mineral was hübnerite, I learned on inquiry that the specimen had been brought from the Atlin district, B. C., by Professor J. C., Gwillim. No information is obtainable as to the mode of occurrence of this mineral, or of the quantity available.

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[1] Summary Report, Geol. Survey, 1908, p. 154.

[2] Summary Report, Geol. Survey, 1908, p. 169.

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