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Tungsten Deposits of British Columbia

by

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and Staff of Department of Mines

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THE GOVERNMENT OF
THE PROVINCE OF BRITISH COLUMBIA

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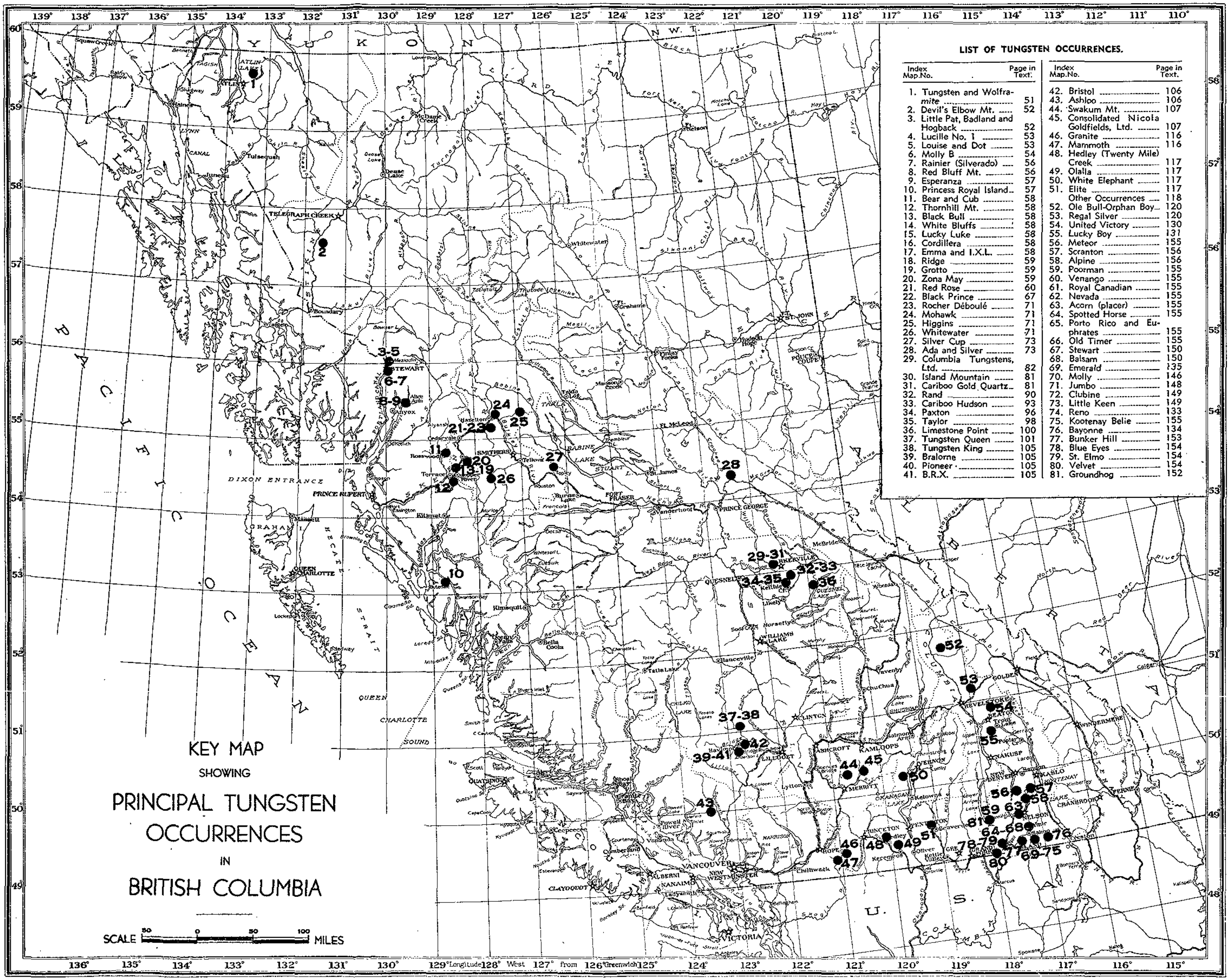

Key map showing principal tungsten
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PREFACE

This Bulletin is a complete revision of one published in 1941 under the same title. Expansion and revision of Bulletin No. 10 was made necessary by the many new discoveries of scheelite made during the last two years, discoveries which have shifted the emphasis on certain sections of the Province and on certain types of deposit. The various data are brought as much as possible up to date of March 1st, 1943, although it has been impossible to keep abreast of all current development.

Tungsten is perhaps the most important strategic metal in Canada and production has increased tremendously during the last two years. The primary reason for the increase is naturally the expanded need for the metal in war industry, coupled with the gradual cutting off of pre-war sources of supply, as a consequence of which the price has increased. Secondary reasons for increased production include improvements in technique of prospecting and improvements in milling methods that have on the one hand brought to light deposits long overlooked and on the other hand have permitted the marketing of formerly sub-marginal ores.

Two general chapters are included prior to the descriptions of British Columbia properties and occurrences. The first, "General Discussion of Tungsten" deals with the mineralogy, geology, and physical attributes of tungsten and its minerals, as well as the testing, assaying, milling and marketing of its ores. The second chapter "World Distribution of Main Tungsten Deposits" outlines the pre-war sources of the metal and brings the subject as nearly as possible up to date.

Chapter III, "Description of British Columbia Tungsten Deposits" describes all the more important deposits in the Province and most, though not all, known occurrences, many of which are of mineralogical interest only. Of these, the following three properties are mining tungsten ore at the present time: Red Rose in the Hazelton area and the Tungsten Queen and Bralorne in the Bridge-River area. In conclusion a section entitled "Hints to Prospectors" is included in the hope that it may prove helpful in the search for new deposits, particularly those of high-temperature replacement type.

The original Bulletin was entirely the work of John S. Stevenson, with the exception of one description by D. Lay. The revision is the work of the same writer, but certain sections have been contributed by other members of the Department of Mines staff.

An information circular dealing with the specifications of tungsten ores and concentrates is published with permission from the Department of Mines and Resources. The Director of the Geological Survey has given permission to print the otherwise unpublished report by Dr. W. E. Cockfield on the Consolidated Nicola Goldfields.

CHAPTER I

INTRODUCTION.

GENERAL DISCUSSION OF TUNGSTEN.

Tungsten is a metal that possesses many exceptional properties. Its melting point of 3000° C is considered to be higher than that of any other metal; its specific gravity of 19.3 to 21.4 is 70 per cent greater than that of lead, and it is particularly resistant to chemical agents (I, Mellor, p. 572). It is very ductile and possesses sufficient strength, hot and cold, to be used as incandescent filaments ranging in diameter from 0.060 to 0.0005 of an inch (III, Sykes, 1935, p. 376). Because of these many desirable properties, tungsten is becoming more and more used in industry with every new advance in metal technology.

TUNGSTEN MINERALS.

Literature mentions thirteen tungsten minerals, but of these only four, scheelite, ferberite, wolframite and huebnerite, are of commercial importance. Table I lists all the tungsten minerals giving their composition. The physical properties of the four more important are given in the paragraphs that follow Table I.

TABLE I. Tungsten minerals

Mineral	Composition	Tungstic Oxide, (WO_3) per cent.
Scheelite	Calcium tungstate ($CaWO_4$)	80.6
Ferberite	Iron tungstate ($FeWO_4$), theoretical iron end-member of wolframite series	75.3
Wolframite	Iron-manganese tungstate (Fe, Mn, WO_4), variable iron and manganese	75.3
Huebnerite	Manganese tungstate ($MnWO_4$) theoretical manganese end-member of wolframite series	75.3

(Cont'd)

TABLE I (Cont'd)

Mineral	Composition	Tungstic Oxide, (WO_3) per cent.
Powellite	Calcium molybdate with up to 10 per cent. WO_3	
Chillagite	Lead tungstate-lead molybdate (3 $PbWO_4PbMoO_4$)	21.7
Stolzite	Lead tungstate ($PbWO_4$) tetragonal crystals	51.0
Raspite	Lead tungstate ($PbWO_4$) monoclinic crystals	51.0
Cuprotungstite	Hydrous copper tungstate ($Cu_2WO_5.H_2O$) (Schaller, 1932, p. 236)	56.7
Cuproscheelite	Impure mixtures of cuprotungstite and scheelite (Schaller, 1932, p. 236)	
Tungstenite	Tungsten sulphide (WS_2)	94.0
Tungstite	Hydrous tungstic oxide ($WO_3.H_2O$)	92.8
Ferritungstite	Hydrous ferric tungstate ($Fe_2O_3.WO_3.6H_2O$)	52.2

Scheelite. Lustre, greasy adamantine. Colour, white, buff, yellowish through brownish to reddish. Streak, white. Hardness, 4.5. Fracture, uneven. Brittle. Specific gravity, 5.9 to 6.2. Granular, compact.

Ferberite. (Reinite in Dana). Lustre, submetallic to metallic. Colour, black. Streak, dark brown to nearly black. Hardness, 5. Cleavage, one perfect. Fracture uneven. Brittle, Specific gravity, 7.5.

Wolframite. Lustre, submetallic. Colour, dark greyish or brownish black. Streak, nearly black. Hardness, 5 to 5.5. Cleavage, one perfect. Fracture, uneven, brittle. Specific Gravity, 7.2 to 7.5. Crystalline, often bladed, granular.

Huebnerite. Lustre, submetallic to adamantine, colour, brownish red to brown to nearly black. Streak, yellowish brown, greenish grey. Hardness, 5. Cleavage, one perfect. Fracture, uneven, brittle. Specific gravity, 7.2 to 7.3. Usually in bladed form.

The minerals ferberite, wolframite, and huebnerite form a continuous chemical series of minerals between the limits of pure iron tungstate (ferberite) and pure manganese tungstate (huebnerite). Ferberite, the iron tungstate, is arbitrarily considered to have less than 20 per cent manganese tungstate; and huebnerite, the manganese tungstate, to have less than 20 per cent iron tungstate (I, Hess, 1917, pp. 21-29). Wolframite is any iron-manganese tungstate with an iron and manganese content between the above limits. A chemical analysis is usually necessary to distinguish between the three minerals of the wolframite series. However, lacking specific chemical analyses, such minerals may be provisionally referred to as wolframites.

Powellite. Lustre, resinous. Colour, grey to yellow; distinctly yellowish in ultra-violet light as compared with whitish colour of scheelite in such light. Hardness 3.5. No distinct cleavage. Fracture, uneven. Specific gravity, 4.3.

Chemical tests should be used to confirm identity of powellite because of similarity to scheelite. The following test adapted from Feigl (I, 1939, p. 66) is a rapid spot test for both molybdate and tungstate, and serves to distinguish powellite from scheelite.

A solution of the unknown mineral is made by first fusing a small amount of the powdered mineral with roughly 5 times the quantity of sodium carbonate and then dissolving the fusion in water. The following steps are then followed:

1. Apply a drop of hydrochloric acid (1:1) to a piece of blotting paper.

2. To the centre of this drop add a drop of the solution of the unknown mineral.

3. Add a drop of potassium thiocyanate solution.

4. Add a drop of stannous chloride solution.

A vermilion-red ring around a colourless core indicates molybdenum. A yellowish-green core and no vermilion-red ring indicates tungsten. When both the red ring and a yellowish-green core are present, both molybdenum and tungsten are indicated. Most powellite, if carefully sampled, will give a positive test for molybdenum only, and most scheelite likewise if carefully sampled, will give a positive test for tungsten only.

FIELD TESTS FOR TUNGSTEN MINERALS.

Field chemical-tests should be made whenever possible to check any preliminary identification of a tungsten-bearing mineral, previously made either on the basis of its physical properties, or its fluorescence in ultra-violet light. Scheelite from a new find should always be checked chemically. The necessary apparatus for these tests is simple and the procedure rapid and decisive. The details of the tests will be given in the following paragraphs.

The presence of tungsten in a mineral is checked by two main methods depending on whether or not the mineral is attacked in dilute acid, the simple acid test may be used, if not, the fusion test must be used. Of the main tungsten-bearing minerals, scheelite is attacked in acid but the wolframites are relatively insoluble and must be fused.

The proper method may be preliminarily determined merely by noting the colour of the mineral; scheelite ranges from white to orange, whereas the wolframites are almost invariably dark brown or black.

Simple acid test: For this test all that is required is some hydrochloric (muriatic) acid, a test-tube or any small glass or porcelain vessel that will not be attacked by acid; and a small amount of zinc or tin in the form of shot or sheets that can be cut into thin pieces.

The mineral to be tested is pulverized to a fine powder and boiled in the acid for a few minutes. If the mineral is a soluble tungsten compound such as scheelite, a yellow powder, tungstic oxide (WO_3), will separate from the solution. To confirm this separation, a few pieces of zinc or tin, or even solder are added to the solution which is boiled gently for a minute or two and, if tungstic oxide has been separated, the solution will turn indigo-blue. This blue colour probably results from the partial reduction of the tungstic oxide (WO_3) to a tungsten oxide, (W_2O_5) (I, McAlpine and Soule, 1933, p. 290) by the nascent hydrogen liberated from the hydrochloric acid by the action of the zinc or tin. The test with zinc or tin is a very delicate one for a soluble or partly soluble tungsten-bearing mineral and is, of course, a splendid test for scheelite.

Fusion test: This test is used for more refractory minerals, such as the wolframites.

The materials required for the test are: sodium carbonate or bicarbonate (ordinary kitchen baking-soda); a fine platinum or steel wire, 2-4 inches long with a loop, about 1/16 - inch diameter at one end made by bending the end of the wire around a needle or pencil-point; an open flame such as a candle, or alcohol lamp; a small blow-pipe; a test-tube or other small acid-resisting vessel such as a glass tumbler or a cup; hydrochloric (muriatic) acid; and zinc or tin metal in small pieces.

The procedure for the fusion test is as follows: Make a soda bead with the platinum or iron loop by dipping the loop into a paste of soda and water, sintering this for a minute or two in a flame and then fusing it before a blow-pipe or in an otherwise very hot flame or hot coals; crush the unknown mineral to a fine powder. Take some of this powder, in quantity about the size of a pin-head, and mix with 5 to 6 volumes of soda; dip the soda bead into this mixture and again fuse the bead plus adhering mineral powder thoroughly; cool the fused mixture; grind to a powder, dissolve in dilute hydrochloric acid; boil gently and if tungsten is present, a yellow powder will form as with the simple acid test. To confirm, add zinc or tin to the solution; boil gently and, again as with the acid test, the solution will turn blue if tungsten is present.

A DEPENDABLE METHOD OF ASSAYING ORE FOR TUNGSTEN*

There have been many requests for the method used in the laboratory of the Department of Mines for the assaying of tungsten ores. The procedure used is essentially that given below and is reprinted by permission from pp. 553-5 of "Applied Inorganic Analysis" by Hillebrand and Lundell, published by John Wiley and Sons, Inc. This procedure is reproduced below. (Note 1), (Note 2), etc. in the quoted procedure refer to comments based on experience gained in the Department of Mines laboratory, which are given at the end of the quotation.

> "PROCEDURE.--Grind the sample of ore or mineral in an agate mortar until all of it is 200 mesh (Note 1) or finer. Transfer one g (Note 2) to a 400 ml beaker, add 5 ml of water, and gently whirl the beaker so as to break up the material and distribute it evenly on the bottom. Add 100 ml of hydrochloric acid (Note 3), cover the beaker, and heat for one hour at a temperature not exceeding 60° C (Note 4) and with occasional stirring to prevent the formation of crusts or cakes on the bottom of the beaker. Now raise the cover on glass hooks, increase the heat and boil to a volume of about 50 ml. Stir the material on the bottom of the beaker until all caked residue is broken up, and then add 40 ml of hydrochloric acid and 15 ml of nitric acid. Cover until danger of spattering is past, then remove the cover and continue the boiling until the volume of the solution has been reduced to about 50 ml. Add 5 ml of nitric acid, break up all caked matter and boil until the volume has been reduced to 10 to 15 ml. Add 150 ml of hot water, stir thoroughly and gently simmer the solution for one-half hour. Add 5 ml of cinchonine solution and digest the solution on a hot plate or water bath at a temperature short of boiling for at least 30 minutes.

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* By G. C. B. Cave, CHIEF ANALYST AND ASSAYER, British Columbia Department of Mines.

"Let the precipitate settle, decant the supernatant liquid through a 9-cm paper (Note 5) containing some ashless paper pulp and wash the precipitate three or four times by decantation with hot cinchonine wash solution. Transfer the precipitate, so far as possible with moderate scrubbing, to the paper and wash the beaker, paper and precipitate thoroughly. Add cinchonine solution to the filtrate and washings (A), mix thoroughly and set aside to make sure that recovery of tungsten is complete. Transfer the washed precipitate to the original beaker by means of a jet of water; no more than about 25 ml should be used. Add 6 ml of ammonium hydroxide (enough to give a slight excess), cover the beaker and warm gently for a few minutes. Wash the inside of the beaker with warm dilute ammonium hydroxide (1:9) containing 10 g of ammonium chloride per liter. Stir the solution well, filter through the same paper as was used before, collect the filtrate in a 400 ml beaker and wash the original beaker, the filter and the residue with warm dilute solution of ammonium hydroxide. Reserve the residue (B). Evaporate the filtrate or gently boil it until the most of the ammonia has been expelled (Note 6). Add 20 ml of hydrochloric acid and 10 ml of nitric acid, and boil to a volume of 10 to 15 ml. Dilute to 150 ml with hot water, add 10 ml of cinchonine solution, stir the solution thoroughly, digest at 80 to 90° C for at least 30 minutes and then allow to cool. Add paper pulp, transfer the precipitate completely to a 9-cm paper and wash thoroughly with hot cinchonine wash solution. This is the main precipitate and is to be ignited together with any additional tungsten obtained as to be described. Thoroughly mix the filtrate and washings (C) and set aside to make sure the precipitation was complete.

"If (Note 7) the material was completely decomposed, any tungsten held in the reserved residue (B) is usually combined with iron or alumina, and can be dissolved by digesting the residue with warm dilute hydrochloric acid (1:9), filtering, washing in turn with small amounts of a hot 0.5 per cent solution of ammonium chloride and the ammonium hydroxide wash solution. The tungsten (Recovery 1) is then precipitated by further treatment with acid and cinchonine as with the boiled ammonium hydroxide extract, with which it should not be combined.

"The (Note 8) residue (D) still left after the treatment with dilute acid and ammonium hydroxide is usually free from tungsten. It may contain silica or undecomposed silicates, cassiterite, and minerals containing columbium and tantalum and can be tested as described under the Earth Acids, III (p. 477), or as follows: Ignite the paper and residue (D) at a low temperature in a porcelain crucible (because of a possible tin content), transfer the ash to a platinum crucible, and volatilize silicon by evaporation with hydrofluoric and sulphuric acids. Fuse the residue with as little sodium carbonate as possible, cool, and extract with water. Filter, acidify the filtrate with hydrochloric acid, boil to expel carbon dioxide and test for tungsten by adding 5 ml of cinchonine reagent and digesting the solution at the side of the steam bath for 30 minutes, and then at room temperature for several hours, preferably overnight. If a precipitate appears in this solution or in the two reserved filtrates and washings (A and C), filter all through the same paper and wash the combined precipitates with cinchonine wash solution. Extract with ammonium hydroxide, precipitate and wash as in the preceding recovery (Recovery 2).

"Transfer the papers containing the main precipitate and the recoveries (1 and 2) to a large weighed platinum crucible, and heat at a low temperature until all carbon has been destroyed. Cool, moisten the precipitate with a little hydrofluoric acid, evaporate to dryness to expel any silica, and then ignite at 750 to 850^{o} C (Note 10). Cool in a desiccator, weigh as impure WO_3 and repeat the ignition until constant weight is obtained.

"The tungstic oxide that is obtained must be examined for contaminants such as molybdenum, silver, iron and phosphorous as follows: Fuse with as little sodium carbonate as possible, extract the melt with water, filter, and wash any residue with a warm 1 per cent solution of sodium carbonate, then with hot water. Reserve the filtrate. Ignite the paper and residue and repeat the operation. Combine the filtrates and set aside. Ignite the well-washed paper and residue, cool, weigh, and correct the weight of tungstic oxide for the oxides found. In the rare event that silver is present, digest the first insoluble residue with ammonium hydroxide, filter, wash the residue and then proceed with the ignition and refusion with sodium carbonate. Treat the ammoniacal filtrate with ammonium sulphide, recover any precipitate and ignite it with that obtained in the combined water extract.

"Acidify the water extracts, boil to expel carbon dioxide, and then add ammonium hydroxide in excess. Ordinarily no precipitate should remain, if one does it must be recovered by filtration, washed, ignited and the weight deducted from that of the tungstic oxide. Add 3 to 5 g of tartaric acid to the clear ammoniacal solution, saturate with hydrogen sulphide, add sulphuric acid until 1 per cent by volume excess, digest for one hour at 40 to 60^{o} C and filter. Wash the precipitate with hydrogen sulphide water containing 5 g of tartaric and 5 ml of sulphuric acid per liter. Reserve the filtrate if tests for phosphorous and vanadium are deemed desirable. As the sulphides may still contain tungsten, dissolve the precipitate in hot dilute nitric acid containing a little bromine, boil to expel the latter, add 1 to 2 g of tartaric acid and render the solution ammoniacal. Again treat with hydrogen sulphide and proceed as before. Finally ignite very carefully at a temperature not over 600° C, cool, weigh and correct the tungstic oxide for the oxides found."

Cinchonine Solution. Dissolve 125 grams of cinchonine in a mixture of 500 ml. hydrochloric acid and 500 ml of water.

Cinchonine Wash Solution. Dilute 25 ml. of the above cinchonine solution to 1 liter with water containing 30 ml. of hydrochloric acid.

Our comments on the foregoing procedure:

Note 1 On most scheelite ore, we have found that satisfactory results are obtained by grinding the ore to pass 150 mesh.

Note 2 On concentrates 0.5 gram is sufficient; on tailings 5 grams is used. We had for some time used 10 grams on tailings but found that the filtrations following both acid and ammonia digestion were too time-consuming.

Note 3 For scheelite ores 75 ml. of hydrochloric acid have been sufficient. Commercial grade hydrochloric acid is as satisfactory as reagent grade, and is much less expensive.

Note 4 Simmering gently for one-half hour has proven satisfactory with most ores.

Note 5 A quite retentive paper is needed.

Note 6 Evaporation should not be continued longer than necessary, for if the volume of solution is reduced to 10-20 ml, the tungstic oxide precipitated on the addition of the acids will often be slimy and difficult to filter.

Note 7 The procedure in this paragraph is somewhat time-consuming for routine assays. On unfamiliar ores we make spectrographic analyses on reserve residue (B). In almost all cases so far a negligible quantity of tungstic oxide has been found. A quick colorimetric test for tungstic oxide in reserve residue (B) seems indicated in place of the method given in the above procedure. Thus, in the absence of molybdenum, the quantitative colorimetric method of Feigl and Krumholz (Angew. Chem. 45, 674-5, 1932), should be of service.

Note 8 The procedure in this paragraph need be used only on an unfamiliar ore. If the residue (B) is decomposed by sodium carbonate fusion, and the procedure of Feigl and Krumholz used to determine the tungstic oxide in the residue (see

Note 7) then the procedure in this paragraph appears unnecessary.

Note 9 Treatment of the tungstic oxide precipitate with hydrofluoric acid should not be omitted in accurate work. It is a particularly important step when assaying tailings. Tungstic oxide almost invariably contains a little silica at this stage of the procedure. The amount of silica varies with the type of ore and perhaps with the particular procedure used in the assay.

Note 10 Regulation of the ignition temperature is quite important. Quoting from Hillebrand and Lundell, "The proper ignition of tungstic acid is a difficult matter, for a temperature of 750° C is needed for complete dehydration of the acid, while the oxide begins to volatilize at 800° C. The rate of volatilization is slow at temperatures below 900° C, however, and so a range of 750 to 850° C is quite safe. Pure ignited WO_3 is not hygroscopic."

ADDITIONAL COMMENTS ON ASSAYING FOR TUNGSTEN

In a complex mixture such as an ore, the mixture of hydrochloric acid and nitric acid will precipitate most, but not all, the tungsten as yellow hydrated tungstic oxide. To the tungsten remaining in solution there must be added the salt of some alkaloid or other organic base. Cinchonine is commonly used. But there seems no reason why one of several other available alkaloids or organic bases should not be satisfactory.

Instead of decomposing the ore with a mixture of acids, it is the procedure in some laboratories to fuse the ore with sodium carbonate, sodium peroxide, or sodium pyrosulphate. Such fusions result in the presence of alkali salts in the solution in which the tungsten is precipitated. It is known that these alkali salts can prevent complete precipitation of tungsten by acids, and can markedly hinder complete precipitation of tungsten by cinchonine. Hence the decomposition of ores by alkalic fusion is not recommended in accurate work. It should be noted, however, that if decomposition is effected in this way, and if the silica is not removed before the final weighing of the ignited tungstic oxide, then some compensation of errors will occur.

Method of recovering cinchonine from tungsten assays

In tungsten assays a considerable amount of cinchonine above that required for precipitating tungsten is used. Owing to the limited supply of cinchonine it is recommended that this excess be recovered from the tungsten assay. This recovery has been practiced in the Department of Mines laboratory for the past year and it has been found that the recovered cinchonine is perfectly satisfactory for use over and over again. The method of recovery developed in this laboratory is as follows:-

Filtrates and wash water containing cinchonine are collected together. To this cinchonine solution is added sufficient tartaric acid to prevent the precipitation of iron by ammonia. The solution is then made distinctly ammoniacal. Cinchonine is essentially insoluble in this ammoniacal solution and separates out as a flocculent white precipitate. After settling, the supernatant liquid is removed by filtering through a Buckner funnel and the cinchonine washed three or four times with cold water (if a Buckner funnel is not available the supernatant liquid may be removed by siphoning and the cinchonine washed by decantation with water). The cinchonine precipitate is then dissolved with dilute hydrochloric acid and the resulting solution is diluted with water to a larger volume and allowed to settle for two or three days. This allows any finely divided particles to settle. The supernatant liquid is then decanted through a filter and a small amount of tartaric acid is added to the filtrate to prevent the precipitation of any iron present when the solution is made ammoniacal. The solution is then made ammoniacal and the cinchonine is thereby reprecipitated. The cinchonine precipitate is filtered as before, and is washed three or four times with water. The washed cinchonine precipitate is now redissolved in weak hydrochloric acid. It is then precipitated a third time with ammonia, a small amount of tartaric acid being added to prevent the precipitation of small amounts of iron. The cinchonine precipitate is then collected by filtering and is washed with cold water. This final precipitate is dried at 105° C. It is then ready for use. Very occasionally three precipitations of the cinchonine are not enough and it is necessary to again dissolve the cinchonine with hydrochloric acid and reprecipitate with ammonia. It has been found in this laboratory that an extremely pure product can be obtained by dissolving the thrice-precipitated dried cinchonine in hot methyl alcohol (i.e. methyl hydrate), filtering hot, and allowing the filtrate to cool, during which cooling the cinchonine will crystallize out.

GEOLOGICAL OCCURRENCE OF TUNGSTEN MINERALS

Tungsten minerals occur in all types of rock including both igneous and sedimentary rocks, and in placers. Deposits that occur in sediments usually have some close and obvious areal relationship to igneous rocks; although deposits that are far away from granitic sources have been recently described from Bolivia by Ahlfeld (IV, 1938). The types of deposits with igneous affiliations include magmatic segregations, pegmatites, high temperature replacement (pyrometasomatic) deposits, and veins. With the exception of magmatic segregations tungsten-bearing representatives of all these types occur in British Columbia.

<u>Magmatic segregations</u>: Magmatic segregations are deposits that have been formed by concentration of the ore minerals in the molten magma prior to its consolidation as an igneous rock. The ore-minerals

usually occur as knots or segregations within the enclosing igneous rock. Tungsten minerals are found in such deposits but only infrequently and in small amounts. An occurrence has been described (I, Hess, 1917, p. 37) from the Whetstone Mountains, Arizona, where small crystals of wolframite are distributed through potash granite. No deposit of this type has been reported from British Columbia.

Pegmatites: Pegmatites are vein-like masses composed of coarsely crystallized minerals, of which quartz, feldspar and mica are much the commonest. Some pegmatites have been found to contain small amounts of tungsten minerals, but seldom in commercial amounts. Such occurrences have been reported from pegmatites in the Black Hills area of South Dakota (I, Lovering, 1933, p. 666) and at Oreana, Nevada (V, Kerr, 1938, p. 390). Scheelite in what appears to be pegmatitic material is found in British Columbia on Thornhill Mountain in the Terrace area. (This report, p. 58).

High-temperature replacement deposits:* Deposits of this type are found in zones of intense metamorphism at or near granitic contacts. They may be as much as several hundred or even several thousand feet from any known intrusive body, but they may be underlain by such a body that is not exposed at the surface. The deposits are found in rock that has been recrystallized at high temperature through the agency of rising hot solutions which, in most instances, have introduced a considerable amount of material from the igneous source.

High-temperature replacement deposits may be found in any type of rock but those containing tungsten as the mineral scheelite are almost always found in limestone. The limestone is completely recrystallized into an assemblage of new minerals of which garnet, diopside, epidote, vesuvianite and calcite are the most common; in some cases, sulphide minerals and magnetite have been introduced. This assemblage of lime-bearing silicates, derived from limestone by intense metamorphism, is known as skarn, whether or not there are iron sulphides or oxides present.

Skarn is a term of long standing that is used in referring to areas or zones of intensely altered limestone. The term tactite is synonymous and is widely used in the United States; where there is a high proportion of garnet the term garnetite may be employed. The older term contact-metamorphic is not used in connection with these deposits because it implies a closer relation to the actual granitic contact than is very often the case; it also implies derivation of mineralizing solutions from the nearby granite whereas in most instances they are known to come from some source deep within the intrusion itself.

Skarn may form in limestone as a selvedge bordering a granitic

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* Discussion of high temperature replacement deposits by M. S. Hedley, British Columbia Department of Mines.

batholith, stock or dyke or it may form as masses of greater or lesser extent in a formation that is otherwise relatively unaltered. Although irregularity in form and extent is to be expected there is a common tendency for skarn to occur as tabular bodies owing to replacement of a limestone band bounded by some other sedimentary rock or owing to selective replacement of a particular band or series of beds within a limestone formation. The preferential alteration to skarn of some band or bands within a limestone formation is believed to be due to the presence of impurities that readily permit recrystallization of the rock to skarn without the necessity for wholesale introduction of material which is necessary in relatively pure limestone. Such skarn bands may be as much as several thousand feet in strike length and may be straight or folded just as are the other less altered members of the sedimentary formation.

Scheelite occurs in skarn as disseminated grains, closely associated with the silicate minerals and with sulphide minerals when present. Minerals of the wolframite group are not as a rule present and if they do occur are found only in minor quantity. The scheelite grains are small, scattered and commonly a dirty white in colour so that their detection in the field is exceedingly difficult without the aid of an ultra-violet lamp.

Scheelite as a rule appears to occur as one of the skarn minerals, although in some instances it is known to have been introduced later through the agency of quartz stringers. Speaking generally, there is no one type of skarn or association of minerals that is especially favourable to the occurrence of scheelite, although the presence of sulphides may generally be considered favourable. Scheelite in small amounts is known in many instances to be very widespread although in commercial amounts it is more commonly restricted to certain parts of a continuous skarn band or else is confined to particular, local occurrences of skarn.

Ore-bodies are characteristically streaky and discontinuous, but although many are irregular in outline there is a strong tendency for them to be tabular. This is because replacement, even when attacking a relatively pure and uniform formation of limestone, is guided at least in part by the original bedding; certain beds appear to be more easily replaced than others, owing probably to minute original differences in composition and perhaps in texture.

The known scheelite deposits in British Columbia of the high-temperature replacement type occur in skarn containing diopside and garnet as the principal silicate constituents. Metallic minerals, commonly present, include the common sulphides pyrite and pyrrhotite, as well as chalcopyrite, molybdenite and rarely sphalerite and other sulphides. The typical rock is patchy, and greenish to reddish-brown in colour owing to the variable proportion of the two chief constituent minerals. The percentage of sulphides in some instances, or in some parts of certain deposits, is high. When the sulphides are preponderant they show a close intergrowth with diopside or with some other pyroxene, and garnet may be small in amount. Although the mineralizing solutions that formed the deposits were not derived from the adjacent granite yet the deposits themselves bear a close spatial relationship to the granite contact even though they may be some distance from it; a favourable situation appears to be in or adjacent to a bay or trough in the contact. Other deposits simply occur as a selvedge bordering granite, and still others occur in skarn bands of wide distribution. Although the matter is not fully understood the generalization may be made that the location of the higher grade deposits was governed by a factor or factors that have in some way localized the passage of mineral-bearing solutions through the receptive limestone.

The most important deposits of this type in the United States are the Humboldt and Stank Mines of the Nevada Massachusetts Company at Mill City, Nevada, (V. Kerr, 1934) and several others near Bishop in Inyo County, California, (V, Hess and Larsen, 1921).

In 1939 such deposits were responsible for the largest part of the United States tungsten.

Discoveries made in 1941 and 1942 indicate that high-temperature replacement deposits are important in British Columbia. In addition to many minor occurrences of scheelite, important amounts of this mineral associated with lime-silicate minerals in limestone--granite contact zones occur in the West Kootenay district. The Emerald mine south of Nelson, a potentially large producer, belongs to the high-temperature replacement type of deposit.

Veins: Important amounts of tungsten minerals also occur in many quartz veins. The tungsten-bearing veins include several structural and mineralogical types that may be grouped as are other quartz veins, into three main classes according to temperatures prevailing at the time of mineral deposition. For convenience of description these vein-types are referred to as low, (epithermal), intermediate (mesothermal) and high (hypothermal) temperature veins.

As a result of having formed relatively close to the surface and under light load or pressure, the structure and texture of low-temperature veins are often characteristic of the class. The vein-walls are often irregular and the vein-matter frozen to the wall-rock. Splitting is a feature of some of the veins and as a result, this type tends to be short and of variable strike and dip. Texturally, extreme brecciation, commonly ascribed to veins formed under light load, and a fine rhythmic banded filling, characterize most of these veins.

The mineralogy of low-temperature veins is distinctive. Quartz is usually fine-grained to dense and occurs as finely banded material representing repeated stages of deposition. Minerals formed at a low temperature that are common in this type of vein but are not usually found in other types of deposits include: cinnabar, stibnite, realgar and chalcedony. High-temperature minerals such as magnetite, tourmaline, garnet and pyroxene are absent.

Low-temperature veins occur most frequently in regions of Tertiary or more recent volcanic activity, not necessarily in the lavas themselves, but often in the adjacent rocks.

Tungsten production from low-temperature veins ranked second in 1939 in the United States. The most important representative of this type in the United States are the scheelite veins of the Atolia district, California, (V, Hulin, 1925, p. 77), the ferberite veins of Boulder County Colorado, (I, Lovering, 1933, p. 669) and the huebnerite veins of the Silverton-Gladstone area in Colorado, (idem, p. 668). The only representative of this class in British Columbia is the Tungsten Queen scheelite deposit in the Bridge River area (see this report pp. 101-104).

Intermediate temperature (mesothermal) veins commonly occupy fissures that are fairly regular in strike and dip. Faulting along the fissures has usually been common and as a result the vein-walls are often marked by films of gouge and are usually free. These veins do not possess the extreme brecciation found in some of the low-temperature veins. In texture they may or may not be banded, but they do not usually possess the fine, rhythmic banding that characterizes low-temperature veins. Open spaces existed at the time of formation of some veins, and vugs lined by crystals are common.

The mineralogy is not strikingly characteristic. Many of the minerals are common to both low-and high-temperature veins. However, such low-temperature minerals as cinnabar, stibnite and chalcedony, and such high temperature minerals as molybdenite, cassiterite and tourmaline, are absent.

In only a few places has tungsten, mainly the mineral scheelite, been found in intermediate-temperature veins in quantities sufficient to justify mining for tungsten alone; usually such veins are mined for their gold-silver, or base-metal content. As a result, the production of scheelite from veins of this type has been small.

Tungsten-bearing veins of the intermediate-temperature type (idem p. 667-668) include the copper and the gold-silver veins of Butte, Montana, many of which carry a small amount of huebnerite the quartz-sphalerite-galena veins of the Patterson Creek district, Idaho, which contain some huebnerite and the scheelite-bearing gold veins from near Murray, Idaho.

The chief representatives of this vein-type in British Columbia are the gold-quartz veins of the Cariboo district (see this report pp. 77-100), which in addition to galena, sphalerite and pyrite, frequently contain scheelite. The Columbia Tungsten's property near Wells, is considered by the writer, to belong to this type. (See this report pp. 82-90.)

High-temperature (hypothermal) veins are commonly lenticular. Fissuring, though sometimes present, is not common, and as a result the vein-matter is usually frozen to the walls. Siliceous replacement of wall-rock is common. Because the extent of this silicification outwards from the original vein-fissure is apt to vary, any variations in width of veins due to lenticularity of the original fissure are further emphasized by variations in width of the wall-rock silicification.

The mineral assemblage is characterized by the presence of molybdenite, cassiterite, pyroxene, amphibole, garnet, ilmenite, magnetite and tourmaline; these minerals occur only rarely in the other vein-types. Examples of tungsten-bearing veins of the high-temperature type in the United States (I, Lovering 1933, p. 666) include the quartz-wolframite deposits in the Deer Trail district, Washington and quartz-wolframite veins near Jardine, Montana. The best examples in British Columbia are the quartz-ferberite-scheelite veins on the Red Rose and Black Prince in the Hazelton area. (See this report pp. 60-71.)

In general, production from the high temperature types of tungsten veins has not been large to date.

FLUORESCENCE AND ITS APPLICATION TO THE STUDY OF SCHEELITE DEPOSITS

The detection of scheelite by its fluorescence in ultra-violet light has of late received considerable deserving attention.

<u>Definition of fluorescence</u>. Fluorescence is the ability of a substance, e. g., a mineral, to absorb <u>invisible</u> ultra-violet wave-lengths of light and to emit <u>visible</u> wave-lengths. Physicists are still somewhat uncertain as to the exact cause of fluorescence. However, they seem to agree in the explanation given in the following sentences. Minerals, in common with other substances are believed to consist of atoms, which are units too small to be visible as such, even under high-power microscopes; their existence and structure are deduced by the physicists by reasoning from the electro-magnetic behaviour of matter. According to the Bohr theory (I, Radley and Grant, 1933, p. 5), atoms are believed to consist of a central nucleus around which electrons revolve in orbits. If an atom is exposed to ultra-violet radiations an electron may be made to pass from an inner orbit to an outer one; energy, furnished by the ultra-violet light, is absorbed during the passage. In this disturbed condition the atom is unstable and in order to re-establish itself the displaced electrons tend to return to their inner orbits. During their return, the electrons emit the energy in the form of radiations absorbed in their displacement outwards. These radiations of wave-lengths of light are visible to the human eye and are known as fluorescent light. Those substances or minerals

capable of emitting such light when exposed to ultra-violet radiations, are known as fluorescent substances or minerals. Ultra-violet wave-lengths are generally considered to be those lying between 136 Ångströms (1 Ångström unit equals 10^{-8} cm.) and 4000 Ångströms, whereas visible wave-lengths of light lie between 4000 and 8000 Ångströms (Radley and Grant 1933 chart facing p. 2).

Fluorescent minerals. Not all minerals fluoresce in ultra-violet light, or even all varieties of the same mineral. The reason for this is not known. Some think that it is due to minute amounts of impurities present in different mineral varieties; these amounts are usually so small that they can only be determined spectrographically.

The natural colour of a mineral cannot be correlated with the colour of its fluorescence; some colourless varieties of the same mineral fluoresce with a brilliant hue, whereas some coloured varieties of the same mineral do not fluoresce. The same mineral will often show different intensities and colours of fluorescence depending on the source of the ultra-violet light. Of the three main sources of ultra-violet light, namely, the argon bulb, iron arc and mercury-vapour arc, the latter appears to produce the strongest fluorescence in the largest number of minerals. The improved results from this type of lamp appear to be due to a greater intensity of the shorter ultra-violet wave-lengths emitted, and a correlation between these shorter wave-lengths and an increased excitation of fluorescence in minerals.

Approximately 125 different minerals have been shown to fluoresce under a strong source of the shorter ultra-violet wave-lengths. A list of those minerals which fluoresce most easily under almost any source of ultra-violet light is given in Table II.

The colour of the fluorescence of scheelite varies somewhat with the type of lamp used. In light from an iron spark most scheelite is reported to fluoresce a blue or light bluish colour whereas under a mercury-vapour lamp most of the British Columbia scheelite examined by the writer fluoresces a brilliant oyster-white. Some scheelites that contain a small amount of molybdenum fluoresce a pale yellow. Greenwood (I, 1943, pp. 56-64) has recently shown that the range in fluorescent colour of different scheelites from pale blue to yellow is proportional, within limits, to the amount of molybdenum and manganese contained as impurities in the scheelite.

Scheelite in high-temperature replacement zones may be confused in ultra-violet light with two other minerals, powellite and scapolite, common to such zones. Of these minerals, powellite is by far the more common. Its canary-yellow fluorescence may be confused with that of scheelite. Powellite is a calcium molybdate and a chemical test (see p. 3 of this report) should be made for molybdenum if powellite is suspected. The less common mineral, scapolite fluoresces a strong orange colour and for this reason, it is less likely to be confused with scheelite. If there is any doubt as to the identity of a fluorescent mineral in ultra-violet light, it should be checked chemically or microscopically.

In discussing fluorescent minerals easily mistaken for scheelite, attention should be called to the probable presence of hydrozincite, a basic zinc carbonate that forms as an alteration product of sphalerite. Hydrozincite is a white, crustiform mineral that fluoresces a brilliant white, and for this reason may be confused with scheelite. However, its close association with sphalerite, often as a coating of that mineral in surface showings, may suggest its identity. Hydrozincite is also commonly found underground as a gelatinous slime issuing from sphalerite-bearing veins. This slime fluoresces a brilliant white. If sphalerite is present in a vein that is being examined care should therefore be taken in identifying small patches of fluorescent material.

TABLE II. Principal fluorescent minerals and their colour in fluorescent light.

Mineral	Colour of Fluorescence
Agate - occasionally fluorescent	variable, greenish
Amber	variable, yellow-green, light blue
Amethyst	deep blue
Apatite	green, grey, blue
Aragonite	variable, green, cream
Beryl	green
Calcite (Not all calcites fluoresce)	variable, chiefly red or white, also yellow, orange, green and gradational
Cerussite	green
Chalcedony (occasionally fluorescent)	green
Fluorite (occasionally fluorescent)	variable, green, blue-green, grey
Hydrozincite (Basic zinc carbonate)	blue
Jasper	green
Opal (does not invariably fluoresce)	bright green
Petroleum (oils, etc.)	strong blue, yellow or green

(Cont'd)

TABLE II (Cont'd)

Mineral	Colour of Fluorescence
Powellite	creamy white to orange
Rhodochrosite	brownish, grey
Rose Quartz (occasionally fluoresces)	pale purple
Scapolite	yellow
Scheelite (invariably fluoresces)	variable and gradational between blue-white, white, blue (rare) creamy white, yellow, orange-yellow--yellowish hues are due to molybdenum content
Smithsonite (zinc carbonate)	green
Sphalerite (occasionally fluoresces)	orange, green, brown
Willemite	bright green, reddish brown, pink
Wulfenite	green
Zincite	bright green

The variable fluorescence of some minerals is due to minor amounts of impurities and is not a characteristic of the mineral itself.

Sources of ultra-violet light. In practice, ultra-violet radiations are obtained from three main sources, namely, argon-glow lamps, "strong-arc" and mercury vapour lamps.

Argon-glow lamps are small, gas-filled bulbs similar in shape and size to old-fashioned electric light bulbs of low wattage. These bulbs have an electrode at each end filled with argon gas. The ultra-violet light is emitted as a relatively steady violet-coloured glow that results from the discharge of electrons through the argon gas between the two electrodes.

Argon-glow bulbs may be used on alternating or direct current; on alternating current they may be connected to the ordinary lighting circuit without the use of a transformer. The bulbs are approximately 60 cents each and as only about ten are necessary for a suitable effect on a few minerals, they are a relatively inexpensive source of ultra-violet light. Inasmuch as the ultra-violet emanations from these lamps are of a fairly long wave-length, reported to be between

3,300 and 3,700 Ångström units, not all minerals will fluoresce in their light, and scheelite is one of those minerals. Argon-glow bulbs are, therefore, not suitable for the detection of scheelite.

The construction of the strong-arc type of lamp has been described by Vanderberg (I, 1935, p. 2). He summarizes the constituent parts as follows:

1. Transformer to step 110 volts A. C. up to 4500 volts.

2. A mica condenser that has a capacity of 0.004 microfarad at 3,500 volts.

3. A spark gap with adjustable and replaceable iron electrodes.

According to Vanderberg, this lamp may be purchased for $35.00.

The wave-length of the ultra-violet light emitted by a high-tension spark between iron electrodes is reported to lie within the range of 4270 Ångström units. Because of the possession of the shorter wave-lengths below 3000 Ångström units, such light will fluoresce many more minerals than the argon-glow lamps, particularly scheelite. Most scheelite is reported to fluoresce to a light blue in light from such a source.

Inasmuch as this type of lamp is not easily adaptable for use with light-weight batteries, it is not particularly useful in general field-work where portability is a first requirement.

Mercury-vapour lamps are constructed so that an electrical discharge is sent through mercury-vapour between metallic mercury electrodes. This type of lamp is perhaps most suitable for general purposes and particularly for the detection of scheelite. This mineral fluoresces brilliantly in such light, usually a bright oyster-white and bluish-white and sometimes a light orange.

Three main types of mercury-vapour lamps, at present in use, have come to the writer's attention, namely:

1. A mercury-vapour tube manufactured under the trade name "Nico" and sold through Ward's Natural Science Establishment, Rochester, N. Y.

2. A high-intensity mercury-vapour arc enclosed in a bulb, also sold through Ward's Ltd.

3. A fused quartz type that is manufactured by several companies in California.

The Nico lamp is described by Ward's in their Catalogue No. 39, 1938, as follows:

"This lamp, which is a modification of the Cooper-Hewitt lamp, has been completely re-designed; the mercury vapour tube, made of lead glass to which small quantities of nickel and cobalt salts have been added, gives greatly improved effects. The tube is provided with universal screw base terminals and is mounted to an Alzac aluminum reflector which permits the maximum reflection of ultra-violet light. The reflector and tube may be mounted in any position from 7° above horizontal to within 10° of the vertical plane.

"The auxiliary unit, containing the transformer, is separate from the reflector permitting it to be placed at some distance from it. A 6 or a 9 foot extension cable is provided which permits the reflector and auxiliary to be separated by this distance. The latter is provided with hooks, bottom cover and tilting brackets. This new equipment is so flexible in design as to meet practically every type of installation. The lamps are attractively finished in mahogany surah. The transmission of the new Nico lamp is between 3030 and 4520 A. U., a much greater range of wave-lengths than that emitted by the old style lamp."

The quoted prices, as of 1938 and f.o.b. factory at Hoboken, range from $50. to $55., depending on the length of tube desired and power available. The tubes range in length from 22 to 50 inches.

This type of lamp is very suitable for permanent installation but not particularly portable and therefore not so adaptable to general field use.

A portable bulb-lamp operating from a 110-115 volt alternating current circuit is also sold through Ward's at a catalogue list-price of $32.50. This unit has the advantage of portability and is less expensive than the Nico unit.

In their catalogue No. 38, 1938, Ward's describe this unit as follows:-

"The light source is a high-intensity Mercury vapour arc enclosed in a bulb. This lamp operates from a reactive transformer producing 440 volts for starting and 250 volts at the arc terminals at a normal arc current of 0.4 amperes.

"The transformer with switch is in a steel box that also acts as a base. From the base projects an 18-inch gooseneck which supports the lamp. The lamp bulb is covered with a cylindrical heat-resisting filter. A chromium reflector shields the eyes from the intense radiations and also concentrates the ultra-violet light. The lamp must be burned about 5 minutes before the maximum brilliance is obtained. When it is once turned off it will not operate again until it has cooled. This usually takes about 5 minutes. The bulb must be operated in the horizontal position. Its life is about 500 hours."

Mercury-vapour lamps of the fused-quartz type are the most suitable source of ultra-violet light for the examination of the fluorescent tungsten mineral, scheelite. This type of lamp transmits an abundance of the shorter wave-lengths of ultra-violet light, especially those in the wave-length region of 2536 Ångström units, the wave-length of one of the principal spectral lines of mercury. Because of the abundance of shorter wave-lengths in the emitted light, this lamp excites fluorescence in many minerals otherwise unaffected, and, in particular excites a very brilliant fluorescence in scheelite.

Several kinds of the fused-quartz type of lamp are made. Portable lamps suitable for use in the field range in weight from 3 3/4 to 25 pounds and in price from about $35.00 to about $100.00 delivered in British Columbia. These lamps may be operated from ordinary dry cells and a transformer or used on any lighting circuit in conjunction with a suitable transformer.

Use of ultra-violet light in detection of scheelite.

Ultra-violet light has recently been widely used by geologists and mine operators in the detection of scheelite. Inasmuch as scheelite is earthy in lustre and varies considerably in shades of white, buff and orange, it is not always distinguishable in ordinary or white light from gangue minerals such as quartz, carbonates and some lime-silicates. In a strong source of the shorter wave-lengths of ultra violet light, however, all scheelite fluoresces, whereas quartz never does and the carbonates only rarely and then usually to a strong pink fluorescent colour easily distinguishable from the usual oyster-white of scheelite. Because of the brilliant fluorescence of scheelite small areas down to pin-point dimensions are readily recognizable on exposed surfaces of mineralized material.

In quartz veins or veinlets in which the scheelite is white in colour and occurs in small grains, it is usually readily detected only by its fluorescence in ultra-violet light.

Scheelite that occurs intimately mixed with sulphides, particularly in a vein in which the proportion of sulphides to gangue is large, is most easily seen by the use of ultra-violet light. The variety and shades of colours possessed by the many different minerals found in calcic-silicate zones makes the field detection of small amounts of scheelite difficult in ordinary light, but relatively simple if made in ultra-violet light.

The detection of scheelite in any new occurrence should always be checked chemically or microscopically. It may be noted that powellite, a mineral commonly occurring with scheelite in calcic-silicate zones, fluoresces strongly and care must be observed that this mineral in particular is not mistaken for scheelite.

In the use of an ultra-violet lamp the best results are obtained in total darkness, especially in underground workings. However, during the daytime an ordinary room which has been darkened will be found suitable.

In the examination of surface workings and outcrops for scheelite, apart from deposits where scheelite is readily recognizable, the writer found that a study of the actual outcrops or workings with the lamp in the field is much more suitable than the method of taking specimens back to camp for study at night or in a darkened room. Examining surface workings at night may be inconvenient, but the results are usually worth it. By observation of the actual outcrop with a lamp, the distribution of the scheelite either within a vein or in an irregular replacement area may be studied and any trends or directions of improved mineralization noted. In addition, the usefulness of sampling may be determined, and if found necessary the nature of the material may be studied, and thus blind sampling avoided.

An ultra-violet lamp may often be used in making a preliminary estimate of the amount of scheelite in the exposures of a vein. This includes determining the total area of exposed scheelite in a measured area of vein-matter. The amount of scheelite can only be satisfactorily determined when exposures are numerous, large, and relatively free from small patches of dirt, moss, or lichen. It is often possible to sweep away such material with a broom or a wire brush.

The areas of scheelite are best measured by means of a comparison card. This is a card in which square holes are cut or punched. The holes range in size from 3 square inches to 0.01 square inch. This card is held in front of the eye, the areas of scheelite in the vein viewed through the square holes and their size compared with that of the measured holes. If the areas of scheelite are larger than 1 square inch, the total outcrop area must be also large to maintain a sufficient disparity between size of individual scheelite grain and total area of exposed vein-matter for a good estimate of scheelite content. It is difficult to estimate accurately the area of a large number of fine grains or specks of scheelite by visual examination. However, fine-grained scheelite is usually evenly distributed within the vein and ordinary sampling methods are satisfactory.

From the area of scheelite and the total area lamped the amount of tungstic oxide (WO_3) in per cent is approximately given by the following proportions:

$$\frac{\text{Area of scheelite in square inches}}{\text{Total area lamped in square feet}} \times 1.2$$

The details of this method of estimating scheelite have been given by Jolliffe and Folinsbee (I, 1942, pp. 91-98). They have used the method in the Northwest Territories and state that "two men can lamp and grade a vein two feet wide and 400 feet long in one day." (Idem. p. 94.)

Ultra-violet lamps are used quantitatively in actual mining and milling operations to make rough estimates of the amount of scheelite present either in a working face or at various places in a mill circuit. After a certain amount of correlation is made between the appearance of an ore-face and assays from the same face, it is possible to tell whether or not the grade of mineralization as seen in ultra-violet light constitutes ore. The use of ultra-violet lamps in routine work of this kind minimizes the amount of rather expensive tungsten assaying necessary. In milling operations, ultra-violet lamps are most commonly used in estimating the percentage of scheelite in products from such machines as jigs, tables and magnetic separators in order to test the efficiency of the machine and to note any changes in the contents of the mill feed. The speed and cheapness with which these observations can be made as against usual long and costly assaying methods, permits repeated checking and, therefore, an increase in total efficiency.

All Plates at the end of the Bulletin, with the exception of Plate IV, were taken under fluorescent light.

MILLING.*

Gravity methods were used exclusively for milling tungsten ore in the past. Within recent years, however, flotation has been employed more and more, until today the greater proportion of concentrates produced have been so treated. Another innovation in late years has been the development of a commercial chemical process for purifying low grade concentrates. The use of flotation, either alone or with gravity, in conjunction with chemical treatment makes possible a material increase in the recovery of tungsten from most ores.

Tungsten minerals have a sufficiently high specific gravity to respond well to gravity separation, but their brittleness gives rise to the formation of excessive slimes during comminution. Despite every attempt to minimize this by stage-grinding with removal of tungsten minerals as soon as unlocked, recoveries seldom exceed 75 to 80 per cent, and are commonly lower. Losses are chiefly confined to the slime fraction of tailings in which tungsten minerals are too fine-grained to be recovered by available gravity methods i.e. jigs and shaking tables.

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* Discussion of milling by J. M. Cummings, British Columbia Department of Mines.

Few gravity mills produce concentrates which are pure enough to meet market requirements without further treatment. Most ores contain sufficient other heavy minerals, such as sulphides and garnet, so that some form of auxiliary treatment is necessary.

Flotation is commonly used to remove sulphides: in some cases from gravity feed, in others from gravity concentrate. The latter, if coarse-grained, is re-ground to reduce sulphides to a size amenable to flotation. In the past pyrite was removed magnetically after being subjected to a magnetizing roast. This practice is still followed in a few mills.

High intensity magnetic separators are used at some plants to eliminate garnet and epidote from scheelite concentrated from low grade products by similar machines.

Owing to stringent requirements in respect to phosphorous, even small amounts of apatite are undesirable. Leaching of concentrates with dilute hydrochloric acid is economically possible unless the phosphorous content is excessively high.

Scheelite, and to a lesser degree wolframite and other tungsten minerals, float readily with such fatty acids and soaps as oleic acid, "Orso," etc. Unfortunately these reagents are not particularly selective and float such minerals as calcite, apatite, etc., almost as well. The separation of scheelite from silicates is fairly sharp, however, and with certain ores it may be possible to produce marketable concentrates directly by flotation.

Several mills are treating scheelite ores by straight flotation, the typical flow-sheet used being as follows: ball mills in closed circuit with classifiers, followed by flotation for elimination of sulphides, then flotation for concentration of scheelite.

At a number of gravity mills flotation is used as a scavenger to recover slimed scheelite from tailings. This practice results in a considerable increase in overall recovery over that possible by gravity alone.

All flotation concentrates produced at present are relatively low grade owing to the presence of calcite and other floatable minerals in the ores treated. Several methods for purifying them are used:

1. Chemical treatment by the process developed by U. S. Vanadium Corporation.

2. Tabling of flotation concentrate.

3. Acid-leaching.

1. Chemical plants for purifying low grade tungsten concentrates are operated by the U. S. Vanadium Corporation at Bishop, California, and at Salt Lake City, Utah. In brief the process is as follows: Finely ground concentrates are digested with sodium carbonate solution at high temperature and pressure, thus converting scheelite to soluble sodium tungstate. The solution is filtered, then treated to remove molybdenum and certain other impurities. Tungsten is then precipitated in the form of calcium tungstate by the addition of lime, or calcium salts. The synthetic scheelite thus obtained is very pure.

This process was developed in the first place to treat, in conjunction with flotation, ores containing fine-grained scheelite and undesirable impurities such as phosphorous, molybdenum, etc., which could not be easily eliminated by other methods.

2. Flotation concentrates are commonly passed over slime-tables to produce high-grade marketable concentrates, and low-grade tailings. The latter may be treated chemically as above. Tabling of this material is relatively inefficient and recoveries rarely exceed 60 per cent.

3. Acid-leaching for removal of carbonates and other soluble ingredients is employed in one or two instances to raise the grade of concentrates to market specifications.

The applicability of this process depends upon the nature of impurities in the concentrates, as well as upon the amount of acid required for their removal.

References may be consulted for more complete data on the milling of tungsten ores in Section II of the bibliography.

The following is a list, quoted verbatim from the Northern Miner (November 19, 1942, p. 5) of Canadian plants in which, according to Eardley-Wilmot, tungsten ores are being or will be treated in the near future:

Department of Mines and Resources, Ottawa

Nova Scotia Technical College, Halifax

Indian Path Tungsten Mines, Lunenburg, N. S.

Provincial Mines School, Val d'Or, Que.

Sullivan Consolidated Mines, Cadillac, Que.

Central Cadillac, Cadillac, Que.

Hollinger Consolidated Gold Mines, Timmins, Ont.

Little Long Lac Gold Mines, Geraldton, Ont.

Pickle Crow Gold Mines, Pickle Crow, Ont.

McKenzie Red Lake Gold Mines, Red Lake, Ont.

International Tungsten Mines, Ltd., Outpost Island, Northwest Territories.

Ruth Mines of the Consolidated Mining and Smelting Co., Yellowknife area, N. W. T.

Goodrock Gold Mines, Yellowknife area, N. W. T.

Consolation Lake Mine, Yellowknife area, N. W. T.

War Metals Research Board, University of B. C., Vancouver, B. C.*

Red Rose Mine, Hazelton, B. C.

Bralorne Gold Mines Ltd., Bralorne, B. C.

Consolidated Mining and Smelting Co., Trail, B. C.

Selkirk Tungsten and Tin Mines, Ltd. (Regal Silver), Albert Canyon, B. C.

Emerald Mine, Salmo, B. C.

Department of Mines, Victoria, B. C.*

ECONOMICS OF TUNGSTEN.

Scheelite is customarily marketed as a concentrate or high-grade cobbed ore that contains 60 per cent or more tungstic oxide (WO_3). Payment is made on the basis of so much per short-ton unit or 20 lbs. in the United States and Canada, and per long-ton unit of 22.4 lbs. in London.

Prices. The price paid for tungsten on a basis of content of tungstic oxide (WO_3) varies. Ores from different districts are quoted at different prices, the premiums or discounts varying with the buyers. Furthermore, the grade of concentrates and limitations of impurities vary with the requirements of the individual buyer and at times with the market. In periods of great demand for tungsten lower grade ores can be sold, but at a discount.

The price graph in (Fig. 1), shows the yearly average price of

* The War Metals Research Board and Department of Mines, Victoria, do test work only.

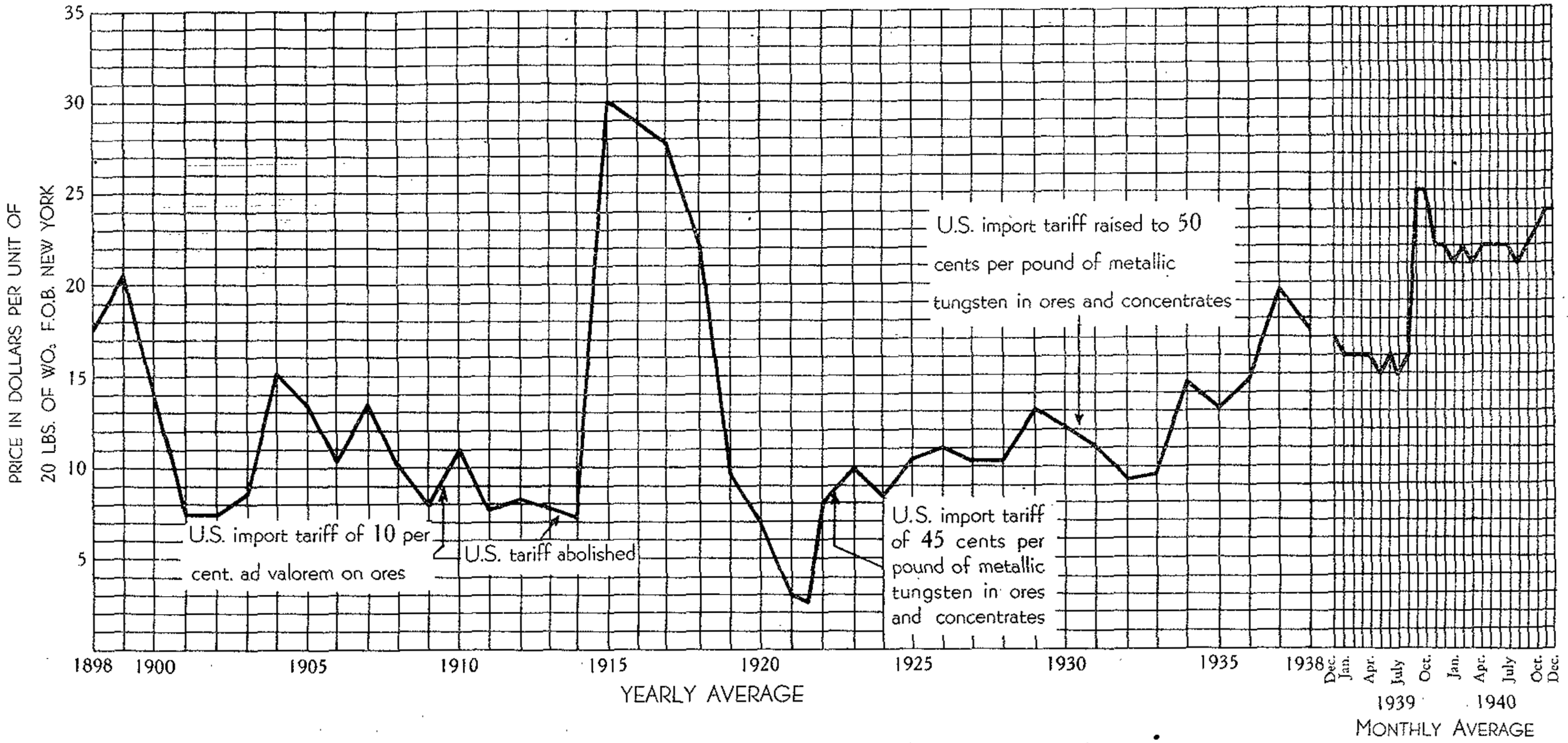

Fig. 1. Graph showing yearly average prices of tungsten for period 1898 to 1938, inclusive, and the monthly prices as of the first few days of each month for period December, 1938, to December, 1940. Sources of information from: Hutchinson and Mann (1928, p. 46); Minerals Yearbook, U. S. Bureau of Mines (1936, p. 448; 1939, p. 623); Engineering and Mining Journal, issues for months December, 1938 to December, 1940.

Note: The Canadian price, as of March 1st, 1943, is $26.50 per unit of contained WO_3.

tungsten for the period 1898 to 1938, inclusive, and the monthly price as of the first few days of each month for the period December 1938 to December 1940, inclusive. The prices are given as f.o.b. New York rather than f.o.b. London, because the economics of tungsten production in the United States is more nearly similar to that of Canada than of Burma or China, the source of most of the tungsten supplied to the London market previous to the present war.

In 1940 the price in Canadian markets for tungsten approximated the New York price less the United States import tariff of $7.931 per short-ton unit of tungstic oxide (WO_3) in ore and concentrates. The quoted price (E. and M. J. Metal and Mineral Markets, New York, Nov. 28, 1940) for tungsten ore, f.o.b. New York was $24.00 nominal per short-ton unit of tungstic oxide (WO_3) for domestic (United States) scheelite ores of good known analysis in carload lots. The prices at that time on Chinese and Bolivian ores, duty paid, f.o.b. New York ore were $24.50 and $23.50 to $24.50, respectively.

At the present time, February, 1943, the Metals Controller, Ottawa, Canada, is paying $26.50 per short ton unit of contained tungstic oxide (WO_3). The specification for acceptable ores are discussed on pp. 29 to 35 of this report.

Mineable Grades. The figures for mineable grades of tungsten ores depend on several factors. In a prospect or small operation they depend on whether, (1) the ore is mined selectively and the tungsten mineral cobbed from the gangue and wall-rock and shipped as high-grade raw ore, or (2) whether the vein-matter is mined across a width of say 3 feet or more and, the tungsten minerals plus gangue and rock mined and milled to a tungsten concentrate of shipping grade.

Because tungsten is a relatively high-priced metal it permits hand-cobbed ore to be shipped direct. On a small scale it is possible to sort ore from a quartz-scheelite or quartz-carbonate-scheelite vein as little as 1 inch in thickness. In general for hand cobbing the scheelite should constitute about one-quarter of the vein-matter and be in grains not smaller than 1/2 - inch diameter and not intimately mixed with the gangue. An ultra-violet lamp is a very useful aid in distinguishing scheelite from waste in any hand-sorting operation.

The method of mining lower-grade tungsten ore for milling is in general similar to that of other ores. The mineable grade depends on whether or not the ore-body is an irregular replacement (pyrometasomatic) type or a relatively more regular vein-type, and if the latter, whether it is a single vein or several veins or veinlets close enough together to be mined as a whole. The nature of the ore-body will determine the mining method to be adopted. Distance from transportation also plays an important part.

Specifications of marketable product. At the present time British Columbia tungsten ores or concentrates may be readily marketed through the Metals Controller, Department of Munitions and Supply, Ottawa, Canada. Export permits from the Metals Controller are required on shipments outside of Canada for any tungsten-bearing ore or concentrates.

The Ore Dressing and Metallurgical Laboratories of the Department of Mines and Resources, Ottawa, have been accepting scheelite ores for customs concentration at Ottawa. An information circular on tungsten ores and concentrates, issued by the Ottawa Department on October 23, 1942, and revised January 27, 1943, gives the necessary details on specifications, prices and freight rates and methods of payment. This circular also quotes information received from the U. S. Vanadium Corporation, New York, concerning the purchase by them of low grade tungsten concentrates, or middling products, for treatment in their chemical plant at Salt Lake City, Utah.

Because the above-mentioned information circular contains many important details covering the sale of tungsten ores and concentrates at the present time, it is quoted in full.

"OTTAWA, CANADA

January 27, 1943.

INFORMATION CIRCULAR ON TUNGSTEN ORES AND CONCENTRATES*

"Beginning January, 1940, the Bureau of Mines at the Ore Dressing and Metallurgical Laboratories, have been accepting scheelite ores for concentration by gravity methods, followed by removal of sulphur by flotation of these concentrates. The following details apply to shipments of ore consigned to the Laboratory for custom concentration.

(1) Ore in carload lots can be handled when received at intervals of approximately from 2 to 3 weeks. Shipments from 200 pounds and upward are accepted. These small lots are accumulated until 2 or more tons are on hand before starting to mill.

(2) Concentrates are purchased by the Metals Controller, Department of Munitions and Supply, Ottawa, Freight rate on concentrates from Ottawa to destination is charged to the shipper. There is also a cartage charge of about 80 cents a ton from Ottawa freight siding to the Laboratory crushing floor.

* Published with the permission of the Department of Mines and Resources, Ottawa, Canada.

(3) Prices paid by the Metals Controller are $26.50 per short ton unit of contained tungsten trioxide (WO_3).

Specifications required by Atlas Steels are as follows:

Tungsten trioxide	WO_3	70%	
Sulphur	S	0.5% max.	
Phosphorous	P	0.05%	
Manganese	Mn	1.00%	
Copper	Cu	0.05%	
Arsenic	As	0.10%	0.25% max.
Antimony	Sb	0.10%	
Tin	Sn	0.10%	
Molybdenum	Mo	0.10%	
Lead	Pb	0.10%	
Bismuth	Bi	0.10%	

In exceptional cases, material running as low as 65% WO_3, with correspondingly low impurities, will be accepted.

(4) Our charges for sampling and milling are $5.00 per ton or fraction thereof. Buyers require a complete analysis of each lot of concentrate shipped to them. They accept our analysis for which our fee is $25.00. When the concentrates from the ores of more than one shipper are combined to make one shipment to Welland, the cost of the analysis is distributed pro rata amongst the interested parties.

(5) No special arrangements have been made with the railroads to handle less than car load lots to Ottawa. Freight rates from various points on these shipments with a declared value of less than $100.00 per ton are:

From	Vancouver	$2.81	per 100 lbs.
	Slocan, B. C.	2.80	
	Waterways, Alta.	3.10	
	Winnipeg, Man.	1.87	
	Hudson, Ont.	1.14	
	Geraldton, Ont.	0.95 1/2	
	Timmins, Ont.	0.78	
	Kirkland Lake, Ont.	0.72	

Falconbridge, Ont.	0.55 1/2
Dupuy, Que.	0.79
Truro, N. S.	0.81

(6) All financial settlements on the concentrates are made by the Metals Controller direct with the shipper. We furnish all data relating to the shipments, analysis, percentage to be credited to each shipper, and a statement of our charges. With the consent of the owners, the Metals Controller agrees to collect our charges, deducting these from their remittance to the interested parties. When small lots from various sources are milled together, each lot is analyzed and the proceeds are distributed in proportion to the weight of WO_3 contained in each lot.

(7) Gravity concentrates containing sulphides are brought up to grade by removing these sulphides by flotation. These concentrates usually contain gold and are returned to the shipper if they so desire.

(8) Normally no attempt is made to recover gold from the shipments apart from by flotation of sulphides. In exceptional cases, such as placer material containing high gold values, free gold is recovered by amalgamation and the bullion sent to the Royal Canadian Mint who issue their cheque payable to the shipper.

(9) Shipments of Wolframite, Ferberite, or Hubnerite are accepted and brought up to grade. Disposal of this class of material is taken care of through the Metals Controller's Office, Ottawa.

(10) The Metals Controller is the only buyer in Canada at the present time and they require the specifications as outlined under (3) and so does anyone else who is making ferro-tungsten direct. Actually a 70% grade of concentrate is obtained from a clean gravity concentrate when impurities such as sulphur, phosphorus, arsenic, lead, and zinc are brought down to specification requirements. For example, a 65% WO_3 product is good if it contains no sulphur or other impurities of the above nature. Silica and iron are not considered as detrimental impurities.

(11) Shipments should be addressed to the Metallic Minerals Division, Bureau of Mines, 552 Booth Street, Ottawa. The material if not in carload lots, should be bagged and preferably sent prepaid freight. If it is inconvenient to ship prepaid, they may be sent freight collect. We then will collect the freight charges through the Metals Controller.

(12) Normally our recoveries range from 70% to 85%, depending on the grade and character of the ores received. Investigational work done on our gravity mill tailing shows that an additional recovery can be obtained by flotation. This produces a low grade WO_3 concentrate of approximately 10%. The overall recovery by table and flotation concentration is 90% or better.

(13) Information has been received from the United States Vanadium Corporation, New York, concerning the purchase of low grade tungsten concentrates originating outside of the United States. This is in the form of a copy of a letter addressed to Mr. G. C. Bateman, Metals Controller, Department of Munitions and Supply, Room 221, No. 3 Building, Ottawa, Canada. Since that time the unit price has been raised.

This states that the communication contains revised information applying to Mexican and Canadian ores and concentrates. Requests for information about contracts from Canadian producers should be addressed to Metals Reserve Company, 811 Vermont Avenue, N. W., Washington, D. C.

Also--quotation--'It is possible that some of the Canadian producers may make a low grade middling product, the treatment of which we would be glad to consider at the plant operated by the United States Vanadium Corporation as agents for the Metals Reserve Company at 568 West 8th South Street, Salt Lake City, Utah, U. S. A., on approximately the following terms:

'The price per unit of contained tungsten trioxide WO_3, delivered f.o.b. railway cars at Salt Lake City, Utah, U. S. A., treatment plant of buyer, shall be all fractions in proportion.

WO_3	Per Unit
3%	$ 9.73
4%	10.77
5%	11.40
6%	12.65
7%	12.82
8%	13.58
9%	14.17
10%	14.65
11%	15.03
12%	15.35
13%	15.63
14%	15.86
15%	16.06

'Canadian shippers desiring to dispose of low grade concentrates should get in touch with the Salt Lake City office as noted above.

'These terms and conditions are subject to withdrawal or change at any time without notice.'

(14) Accompanying the communication was a schedule of prices for tungsten ores and concentrates of higher grade than the above.

Quotation--'The present purchasing policy of Metals Reserve Company is subject to change without notice and the terms and provisions of each contract will be based on conditions and circumstances existing at the time the contract is negotiated.

'Purchase of such tungsten ores and concentrates will be considered under the following general specifications and prices (more detailed information can be obtained by submitting an analysis of the material offered when applying).

'<u>Quantity</u>--Minimum of 1000 short ton units of contained WO_3 deliverable before March 31, 1943, in lots of not less than 5 short tons of ore or concentrates, the material to be packed in suitable containers.

'<u>Price</u>--The base price per short ton unit of contained tungsten trioxide (WO_3) delivered f.o.b. railway cars at such point as Metals Reserve Co. may designate, shall be as set forth in the table following (all fractions in proportion) less penalties as hereinafter specified:

Base Price Per Short Ton Unit

% WO_3	Scheelite Ores & Concentrates	Wolframite Hubnerite-Ferberite Ores & Concentrates
65 & over	$ 21.00	$ 21.00
64	21.00	20.95
63	21.00	20.91
62	21.00	20.86
61	21.00	20.86
60	21.00	20.77
59	20.91	20.68
58	20.82	20.59
57	20.73	20.50
56	20.64	20.41
55	20.55	20.32

(14) (Cont'd)

Base Price Per Short Ton Unit

% WO_3	Scheelite Ores & Concentrates	Wolframite Hubnerite-Ferberite Ores & Concentrates
54	$ 19.46	$ 19.23
53	19.37	19.14
52	19.28	19.05
51	19.19	18.96
50	19.10	18.87
49	19.01	18.78
48	18.92	18.69
47	18.83	18.60
46	18.74	18.51
45	18.65	18.42
44	18.56	18.33
43	18.47	18.24
42	18.38	18.15
41	18.29	18.06
40	18.20	17.97

Penalties

Scheelite Ores and Concentrates --		Per Short Ton Unit of WO_3
Arsenic	- over .5 but less than 1%	15¢
	1% or over	30¢
Sulphur	- over 1% but less than 1.5%	1.00
	1.5% or over	1.25
Copper	- over 0.2% but less than .5%	1.00
	0.5% or over	1.25
Tin	- for each .1% above .5%	.03¢

If a shipment consists of mixed scheelite and wolframite material, it will be classified under the scheelite schedule, or under the wolframite schedule if its WO_3 content is predominantly of the wolfram type.

'Buyer will make customs entry at port of entry and will attend to all phases of United States import duty. All other charges, including taxes and export duties, are for the account of and are to be paid by seller.

'Weighing, Sampling, and Analysis--Each shipment shall be weighed, sampled and assayed on arrival at treatment plant by Ledoux & Co. Inc., New York, whose results shall be final and shall be the basis of settlement. Expenses of weighing, sampling, and analysis shall be shared equally by buyer and seller.

'Payment--Payment will be made by buyer for each shipment promptly after determination of weights and analysis.

'The term "ton" used above means a short ton of 2000 pounds avoirdupois, dry basis and the term "unit" means a short ton unit (20 pounds avoirdupois dry weight). The money mentioned is United States currency.

'Applications for Contracts--Requests for information about contracts for such tungsten ore and concentrates should be addressed to Metals Reserve Company, Washington, D. C., and should contain the following information.

(1) Name of applicant, with business references and a statement of experience in connection with mining the above types of ores, other ores or non-metallic products.

(2) Description of mining property from which it is expected to offer production, with data to show that ore is available, or can probably be made available in quantity to meet the contract requirements.

(3) Statement of the tonnage offered for sale, rate of delivery, complete analysis of the ore to be delivered, and the location on the railroad from which shipment will be made and port of entry into the United States.'

(15) Before taking up the matter of the sale of tungsten ores or concentrates with the Metals Reserve Company, Canadian producers should communicate with Mr. G. C. Bateman, Metals Controller, Department of Munitions and Supply, Ottawa, Canada. Export permits are required on all classes of tungsten bearing material."

Production. The world output of tungsten by countries producing over 100 tons in 1938 is given in Table III, and a graph showing world production from the year 1895 to 1937 is given in (Fig. 2).

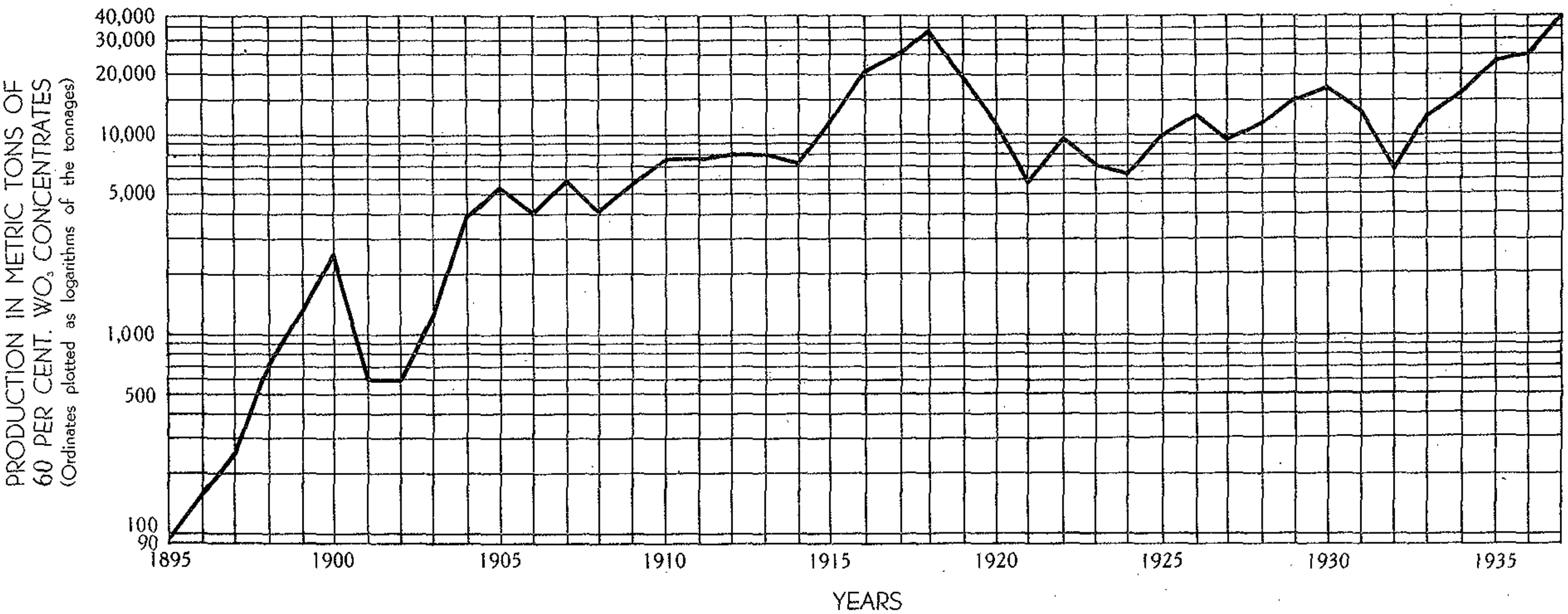

Fig. 2. Logarithmic curve showing world production of tungsten by years from 1895 to 1937, inclusive. Data compiled from Mineral Industry, by G. A. Roush (1931, p. 564); Minerals Yearbook, U. S. Bureau of Mines (1932, pp. 276-277; 1936, p. 453; 1940, pp. 14-15); Hutchinson and Mann (1928, p. 46).

TABLE III - World Production of Tungsten Ores in Metric Tons of Concentrates containing 60 per cent, Tungstic Oxide (WO_3) for Countries Producing over 100 tons in 1938; and arranged by countries in order of importance during the year 1938.

(As abstracted from compilation by M. T. Latus, U. S. Bureau of Mines, Minerals Yearbook, 1940, pp. 630-631).

Country	1938	1939
China	13,387	11,580
Burma	6,334	'
Portugal	2,810	3,851
United States	2,761	3,889
Bolivia	2,530	3,334
Argentina	1,195	'
Malay States	1,000	297
Indo China	545	'
Australia	1,185	859
Southern Rhodesia	329	270
Cornwall, England	258	'
Thailand	251	'
Sweden	180	'
Peru	170	'
Union of South Africa	127	100
' Data not available.		

Consumption. The apparent consumption of tungsten by the principal users of the metal is given in Table IV. The figures in this table are the results of calculations made from the figures for production, exports and imports of the various countries as given in the Statistical summary of the Imperial Institute, (III, 1939, pp. 416-420), Mineral Raw Materials (1937, p. 217) and from the Minerals Yearbook, U. S. Bureau of Mines (III, 1939, pp. 620-629).

TABLE IV - Apparent Consumption by Countries of Tungsten by the Principal Users of the Metal

Country	Consumption (reduced to equivalent of 60 per cent. tungstic oxide, WO_3) In Metric Tons				Per cent. of Consumption by Countries Listed			
	1934	1936	1937	1938	1934	1936	1937	1938
Germany	4,700	10,060	13,000	16,340	27.0	38.3	41.0	60.5
United Kingdom	3,900	10,260	10,100	7,750	22.4	39.3	31.9	28.7
United States	3,020	5,850	8,580	2,910	17.5	22.4	27.1	10.8
Belgium-Luxemburg	2,100				12.1			
France	1,800				10.3			
U.S.S.R.	800				4.6			
Japan	1,070				6.1			

USES OF TUNGSTEN.

Tungsten is consumed mostly in alloys used in the manufacture of cutting tools and dies. Such alloys retain their hardness and strength at high temperatures and can therefore take a heavier cutting load on harder materials than the ordinary carbon steels.

The following four types of tungsten alloys are used either for the manufacture of dies or cutting tools or both:

1. cemented tungsten carbides,
2. high temperature tool steels,
3. stellites, and,
4. carbon-free-iron-base tungsten alloys.

Cemented tungsten carbides are alloys of tungsten, carbon and cobalt produced by methods of powder metallurgy. In the United States the carbides are manufactured under the trade names "carbaloy," "ferthite," "ferthalloy" and "dimondite." Powder metallurgy is becoming a very important consumer of tungsten and for that reason it will be discussed somewhat more fully than other uses.

In view of the general assertion that powder metallurgy is a recent development, the following quotation from Mining and Metallurgy, American Institute Mining and Metallurgical Engineers, New York, for October, 1940, p. 478, in reference to a powder metallurgy conference held at the Massachussets Institute of Technology in Cambridge, Massachusetts, U. S. A. is of interest:

> "Cyril S. Smith opened the conference with a challenge to any claim that powder metallurgy is something of a recent development, stating that the art could be called at least 5,000 years old; iron was made by compressing powder as early as 700 B. C., and Indian smiths of 1,600 years ago fabricated articles of some 6 1/2 tons gross weight by compressing and welding, a size of article that modern powder metallurgists have not yet equaled."

Sykes (1938, pp. 1-2) has summarized the principal steps in the manufacture of cemented carbide alloys as follows:

"1. Formation of the metal carbide in the form of powder by heating a mixture of carbon and the metal powder or oxide for several hours at a temperature between 1500 degrees and 2400 degrees C., usually in a carburizing atmosphere.

2. Intimate mixing of this carbide powder with the binding metal, usually cobalt or nickel, also in the form of powder.

3. Compressing this mixture in steel molds of various designs at a unit pressure of from 15 to 30 tons per square inch.

4. Initial sintering in some inert atmosphere, such as hydrogen, at a temperature of 800 degrees to 900 degrees C., to impart to the pressed metal sufficient strength for handling and shaping.

5. Final sintering at a higher temperature (in the range of 1400 degrees to 1600 degrees C.), which results in a considerable diffusion of the components and a real alloying action. This operation is also carried out in an inert or carburizing atmosphere."

Cemented tungsten carbides cannot be profitably used for all types of dies and cutting operations.

Sykes (III, 1938, pp. 9-10) has summarized the best uses of the different carbides as follows:

"The commercial success of a new alloy depends largely upon the judicious selection of its applications in the field of industry. While physical and mechanical properties may point the way to suitable uses, the final decision must be made from service records extending over long periods of time.

"Upon the basis of such experience, the alloys of tungsten carbide and cobalt that have been described thus far fall into several classes of service, which are determined by the cobalt content, as might be expected. The 13 per cent Co grade is employed extensively in the form of large dies for drawing, extrusion and shaping operations that demand a material of high strength. For smaller dies, and to a limited extent for cutting tools, a 9 per cent Co grade is used. In the field of cutting tools for machining cast irons, most nonferrous alloys and many nonmetallic substances, the 6 per cent Co alloy finds a wide variety of applications. In operations involving fine cuts at high speeds, a tool material containing as little as 3 per cent Co is often employed. In such service, the higher resistance to abrasion contributed by the tungsten carbide constituent in the tool may be profitably utilized, since no excessive demands are made upon its strength or resistance to shock.

"It will be observed that steel was omitted from the list of materials that can be profitably machined with tools of cemented tungsten carbide. The failure of tungsten carbide to cope with the cutting of steel appears to be associated with the higher cut pressures involved in

> such work, which lead to early failure of the tool by the phenomenon known as 'cratering' or 'loading.' In this type of failure, fragments of the steel chip weld to the tool and break out small particles of the carbide alloy, in time causing the cutting edge to crumble."

Previous to the advent of cemented tungsten carbides, and still important, are high-speed tungsten steels, chiefly used for cutting tools. The usual composition of such steels is: tungsten, 18 per cent; chromium, 4 per cent; vanadium, 1 per cent and carbon, 0.6 to 0.75 per cent. (III, Sykes, 1935, p. 387).

Stellite, an alloy containing tungsten, 3 to 17 per cent; cobalt, 45 to 70 per cent and chromium 28 to 35 per cent; is also used for machine tools. Its chief virtue lies in its resistance to tarnish and corrosion, and it is, therefore, used in the manufacture of surgical instruments. Alloys that are also widely used in cutting tools are the carbon-free alloys of iron and tungsten containing, tungsten 20 to 30 per cent; and cobalt, 30 per cent. Tungsten alloys of slightly different composition have been used for hack-saw blades and hot-forming dies.

Tungsten steels with varying amounts of tungsten have been used in the manufacture of armor plates and certain types of projectiles. Such steel has also been used in the lining for cannons.

Unalloyed, metallic tungsten is consumed in the manufacture of electric light and radio filaments. However, although many miles of thin filament wire are made yearly, the actual amount of tungsten used for this purpose is small.

A small amount of tungsten is used in the manufacture of various pigments and in the tanning of white leather.

CHAPTER II

WORLD DISTRIBUTION OF MAIN TUNGSTEN OCCURRENCES

AFRICA

Southern Rhodesia. Southern Rhodesia produces tungsten from lode deposits of scheelite. In 1937 (III, Roush, 1937 p. 612) the chief mines were the Gold Valley, which produces scheelite as a by-product from operations for gold, the Scheelite and the Sequel. It is noted that the Sequel mine operated a 100-ton mill in 1937.

SOUTH AMERICA

Argentina. Tungsten is one of the chief mineral products of Argentina, and this republic ranked sixth in world production of tungsten during 1938. The most important deposits are in the Pampa Range in the Provinces of San Luis and Cordoba. At least 50 small operations were reported active in 1940 (Minerals Year Book, U.S.B.M. 1941, p. 622). In 1941 the largest production came from the Condores Mine (Eng. and Min. Journal, Aug. 1942, p. 103). The deposits are all lode and consist chiefly of wolframite with a smaller amount of huebnerite and scheelite in quartz veins. Cassiterite, mica, bismuthinite, molybdenite, pyrite and galena also occur in the veins. The ores in general range from 0.5 to 1.5 per cent tungstic oxide (WO_3) (III, Roush, 1937, p. 607). Mining and transportation costs are relatively high.

Bolivia. Bolivia, ranking fifth in world tungsten production in 1938 and 1939, is the chief largest producer in South America. The Bolivian deposits, all lode, occur in the "tin-belt" but they are, however, separate from the tin deposits. Most of the tungsten ore is wolframite, and only a small amount scheelite. The main deposits are in the Departments of La Paz and Oruro. Concerning the future of the Bolivian tungsten deposits, the following statement by Lilley (I, 1936, p. 431) is of interest: "Bolivia probably contains the largest quantity of developed medium-cost primary ore in the world."

ASIA

Burma. Burma, ranking second in 1938 in world production, produced most of the tungsten mined in the British Empire previous to the occupation of Burma by the Japanese. The mineral wolframite is the main source of Burmese tungsten. Although it occurs in alluvial and placer deposits most of this mineral was derived from lode deposits. Much of the wolframite is associated with cassiterite, and many mines produced both tungsten and tin. Because of this dual production, the majority of tungsten-tin mines had been able to operate fairly continuously even when prices were low. Those properties producing only tungsten had usually been able to operate only when high prices for the metal prevailed. Most of the Burmese tungsten (IV, Brown, pp. 142-145) came from the Tavoy and Yamethin districts, the Tavoy being the more important district of the two. The largest mines in the Tavoy district were the Hermyingyi, Widnes, Kanbauk, Taungpila and Kalonta. In the Hermyingyi mine (IV, Dunn, 1938), about 60 veins were worked. They range from 10 inches to 5 feet in width and from 500 to 1,100 feet in length. The tungstic oxide to tin oxide ratio (WO_3: SnO_2) is 2:1. The largest mine in the Yamethin district was the Mawchi mine in Karenni where 27 tin-tungsten veins were worked (idem. 1938).

China. Most Chinese tungsten is won from placer deposits of scheelite and wolframite, although it is probable that in recent years some has come from lode deposits. Previous to the second World War Chinese material could be mined, shipped and sold in European and American ports far below the price of domestic ores. The cost of producing tungsten from the Chinese deposits was very low. Lilley (I, 1936, p. 430) thinks that the reason was not due solely to the low cost of labour, but also to the quality and extent of the deposits. The Chinese production came from the provinces of Southern Kiangsi, northern Kwangtung, south-easterly Hunan and north-easterly Kwangsi, all in the south-easterly part of China. Sino-Japanese hostilities have adversely affected the tungsten industry in China.

Indo-China. Indo-China, ranking eighth in world production in 1938, accounted for the largest production from French territory, previous to Japanese occupation of that country.

In general the tungsten, chiefly in wolframite intimately associated with cassiterite, is obtained as a by-product from tin-bearing alluvials.

Malay States. The Malay States, ranking seventh in world production of tungsten during 1938, produced scheelite concentrates from lode deposits. Most of this came from a scheelite-fluorite ore-body at the Krannat Pulai mine near Ipoh in the Federated Malay States and some from mines in the State of Trenganni, the Unfederated Malay States.

Thailand (Siam). The production from Thailand (Siam) was chiefly in the form of wolframite concentrates.

AUSTRALASIA

Australia, Tasmania, New Zealand. Small deposits of tungsten minerals are widespread in Australia, Tasmania and New Zealand. The production appears to have been made chiefly from lode deposits of scheelite.

EUROPE

Cornwall, England. Wolframite and some scheelite, associated with cassiterite, occur in the tin lodes of Cornwall. The deposits of tungsten are not extensive.

Portugal. Portugal is the most important producer in Europe and ranked third in world production of tungsten in 1938. Because of attractive prices offered for tungsten, the production of tungsten ores in Portugal has increased considerably in the last few years. Most of the tungsten ore is mined from deposits of tungsten minerals in association with tin minerals in lode and alluvial deposits in the province of Beira Baixa between the Duro and Tagus Rivers. The tungsten minerals are mainly wolframite and huebnerite, and occur chiefly in quartz veins that cut granites and schists.

U.S.S.R. The production of tungsten from Russia has been small in the past. However, the accounts of new finds, appearing in abstracts of the recent Russian literature, suggest the possibility of increased production. The writer has reference to quartz-wolframite veins in the Transbaikalia region (IV, Fiveg and Dorfman, 1938), to tin and tungsten deposits in the Amur basin (IV, Baturin and Krasnyi, 1937), to quartz-scheelite veins near Sverdlovsk in the Urals (IV, Kolodkin, 1937), to quartz-wolframite veins in the Kazakstan steppes north of Lake Balkash (IV, Nahovnik, 1937), to high-temperature replacement (pyrometasomatic) deposits of scheelite and cassisterite in the Zeravshan Range (IV, Magakyan, 1937), to occurrences, reported to be of economic value, of scheelite in garnet zones in the Minusinsk basin in the Karysch region (IV, Speit, 1934) and to the "Third Year of Five Year Plan" tungsten deposit in the Chelyabinsk region of the Urals (IV, Kolodkin, 1936).

UNITED STATES

In 1938 the United States ranked fourth in world production of tungsten, but in 1939 it rose to third place. Because of incomplete statistics, its position in the years 1940-42 is not known. The production in 1940 by States is given in Table V.

Geologic data concerning several tungsten mines in the United States are given in Table VI. These data are particularly significant because of the geologic similarity between the United States and the British Columbia tungsten deposits. It is hoped that this similarity may aid in the recognition and development of worthwhile tungsten prospects in British Columbia.

TABLE V. United States production by States in 1940*

State	Production in short tons	Equivalent per cent of WO_3 content in quoted figures
California	2076	59.83
Nevada	1748	61.67
Colorado	849	48.95
Arizona	302	69.33
Idaho	240	65
Washington	53	67.78
	33	14
Montana	42	70.62

CANADA (Excepting British Columbia)

The distribution of tungsten minerals in Canada is widespread. Jolliffe (Northern Miner, June 1942, page 26) lists 152 occurrences from the Dominion. Previous to 1940 the greatest number of known occurrences was in Nova Scotia and British Columbia. However, within the last two years, many new finds have been made, particularly on gold properties, in Quebec, Ontario, Manitoba and the Northwest Territories. Of the 152 occurrences mentioned by Jolliffe, many are of mineralogical interest only. A great many of the occurrences are gold mines in which it is possible to obtain enough by-product scheelite to warrant the extra cost of saving it.

Much of the information in the following paragraphs about the occurrences of tungsten in Canada, excepting British Columbia, has been abstracted from a very comprehensive article on tungsten by Eardley-Wilmot (VI, 1942, pp. 51-62).

<u>Nova Scotia</u>. Tungsten occurs in small amounts at many places along the south-eastern coast of Nova Scotia. The deposits are found in quartz veins that are mineralogically and structurally similar to the gold veins of the same region (VI, Newhouse, 1936, p. 827). In general, the quartz veins of this region are bedded with strongly folded Cambrian slates and quartzites which have been intruded by Silurian granitic rocks (I, Lindgren, 1933, pp. 561 - 562). The tungsten mineralization appears to have been concentrated along the crests and troughs of steeply pitching folds.

In 1931, Messervey (VI, 1931, p. 30) summarized the geographic distribution of tungsten minerals in the Province as follows:

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* Data compiled from: Minerals Yearbook, U. S. Bureau of Mines, Review of 1940, pp. 618-620.

TABLE VI - SUMMARIZED GEOLOGIC DATA ON SEVERAL TUNGSTEN PROPERTIES IN THE UNITED STATES
(Listed in order of 1940 production by States)

Property or Mining Company	Tungsten-bearing Mineral	Type of Deposit	References (for complete titles see bibliography at end of report).
CALIFORNIA			
Atolia Mining Co. San Bernardino County	Scheelite	Series of veins in zone of shearing; ore widths usually less than 1 foot, occasionally 5 feet. Ore shoots up to 1,100 feet long and one to 700 feet deep.	V, Hulin (1925, pp. 70-78).
Pine Creek Tungsten Mine, near Bishop, Inyo County	Scheelite	With sulphides in calcic-silicate zone, (tactite).	V, Hess and Larsen (1921, p. 274) U. S. Geol. Surv. Bull. 931E, pp. 89-92, 1941.
Tungstar Mine, Inyo County	Scheelite	Two calcic-silicate (tactite) lenses	U. S. Geol. Surv. Bull. 931E, p. 93, 1941.
Rossie Mine near Bishop, Inyo County	Scheelite	Calcic-silicate (tactite) zone	Cal. Journ. Min. and Geol., Oct. 1938, p. 403, U. S. Geol. Surv. Bull. 931E, pp. 102-103, 1941
Tungstore, Tulare County	Scheelite	Calcic-silicate (tactite) zone limestone foot-wall and granite hanging-wall.	Cal. Journ. Min. and Geol. April, 1941, pp. 318-319
NEVADA			
Nevada Massachusetts Co., near Mill City	Scheelite	Calcic-silicate (tactite) zones known as "ore-beds" usually 5 feet wide by several hundred feet long.	V, Kerr, 1934, p. 21

Silver Dyke Mine, Mina	Scheelite	Lenses of scheelite in quartz veins	U. S. Bur. Mines, Inf. Circ. 6852.
COLORADO Cold Spring Mine, near Nederland	Ferberite	Ferberite-bearing quartz in fissure veins	U. S. Bur. Mines Inf. Circ. 6852; Hess and Schaller, 1914, U. S. Geol. Surv. Bull. 922F, 1940
Conger Mine, near Nederland	Ferberite	Ferberite-bearing quartz in fissure veins	I, Hess, Schaller, 1914; U. S. Geol. Surv. Bull. 922F, 1940.
ARIZONA Boriana Mine, near Kingman	Scheelite and wolframite	In quartz veins in slates and schists	Mining World, March 1941, pp. 9-15
IDAHO Ima Mine	Huebnerite	Huebnerite associated with sulphides in quartz veins	U. S. Geol. Surv., Bull. 931A, pp. 16-19, 1941
WASHINGTON Germania Mine, Stevens County	Wolframite	Lenticular deposits of wolframite in quartz veins with fluorite and tourmaline. Vein averages 2 feet wide.	V, Bancroft, 1914, p. 29; I, Lovering, 1933, p. 667.
MONTANA Jardine Mine, Park County	Wolframite	Wolframite and arsenopyrite in quartz veins that cut Precambrian schists.	I, Lovering, 1933, p. 667.

Halifax county, Moose River, Waverly and Oldham.

Lunenburg county, Indian Path and New Ross.

Queens county, Fifteen Mile Branch and Molega.

Recently the following properties have been examined or prospected for scheelite. Hyland, Sackville, Kirkpatrick (Goff) Guysborough Gold Mines Ltd., Scheelite Mines Ltd. and Indian Path Mine.

In 1940 the Kirkpatrick Tungsten Syndicate (III, Dominion Bur. Statistics, 1940. p. 30) made a shipment of tungsten concentrates from their property at Goff, Halifax county.

New Brunswick. In New Brunswick, tungsten occurs at Burnt Hill, in York county. The deposit (VI, Camsell, 1916, p. 248) consists of a wolframite-bearing quartz vein in argillites that are cut by granite about three-quarters of a mile distant. An all-gravity concentrator was built on this property in 1916, and in 1917 the mill was treating about 15 tons of ore per day, averaging 1 per cent or less tungstic oxide (WO_3) (VI, Gwillim, 1917, p. 197). The only production from this property appears to have been 11 tons of concentrates obtained in 1918 (III, Dom. Bur. Statistics, 1939, p. 30). The property was prospected in 1941 but abandoned because of high costs.

Quebec. In 1939 a tungsten-bearing deposit near Guigues in the Lake Temiskaming area, was prospected (III, Dom. Bur. Statistics, 1940, p. 30).

Scheelite has been found in several of the gold mines in the Province. Lamaque and Wood Cadillac have made shipments to Ottawa and Sullivan Consolidated are saving scheelite from their picking belt and shipping a few hundred pounds each month.

Ontario. Scheelite is found in several of the gold mines. The Hollinger mine has been milling scheelite-quartz ore in a 75-100 ton mill since early in 1942. The Preston East Dome, McIntyre, Dome, and Delnite gold mines have shipped some cobbed ore to Ottawa. Upper Canada Mine is reported (Northern Miner, January 14, 1943, p. 1) to have found considerable scheelite in its underground workings.

The Little Long Lac gold mine is erecting a small customs mill to handle scheelite from its own mine and from other properties in the area.

Scheelite is found in several gold mines in the Red Lake and Crow Lake areas.

The Dome Mines Ltd. is reported (Northern Miner, November 19, 1941, p. 1) to have made a scheelite find of considerable promise a few miles north of the Albany River.

Manitoba. In eastern Manitoba scheelite was found near Falcon

Lake in 1918 and some development work was done during that year (III, Dom. Bur. Statistics, 1940, p. 30). The deposit consists of scheelite in lenticular replacement-zones or veins within schists that are adjacent to large areas of granitic rocks (VI, DeLury, 1918, pp. 186-188); ore is reported (idem. p. 188) to occur in a zone measuring from 3 to 5 feet wide.

Scheelite is also reported (VI, Wilmot, 1942, p. 54) from the Apex mine and others in the Herb Lake area.

Northwest Territories. In the Northwest Territories tungsten has been found at Outpost Islands in Great Slave Lake and in the Yellowknife-Gilmour Lake area.

The Great Slave Lake occurrence (VI, Hawley, 1939, pp. 53-67) consists of mineralized shear-zones in micaceous quartzites. A mill was erected on this deposit by the International Tungsten Mines but it closed down in September 1942.

According to Eardley-Wilmot (VI, 1942, p. 54) Jolliffe and Folinsbee of the Geological Survey of Canada have reported scheelite in about 1000 veins, including the gold mines, in the Yellowknife-Gilmour Lake area. During the summer of 1942 a small mill was in operation on Consolation Lake and another mill was being erected on the Goodrock property on Gordon Lake.

Yukon. Placer scheelite has been found in some of the Yukon placer areas, and small shipments of scheelite have been made from Dublin Gulch and Haggard Creek in the Mayo district. Cairnes (VI, 1916, p. 17) mentions the occurrence of wolframite and cassiterite with the scheelite in this area. The only lode scheelite reported in the area consists of small amounts in quartz stringers that occur in pegmatitic zones within the granite.

Placer holdings on Canadian Creek, northwest of Selkirk, were prospected by Bralorne Mines in 1942.

CHAPTER III

DESCRIPTIONS OF BRITISH COLUMBIA TUNGSTEN DEPOSITS

Occurrences of tungsten minerals are widespread throughout the Province as may be seen on the key map in the frontispiece. Tungsten is found in the Coastal areas, the Northern and Southern Interior and in the West Kootenay district.

Of the tungsten-bearing minerals, scheelite is by far the most abundant in British Columbia. Wolframite, the other common ore-mineral of tungsten, has been found at the Tungsten-Wolframite prospect in the Atlin area, at the Red Rose and Black Prince in the Hazelton area, and in the Sheep Creek area. Tungstic oxide minerals and stolzite, a lead tungstate, have been found in the Taylor prospect in the Cariboo district. Tungstite has also been found in the Reno mine in the Nelson district. Powellite, which is a calcium molybdate and sometimes contains tungsten, commonly forms as an oxidation product of molybdenite in the presence of scheelite. Powellite occurs in some of the high-temperature replacement (lime-silicate) deposits of scheelite in the Southern Interior and West Kootenays. Other than scheelite, none of these minerals afford any promise of tungsten production from the deposits found so far.

In British Columbia scheelite is found in many different types of veins and in high-temperature replacement (lime-silicate) deposits. In the Bridge River area it is found in narrow, carbonate-stibnite veins at the Tungsten Queen and Tungsten King mines, and in gold-bearing quartz-veins in some of the gold producing mines of the district. At the Regal Silver mine near Revelstoke it is associated with lenses of heavy pyrite in quartz veins. In the Cariboo it is found in gold-bearing quartz veins variously associated with pyrite, galena, sphalerite and tetrahedrite. In the Telkwa-Hazelton area it occurs in lenticular quartz veins associated with apatite and orthoclase.

More detailed descriptions of these different types of scheelite veins will be found in descriptions of properties.

In the Nelson area, important scheelite deposits of the high-temperature replacement (lime-silicate) type were found in 1942. The deposits are in limestone and associated sediments close to contact with granite rocks. The mineralization is characterized by quartz, lime garnet, diopside, vesuvianite and in places pyrite and pyrrhotite; magnetite is apparently absent. In some places limestone beds have been completely and uniformly replaced by these minerals and the resulting rock is locally referred to as "skarn." Similar rock associated with scheelite is referred to as "tactite" in California and Nevada. Since the discovery of important quantities of scheelite in the Nelson area, particularly at the

Emerald mine, numerous other discoveries in lime-silicate rocks have been reported from the southern part of the Province. A more detailed discussion of the Nelson deposits and those in the Southern Interior may be found on pages 133-156 of this report.

In common with the Western United States, British Columbia is part of that geologic unit known as the Cordilleran region which extends north-westerly and south-easterly along the westerly part of North America. The deposits responsible for the United States production of tungsten lie within this region, and it is therefore reasonable to expect somewhat comparable deposits in the part of the same region in British Columbia. Because of these favourable conditions, further prospecting for tungsten minerals within the Province, and the development of likely prospects might be expected to yield favourable results.

ATLIN AREA

TUNGSTEN and WOLFRAMITE*

These adjoining groups are at the head of Boulder Creek, one of the main tributaries of Pine Creek. The property was staked by the Consolidated Mining and Smelting Company of Canada Ltd., in 1939.

This company prospected the ground and did extensive stripping and open-cutting on the veins, but in 1942 they turned the work over to Norman Fisher and Ole Olsen. Fisher and Olsen plan to develop the property as an individual operation and to hand sort ore for shipment.

The property is reached by 13 miles of motor-road from the town of Atlin to the Consolidated Camp on Boulder Creek. From thence the showings are reached by trail or easy traverse through open country.

The mineral deposit consists of irregular quartz veins in feldspar porphyry and granodiorite. The quartz is generally barren, but wolframite occurs in very sparse and widely-scattered patches and specks.

A bulk test-sample weighing 98 pounds, stated by the shipper to be representative of the sorted and cobbed product, shipped in December 1942 to the Government Sampling Plant at Prince Rupert, assayed: tungstic oxide (WO_3) 19.5 per cent; manganese, 1.2 per cent; iron, 6.8 per cent; phosphorus, 0.01 per cent; silica, 66.4 per cent.

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* Report by J. T. Mandy, British Columbia Department of Mines.

STIKINE AREA

DEVIL'S ELBOW MT. In 1942 scheelite associated with galena was detected in specimens from this locality.

PORTLAND CANAL AREA

This area lies northerly from Prince Rupert and includes the towns of Alice Arm and Stewart. Stewart is served by coastal steamers from Prince Rupert and Vancouver and Alice Arm by periodical mail boat.

Small amounts of scheelite are found in several properties in the area, but only in the Molly B has it been found even in moderate amounts. Two of the deposits, the Molly B and the Dot and Louise, are high-temperature (lime-silicate) replacement deposits and the others, the Little Pat, Badland, Hogback, Silverado, and the Esperanza, are quartz-vein deposits. Scheelite has also been reported from Lucille No. 1 and showings on Red Bluff Mountain.

The deposits are in sediments and volcanics, although some are close to areas of granitic rocks related to the Coast Range Batholith.

LITTLE PAT, BADLAND and HOGBACK* The Little Pat, Badland and Hogback are situated on the northeast side of Bitter Creek valley east and southeast of the bridge on the Bear River road over Bitter Creek. The claims are held by location by Arthur Cameron of Stewart and his partner Arthur Boyle. On these claims and on open ground adjacent to them there are a number of narrow fissure veins in quartz-diorite which contain quartz, pyrite, chalcopyrite and scheelite. The showings are three-quarters of a mile or less southeast of, and about 1,000 feet above the Bitter Creek bridge and can be reached from that point on foot in half an hour. The bridge is 9 miles by road north of Stewart.

The main showing, on the hogback from which one claim received its name, is at an elevation of 1,200 feet and about 4,000 feet south 40 degrees east of the bridge. It consists of a narrow fissure-vein cutting quartz-diorite. The vein strikes north 30 degrees west and dips at 90 degrees. It varies from 6 inches in width at the main cut to 1 inch or less in cuts about 100 or 200 feet northwest, and to 2 1/2 inches in a cut 25 feet southeast. The mineralization consists of quartz, chalcopyrite, pyrite, locally molybdenite and scheelite. Samples assayed: WO_3, nil, across 6 inches; and WO_3, 0.11 per cent across 3 inches.

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* Report by W. H. Mathews, British Columbia Department of Mines.

To the northwest of the main showing and about 150 feet lower in elevation is another vein, 8 inches wide, striking north 70 degrees west and dipping 85 degrees northeast. It is sparingly mineralized with scheelite. To the northwest and about 50 feet below this exposure is an open-cut on what may be the same vein, measuring from a fracture to 6 inches wide, striking north 40 degrees west and dipping 60 degrees southwest. It is mineralized with quartz, pyrite, chalcopyrite and a little scheelite.

To the northwest and about 100 feet below this last showing is still another vein, from a fracture to 8 inches wide, striking north 45 degrees west and dipping 85 degrees northeast. It consists of quartz with small amounts of pyrite, chalcopyrite and scheelite.

About 100 feet above and to the northeast of the hogback showing is still another vein, or rather a series of lenses of quartz, sometimes with open cavities and comb structure, mineralized with pyrite, chalcopyrite and scheelite. The widths are extremely variable, two or more lenses might parallel each other, each up to 4 and 6 inches in thickness. An average width might be 6 inches. A sample representative of the open-cut assayed: WO_3, 0.12 per cent.

About 1,000 feet north of and at the same elevation as the hogback showing is a quartz vein, striking north 45 degrees west and dipping 60 to 70 degrees northeastward, cutting quartz-diorite and quartz porphyry. The vein is lenticular and varies in width from 3 to 6 inches. It is mineralized with quartz, pyrite, sphalerite, scheelite, some galena and tetrahedrite. It is reported to assay: Gold,0.25 and silver,11 oz. per ton. Assays for tungsten of a composite sample of the vein gave: WO_3, 0.01 per cent; gold, 0.01 oz.; silver, 4.3 oz. per ton.

The occurrences of scheelite in this area offer some promise of interesting quantities, but the existing showings are too low grade and too small to be commercial, even as a by-product of gold production.

LUCILLE No. 1. (UNITED EMPIRE)

Scheelite was discovered in the workings on this claim in the Stewart area by the owner, Ernest Low of Stewart.

LOUISE and DOT*

Two claims, the Louise and the Dot, were staked in August 1942 on a small scheelite showing by Arthur Cameron of Stewart. They are on the steep, lower slopes of the west wall of the Bear River valley, about 4 1/2 miles north of Stewart.

The only workings consist of one old open-cut and a recent small

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* Report by W. H. Mathews, British Columbia Department of Mines.

excavation 20 or 30 feet below it, at an elevation of 400 feet above sea-level, or slightly more than 300 feet above the floor of the Bear River valley. They are reached by a foot-trail, brushed out along the river-flats, leading for 1 3/4 miles from the road-bridge across the Bear River. If the property shows promise of production, a cable bridge could readily and cheaply be erected across the Bear River at this point to the road on the east side. The cuts are in a small draw sloping steeply (35 to 50 degrees) southeastward, amid a number of cliffs and thickly wooded hillside.

Small amounts of scheelite are found in a bed of lime-silicate rock 2 to 6 feet thick and in lenses of the same type of rock from 1 1/2 to 2 feet thick and 3 feet long. Two grab samples, one from a well-mineralized part of a lens, assayed: Tungstic oxide (WO_3), 0.04 to 0.27 per cent.

A large body of granite outcrops 150 feet from the lime-silicate rock and associated metamorphosed sediments.

MOLLY B* The Molly B molybdenite-scheelite showings are on the east bank of Bear River on a steep hillside that extends from the water's edge to an elevation of 105 feet, directly across from the town of Stewart. They are reached from Stewart by row boat.

The property consists of 10 claims, the Molly B, the Gold Axe Nos. 1 to 4 inclusive, the Big Bell Nos. 1 to 4 inclusive and the Big Bell Fraction, held by location by the Stewart Canal Gold Mines Ltd., N. P. L. care of E. T. Applewhaite, Secretary, of Stewart. The molybdenite-scheelite showings are on the Skamakoonst Indian Reserve, and it is necessary to obtain permission to operate from the Department of Indian Affairs. During the last war a small amount of molybdenite was shipped from this property.

The workings consist of 4 open-cuts and 1 short adit on the steep hillside above the Bear River. The lowermost open-cut, at elevation 10 feet has been driven south-easterly for 10 feet, the adit, at elevation 30 feet and 12 feet easterly from the last open-cut, has been driven south-easterly for 10 feet. An upper open-cut, at elevation 50 feet and 40 feet easterly from the lower open-cut, has been driven easterly 6 feet, another open-cut, at elevation 90 feet and 60 feet easterly from the middle one has been driven easterly for 6 feet. The uppermost open-cut, at elevation 105 feet and 12 feet easterly from the last, has been driven easterly for 5 feet. They have all been driven on the same mineralized bed.

The scheelite and molybdenite are found in a band of lime-silicate rock formed by high-temperature replacement of a bed of

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* Report by W. H. Mathews, British Columbia Department of Mines.

limestone. This bed, which strikes south 60 degrees east and dips from 65 to 75 degrees southwestward is 8 feet in width in the lowest open-cut but decreases gradually to a thickness of 2 feet up the hill, then, where next exposed, in the open-cut at elevation 50 feet, it is 4 feet in thickness, and finally, in the uppermost open-cut at elevation 105 feet, it abruptly narrows from 4 feet to less than an inch. The bed can be traced for only a few feet beyond this cut. The rock, originally an impure limestone, has been metamorphosed to a mixture of diopside, garnet, and epidote. Calcite, which may or may not be part of the original limestone, is found in places. This bed, evidently favourable for replacement, has been mineralized with scheelite, molybdenite and pyrite. The adjacent beds, both above and below the mineralized bed, consist of hard, relatively thin-bedded tuff or impure quartzite, often containing significant amounts of lime-silicate minerals, but no excess calcite, and probably for this reason they were unfavourable for mineralization.

Granite is exposed at the river level about 1,000 feet north of the workings. Its contact apparently plunges steeply south and presumably passes under the workings at a considerable depth. Granite outcrops at the river level a little over half a mile south-westerly. Hanson (Geological Survey of Canada, Memoir 159, p. 17) describes an important fault following the Bear River, and maps it as passing approximately 500 feet west of the showings. Whether this fault, if it exists in this vicinity, has had any influence on the mineralization or on the continuity of the limestone horizon, is a problem which cannot be solved at the present time.

The grade of the molybdenite and scheelite is not high. A 360-pound shipment sent to the Government Sampling Plant at Prince Rupert of hand-sorted material taken from the lowest open-cut assayed: Molybdenum, 4.2 per cent and tungstic oxide (WO_3), 1.5 per cent. Impurities included:

Iron	11.0%	Copper	trace
Sulphur	3.5%	Arsenic	trace
Silica	40.4%	Manganese	0.9%
Zinc	0.4%	Tin	trace
Phosphorus	0.24%	Antimony	nil
Lead	trace	Bismuth	nil

A channel sample, taken across the face of the adit, a length of 5 1/2 feet, assayed: Tungstic oxide (WO_3), 0.37 per cent; molybdenum (Mo), 0.17 per cent. A second channel, taken across 4 feet on the cut 90 feet above the river level assayed: Tungstic oxide (WO_3), 0.22 per cent; molybdenum (Mo), 0.02 per cent. A 148-pound sample blasted from the lowest cut and from the face of the adit assayed: Tungstic oxide (WO_3), 0.15 per cent; molybdenum (Mo), 0.2 per cent. Examination with an ultra-violet lamp shows that scheelite is present throughout the exposures, with somewhat lower grade in the constricted parts of the bed than elsewhere. Occasionally high-grade streaks or patches of scheelite-bearing material are found, but these are not sufficiently large to form shipping ore. Elsewhere scheelite is too fine-grained or too uniformly distributed to permit any appreciable concentration by hand-sorting. It is doubtful whether the molybdenite shows the same uniformity of grade throughout the deposit as does the scheelite; in general, it appears to be concentrated in the lower exposures.

RAINIER (SILVERADO)*

Scheelite had been discovered in samples from the lower workings of the Silverado mine by Arthur Cameron of Stewart, and a visit was made to the property by the writer to determine if it existed in commercial amounts.

The lower workings of the Silverado mine are situated at an elevation of from 1,700 to 1,800 feet above sea level on the north fork of Portland creek, a point about 1 1/4 miles southeast of the town of Stewart. They can be reached by a trail, now partly overgrown, leading from the shores of Portland Canal about 1 mile south of Stewart or by way of river flats, rock slides, bush and canyons from the Molly B property on the east bank of the Bear River directly across from Stewart. The main exposure is situated in the bottom of a fairly deep canyon which can be approached from one point. A fixed rope has been installed to aid in the descent.

These workings are situated on the Rainier claim which, together with the other claims of the Silverado group, some years ago reverted to the crown and has since been bonded by the Rainier Syndicate, Incorporated, with registered offices at 122 Pemberton Block, Victoria, B. C.

Small amounts of scheelite are found in sub-parallel quartz veins, 3 to 6 inches wide, which form a network in a shear-zone 4 to 6 feet wide. The shear-zone has been followed for 35 feet by a drift, elevation 1,750 feet, driven northwesterly from the canyon floor.

A sample taken across 5 1/2 inches of the best mineralization assayed: Tungstic oxide (WO_3), 0.22 per cent.

The rocks near the workings are massive volcanics.

RED BLUFF MOUNTAIN

Scheelite has been found by J. Flynn of Alice Arm, on the Washout Creek slope of Red Bluff Mountain.

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* Report by W. H. Mathews, British Columbia Department of Mines.

ESPERANZA*

Scheelite is found in the underground workings of this silver property. The mine is on the west side of the Kitsault River Valley, about 1 mile north of Alice Arm, and is owned by the Esperanza Mines Ltd. (N. P. L.) with registered offices at Victoria.

The rocks on this property include argillites and quartzites. The nearest large area of granitic rocks lies 3 miles to the west.

The workings consist of 10 adits, 5 of which, Nos. 1, 2, 2a, 3 and 4, are on the scheelite-bearing vein and the remainder are on other veins. Adits Nos. 2 to 4 are connected by stopes.

Small, ill-defined patches of scheelite are found in No. 1 adit, half way up the stope connecting No. 2a and No. 3 adits, and in Nos. 3 and 4 adits.

The scheelite occurs in a quartz vein which is mineralized with several sulphides including such argentiferous varieties as freibergite and ruby silver. The quartz vein ranges in width from 3 to 9 inches in general, although in the central part of the workings it widens to about 3 feet.

The scheelite has three modes of occurrence: first, as widely separated patches of small grains within the vein, second, as scattered grains in closely spaced, parallel veinlets of quartz which branch from the main vein at an acute angle and third, at a few places as grains scattered through wall-rock close to the vein.

The size of the areas within which scattered grains of scheelite are found is usually small; the largest of such areas seen was roughly 20 feet in diameter.

Ten samples taken across the best concentrations of scheelite grains in these areas gave an average assay of: Tungstic oxide (WO_3), 0.3 per cent for an average quartz-vein thickness of 14 inches over a possible aggregate area of 500 square feet.

The dump contains only a negligible amount of scheelite.

COAST AREA

PRINCESS ROYAL ISLAND

Gottfrid Knutson, of Butedale, reports finding scheelite in specimens obtained from the Butedale area.

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* Report by W. H. Mathews, British Columbia Department of Mines.

TERRACE - USK AREA

The Terrace-Usk area is in northern British Columbia and centres around two small towns, Terrace and Usk, on the Canadian National Railway, 95 and 107 miles respectively east of Prince Rupert.

Small amounts of scheelite are found in many of the quartz veins in the area and in pegmatite on the Ptarmigan group on Thornhill Mountain.

The Terrace-Usk area is characterized by bodies of granitic rocks ranging from 1 mile to 16 miles in diameter.

BEAR AND CUB

Scheelite has been reported from a quartz vein on the Bear and Cub mineral claims on Maroon Mountain, east of Kitsumgallum Lake. The claims formerly owned by Matt Allard of Terrace are now owned by W. J. Asselstine and associates of Victoria.

THORNHILL MT.

Scheelite has been reported from the St. Paul claim in the Ptarmigan group on Thornhill Mt. (VII, Hanson, 1925, pp. 110 to 118; VII, Marshall, 1926, pp. 39 to 41; VII, Mandy, 1930, p. 78; VII, Kindle, 1937, p. 9), owned by J. A. and A. Michaud of Terrace. The scheelite is found as nodules as much as 3 inches in diameter in a pegmatitic quartz vein that ranges from 6 inches to 2 feet wide and has been traced for 200 feet.

BLACK BULL

Scheelite has been found in workings on the Gem claim by W. Hagen, the owner, of Copper River. The property is on the western shoulder of Kleanza Mountain in the Zymoetz River area.

WHITE BLUFFS

Tungsten has been reported (Jolliffe, Northern Miner, June 25, 1942, p. 26) from this group, owned by T. Turner of Terrace, on the northwest shoulder of Kleanza Mountain, 6 miles east of Terrace (VII, Kindle, Mem. 205, 1937, p. 49).

LUCKY LUKE

Tungsten has been reported (Jolliffe, Northern Miner, June 25, 1942, p. 26) from this property on the east slope of Kitsalas Mountain, 1 1/2 miles south-westerly from Usk. The property is owned by L. E. Moodie and R. Lowrie of Usk (VII, Kindle, Mem. 205, 1937, p. 49).

CORDILLERA

Tungsten has been reported (Jolliffe, Northern Miner, June 25, 1942, p. 26) from this property 1 mile south-westerly from Usk. The property is owned by the Usk Mining Co. (VII, Kindle, Mem. 205, 1937, p. 46).

EMMA and I.X.L.

J. Bell, of Usk, reports finding scheelite in the old workings on these reverted Crown-granted claims. The claims lie 1 mile north-easterly from Usk, on the east bank of the Skeena River and about a quarter of a mile from the highway.

RIDGE — J. Bell of Usk, the owner, reports scheelite in quartz veins on this property. The property is 4 miles north of Usk, at an elevation of about 3,000 feet on the ridge between Hardscrabble and Nicholson Creeks on the west side of the Skeena River.

GROTTO — Tungsten has been reported from this group (Jolliffe, Northern Miner, June 25, 1942, p. 26) on Hardscrabble Creek about 1 1/2 miles from Pitman flag station on the Canadian National Railways. It is owned by G. Alger and associates of Usk (VII Kindle, 1937, Mem. 212, p. 38).

ZONA MAY — Tungsten has been reported from this group (Jolliffe, Northern Miner, June 25, 1942, p. 26) on the east side of the south fork of Legate Creek about 14 miles by trail south-easterly from Pacific (VII Kindle, 1937, Mem. 212, p. 38).

TELKWA - HAZELTON AREA

The Telkwa-Hazelton area extends from Telkwa northerly for 57 miles to Hazelton and includes the mountainous country lying west of the Bulkley River and east of the Skeena River. Smithers is the largest town in the area. Telkwa, Smithers and Hazelton may be reached by motor-road northerly from Vancouver, the distances being 773, 781 and 830 miles respectively. They are on the northern line of Canadian National Railways. Hazelton being 80 miles, Smithers 129 miles and Telkwa 137 miles from Prince Rupert.

The tungsten properties in the area include the Red Rose and Black Prince in the Rocher Déboulé range south of Hazelton and the Whitewater in the mountains at the head of the Telkwa River westerly from Telkwa. Tungsten minerals of mineralogical interest only have been reported by Jolliffe (Northern Miner, June 25, 1942, p. 26) from the Rocher Déboulé mine south of Hazelton and from the Mohawk and Higgins north-easterly from Hazelton.

The regional distribution of the Telkwa-Hazelton deposits is significant. They are all either in or close to small batholiths of granitic rocks. The Red Rose and Black Prince lie on the west and east sides respectively, of the Rocher Déboulé batholith, and the Whitewater lies on the east side of a small batholith at the head of the Telkwa River. The Mohawk mine is on the border of a small stock that constitutes Four Mile Mountain, north-easterly from Hazelton, (Kindle, 1942, p. 36) and the Higgins is on the borders of a granodiorite stock about 30 miles east of Hazelton (idem. p. 22).

The close association of the more important deposits with the Rocher Déboulé batholith and the batholith at the head of the Telkwa River indicates that these batholiths and their borders should be prospected for possible additional occurrences.

RED ROSE

This property consists of the mineral claims Tungsten Nos. 1 to 8, inclusive, owned by Mrs. Barbara S. Sargent, New Hazelton P. O. The property is on the west side of the Rocher Déboulé range south of Hazelton, and the workings are between elevations of 5,200 and 6,360 feet on the divide between Red Rose (Balsam) and Armagosa Creeks, westerly-flowing tributaries of Juniper Creek (see Map No. 3 D, Department of Lands, British Columbia, 1937). Juniper Creek flows south-westerly into the Skeena River at Skeena Crossing, approximately 15 miles down-stream from Hazelton.

The Red Rose property was first staked and owned by Messrs. C. Peterson and C. Ek, and preliminary work was done about 1914 (Galloway, VII, 1914, p. 190; 1916, p. 113). Prior to 1923, only the gold-silver showings were explored, the existence of tungsten on the property being unknown. Kindle (VII, 1940, p. 56) mentions this work as follows:

> "The original group of five claims, staked by C. Peterson and C. Ek about 1913, were named as follows: Red Rose, Yellowhammer, Prosperity, Juniper, and Summit. In 1914, a syndicate headed by T. J. Vaughan-Rhys secured an option and drove two adit drifts at elevations of 5,450 and 5,690 feet on a sheared zone that contains a little gold and copper. At elevation 5,150 feet a crosscut adit was driven 430 feet to intercept the downward continuation of the sheared zone, but without success. In 1916 the Skeena Development Company continued the work, driving the adit at elevation 5,450 feet a total distance of 250 feet, and the upper adit a total distance of 160 feet along the sheared zone."

About 1923, tungsten-bearing minerals were recognized in a quartz vein that outcropped on a shoulder 700 feet above the upper-most gold-silver workings. This tungsten discovery was first reported upon by Galloway (VII, 1923, p. 106) and a further description of the occurrence is given by Hurst (VII, 1924, pp. 44-45). It is understood that since the discovery of tungsten little work, other than assessment, was done until the summer of 1940 when the Consolidated Mining and Smelting Company, Limited, optionees, commenced diamond-drilling; this was started after the writer's first visit to the property in July, 1939. Since that time the company has done considerable underground work and early in 1942 they commenced milling.

In addition to the reports mentioned above, the property has been described by O'Neill (VII, 1919, pp. 18-19); Lay (VII, p. 126) and Hurst, (VII, 1927, pp. 49-50).

The property is reached by motor-road from Hazelton to Skeena Crossing, a distance of 15 miles, thence by newly graded road up Juniper and Red Rose Creeks for 11 miles to the main camp and mill at 3,900 feet elevation. From the main camp a tractor road leads up the mountain-side to the mine camp at 5,600 feet elevation. A surface-track connects the mine-camp and the lower adit (as of August 1942) at an elevation of 6,130 feet. A gravity aerial tram 5,240 feet long connects the mine with the mill.

The mountain-side in the vicinity of the workings extends between 1,000 and 2,200 feet above timberline. Slope angles reach 35 degrees or more, and are characterized by alternating rock-bluffs and talus-slides.

The details of the surface geology as interpreted by the present writer are given in (Fig. 3).

The rocks consist of sediments, now mostly hornfels, that have been intruded by sill-like masses of diorite and diorite-porphyry. These rocks strike north-easterly at right angles and towards a large mass of granodiorite, the westerly contact of which lies about 750 feet east of the tungsten showings. The youngest rock noticed was a small dyke of feldspar porphyry intrusive into the granodiorite.

In the vicinity of the workings the sediments are chiefly dense, massive hornfels rocks with 1-inch shaly partings spaced from 6 inches to 2 feet apart. The rocks weather to light-brown but fresh surfaces are grey or brownish as a result of the presence of fine biotite flakes. Well-defined sedimentary banding is lacking and determinations of attitudes have to be made where shaly partings are sufficiently well developed.

Approximately 2,000 feet and beyond to the west, the sediments are still fine-grained, but are definitely more argillaceous, blacker in colour and less massive. The brownish cast on the fresh surfaces is absent. This change is the result of the gradual disappearance of biotite farther away from the granodiorite where the contact metamorphic effects become less pronounced. These rocks are probably argillaceous tuffs.

The diorite and diorite-porphyry are dark grey to greenish weathering rocks, grey to black-white on the fresh surface and massive in structure. Texturally the diorite is fine-grained granitic, most of the grains being approximately 0.5 mm. in diameter. The diorite-porphyry consists of well-shaped plagioclase-feldspar crystals averaging 1 by 2 mm. set in a fine-grained to dense groundmass.

The granodiorite is a massive, light-grey rock and much lighter in colour than any of the other rocks. Although it is fairly even-

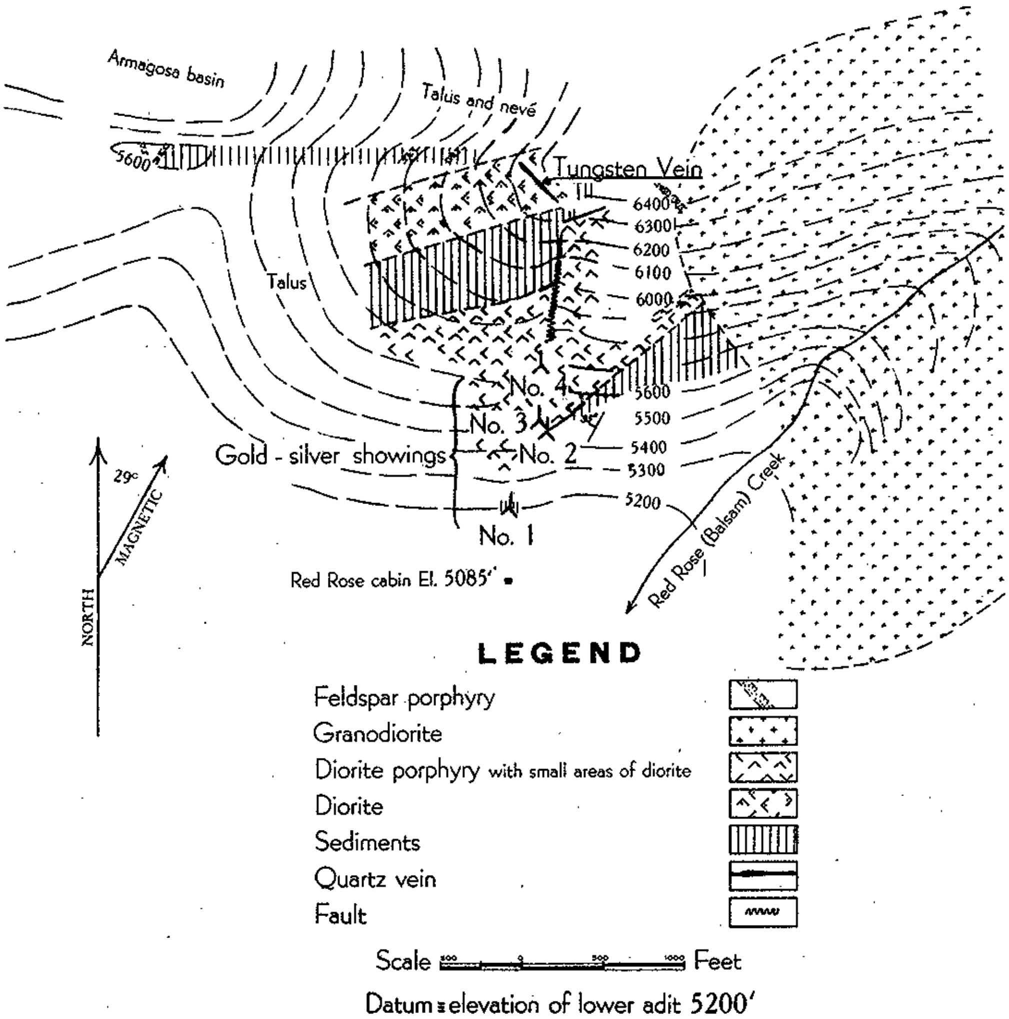


Fig. 3. Red Rose. Plan showing surface workings and local geology. Barometer, pace and compass survey. July, 1939.

grained in texture, the grain-sizes range from 2 to 10 mm. in average diameters.

From the few strikes and dips obtainable the writer concludes that the rocks in the vicinity of the Red Rose workings strike in a general north-easterly direction and dip north-westward. Bedded rocks in bluffs half a mile southerly across Red Rose Creek strike north 35 degrees east and are approximately vertical. The north-westward dip of the sediments in the vicinity of the Red Rose workings, a definite north-westward dip of 35 degrees was observed in the No. 2 adit, is at variance with the general south-eastward dip of the sediments in the Juniper Creek basin as given by O'Neill on the areal map (VII, 1919, Map No. 1731) accompanying his memoir. This variance may be explained by a slight roll or small fold superimposed on the major south-eastward dipping structure.

The major structural features in the vicinity of the workings are a diorite sill about 400 feet thick, and a diorite-porphyry sill about 800 feet thick. These sills strike north-easterly and dip north-westward. The smaller one appears to have had a localizing influence on the main tungsten mineralization.

The mineral showings on the Red Rose property are described under two headings: first, the old Red Rose vein that contains gold-silver and copper on which work prior to 1923 was done; and second, a description of the tungsten occurrences above but on the same hillside. The present work is being done on the tungsten showings. Inasmuch as the present examination was made as part of a general tungsten survey, the gold-silver and copper veins will be referred to only insofar as they have geological bearing on those containing tungsten.

The most recent report on the old workings is by Kindle (VII, 1940, p. 57), who describes them as follows:

> "The No. 1 cross-cut adit, driven 430 feet north at elevation 5,150 feet is entirely in sediments.
>
> "The sheared zone on which most of the early work was done outcrops at intervals up a steep ravine (slope of 34 degrees) between elevations of 5,425 and 5,825 feet. It strikes from north 30 to north 45 degrees west and dips 45 degrees southwest. In the No. 3 adit, at elevation 5,450 feet, the sheared zone ranges from 1 to 4 feet in width. It consists of soft, rusty, pulverized rock largely leached of its sulphide content. An 18-inch channel sample taken across this material, 65 feet from the face of the adit, assayed: gold, 0.015 ounce a ton; silver, 0.09 ounce a ton, tungsten, none. In the No. 4 adit at elevation 5,690 feet the sheared zone is also composed largely of soft, ground-up, rusty, altered rock and has an average width of 3 feet. For 70 feet from the portal the sheared

zone is in sediments, but from 70 feet to the face of the drift the hanging-wall is diorite. Along the part of the drift in the sediments the sheared zone is replaced by considerable vein quartz that carries a little pyrite. A channel sample taken across the vein 50 feet from the portal, where there is a 24 inch width of vein quartz containing 3 per cent of pyrite, assayed: gold, 0.54 ounce a ton; silver, 0.79 ounce a ton; tungsten, none.

"No. 2 adit is 100 feet southeast of and 35 feet below the No. 3 adit. It is driven 50 feet along a vein that lies parallel to the main sheared zone. This vein ranges from 6 to 24 inches in width, and has been traced less than 100 feet. The hanging-wall is diorite and the foot-wall is altered argillite. The vein consists of the following gangue minerals, in order of abundance, hornblende, quartz and biotite, and carries a little pyrrhotite, arsenopyrite and chalcopyrite."

The tungsten occurs in a vein that outcrops on the hillside as shown in (Fig. 3). The vein strikes north 45 degrees west, dips from 55 degrees to 60 degrees south-westward and ranges in width from 18 inches to 8 feet. The exposures, three in number, indicate a strike length of 290 feet and a third reported exposure, covered by snow and ice at the time of the writer's first visit in July, 1939, would extend this length to 330 feet. The vein-matter consists of quartz, orthoclase, apatite, biotite, scheelite, ferberite, a little tourmaline and very small amounts of chalcopyrite and molybdenite.

This tungsten vein is in part a siliceous replacement, along a shear-zone, by murky, grey quartz, and in part a filling of later fractures by veinlets and lenticular areas of white, milky quartz. The milky quartz is the more abundant of the two types of silicification. The extreme width and rather indefinite walls of the vein towards the north-west end of the outcrop is perhaps explained by a gradual silicification of the wall-rock from the central fracture. It is to be noted that most of the later mineralization appears to be confined to the white milky quartz.

Chalcopyrite occurs as scattered grains within milky quartz, and molybdenite as occasional, 1/4-inch sulphide-filled fractures that extend for a length of only a few inches within the quartz.

Orthoclase feldspar, apatite and scheelite, (See Plate 1-A) all nearly colourless, and ferberite, dark brown in colour, not only occur abundantly as clusters either together or separately within the milky quartz, but also in small amounts in the grey replacement quartz. In the most south-easterly exposure scheelite and ferberite occur together in patches ranging from 1/4-inch to 2 inches in diameter. In the most north-westerly exposure the minerals are found separately, the ferberite as irregularly scattered small blades and the scheelite as an indefinite streak of 1/2-inch crystals, the streak ranging from 1/2-inch to 2 inches and traceable for 3 feet before dying out in vein-quartz. Elsewhere, the scheelite, of more widespread distribution than the ferberite, is seen as small grains not readily distinguishable without the aid of ultra-violet light.

Relationship Between the Tungsten Vein and the Old Red Rose Vein.

Whether the tungsten vein and the gold-silver vein of the old workings are one, cannot be proved definitely. Talus between the ends of the two obscures any possible outcrop connection between them. However, certain features indicate that they may be the same vein. The projected strike of either vein on the hillside approximates the position of the other, but they differ mineralogically. The tungsten vein contains scheelite, ferberite, a little molybdenite and chalcopyrite. The gold-silver vein contains a small amount of scheelite, chalcopyrite and safflorite. It may be noted, however, that there appears to be a decrease in the sulphide content of the gold-silver vein up the hill, and the upper part is all quartz and lacking in sulphides. Although there has been a change in mineralogy between the gold-silver showings and the tungsten showings, the minerals in both belong to a group of minerals that characteristically form within the same high temperature range. Therefore, though not definitely proved, it is probable that the tungsten vein is a continuation of the gold-silver vein.

Faulting appears to have occurred along the site of the gold-silver vein. This vein is a mineralized shear-zone that outcrops on the hillside between elevations of 5,750 and 6,100 feet (see Fig. 3), strikes north-westerly and dips approximately 45 degrees south-westward. The shear-zone is marked by well-defined faults for a distance of approximately 500 feet northerly from Number 4 adit (see Fig. 3) and then by a quartz lens, ranging from 1 foot to 5 feet in width and extending from an elevation of 6,100 feet to 6,225 feet. Faulting along this shear appears to have displaced the rocks on either side of it. A specific indication of the amount of the displacement may be seen in the uphill contact of the lower diorite-porphyry sill. The north-easterly extension of the contact has been faulted approximately 400 feet northerly on the slope of the hill. Extensive talus prevents continuous tracing of contacts, but mapping of the rock types on either side of the shear also indicate a northerly displacement of the rocks on the east side of the shear. When this displacement is considered with the north-westerly strike and the south-westerly dip of the fault, it is seen that such a displacement could be caused by a normal fault.

The quartz-sulphide mineralization of the old Red Rose working apparently follows the shear. Judging from the indicated replacement of sheared rock by the quartz in the lens that outcrops between elevations of 6,190 and 6,225 feet, major movements along the shear are considered to have antedated vein-formation.

The tungsten vein is exposed in five and possibly six surface workings which will be described from the south-east to the north-west along the strike of the vein.

Number 1 working, at an elevation of 6,350 feet, is an open-cut that has been driven north 30 degrees west for 12 feet to a 5-foot face. The cut was badly sloughed, but at the top of the face an 18-inch width of vein-quartz was seen. A study of the vein-matter in the dump indicated the presence of a considerable amount of scheelite and ferberite, the scheelite being slightly more abundant. A selected sample of mineralized fragments from the dump assayed: Tungstic oxide (WO_3), 22.2 per cent.

Number 2 working, at an elevation of 6,360 feet and 27 feet north 60 degrees west from Number 1, is a small trench in dirt and talus, no vein-matter is exposed.

Number 3 working, at an elevation of 6,350 feet and 45 feet north 75 degrees west from Number 2, is also a small dirt cut with no vein-matter exposed.

Number 4 working, at an elevation of 6,350 feet and 50 feet north 20 degrees west from Number 3, is an open-cut that has been driven north 60 degrees east for 12 feet. This cut exposes a vein-width of 8 feet. No mineralization other than quartz was seen in the vein-matter.

Beginning at a point, elevation 6,350 feet and 125 feet north 45 degrees west from Number 4 working, the vein is continuously exposed by a rib-like outcrop for 45 feet in a direction north 40 degrees west to an elevation of 6,330 feet. The vein-matter ranges from 6 to 10 feet in width, and consists of quartz with small amounts of chalcopyrite, ferberite and scheelite. A few scattered blades of ferberite only were seen at the south-east end of this outcrop. Scheelite was observed only at the north-west end of the outcrop, where it occurred as an indefinite streak of 1/2-inch crystals in solid vein-matter lying close to and paralleling the foot-wall of the vein. This streak ranged from 1/2-inch to 2 inches in width and could be traced for approximately 3 feet before dying out in vein-quartz; associated fissuring was absent.

Number 5 working, the last to the north-west, is at an elevation of 6,310 feet and 45 feet north 30 degrees west from the north-west end of the outcrop described above. This working was filled with snow and ice at the time of the writer's first visit, but it evidently was an open-cut that had been driven south-easterly, presumably along the vein.

The underground workings consist of two drifts on the vein at elevations of 6,237 feet and 6,130 feet. When the writer visited the property in August 1942 a third low-level adit, at an elevation of

5,920 feet was being started to cut the vein at greater depth. The two upper adits explore the vein for drift-lengths of about 300 and 330 feet respectively. Stopes were started on the vein.

As seen in the drifts, the vein is lenticular, pinching and swelling from a few inches to several feet within drift-lengths of a few feet. The amount of scheelite per lineal foot of vein is usually directly proportional to the width of the vein. However, even in sections of the vein moderately uniform in width, the amount of scheelite varies and results in shoots of good grade ore alternating with those of poorer grade material. Mining has not progressed far enough to determine the exact size and shape of the ore-shoots.

BLACK PRINCE

This property consists of the mineral claims Cariboo and Black Bear, owned by Mrs. Barbara S. Sargent of New Hazelton.

The property is on the east side of Rocher Déboulé Mountain between elevations 4,650 and 5,020 feet at the headwaters of Mudflat Creek, (see Map No. 3 D, Department of Lands, British Columbia, 1937). Mudflat Creek joins the Bulkley River approximately 1 mile above the mouth of the Suskwa River.

Most of the present surface work on the tungsten showings appears to have been done before 1916, as described by Galloway (VII, 1916, p. 118) under the name of Black Diamond. Other than possibly extending the open-cuts a few feet, very little development appears to have been done since that time.

The writer can find no record of production from the property.

The property is reached by following the motor-road for 9.2 miles south-easterly from New Hazelton to a wood-road that turns off to the west. This road may be followed by motor for half a mile and then by foot for approximately 1 mile. Thence a pack-horse trail branches to the north-west and leads to an abandoned camp-cabin 6 miles distant and at an elevation of 4,150 feet.

The mountain-side in the vicinity of the workings is steep and consists mostly of bare rock and talus-slopes that form the south-easterly wall of a large cirque, now occupied by two cirque-lakes, one in a northerly direction 1,000 feet below the workings, and the other in a north-westerly direction, 400 feet below the workings. Water from small glaciers a few hundred feet above, flows into the upper lake and thence cascades into the lower lake about 600 feet below.

A small cabin, now in disrepair, stands on the edge of a small sod-swamp that lies between the two cirque-lakes.

The showings are in a mineralized shear-zone in granodiorite that forms the easterly margin of the Rocher Déboulé intrusive mass. Sedimentary rocks lie approximately 1,500 feet to the north-east and extend in that direction for several miles down Mudflat Creek and across the Bulkley River; in the vicinity of the Black Prince the granodiorite-sedimentary contact trends northerly. The relationship of the Rocher Déboulé intrusive mass to the main east batholith has already been given on pages 59-60.

The tungsten-bearing shear-zone strikes north 35 degrees west, dips from 60 to 72 degrees south-westward and ranges from 18 inches to 2 feet in width. The workings seen by the writer indicate an exposed horizontal length of 80 feet, through a vertical distance of 70 feet, between elevations of 4,950 and 5,020 feet. However, the shear continues north-westerly and south-easterly beyond the extremities of the exposed section. North-westerly, the presence of the shear has been noted by Kindle (VII, 1940, p. 47) at an elevation of 4,650 feet in a cut inaccessible to the present writer. For 500 feet south-easterly beyond the last open-cut the shear may be seen extending up the face of a rock bluff towards the mountain-top. It appears only as a streak of rust in this bluff and probably contains little vein-matter. This indicates a probable horizontal length of the shear, though not necessarily of the vein-matter, of approximately 900 feet through a vertical distance of approximately 600 feet.

The quartz lenses in a shear-zone enclosed in sheared granodiorite are from one to three in number, are generally continuous and range from 6 to 14 inches in width. These lenses contain abundant limonite and small amounts of unoxidized pyrite, molybdenite, ferberite and scheelite. Thin streaks of feldspar crystals and bleached mica flakes also occur in the vein-matter.

Scheelite and ferberite are found as discrete grains in about equal amounts within quartz vein-matter on the dump from an open-cut, elevation of 5,020 feet; none was recognized elsewhere. The scheelite is widely scattered throughout this material as grains averaging 1/16th of an inch in diameter and more rarely as well-shaped crystals measuring about 1/8-inch to 1/4-inch. The ferberite, less widely scattered than the scheelite, occurs in crystals up to 1/4-inch in size. Larger crystals and grains of ferberite have been described in earlier reports, but most of this material appears to have disappeared.

Extreme weathering and oxidation of the exposures is marked. Abundant snow and ice water having relatively easy access to vein-matter plus an original abundance of sulphides along the shear-zone have caused the extreme weathering and oxidation of the sulphides. These processes have resulted in the development of cellular quartz and residual limonitic material left within the cell spaces. The writer believes that weathering, plus oxidation, have decreased the amount of scheelite and ferberite at present visible in the vein-exposures. The existence of more scheelite in the vein-matter before oxidation is suggested by the fact that the unoxidized material carries a larger percentage of the mineral.

Although it is improbable that scheelite would be destroyed by oxidation, a decrease, in the amount originally present in a surface showing, could be attributed to the turbulent and erosive action of the run-off water. This action would be particularly strong at this altitude and on such steep slopes.

The suggestion that more ferberite than is at present seen, existed in the vein-matter before oxidation, is warranted for two reasons: (1) the writer observed small residual fragments of ferberite embedded in crystal-shaped casts of limonite, (2) although ferberite and all other minerals of the wolframite series are commonly considered refractory, its alteration to iron oxide, has been noted by several writers. For a discussion of the oxidation of tungsten minerals (see I, Emmons, 1917, pp. 427-432).

In view of these arguments in favour of the former existence of scheelite and ferberite in now oxidized vein-matter, the writer suggests that an estimate of the tungsten content of the vein can be made only in fresh, unoxidized vein-matter. To obtain this it is necessary to extend the present workings to points below the zone of destructively strong oxidation.

The workings, 500 feet above timber-line, extend up a slide- or talus-filled draw, up the rock bluffs that feed the draw and on to a grassy, partly heather-covered shoulder.

A description of this exploration will begin at the lowest showing on the vein-shear accessible to the writer in July.

Number 1, at an elevation of 4,953 feet, is a small stripping on a 60-degree face, 4 feet high, that exposes a 14-inch width of shear, containing 12 inches of leached quartz mineralized with a little pyrite and molybdenite. Kindle (VII, 1940, p. 47) describes an exposure on the vein at an elevation of 4,650 feet. The guide, John Sargent, advised the writer that the lowermost showing, probably that seen by Kindle at 4,650 feet, was formerly accessible by ladders running across the face of the bluff.

Number 2, 30 feet vertically above and south 35 degrees east from Number 1, is an open-cut that has been driven south 35 degrees east for 15 feet to an 8-foot face. The face exposes a footwall- and hangingwall-shear. The footwall-shear is 8 inches wide at the floor but upwards and towards Number 3 working it dies out to 1 inch. The hangingwall-shear, 20 inches wide, constitutes the main vein-shear, continuing upwards from Number 1 working and past Number 2 to Number 3 and beyond to the last exposure in Number 4. This shear consists of three quartz ribs, 1-inch, 2- and 3-inches wide within sheared and decomposed granodiorite. Three other minor shears in the hanging-wall of this main shear are exposed by adjacent bluff-faces. These shears range from a knife-edge to 3 inches in width and consist of sheared rock and small amounts of relatively unmineralized quartz.

Number 3 working, at an elevation of 5,003 feet and south 35 degrees east from Number 2, is an open-cut that extends south 35 degrees east for 10 feet to the portal of an adit that is driven in the same direction for 10 feet to the face. This combined open-cut and adit is on the upward continuation of the main hangingwall-shear from Number 2 working. This shear is 18 inches wide and contains from 6 to 14 inches of quartz which is badly leached and the cavities partly filled with limonitic material. Some areas of the quartz contained decomposed crystals of feldspar and mica, and the texture suggested pegmatitic material. Small amounts of unoxidized pyrite and chalcopyrite still remain in the quartz.

Number 4 working, at an elevation of 5,020 feet and south 35 degrees east from Number 3, is an open-cut that has been driven south 35 degrees east for 16 feet. It is on the same vein-shear that extends upwards from Number 1 through Numbers 2 and 3 workings. In Number 4 the shear is 2 feet wide at the face and consists of three lenses of cellular quartz, combining a footwall-lens 5 inches wide, a middle lens 6 inches wide and a hangingwall-lens 6 inches wide. With the exception of a few remnant grains of pyrite, ferberite and scheelite, the quartz contained patches of limonitic material only.

The vein-shear has been stripped for approximately 200 feet south-easterly from Number 4 working on the brow of the bluff. However, as seen in this stripping, the vein loses its identity in an almost unrecognizable shear in the granodiorite. In a small pit within the stripping, the granodiorite has been leached for a distance of 1 foot on either side of the vein-shear and has been mineralized with disseminated pyrite.

South-easterly beyond the end of the stripping the continuation of the vein-shear is covered for 500 feet by heather and talus. However, what may be the vein-shear is seen 100 feet above the base of an unscalable bluff 500 feet south-easterly. In this bluff two rusty shears may be seen. These are 6 feet apart and seem to range in width from 6 inches to 1 foot, and one of them seems to contain some quartz. These shears are much less well-defined than the main vein-shear in which the cuts have been made.

About 1,000 feet in a direction north 20 degrees east from Number 1 working, an adit has been driven south-easterly for 125 feet. This adit follows a quartz-sulphide vein that strikes north 35 degrees west, dips 54 degrees south-westward and ranges from 1 inch to 6 inches in width.

The vein-quartz contains small amounts of ankeritic carbonate and clusters of black tourmaline crystals, and is ribboned with moderate amounts of pyrite and chalcopyrite. Small amounts of scheelite are found at places in the vein where the sulphides are most abundant. It is commonly found in parallel streaks with the sulphides. The scheelite grains range in size from pin-points to areas that measure 1/2-inch by 1 inch. They are white in ordinary light and oyster-white in ultra-violet light. A chip-sample taken along the vein at places where scheelite could be seen in ultra-violet light assayed: Tungstic oxide (WO_3), 2.45 per cent; copper, 1.2 per cent; gold, nil and silver, trace. As seen in this adit, the scheelite is not found in amounts either large enough or continuous enough to constitute a commercial shoot of tungsten-ore.

This property was examined in July, 1940, and again in August, 1942.

ROCHER DÉBOULÉ

Tungsten has been reported from this mine (Jolliffe, Northern Miner, June 25, 1942, p. 26) on Rocher Déboulé Mountain about 6 miles south of Hazelton (VII, Kindle, 1940, Mem. 223, p. 50).

MOHAWK

Tungsten has been reported from this property on Four Mile Mountain, 5 miles east of Hazelton (Jolliffe, Northern Miner, June 25, 1942, p. 26). The original owner of the property was E. L. Kinman of Vancouver (VII Kindle, Mem. 223, 1940, p. 35).

HIGGINS (HAEGEN)

Tungsten has been reported (Jolliffe, Northern Miner, June 25, 1942, p. 26) from this property on the Babine trail 30 miles east of Hazelton.

WHITEWATER

The Whitewater group comprises the Whitewater Nos. 1 to 4 mineral claims, staked in July, 1942, by the present owners, Tom Blythman and Jock Wilson of Telkwa.

The claims are on Silver Creek at the head-waters of the Telkwa River, approximately 40 miles westerly from the village of Telkwa on the Canadian National Railways. They may be reached by pack-horse trail from Chapman's ranch, which is 5 miles up the Telkwa River from Telkwa. The ranch, elevation 2,050 feet, is 14 1/2 miles southerly by motor-road from Smithers, elevation 1,640 feet. From the ranch an old pack-horse trail leads up the Telkwa River for approximately 35 miles to Blythman's camp-site, elevation 2,500 feet. From the camp-site a foot-trail 2 miles long follows a side-hill into Silver Creek and then to the showings which are 1,400 feet above the creek at an elevation of 4,680 feet. They are about 200 feet above the timberline.

The showings consist of a lenticular quartz vein that outcrops in the base of a bluff at the top of a long talus slope and in scattered rock exposures amongst talus at about the same elevation as the bluff showings. The vein is intermittently exposed for approximately 350 feet. Scheelite occurs in varying amounts at different places along this vein. The quartz vein ranges from 3 inches to 3 feet in width, strikes north 25 degrees east and dips 25 degrees westward. Southerly the vein disappears under overburden and northerly it dies out against the sheared wall of a north-easterly trending syenite dyke 50 feet wide.

Scheelite occurs in very small quantities at widely scattered points along the outcrop of the quartz, but only at one point is it found in mineable amounts. At this point a short adit has been driven north-westerly down the dip of the vein for 10 feet. It follows two lenses of quartz which branch from the main quartz vein. These lenses comprise a footwall-lens 8 inches thick and 1 foot distant, and a hangingwall-lens 6 to 14 inches thick. Scheelite is abundant in these vein-branches over their full thickness but only for 4 feet down the dip and for an equal distance along the strike. The scheelite ore-shoot probably extends down the dip of the vein beyond the face of the adit. Whether the length of the ore-shoot increases or decreases with depth can only be discovered by sinking on the vein. On the surface the scheelite does not extend beyond the portal of the adit, except for the very small quantities previously mentioned.

The writer sampled the vein in the short adit because this is the only place in the quartz exposures where scheelite occurs in moderate amounts or better. Elsewhere it is readily detectable with an ultra-violet lamp but because of the small amounts and very scattered mineralization, samples would have no significance. The presence of scattered scheelite in these small amounts at places other than in the adit merely indicates that scheelite does occur sporadically over the 350-foot length of the vein.

The samples and resulting assays of samples taken in the short adit are given in the following table:

Certificate No.	Width Inches	Location	Gold oz.	Silver oz.	Lead %	Zinc %	Tungstic Oxide (WO_3)%
367E	10	Footwall-branch at portal of adit	0.50	2.0	2.1	13.0	20.28
368E	10	For 3 feet along hangingwall-branch	0.2	0.8	3.5	3.9	7.42
369E	14	Hangingwall-branch at face	0.44	2.3	5.6	20.2	8.33
370E	6	Hangingwall-branch in north wall	Trace	Nil	0.1	0.9	5.85
371E	8	Hangingwall-branch in the back	0.42	0.4	1.3	2.3	13.98

Because of the isolated position of the property, 32 miles by pack-trail from a motor-road, the small amount of scheelite apparent at the present time (August, 1942), warrants only the cobbing of high grade ore that can be taken out by pack-horses. However, the occurrence of scheelite here, close to the borders of a small batholith, warrants further prospecting of the batholith for other possible deposits of either scheelite or wolframite.

The writer examined this property in August, 1942.

TOPLEY AREA

SILVER CUP — The owner, Mathew Sam, of Topley, has found scheelite in quartz veins in the underground workings on this property on Friday Creek, about 7 miles northerly from Topley Station.

NORTH POINT OF FRASER RIVER AREA

The North Point of the Fraser River area is adjacent to the most northerly point or bend of the Fraser River. The main settlement in the area is Hansard, a station on the Canadian National Railways 46 miles east of Prince George. From Hansard travel is by way of private motor-boats or "kickers" on the river.

The scheelite occurrences on the Ada claim and Silver group in the area have been described by Lay (VII, 1935, pp. c-30 to C-32) as follows:

> "In this region the formation consists of silicified schists, mainly quartz-muscovite schist, quartz-biotite schist, and quartz-sericite schist, in which occur a number of quartz veins. These veins are in most cases sparingly mineralized with pyrite and some contain in addition galena and sphalerite. They vary in width from a few inches up to several feet and have free walls. On the Ada claim, owned by the estate of the late Oscar Eden and developed by an adit and drift therefrom, one vein contains a noteworthy amount of scheelite. This mineral has also been found, although not to the same extent, in a vein on the Silver group occurring in similar formation, situated about 1 mile to the east on Averil Creek.
>
> "Most of the veins exhibit evidence of post-mineral movement, and the two veins in which scheelite occurs also contain considerable amounts of graphite. In no other vein was graphite observed.
>
> "Good water transportation is available for quite large craft between the Canadian National Railways at 'Hudson's Bay Spur,' about 2 miles west of Hansard, and

this property, a distance of about 24 miles. In view of this fact and because of the comparatively small expense involved, some additional development on the vein mentioned on the Ada seems justified to further test tungsten possibilities.

"No commercial possibilities are apparent in so far as gold, silver, or lead contents are concerned.

"Although these properties have been previously examined and an account appears in the 1928 Annual Report of the Minister of Mines, British Columbia, on page 191 and 192, they were re-examined this year, in view of the interest evinced at the present time in tungsten properties, and also because additional work had been done in the interim on the Silver group.

ADA

"This mineral claim, owned by the estate of the late Oscar Eden, is situated contiguous to the eastern boundary of Pre-emption Lot 9606, at the most northerly point and on the right bank of the Fraser river. Low-lying meadow-land flanks the right bank of the Fraser river, extending back for a distance of about 1,500 feet. From this point the valley-rim, covered with dense vegetation and heavily timbered, rises abruptly at an angle of about 40 degrees. The property is readily reached by motor-boat from Hansard, from which it is distant about 25 miles.

"The formation consists of silicified quartz-muscovite schist which strikes north 57 degrees west and dips about 60 degrees south-west. Within this host-rock two quartz veins are exposed in the adit on the property. These conform on strike and dip with the planes of schistosity of the enclosing rocks and are from 3 1/2 to 4 feet in width. Mineralization consists of pyrite, galena, and scheelite. The last-mentioned mineral is exposed, as far as is known, in one vein and only in the underground workings.

"The veins show evidence of intense post-mineral movement and in one case the amount of graphite present is noteworthy. The schist formation gradually passes into an acid rock of granitic texture towards the face of the underground workings.

"The property was originally staked or acquired by the late Oscar Eden, and in 1922 the North Point Mining Company, Limited, was incorporated for its development. This company carried out the underground development described below, and subsequently another company, called the Granite Mining Company, was incorporated for the purpose of operation. No work has, however, been done at this property for more than ten years. It seems evident that the gold-silver-lead possibilities were originally deemed worth investigating as tungsten was not exposed on the surface, nor its extent investigated when found underground.

"Surface workings have now entirely caved, but consisted originally of a shallow shaft 15 feet in depth and a drift 30 feet in length. These workings were driven in a vein 5 feet in width composed of quartz, with pyrite and galena. In the 1922 Annual Report it is stated that this drift 'Shows the vein to be only slightly mineralized.' A sample taken in 1928 from a small dump of the most heavily mineralized pieces assayed: Gold, 0.04 oz. per ton; silver 4.2 per ton; lead, 10 per cent.

"As determined by aneroid this year the elevation of the shaft is 310 feet above the river.

"To explore the region below the above-mentioned vein an adit has been driven a total distance of 675 feet on a bearing north 48 degrees east at a depth of 210 feet below the collar of the shaft. Two veins were cut by the adit--one at 372 feet from the portal and the other at the face. Both veins conform in strike and dip with the enclosing quartz-muscovite schist, striking north 57 degrees west and dipping at about 60 degrees south-west. The former is quartz-filled, sparingly mineralized with pyrite, and 3 1/2 to 4 feet wide. To intercept its north-westward continuation a branch crosscut was run a distance of 65 feet on a bearing north 8 degrees east at a point 340 feet from the portal of the main adit, without results. The vein cut at the face of the main adit was followed by a drift for a distance of 33 feet south-east, and the width showing in the drift-face is 4 1/2 feet. The filling consists of intensely sheared material, quartz, scheelite and graphite. A sample taken across a width of 2 feet at this point assayed: Gold, trace; silver, trace; tungsten, 4.05 per cent. It is evident from a small dump in a shed at the portal of the adit that the small amount of drifting yielded a very encouraging quantity of scheelite. The latter occurs in the form of graphite-coated nodular lumps, due to post-mineral movement, and lends itself readily to sorting by hand. Presumably at the time this mineral was struck the operators were interested only in gold-silver-lead possibilities and did not deem it worth further investigation. This showing appears to merit some further investigation which could be carried out at relatively low cost by hand-mining, because men and material can be transported by motor-boat from Hansard very readily and inexpensively. The advisability of continuing the drift started on the vein in both directions is indicated. A small amount of raising and sinking also seems advisable."

During the summer of 1942, Pioneer Gold Mines of B. C. Ltd. had an option on the Ada claim. The company drove an additional 50 feet south-easterly from the former face of the drift at the end of the long crosscut. This new work exposed scattered scheelite mineralization across narrow widths in short lenticular areas.

SILVER — "This group consists of seven claims owned by Fred Peterson, of Prince George. The property is situated on and about 1 mile above the mouth of Averil Creek, which flows into the Fraser River on the right bank of the latter about 1 mile east of the eastern boundary of Pre-emption Lot 9606. It is readily reached by motor-boat 24 miles from Hansard. The valley is somewhat deeply incised, affording numerous rock-exposures on the rims near the creek. A short distance from the creek, however, the ground is covered with a thick growth of timber and dense vegetation.

"The formation, consisting of silicified quartz-sericite schist and quartz-biotite schist striking from north 77 degrees west to north 52 degrees west and dipping steeply south-west, contains several conforming quartz-filled shear-zones. Of these, only one of possible commercial significance reaches a maximum observed width of 10 1/2 feet and is exposed by surface and underground workings for a distance of 335 feet along its strike. It is filled with quartz-lenses and sheared rock and in the parting seams there is a heavy development of graphite. The quartz is sparingly mineralized chiefly with pyrite galena, and sphalerite, except in one place where heavy pyrite mineralization occurs. Scheelite was observed at one point in the outcrop, but this mineral has not at present been found in the underground workings.

"The shear-zone is cut diagonally by Averil Creek at two points, 135 feet apart, and the surface exposures occur at these points immediately above the creek, also at a third point about 100 feet farther south-east on the line of strike. A 9-foot sample of quartz slightly mineralized with pyrite from the 10 1/2-foot shear-zone assayed: Gold, nil; silver, nil; tungsten, nil. Distant 135 feet on a bearing south 70 degrees east, the second outcrop occurs, on which the adit described below has been driven. The third outcrop is about 75 feet above the adit on the steep bank of the creek. While this outcrop is now rather obscured by sloughing, pieces of solid pyrite were observed at this point and also a little scheelite.

"The adit, 203.5 feet long, is situated a few feet above creek-level, and for the first 126 feet follows a bearing south 77 degrees east, and for the remaining 77.5

feet a bearing south 72 degrees east. At the face on the north side a crosscut is driven a few feet towards the footwall.

"The adit follows the hanging-wall of the shear-zone apparently throughout, the succession of mineralized quartz-lenses occurring on that side. These are to a great extent sparingly mineralized with pyrite and sphalerite. The first quartz-lens, 10 feet long, is 30 feet from the portal. Quartz appears at 65 feet from the portal and again at 120 feet, but is not continuous between these points, although it may exist in the footwall. The quartz-lens is continuous in the back of the adit between points 120 and 150 feet from the portal. At 160 feet another quartz-lens appears and continues for a length of 35 feet. The widest quartz-lens observed was 3 feet. The face exposes a width of 7 feet on the hanging-wall consisting of pyritized silicified quartz-sericite schist and brecciated material, in which are fragments of quartz mineralized with pyrite. The average dip of the hanging-wall in the adit is 76 degrees south-west. At the face the footwall of the shear-zone is not exposed.

"Scheelite, so far as is known, has not been discovered in the adit, although it was observed in the outcrop. As mentioned, the latter is also heavily mineralized with pyrite at one point, but a sample of this assayed: Gold, trace; silver, 0.04 oz. per ton. A sample taken from a quartz-lens at 126 feet from the portal assayed: Gold, nil; silver, nil. The average amount of galena and sphalerite in the quartz-lenses is obviously low. A sample taken of selected mineral only assayed: Gold, trace; silver, 10 oz. per ton; lead, 11 per cent.

"It is suggested that, inasmuch as the general character of this vein is very similar to that on the Ada claim described above, and as scheelite has been found at one point, some prospecting might be undertaken along the out-crop of the shear-zone at points farther south-east of the adit, in the hope that this mineral may be found."

THE CARIBOO AREA

The Cariboo is an active gold-mining area in Central British Columbia. That part with which this report is concerned centres about Wells and Barkerville, two towns, 4 miles apart. Wells, the larger of the two, is 278 miles in air-line northerly from Vancouver. It may be reached by road from Vancouver by following Highway routes 1 and 2 to Quesnel, 448 miles north of Vancouver, thence easterly along the Quesnel-Wells-Barkerville road for 58 miles to Wells. The nearest rail point is Quesnel, the northern terminus of the Pacific Great Eastern Railway. Quesnel is 347 miles by rail north of

Squamish the southern terminus of the railway. Squamish is 50 miles by water from Vancouver and is served by a regular steamer service from that port.

In the Cariboo, scheelite occurs in varying amounts in quartz veins. Scheelite associated with calcic (lime) silicate replacement deposits is as yet unknown in the district.

The scheelite-bearing quartz veins and the gold-bearing quartz veins of the Cariboo occur in slightly metamorphosed Precambrian quartzites, argillites and limestones, known as the Cariboo series. The series has been sub-divided into three formations: the Pleasant Valley, Barkerville and the lowest, Richfield.

Igneous rocks consist of a few dykes and sills of quartz-porphyry and other similar acidic rock-types, known as the Proserpine intrusives. They are considered to be pre-Mississippian and possibly Precambrian in age. Stock-like or larger masses of granitic rocks are absent. There are no large granitic intrusives anywhere in the region, and the nearest small stock-like areas lie approximately 30 miles to the south-west of Barkerville. They consist of outcrops of granitic rocks on the Quesnel River (Lay, verbal communication), a large stock of alaskite on Spanish Mountain (Lay, VII, 1933, p. 135) and small areas of syenitic to monzonitic and pyroxenitic rocks in the Quesnel Forks area (Cockfield and Walker, VII, 1932, pp. 83 to 84).

The main structure in this belt of quartz-scheelite veins is a broad, north-westerly trending anticline, the medial part of which is exposed for a width of 15 miles and a length of more than 50 miles (Hanson, VII, 1935, pp. 1 to 2). With two exceptions, the scheelite occurrences mentioned in this report are on the north-easterly limb of this anticline. The two exceptions are the Taylor and Paxton prospects on the Snowshoe Plateau. These occur on the south-westerly limb at a place approximately three-quarters of a mile from the crest-line of the anticline.

SCHEELITE-BELT

Geographically most of the occurrences of scheelite in the Cariboo are confined to a belt that ranges from half a mile to one mile in width and extends for a distance of 43 miles from Hard-scrabble Creek south-easterly to Limestone Point in the North Arm of Quesnel Lake. Although this belt is also coincident in part with the Barkerville gold-belt it will be referred to as the scheelite-belt in this Bulletin. So far only two scheelite-bearing veins, those on the Taylor and Paxton prospects, are known to occur off the belt.

Geologically the scheelite-belt follows the upper part of the Richfield formation. Where detailed mapping has been done this belt appears to be confined to the Rainbow member in the upper part of the Richfield. So far, no scheelite has been found in any of the formations that underlie or overlie the Richfield. The Taylor and Paxton properties which lie beyond the scheelite belt are probably still in the upper part of the Richfield formation, but they lie south-westerly across an anticlinal axis from those on the scheelite-belt.

South-easterly from the Cariboo Hudson mine, the Cariboo series of rocks, which includes the Richfield formation, begins to bend easterly to form the nose of the large canoe-shaped fold that is shown by Lang on the Little River Sheet published by the Geological Survey of Canada in 1940 as Map 561A. It is not known how this bend in the general strike of the Richfield formation will affect the possible south-easterly extension of the scheelite-belt beyond the North Arm of Quesnel Lake.

Large areas of the Cariboo remain to be prospected. However, because most of the scheelite veins known so far, are confined to a relatively narrow north-westerly-trending scheelite-belt, the writer suggests that the search for tungsten in the Cariboo be confined to this belt. Many of the scheelite occurrences on the belt are very widely separated and much of the intervening ground remains to be prospected.

SCHEELITE IN STREAM GRAVELS

During the 1942 field-season black-sand concentrates from placer operations and gravels from many creeks in the Cariboo were examined for scheelite. These concentrates were studied to determine whether or not they would be worth saving for their scheelite content. Because of the small quantity of black-sand handled during a season and the low proportion of scheelite even in the best concentrates, it was found that such sands could not be considered as an economic source of scheelite.

As an aid in prospecting for lode-scheelite, gravels from many creeks were panned and examined in ultra-violet light. All open-cuts and surface workings which would yield gravels to scheelite-bearing streams were also examined in this way. The combination of these two methods of prospecting was responsible for finding scheelite in out-crops on Penny Creek and Peter-Gulch Creek.

Placer scheelite in pieces ranging from the size of sand grains to pebbles 2 inches in diameter has been found in clean-up concentrates from placer operations on several creeks that cross the scheelite-belt. Concentrates from these operations have yielded small amounts of both sand and pebble-scheelite in the following places: Hard-scrabble Creek, Red Gulch, Lowhee Creek, Stevens Creek, California Gulch and Nugget Gulch. In these concentrates the scheelite is in small quantities and even in the larger placer operations amounts to only a few pounds in total concentrates from a season's clean-up.

Concentrates from placer operations on creeks which do not cross the scheelite-belt contain little, if any scheelite and when present it is usually detectable only in ultra-violet light. Black-sand concentrates from several operations off the scheelite-belt were examined for scheelite but only a few grains were seen in any one sample.

Barite often occurs in black-sand concentrates and because of its high specific gravity is frequently mistaken for scheelite. However it does not fluoresce in ultra-violet light and under such light it is readily distinguishable from scheelite. Much of the material occurring as small, yellowish fluorescent grains in black sands is fluorescent zircon.

In prospecting for scheelite by panning creek-gravels in the Cariboo, care must be taken to avoid gravels which lie downstream from placer operations. These gravels consist mainly of re-worked tailings and consequently are not representative of the original gravel. Even when enough scheelite is present in the original gravel to accumulate as moderately abundant material in placer concentrates, it has been thrown aside into tailings-stacks or periodically washed down the sluice-boxes. In either case, it would tend to be very sporadically distributed in the re-worked tailings found downstream from the sluice-boxes.

Since the origin of placer-gold in the Cariboo is not definitely known, the origin of placer scheelite in concentrates from gold-placer operations is likewise uncertain. However, because of its extreme friability, it is improbable that the medium to coarse scheelite found in placers, has travelled far from its source. The restriction of scheelite-bearing gold-placers to creeks that cross the relatively narrow scheelite-belt, affords proof, in part, that such scheelite has not been carried far from its source.

Scheelite found in creek-gravels upstream from placer-operations, particularly near the headwaters of creeks, is more easily traced to its origin than scheelite which is found in placer concentrates. Gravels in these upstream sections represent a first concentration of eroded material and their scheelite content increases uniformly upstream to the original vein-outcrops. The writer found in the Cariboo, that scheelite, in particles larger than mere specks, did not travel far from its source nor did it become widely dispersed in the creek-gravels. When found in moderate amounts in a pan it could usually be traced easily to its source. Abundant scheelite was found in pans from the gravels of Penny (Copper) Creek for one-half mile downstream from scheelite-bearing outcrops and was also found in gravels from Peter-Gulch Creek over a similar distance downstream from mineralized outcrops.

VEIN SCHEELITE

Scheelite-bearing quartz-veins are found at several places along what has been previously referred to in this report as the scheelite-belt, and also at two properties which lie 5 miles south-westerly from the belt. It is found in minor amounts in many gold-quartz veins in the gold mines in the area. These include the Island Mountain, Cariboo Gold Quartz and Cariboo Thompson mines. The veins in these mines are mineralized with gold, pyrite, arsenopyrite, galena, sphalerite, bismuth-lead sulphide, marcasite, and telluride in a gangue of quartz, ankerite, scheelite and less sericite, (Hanson, VII, 1935, p. 12). In some veins, pyrite comprises 50 per cent of the vein by volume, but in most veins the quantity is much less; arsenopyrite, if present, is always a minor constituent.

In the gold properties, the scheelite occurs as scattered grains or more commonly as nodules, ranging from 1 inch to 6 inches in diameter, within the quartz and sulphides of many of the veins. The distribution of these nodules is very erratic. The chemical and physical factors controlling the localization of the scheelite are not evident, and it is impossible to predict its occurrence within a vein from any local geological or structural features of the vein. In the operating gold mines of the area, the distribution of the nodules is not sufficiently continuous within a vein to warrant mining of even selected sections for scheelite alone. However, it is understood that in 1938, one gold property, the Cariboo Thompson, shipped 4 tons containing 500 lbs. of tungstic oxide (WO_3) from one short shoot of quartz-sulphide ore.

With the exception of the Cariboo Thompson, no attempt to date has been made by the Cariboo gold mines to save the scheelite. This mineral slimes very readily during grinding and although experimental work (II, Leaver and Royer, 1938) has been done on tailings elsewhere and scheelite concentrates obtained, very little has as yet been attempted on a commercial scale. However, it is understood that metallurgical experiments with a definite view of commercial production are being conducted on tailings from one of the larger Cariboo mills.

Scheelite, though not abundant, is the main mineral constituent in the quartz veins on the tungsten properties in the area. It is found with small amounts of carbonate and sulphide in quartz veinlets on the property of the Columbia Tungstens Co. Ltd., on Hardscrabble Creek. It is associated with small amounts of tetrahedrite, sphalerite and galena in lenticular quartz-veins in outcrops on Penny (Copper) Creek on the Rand group. It is found with small amounts of sphalerite and galena in quartz-ankerite replacement lenses on the Cunningham No. 1 and Cutler No. 1 claims of the Cariboo Hudson mine. It is associated with tungstic oxide, stolzite (lead-tungstate) and galena in a quartz lens on the Taylor prospect and with small amounts of galena and pyrite in a quartz vein on the Paxton prospect, both properties on the Snowshoe Plateau.

Quartz veins in the Cariboo, both scheelite-bearing and gold-bearing, may be grouped according to the angular relationship between the strike of the veins and the strike of the enclosing schists.

In general, the schists on the mineralized belt strike north-westerly. The veins may cut the schists diagonally, transversely or may be bedded with the schists, and are accordingly referred to as diagonal veins, striking northerly or easterly; transverse veins, striking north-easterly; or bedded veins, striking with the schists.

Most of the scheelite veins on the south-easterly part of the belt include northerly-striking diagonals and easterly-striking diagonals. Northerly-striking diagonals are found on the Rand group (Cariboo Thompson mine) and, in part, on the Cunningham No. 1 claim of the Cariboo Hudson mine. Easterly-striking diagonals are found south-westerly from the scheelite-belt on the Taylor and Paxton properties. None of these veins can be called transverse veins. One bedded vein was seen on the Cunningham No. 1 claim.

Most of the scheelite-bearing veins towards the north-westerly end of the belt are transverse veins cutting the strata roughly at right angles. With the exception of the veins on the Hardscrabble Creek property of the Columbia Tungstens Company Ltd., these veins are mined for their gold content, and the scheelite, of sporadic occurrence, is only incidental and is not produced commercially. On these properties transverse veins are several times more numerous than diagonal veins.

COLUMBIA TUNGSTENS COMPANY, LIMITED (HARDSCRABBLE)

The Columbia Tungstens Company, Limited, 19 Rector Street, New York City, owns several claims on Hardscrabble Creek; these claims constitute the old "Hardscrabble scheelite deposit." They include two Crown-grants, the Mabel and Dawson, and the following nine mineral claims staked in 1936 and 1938, Mabel Extension, Dawson Extension, Dawson North-east, Dawson East, Dawson South-east, Willow River No. 1, Willow River No. 2, South Mabel and South Dawson. The property extends up Hardscrabble Creek from its junction with Willow River. The main workings are on the Mabel and Dawson approximately half a mile above this junction.

The property is accessible by good motor-road from the town of Wells, 5 miles distant.

Scheelite appears to have been discovered on Hardscrabble Creek in 1904. Mr. W. C. Fry found it in sluices while working his placer claim. The mineral was known locally as barite or heavy spar; however, it was correctly identified in the same year, 1904, by Mr. Austin J. R. Atkin, assayer and metallurgist and associate of Mr. C. J. Seymour Baker. The scheelite, as originally found, occurred only in gravel, but it was soon discovered in place and between 1904 and 1908 a shaft was sunk 30 feet in rock and a drift driven along the scheelite zone for approximately 60 feet.

After 1908 very little work appears to have been done on the property until the summer of 1917 when the old workings were cleaned out and prepared for examination. At that time J. A. Macpherson of Stanley, B. C. was in control.

The workings as of 1918 have been described by Galloway (VII, 1918, p. 135) as follows:

> "Entrance to the workings is by a shaft 60 feet deep, from which a drift extends northerly for 153 feet.
>
> "At this point a winze has been sunk to a depth of 20 feet, and a drift run to the east for 49 feet. The main shaft is in gravel throughout, and the main drift north is in gravel for half its distance before breaking into solid rock.
>
> "Thirty feet below these workings a drain-tunnel 1,900 feet in length was driven to draw the water from the gravel to facilitate the workings of the placer-gravel. South of the main shaft an opening downward connects with this drain-tunnel and the water is carried off. Above the main workings numerous gravel-drifts have been made in the course of mining out the auriferous gravel."

For some time after 1918 the workings seem to have been abandoned, for they are described in 1922 as being inaccessible. However, in 1927, the shaft was repaired and 400 lbs. of ore is reported to have been taken out by C. J. Seymour Baker, who held it under lease at the time from the Government. The property lay comparatively idle until 1935 when the present Columbia Tungstens Company Limited, began a small-scale development programme. The Company milled on its property intermittently from 1937 to July 1941, at first in a small pilot-mill and latterly in a 50-ton mill. Operations ceased in July, 1941.

The workings are on a relatively flat part of a hillside that slopes gently southward down the course of Hardscrabble Creek toward Willow River. The area in the vicinity of the workings is densely wooded and covered with a considerable depth of overburden.

General Statement of local geology:

The rocks, as exposed in the underground workings are mainly grey, fissile quartzites and black to grey phyllites. They range in strike from north 65 degrees east to south 85 degrees east and in dip from 20 degrees to 47 degrees northward, nearly vertical dips were observed in only one place. These rocks are cut by two fault-zones, the larger of which strikes north 20 degrees west and dips steeply south-westward, (Fault-zone A on Fig. 4), and the other strikes in general, north 70 degrees west and dips 60 degrees north-eastward (Fault-zone B on Fig. 4).

Mineralization has been varied, resulting in the formation

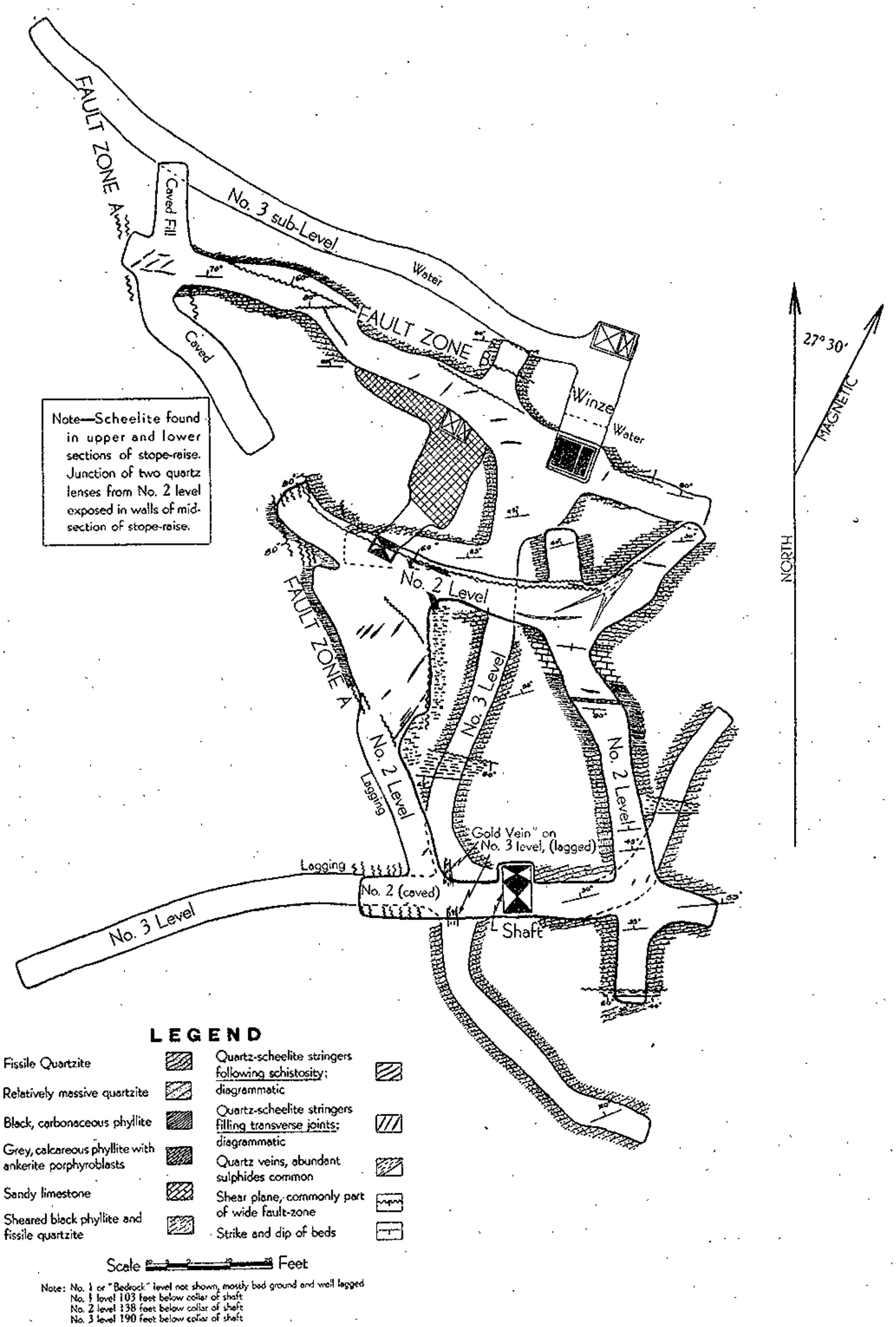


Fig. 4. Columbia Tungstens Company, Limited (Hardscrabble).
Plan of underground workings (after Company's plan)
showing underground geology.

of different types of quartz-sulphide and quartz-carbonate scheelite veins and veinlets which may occupy either faults or joints, or follow the schistosity of the enclosing rocks. The local structural control of the scheelite stringers at the Hardscrabble property, was not evident at the time of the writer's examination (June, 1940).

The property is in an area of rocks mapped as "Cariboo Series (undivided)" by Hanson (VII, 1938, Map 336-A) and no attempt at further subdivision of the rocks was made by him. The property lies across the north-westerly projected position of the Barkerville Gold Belt. However, because of northeasterly-striking faults of unknown displacement that cut the rocks at points between this property and the gold properties in the Gold Belt, it is impossible to establish the stratigraphic position of the Hardscrabble rocks in relation to the rocks of the Gold Belt without further detailed areal mapping. One such fault has been mapped by Uglow (VII, 1926, Map accompanying Mem. 149), as being only about half a mile southeasterly from the property and as extending from Slough Creek northwesterly to the Willow River (idem.).

Igneous intrusives are lacking from the immediate vicinity of the deposit. The nearest are some pre-Carboniferous quartz-porphyry dykes and sills mapped on Shepherd Creek, approximately 4 1/2 miles easterly from the property. The nearest large area of intrusive rocks is on Mount Murray (Johnston and Uglow, VII, 1926, Map accompanying Mem. 149), approximately 7 miles easterly. Here Uglow maps an area 3 miles by 1 mile that consists predominantly of basic dykes and sills.

The rock-types on the property include fissile quartzite, relatively massive quartzite, calcareous phyllite, relatively pure phyllite and sandy limestone; the fissile quartzite is the most abundant rock-type. The distribution of these rock-types is shown in (Fig. 4). It is to be noted that these rock-types are somewhat gradational into each other, and that therefore the position of a plotted boundary between them is arbitrary.

The fissile quartzite is light grey in colour and varyingly schistose in texture, the schistosity depending on the amount of micaceous material present. It characteristically consists of layers of relatively pure quartzite which range from 1/16-inch to 1 inch in thickness, separated by paper-thin layers of white mica or sericite. The individual beds of quartzite are frequently lenticular and gently plicated into shallow, open S-shaped folds. Under the microscope the rock is seen to consist of large grains of fractured, badly strained quartz set in an aggregate of finer grains of clear, unstrained quartz; sericite and occasional carbonate grains are also present. Grains of quartz that are both fractured and badly strained are prevalent in quartzite, that is neither in a fault-zone nor immediately adjacent to it. This evidence of mechanical deformation in rocks neither in, nor adjacent to, zones of localized movement such as fault-zones, indicates that the quartzite in general has been subjected to widespread dynamic metamorphism.

Massive quartzite with beds up to 3 feet thick occurs at one place on Number 2 level (Fig. 4).

Phyllite, as applied by the present writer to the Hardscrabble rocks, is dark grey to black in colour and very thinly fissile in beds that are 1/16-inch or less in thickness. The beds consist of paper-thin to 1/16-inch layers of quartz grains, separated by films of micaceous material; a little chlorite is sometimes present.

A grey, calcareous phase of the ordinary phyllite occurs on Number 2 level (Fig. 4). This phase has a pseudo-porphyritic or porphyroblastic texture that results from the presence of well-shaped crystals of ankerite lying across the schistosity of the phyllite. The development of ankerite is probably due to recrystalization during metamorphism of calcareous matter originally present in the sediment.

A small amount of sandy limestone occurs on Number 2 level. This limestone is dark grey in colour and laminated in layers averaging 1 inch in thickness. In addition to abundant calcite, the limestone contains small amounts of quartz and sericite. The rock probably represents an impure, sandy, limy sediment.

The attitude of the rocks, as seen underground is fairly uniform. The strikes range from north 65 degrees east to south 85 degrees east and the dips from 25 degrees to 47 degrees northward. Departures from this range of strikes and dips are few; the most pronounced being in the east cross-cut in Number 2 level where the fissile quartzite and adjacent sandy phyllite change from a dip of 25 degrees north-west to 80 degrees south-east.

Faulting of the rocks has been pronounced, but for the most part, it has been confined to two main fault-zones. The larger, marked Fault-zone A on (Fig. 4) strikes north 20 degrees west and the other marked Fault-zone B on (Fig. 4), strikes north 70 degrees west. Fault-zone A is reported to be as much as 40 feet wide, but owing to caved ground and lagging, only 20 feet of this width was seen by the writer. Where crushing and shearing have been most intense the material in the fault-zone consists of lustrous black, graphitic phyllite that is in part badly crushed and in part cut by numerous curved, slickensided shear-slips. In some places along fault-zone A, as in the vicinity of the ore occurrence on Number 2 level, the back of the workings consists of large areas of fissile quartzite and phyllite that are bounded by numerous slips and gouge seams. Many of these minor faults parallel the direction of the fault-zone and are undoubtedly genetically related to it.

Movement of ground within fault-zone A has been considerable, and the writer thinks that much of it is drag-ground. The two following features suggest this: (1) the occurrence of graphitic phyllite in a position that is athwart the strike of wall rock of a different rock type, namely fissile quartzite, and (2) the extreme friability of much of the quartz within the fault-zone. These two features are well shown in the vicinity of the scheelite-bearing ground in this zone on Number 2 level and in part on Number 3 level.

Insufficient data were available at the time of the writer's examination to establish the direction of movement along fault-zone A. However, the direction of bending of a quartz lens, where sliced by a shear-slip in the back of the west crosscut on Number 2 level, is such as to indicate that the east sides of slips have moved southward. Hanson (see marginal notes on Map 336-A, 1938, of the Geological Survey of Canada), notes that the movement along north-trending faults has been such that the east side of any one fault has been displaced southwards with respect to the west side. It has been impossible up to the present to determine the amount of displacement along the fault-zone.

Fault-zone B on (Fig. 4) is much narrower in width than fault-zone A. The surface of the main-slip in zone B curves slightly, but in its longest straight section it strikes north 70 degrees west and dips 60 degrees north-eastward. In general, it is marked by a conspicuously slickensided hanging-wall and by 2 inches to 2 feet of crushed rock. A few minor slips branch at various angles from the main fault. A small amount of drag-quartz occurs in this fault on Number 3 level and some drag-scheelite on Number 2 level. The direction of movement along fault-zone B is only imperfectly known, and the amount of displacement not at all. If this fault is considered to be normal, the direction of fluting suggests that the north, or hangingwall-side, has moved down on a pitch-angle of 40 degrees in a direction north 45 degrees west.

Mineralization:

Mineralization has resulted in three kinds of veins (1) a gold-bearing lenticular quartz vein, (2) two apparently non-gold-bearing, quartz veins and (3) scheelite-bearing quartz veinlets or stringers.

On Number 3 level, at a point 10 feet west of the shaft, a quartz-sulphide lens that contains appreciable gold values has been cut; this has been referred to as the "Gold Vein" (Fig. 4). At the time of the writer's visit the lens had been tightly lagged because of bad ground, however, as seen between the lagging, the lens ranged in width from 6 inches to 2 feet. Two samples taken across 10-inch and 2-foot widths assayed: Gold, 0.26 ounces and Gold, 1.2 ounces per ton, respectively. Surface dump material, reported to be from this vein, was examined and several specimens were seen to contain free gold.

The two non-gold-bearing quartz-sulphide veins occur in Numbers 2 and 3 levels; a small one on Number 2 level, and a large one on Number 3 level at a point 20 feet northerly from the shaft (Fig. 4). The foot-wall of each vein is bounded by fault-gouge. The clean-cut nature of both walls and the fault-gouge on one wall of each vein suggests that these are quartz-filled fissure-veins. The vein-filling consists of quartz and the sulphides--pyrite, sphalerite and galena. Although sulphides are abundant, the amount of gold is negligible. A picked sample of vein-matter from the vein in Number 3 level assayed: Gold, nil; lead, 21.2 per cent; zinc, 17.5 per cent.

The scheelite-bearing veinlets comprise two types, (1) filled "tension" joints that transect the bedding of the rocks, and (2) veins or stringers that follow the bedding and schistosity of the enclosing rocks.

The veinlets that occupy tension joints strike north 32 degrees east and dip steeply south-eastward; they definitely cut the bedding which, in the immediate vicinity of the joints strikes from north 65 degrees east to due east and dips 25 degrees north-westward. These veinlets range in length from a few inches to several feet, in width from 1/4-inch to 3 inches, and in spacing intervals from a few inches to several feet.

The bedding-plane veinlets and lenses tend to be more lenticular and discontinuous than those filling tension joints; a definitely lenticular cross-section is common. Although most of these follow the bedding, some of the lenses tend to cross it at small angles in the form of irregular veinlets. The lenticular veinlets range from 1 inch to several inches in width and from a few inches to approximately 1 foot in length.

The mineralogy of both types of veins is similar. The minerals, listed in order of abundance are: quartz, ankerite, calcite, scheelite and traces of sphalerite and galena. All of them are not always present in the same vein.

The amount and habit of scheelite is extremely variable, ranging from 100 per cent in one kidney that measured 1/2-inch by 1 inch (Plate 1-B.) to a fraction of a per cent in many veinlets. Within the quartz-ankerite veinlets the scheelite may occur as a middle layer of pure mineral, as disconnected patches or as thin irregular stringers more or less parallel to the wall of the veinlet. (Plate II-A). This varied habit is due to the different stages of replacement of the scheelite by ankerite and by a late generation of quartz. Slicing and crushing of scheelite and associated gangue minerals within veinlets that occur in the fault-zone on Number 2 level, indicates the pre-fault age of these veinlets.

Inasmuch as the veinlets are discontinuous and widely spaced, ordinary methods of channel-sampling are not satisfactory; the results of such sampling are only indicative of what the exposed rock surface contains. The only satisfactory type of sampling is obtained by running several tons of rock through a mill. This is the method, as of June, 1940, contemplated by the company.

The following samples, taken by the writer within fault-zone A where Number 3 level intersects it, are to be considered only indicative of the extent of mineralization as represented by number and size of scheelite veins:

Sample No.	Length Inches	Description	Assay % WO_3
3390-B	24	Up south wall across crushed quartz-scheelite veinlets.	1.9
3391-B	46	Horizontally along south wall, no veinlets.	nil
3392-B	26	Diagonally across wall near back, across quartz-scheelite veinlets.	1.8
3393-B		Picked vein-matter from near face.	1.01

It is difficult to estimate tonnage of scheelite-bearing ground inasmuch as it is not defined by any vein-system or by any mineralized shear-zone. It is a matter of how close together the scheelite veinlets or lenses are and the amount of scheelite which these veinlets contain, that determines the extent to which ground may be considered potential.

Bearing in mind the statements in the preceding paragraph, the following sections may be considered as possible ore-bearing ground:

(1) Number 2 level, in west working that is partly stoped in vicinity of fault-zone A; this section measures approximately 30 feet by 12 feet wide, its vertical extent is unknown.

(2) Number 3 level, two sections in the west drift in vicinity of fault-zones A and B. One section in fault-zone A measures 10 feet long by 5 feet wide, the other section in the vicinity of the winze and close to fault-zone B extends east and west from the winze, and measures 50 feet long by 5 feet wide; the vertical extent of both sections is unknown.

All surface workings have either sloughed or been destroyed during mining operations. The underground workings consist of a vertical shaft 300 feet deep, from which three levels have been driven and a new one, Number 4, 111 feet below Number 3 level was started in June, 1940. These levels are numbered from the top down, namely Numbers 1 to 4 inclusive. All levels but Number 1 were examined by the writer. Number 1, also known as the "Bedrock" level, is in bad ground and so well lagged that a thorough examination was prevented. The plan of the Numbers 2 and 3 levels, with accompanying geology, is given in (Fig. 4).

The quality of the concentrates was high as is shown by the following analysis made in 1939 by the Department of Mines and Resources at Ottawa on 100 pounds of scheelite concentrates:

	Percentage
WO_3	78.51
CaO	18.97
P_2O_5	0.005
S	0.13
MnO	0.052
Fe_2O_3	0.73
Al_2O_3	0.60
MgO	0.051
SiO_2	0.17
Sb)	
As)	
Sn)	none detected
Mo)	
Bi)	
Pb)	
Ti	trace
Cu	0.002
Loss on ignition	0.30

This property was last examined by the writer in June, 1940.

RAND (CARIBOO THOMPSON) In 1942 scheelite was found by the British Columbia Department of Mines in surface exposures on the eastermost claims of the Rand group, owned by Jos. Wendle, W. Thompson and R. Calder of Barkerville. This is a gold property formerly known as the Cariboo Thompson mine, on which several gold-bearing quartz veins have been prospected by ground-sluiced trenches and adits. It is understood that in 1938 the <u>Cariboo Thompson</u> shipped 4 tons of gold ore containing 500 pounds of tungstic oxide (WO_3) from a short shoot on a gold vein in the old workings. The 1942 scheelite discoveries to be described in the following report are about one-half mile south-easterly from the underground workings which comprised the Cariboo Thompson mine.

The scheelite claims are on Penny (Copper) Creek, on the south-westerly slope of Roundtop Mountain. They are reached by following the Cariboo Hudson mine road south-easterly from Barkerville for 16.5 miles to the Penny (Copper) Creek bridge.

The showings are in the banks of Penny Creek, at elevation near 4,900 feet, between 100 and 600 feet downstream from the Penny Creek bridge.

Overburden is deep and extensive, and outcrops are scarce except where the creek has exposed them, so that any projected prospecting away from the creek can only be done by deep trenches. The slopes are moderately steep and heavily wooded with spruce, balsam and dense underbrush.

The showings consist of lenticular quartz veins in a series of silver-grey schists, graphitic schists and grey limestone. In general the rocks strike north-westerly and dip steeply north-eastward. The veins strike from north 10 degrees west to north 20 degrees east and dip steeply eastward, cutting the schist at small angles. They are north-south diagonal veins, and constitute a common group of ore-bearing veins in the Barkerville gold-belt. In addition to scheelite, the quartz veins contain moderate amounts of tetrahedrite and very small amounts of sphalerite and galena.

The first showing is approximately 100 feet downstream from the Penny Creek bridge. Stripping and blasting have exposed two scheelite-bearing quartz lenses. Silver-grey schist, striking north 30 degrees west, and about vertical, encloses the lenses. The upstream lens ranges from 6 to 60 inches in width over a length of 14 feet. One wall strikes north 20 degrees east and the other north 37 degrees east, both walls dip steeply south-eastward. The vein filling consists of quartz, ankeritic carbonate, and small amounts of galena and scheelite. The downstream lens, 7 feet distant, ranges from 12 to 15 inches in width. It strikes north 7 degrees east toward the upstream lens. At the creek it is 10 feet from the upstream lens, but 10 feet farther north-easterly it is only 2 feet from this lens so that the two lenses presumably join a short distance north-easterly. The vein-filling consists of quartz, ankeritic carbonate, tetrahedrite and a moderate amount of scheelite. A sample taken across 12 inches of this vein-matter assayed: Tungstic oxide (WO_3), 3.8 per cent.

The second showing outcrops in the south-east bank of Penny Creek approximately 500 feet downstream from the first. Here an open-cut has been driven south-easterly for 6 feet to a face 6 feet high. The cut exposes a compound quartz zone 42 inches wide which consists of 2 lenses of quartz striking north 10 degrees west and dipping 65 degrees eastward. The hangingwall-lens is 1 foot wide and the footwall-lens is 16 inches wide. They are separated by 14 inches of badly crushed, graphitic schist. The hanging-wall is grey, talcose schist, strike north 50 degrees west and about vertical, but the foot-wall is grey, massive limestone. The mineralization in these lenses consists of quartz, scheelite and small amounts of tetrahedrite, galena and sphalerite. Most of the scheelite in the zone is in the footwall-limestone immediately adjacent to the vein-wall. Here the scheelite occurs as high-grade patches of mineral measuring up to 4 feet by 16 inches in surface area, but probably only a few inches in thickness. Insufficient work has been done to determine the continuity of these patches northerly along the strike of the zone. Smaller amounts of scheelite occur as ribbons of discontinuous grains in and near the foot-wall of the footwall-lens.

A gouge seam, 1 inch thick, lies in the hanging-wall of the hangingwall-lens. The gouge and the abundant crushed rock within the zone indicate much post-mineral movement. The strike of the schist and its position relative to the limestone suggest that the west side of the zone has moved northerly.

The following samples were taken on the showing:

Footwall-lens:		Tungstic Oxide
3 feet from floor;	16 inches wide	0.2 per cent.
5 feet from floor;	14 inches wide	Tr.
Footwall-limestone:		
1 foot from floor;	Across 14-inch patch of mineralization, vertical;	12.6 per cent.
1 foot from floor;	Across 14-inch patch of mineralization, horizontal;	18.2 per cent.

Seven other small veins of quartz within a radius of 1,000 feet of these showings were examined in ultra-violet light and seen to contain small amounts of scheelite.

In particular, the area south-easterly and southerly from these showings seems to warrant prospecting. However, abundant overburden and the absence of outcrops will necessitate much stripping.

The writer examined this property in July, 1942.

CARIBOO HUDSON

During the summer of 1942, moderate amounts of scheelite were discovered by the British Columbia Department of Mines on the Crown-granted claims Cunningham No. 1 and Cutler No. 1, survey lot Nos. 5905 and 10596 respectively. These belong to a group of claims owned by the Cariboo Hudson Gold Mines Ltd., c/o Canadian Credit Men's Trust Ass'n. Ltd., 602 West Hastings St., Vancouver.

The Cariboo Hudson mine lies south-east of Barkerville, and is accessible by 18 miles of moderately good motor-road.

The scheelite showings on the Cunningham No. 1 and Cutler No. 1 are between elevations of 4,900 and 5,000 feet on the east and west banks of Peter Gulch Creek. They are approximately three-quarters of a mile westerly from the main underground workings of the Hudson mine.

Near the showings the hillside slopes up steeply from the creek-bed at angles ranging from 30 to 35 degrees. The slopes are heavily wooded and covered with overburden that ranges from 1 foot to about 15 feet in depth.

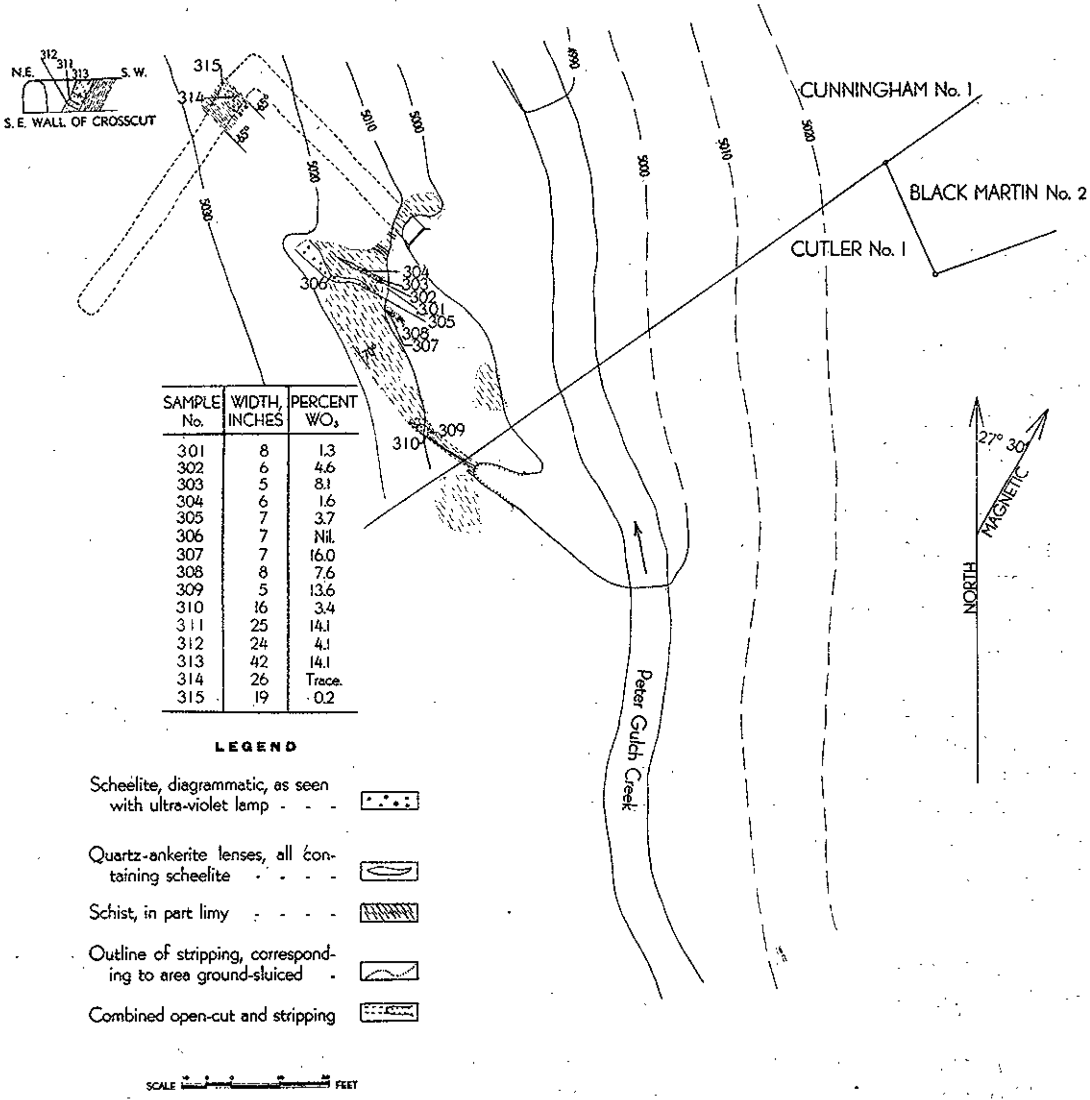
The rocks are mainly quartz-sericite schist, silvery-grey where unweathered and buff-coloured where weathered. Some of the schist is limy. The schist ranges in strike from north 40 to north 50 degrees west and in dip from 65 to 80 degrees north-eastward.

Scheelite occurs in surface outcrops that have been exposed and cleared by ground-sluicing and in a short adit below these outcrops. The present exposures disclose several mineralized lenses which occur at several places along a zone that ranges from 2 to 25 feet wide over a length of 210 feet. The present workings show that the scheelite has a vertical extent of at least 25 feet within this zone.

The workings consist of a stripping approximately 60 square feet in area and a short adit below this stripping (see Fig. 5).

A small stripping has been made on a scheelite-bearing lens on the opposite side of the creek from the adit and 170 feet up-stream.

In the main stripping the scheelite occurs as scattered patches of mineral in 5 quartz-ankerite lenses. These lenses range from a few inches to 18 inches in width and from 2 to 15 feet in length. They are in part bedded with the schist and in part constitute east-west diagonal lenses cutting the schist. Overburden covers the extension of some of the lenses. The lenses are separated across the width and along the length of the zone by barren schist.



SAMPLE No.	WIDTH, INCHES	PERCENT WO_3
301	8	1.3
302	6	4.6
303	5	8.1
304	6	1.6
305	7	3.7
306	7	Nil.
307	7	16.0
308	8	7.6
309	5	13.6
310	16	3.4
311	25	14.1
312	24	4.1
313	42	14.1
314	26	Trace.
315	19	0.2

Fig. 5. Cariboo-Hudson. Tape and compass survey of scheelite showings on Cunningham No. 1 and Cutler No. 1 claims.

The minerals in the lenses include the following, listed in order of abundance: ankeritic carbonate, vein-quartz, scheelite and galena. Much of the quartz is fine-grained and intimately intergrown with both the ankerite and the scheelite. The scheelite areas range from 3 by 6 inches to walnut-size. The smaller areas usually are intricately replaced by quartz. Galena occurs as only a few small grains and is rarely in contact with scheelite.

In the adit, the scheelite occurs as nodules which lie within an 8-foot shear-zone in the schist (see Fig. 5). However, the scheelite is confined to a 40-inch width in the hanging-wall of the zone, and from 1-inch to 4-inch lenses of barren quartz lie in the remaining width. The scheelite occurs as nodules or lenses of the pure mineral within the sheared schist and is not associated with any other mineral. It is most abundant on the south-easterly wall of the crosscut, becomes less abundant across the back and is in only small amounts on the north-westerly wall. However, the shear-zone continues north-westerly and the scheelite may also occur in this direction.

Scheelite also occurs in a small stripping on the east side of the creek approximately 150 feet south-easterly from the main stripping (see Fig. 5). This small stripping exposes a scheelite-bearing lens of quartz and carbonate 10 inches wide in a vertical face. Because of the overburden, nothing is known of the extent of this lens. However, it lies along the south-easterly extension of the strike of the mineralized lenses of the main stripping and probably belongs to the same general zone.

Fifteen channel samples, each 1/2-inch deep and 3 inches wide, were taken across the scheelite-bearing lenses. The locations, widths and assay results of these samples are shown in (Fig. 5). Solid circles indicate the distribution of the scheelite, as seen in ultra-violet light.

The nature of the distribution of the scheelite makes it impossible to determine the grade of ore accurately over any sizeable area of outcrop without taking innumerable samples. In order to determine an approximate figure for the grade of ore in the present exposures and the adit, the writer made calculations based on assays of the 15 channel samples mentioned above. These assays were weighted for width of lens; also for length of lens, assuming that each sample would be taken for every 5 feet of lens-length. For the surface the resulting "average" assay is Tungstic oxide (WO_3), 2.1 per cent over a width of 7 inches for an aggregate lens-length of 45 feet. In the adit the weighted average of samples taken on both walls and on the back was Tungstic oxide (WO_3), 3.5 per cent, over 30 inches for 5 feet of length.

It is suggested that the area north-westerly from the surface showings should be stripped in order to determine the north-westerly extent of the mineralized zone on the surface. At the same time drifting could be continued underground north-westerly along the shear-zone which strikes diagonally into a steep hillside.

The general zone in which the scheelite-bearing lenses occur is wide, well defined and well mineralized, so that continuity beyond the 210 feet already known might be expected.

The writer examined this property at various times in May and June, 1942.

PAXTON

Arthur Paxton and associates of Wells own a group of mineral claims on the Snowshoe Plateau that comprises the Pacific Nos. 1 to 3 inclusive, and the Breakneck Nos. 1 to 3, inclusive; these were staked in 1937 and 1939.

The showings, at an elevation of 5,500 feet, are at the base of north-westerly facing bluffs that comprise Breackneck Ridge, a ridge on the west side of Aster Creek, a northerly-flowing tributary of the Swift River. (See Cariboo Lake, sheet $93\frac{A}{14}$, National Topographic Series, Dept. of Mines, Ottawa.)

Steep, rocky bluffs extend upwards from the showings for approximately 500 feet to the top of Breakneck Ridge. These bluffs appear to form the head of a small cirque, the floor of which slopes gently westerly from the workings downstream past the cabin.

The property may be reached from Wells by following a good motor-road for approximately 23 miles to the Cariboo Hudson mine at an elevation of approximately 5,500 feet, thence westerly by poor road and trail over the Snowshoe Plateau, at elevations ranging from 5,500 to 6,000 feet for 7 miles to the showings.

The occurrence consists of scattered patches of scheelite in a quartz vein that ranges from 5 to 8 inches in width. In addition to the scheelite vein, three separate lenses of quartz, sparsely mineralized with sulphides, occur in the workings. They differ from the scheelite vein in being definitely lenticular and discontinuous within short distances.

The rocks comprise grey, fissile quartzite and a small amount of graphitic fissile argillite. They belong to slightly metamorphosed rocks of the Richfield formation as described by Lang (VII, 1938, pp. 5 - 9). In the vicinity of the Paxton property, the rocks form the gently-dipping, south-west limb of a north-westerly striking anticline, the crest line of which lies approximately three-quarters of a mile north-easterly from the property. (Geol. Surv. Canada, Map 562 A). As far as the writer is aware, there are no granitic intrusions in the area.

The workings consist of one open-cut and one adit. Scheelite was seen only in the adit and in dump-material from the adit.

The open-cut has been driven south 50 degrees east for 27 feet to a 15-foot rock face. At a point approximately 10 feet from the mouth, this open-cut intersects a quartz lens 18 inches wide that strikes east and dips 70 degrees southward. The quartz contains a small amount of galena and pyrite. The south-west corner of the face exposes a larger lens that is approximately parallel to the first one and 10 feet distant southerly across the dip. The main part of the lens ranges from 18 inches to 2 feet in width, but in one 4-foot section it splits into three 6-inch veins that continue separately for a strike length of 4 feet and then coalesce again to form one vein or lens. The mineralization in this quartz lens consists of 6-inch clusters of sulphides, which contain abundant pyrrhotite, a little pyrite, sphalerite, chalcopyrite and galena. Neither of these lenses contain scheelite.

Beginning at a point 20 feet north-easterly from the mouth of the open-cut, a barren quartz lens outcrops for 25 feet in a north-easterly direction. The lens is 8 feet thick, strikes north-easterly and dips 50 degrees south-eastward.

From a point 15 feet below the open-cut and 25 feet in a direction south 70 degrees west from its mouth, an adit has been driven south 43 degrees east for 50 feet. Between points 25 feet and 40 feet, respectively, from the portal, the adit intersects the downward and south-westerly extension of the large quartz lens that outcrops 20 feet north-easterly from the mouth of the open-cut. The two lenses that are exposed in the open-cut appear to be cut off in their downward continuation by a fault, strike north 30 degrees east and dip 40 degrees south-eastward, in the hanging-wall of the large lens, before they reach the level of the adit. The adit cuts the fault at a point 40 feet from the portal.

The adit intersects a scheelite-bearing quartz vein at a point 40 feet from the portal. This vein extends for a distance of 8 feet diagonally across the adit to the north-east corner of the face. The vein is 6 inches wide, strikes north 73 degrees west and dips 55 degrees south-westward. The vein-matter consists of abundant quartz, a little galena and pyrite and scattered clusters of scheelite. Only a little scheelite was seen in the adit but judging from an examination of material on the dump this mineral occurs in occasional patches from 1/2-inch to 2 inches in diameter within the quartz.

The same vein outcrops for a distance of approximately 6 feet at a point 25 feet above the adit but contained no visible scheelite.

The north-westerly extension of the scheelite vein is terminated by the fault at a point 8 feet north-west of the face in the hanging-wall of the large quartz lens; the south-easterly continuation on the surface is covered by drift, but the exposure in the adit, which is farther south-easterly along the strike, indicates that the vein continues in this direction.

This property was examined by the writer in July, 1940.

TAYLOR Scheelite has been recently discovered by Ed. Taylor, Wells P. O. on what Mr. Taylor referred to as the Gold Coin mineral claim on the Snowshoe Plateau. The discovery was made at a point about 500 feet above the underground workings on the Hebson group, also owned by Mr. Taylor.

The property, at an elevation of 6,000 feet, is towards the south-westerly rim of the Snowshoe Plateau at the head of the west branch of Little Snowshoe Creek. The Snowshoe Plateau, of an average elevation of 6,000 feet, lies between Barkerville and the settlement of Keithley Creek. The following streams rise in this Plateau: Keithley Creek, Swift River, Antler and Cunningham Creeks and the Swamp (Cariboo) River. Yanks Peak, at an elevation of 6,242 feet, is the highest mountain on the Plateau (see Cariboo Lake, sheet 94 A/14, National Topographic Series, Dept. of Mines, Ottawa).

The property may be reached either from Wells or Keithley Creek P. O.; the route from Wells is reported to be the better of the two, and was followed by the writer. From Wells the route is by a good motor-road for approximately 23 miles to the Cariboo-Hudson, elevation approximately 5,500 feet, thence by a poor road for 1 1/2 miles and lastly by a good trail for 4 1/2 miles westerly to the workings.

The showings are in surface workings on the open, grassy top of the Plateau, at a point where the ground slopes gradually down over a distance of several hundred feet to the steeper slopes that form the south-westerly side of the Plateau. Rock outcrops are very scarce.

The tungsten occurs in a lenticular quartz-scheelite vein, strike north 60 degrees west and dip 75 degrees south-westward, that ranges in width from 1-inch to 4 inches and is exposed for approximately 18 feet before disappearing into sheared rock. The vein-shear cuts fissile quartzites and sericite schists that strike in general north 15 degrees west and dip 50 degrees south-westward; these rocks comprise part of the Richfield formation. In the vicinity of the vein-shear the rocks have been impregnated by small amounts of pyrite and galena.

Structurally the rocks in the vicinity of the Gold Coin form the south-west limb of a north-westerly striking anticlinal fold, the crest-line of which lies about three-quarters of a mile north-easterly from the property (Lang, Geol. Surv. Canada, 1938, p. 16, and Map 562-A).

The workings consist of two trenches and in one of them a shaft. Elsewhere two pits have been dug.

Number 1 trench extends north-westerly for 38 feet. It is 6 to 7 feet wide, 1 to 2 feet deep and towards the middle a shaft 6 feet in diameter and 6 feet deep is sunk.

Number 2 trench, in direction transverse to that of Number 1, lies north-westerly from it. The north-east end of Number 2 trench, extending for 35 feet in a south-westerly direction, is 15 feet north from the north-west end of Number 1. It is 4 feet wide, 6 feet deep at its north-east end and 1 foot deep at its south-west end.

Scheelite was seen only in Number 1 trench.

The vein is a quartz-filled shear that cuts fissile quartzites and sericite schists. Its best exposure is in the north-west face of the shaft in Number 1 working, where the vein is slightly lenticular, ranging from 3 to 4 inches in width and is bordered by 1/8 inch of sheared rock. The vein-matter consists of large, poorly-defined crystals of quartz arranged perpendicularly to the walls of the vein and enclosing patches and crystals of scheelite, its oxidation product tungstite (Plate II-B) and stolzite. A small amount of galena occurs as widely-scattered grains in the adjacent sediments. The amount of scheelite is quite variable, ranging in places from a fraction of a per cent to about 50 per cent of the vein-matter. A representative 30-pound sample taken along the full 4-inch width of the vein and over a 4-foot length in the north-west face of the shaft assayed; Tungstic oxide (WO_3), 26.2 per cent.

The scheelite vein extends south-easterly for 18 feet from the north-west side of the shaft. The writer did not see any scheelite in the last 12 feet of the vein but it is reported to have been found when digging the trench. In a north-westerly direction the vein narrows to a barren shear within a few inches of the side of the shaft, and as such, disappears under the debris that covers the floor of the trench dug along the projected extension of the vein. No. 2 trench cuts across the projected strike of the vein at a point 30 feet north-westerly from the shaft but does not expost any vein-matter or well defined vein-shear.

The vein appears to cut three earlier bedded quartz veins, barren of scheelite. One of the bedded veins extends along a bedding plane in the sediments for a distance of 3 feet northerly from the scheelite vein. The other two bedded veins extend south-westerly from the scheelite vein for 1 foot along bedding planes of the sediments. These bedded veins appear to have been fed by the fissure now occupied by the scheelite vein. The formation of these bedded veins would therefore have antedated the deposition of the scheelite in the main vein.

A shallow pit has been dug in the banks of a small southwesterly-flowing creek at a point approximately 570 feet north-westerly from Number 1 pit. This working exposes a small amount of galena which occurs as (1) grains in bedded quartz lenses 1 inch thick and 1 foot to 2 feet in length, and (2) as grains disseminated in fissile quartzite adjacent to the quartz lenses. A low percentage of pyrite and sphalerite is associated with the galena.

Fourteen feet upstream from the last pit, another working 6 feet in diameter and 5 feet deep exposes a 2-foot length of a quartz lens 1 foot thick that contains pyrite, marcasite, galena and sphalerite.

The rocks in these two pits are nearly flat-lying, fissile quartzites that appear to strike in a general north-westerly direction and dip 10 degrees south-westward.

Since the property was examined by the writer in July, 1940, 2 new pits have been sunk 10 feet and 8 feet on the main tungsten showings and it is understood an adit was started late in the season of 1942 to get under these showings. However, the work has so far failed to disclose additional ore.

It is understood that the work in 1942 was done by the Cariboo Scheelite Syndicate, with offices at 422 Metropolitan Building, Vancouver, B. C.

LIMESTONE POINT

Small amounts of scheelite were found in 1942 by Otto Baer of Likely, in the limestone bluffs of Limestone Point on the North Arm of Quesnel Lake. This point is about 40 miles by water north-easterly from Likely. Scheelite was found in large boulders of talus below the bluffs and at a few places in the bluffs. It occurs as small grains in patches of criss-crossing quartz veinlets that cut grey unaltered limestone. The scheelite is small in amount and widely scattered in the limestone without any definite structural control. However, the occurrence is of importance inasmuch as it shows that scheelite is found on the projected extension of the scheelite belt south-easterly from the scheelite showings on the Cariboo-Hudson. It may therefore be profitable to prospect for scheelite north-westerly from Limestone Point in the general direction of the Cariboo-Hudson mine.

BRIDGE RIVER AREA

This is a gold-mining area in the upper part of the Bridge River valley, approximately 112 miles in an air-line northerly from Vancouver.

Scheelite is found in many of the gold-quartz veins in the area. At one gold mine, the Bralorne, a moderately large-sized shoot of scheelite ore has been mined. Small amounts of scheelite have been found in the Pioneer, B. R. X. and Bristol mines in the area. Scheelite is found as the main constituent of veins on the Tungsten Queen and Tungsten King mines. Shipments of tungsten ore and ore concentrates have been made from the Bralorne, Tungsten Queen, and Tungsten King mines.

TUNGSTEN QUEEN

This property was formerly known as the Phillips' Tungsten property and was described under that name in the 1940 edition of this bulletin. Since the publication of the early edition of Bulletin No. 10, 3 adits had been driven, 171 feet, 54 feet and 23 feet respectively and an underhand stope and several hundred feet of trenches and open-cuts have been dug. About 41 tons of cobbed high-grade ore and 20 tons of low-grade ore have been mined. The Consolidated Mining and Smelting Company had a lease on the property from September 1941 until September 1942. At the present time mining operations are being carried out under the direction of the owner, Ed. Phillips.

The following describes the property as it was when first examined by the writer in September, 1939.

Scheelite was discovered in the summer of 1939 in Tyaughton Creek Valley, in the Bridge River Area on ground owned by Edwin Phillips of Minto City and staked originally for cinnabar. The property comprises the mineral claims Cinnabar Nos. 1 to 4, staked in July, 1938, Tyax Nos. 11 and 12, staked in October, 1936, and the Sandy Nos. 2 to 8 inclusive, variously staked September, 1936, August, 1937 and April 1938.

The property, is on the east side of Tyaughton Creek at a point which is 2 miles by road northerly or up-stream from its confluence with Noaxe Creek, a westerly-flowing tributary of Tyaughton Creek (see Map 546A, Tyaughton Lake, Department of Mines and Resources, Ottawa, 1940). The exact position of the scheelite outcrop is described by referring its position to that of a cabin owned by Mr. Phillips. This cabin is on the east side of and adjacent to the road at a point which is 2.4 miles by road northerly up Tyaughton Creek from its junction with Noaxe Creek (see above Map 546 A). The scheelite occurs 65 feet above the road on the south side of a dry rock-gulch that crosses the road 1,175 feet southerly from the cabin.

The scheelite showing is on an open hillside that slopes southwesterly with an approximate slope-angle of 30 degrees to the bottom of Tyaughton Creek. The ground is open, grassy, and in part, taluscovered and except for a few serpentine bluffs, is covered by an unknown depth of overburden.

The property may be reached conveniently by motor-road from Minto City by following the Tyaughton Lake road up the creek for approximately 14.3 miles from Minto City. Minto City is in the Bridge River Valley approximately 29 miles by good motor-road from Bridge River, a station on the Pacific Great Eastern Railway 105 miles north of Squamish. Squamish is the tidewater terminus of the railway approximately 50 miles up Howe Sound from Vancouver, and is

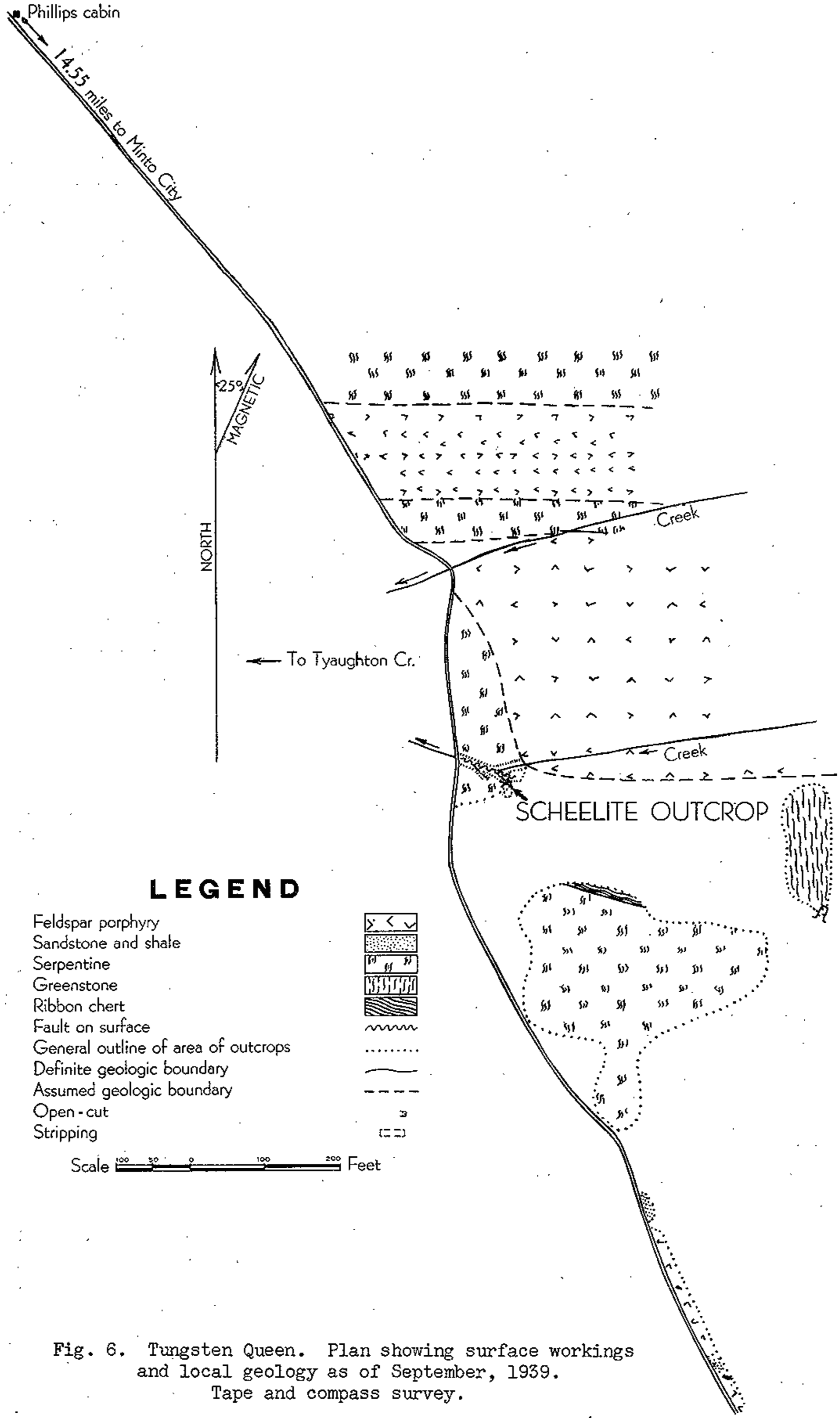


Fig. 6. Tungsten Queen. Plan showing surface workings and local geology as of September, 1939. Tape and compass survey.

served from Vancouver by regular boat service of the Union Steamship Company.

Geology. The distribution of rock types in the immediate vicinity is shown in (Fig. 6). In the following paragraphs the geology will be referred to the scheelite outcrop, as a reference point. A large irregular area of carbonatized serpentine, in which the scheelite veins occur, intrudes both ribbon chert and volcanics but is, in turn, intruded by many dykes and irregular masses of feldspar porphyry. The serpentine, forming the host-rock for the scheelite veins, extends as an irregular area for 200 feet north-westerly and south-easterly, 100 feet south-westerly, and 30 feet north-easterly from the scheelite outcrop. The serpentine has been extensively carbonatized and consists almost exclusively of ankeritic carbonate with small amounts of mariposite, residual antigorite and chromite.

The ribbon chert, in contact with serpentine, outcrops approximately 200 feet south-easterly from the scheelite. The chert, strike easterly and dip vertical, consists of slightly crenulated ribbons of dark grey to black chert that range from 1 to 3 inches in width.

Volcanic rocks, or greenstone, consisting of flow rocks and volcanic breccia, begin to outcrop 400 feet easterly from the scheelite and extend for an unknown distance eastward. The flow-rocks consist of massive, fine-grained andesitic lava with an amygdaloidal phase. The volcanic breccia consists of poorly defined angular fragments of andesitic material similar to that of the flow rocks, and set in an altered groundmass of the same material.

Feldspar porphyry, the youngest rock on the property, occurs as dykes that range from 500 to 100 feet in width, and as an irregular stock-like area with an exposed diameter of 300 feet. It is a medium-grained, porphyritic rock that contains closely-packed feldspar phenocrysts, averaging 1/8-inch in maximum dimension, set in a brown weathering altered matrix consisting mostly of carbonate. No quartz was seen in any of the specimens examined.

Veins.

The scheelite outcrop consists of two small parallel veins, one of which is predominantly stibnite and the other predominantly scheelite. These veins are 2 feet apart and range from 1 inch to 3 inches in width. They strike north-westerly in conformity with the contact between the serpentine and feldspar porphyry but lie 30 feet south-westerly from the contact.

Over the short distance exposed, the veins maintain a uniform strike and dip, and a fairly uniform width. They frequently split and smaller veins branch sharply from the main vein, and extend for 2 or 3 feet into the wall-rock and die out or may turn, following other branch-fractures that lead back into the main vein. Shearing along the vein walls and branch-fractures appears to have been absent for there are no slickensides and the veins are frozen to the wall-rock. This branching type of fracture is suggestive of fracturing under a light load, presumably near the surface.

The veins show marked crustification or banding by deposition. Crustification is particularly well shown in the stibnite-scheelite vein where scheelite is followed inwards from both walls of the vein by finely crystalline chalcedonic quartz, then by coarsely crystalline comb-quartz, and finally by a central band of stibnite.

A definite comb-structure is shown both by the coarsely crystalline quartz and by the scheelite. This structure is expressed in the development of pyramidal crystals that have grown normal to the walls of temporary openings within the vein.

Mineralogy. The vein-minerals include, listed in order of abundance: scheelite, stibnite, quartz and carbonate. These minerals are distributed between the scheelite vein and the stibnite-scheelite vein. The scheelite vein (Plate III-A) ranging from 1 to 3 inches wide, consists predominantly of scheelite and carbonate with some quartz and isolated crystals of stibnite. In sections of the vein, sometimes as much as 3 feet in length, scheelite amounts to 75 per cent of the vein-matter (equivalent to assays of 60.7 per cent WO_3). In other sections there is less scheelite and in places it is completely replaced by carbonate. The stibnite-scheelite vein, ranging from 1 inch to 3 inches wide, consists predominantly of stibnite with varying amounts of scheelite, carbonate and quartz. Scheelite is more abundant in the stibnite vein than stibnite in the scheelite vein; in one place the scheelite amounts to 38.5 per cent. (equivalent to 31.1 per cent WO_3) of the vein-matter.

A partial analysis of as pure a sample of scheelite as could be obtained by panning and by separation with methylene iodide, gave the following results:

WO_3	79.7 per cent
CaO	19.3 per cent
MoO_3	trace

At the time of the writer's examination, the only development work on the scheelite veins consisted of a stripping measuring 4 feet wide by 14 feet along the strike. At a point 450 feet in a direction south 65 degrees east from the scheelite stripping, a small open-cut has been driven northerly for 20 feet on an outcrop of greenstone containing very sparsely disseminated grains of cinnabar.

TUNGSTEN KING — This property is about 1 mile northerly along the road from the Tungsten Queen. It comprises the mineral claims Tungsten King Nos. 1 to 5 inclusive, the June Nos. 1 to 3 inclusive, Mercury No. 14, Silvertip No. 3, and Tungsten Nos. 5 to 12, owned by Egil H. Lorntzsen of Minto, and Gunnar Lundborg of Gold Bridge, B. C. The Tungsten King and June claims were staked in June 1942 but the other claims are re-stakings of cinnabar showings on ground originally staked by Lorntzsen in 1936.

The claims are on the east side of Tyaughton Creek, between elevations of 3600 and 6000 feet. The topography is much the same as that of the Tungsten Queen.

The workings are on the north bank of a small creek, locally known as Mercury Creek, which flows south-westerly into Tyaughton Creek. They are reported* to consist of open-cuts and 2 short adits, 25 and 50 feet long respectively. They are about 900 feet by skidroad from the main Tyaughton Creek road.

The rocks found on the property are somewhat similar to those found on the adjacent Tungsten Queen. However, the scheelite vein is reported to be in limestone and not in carbonatized serpentine as on the Tungsten Queen. It is understood that scheelite occurs with dolomite and stibnite in a fracture zone 6 feet wide.

The owners have mined several tons of medium grade ore from the surface workings and shipped it to the Bralorne mine for concentration. They have sorted out about a ton of high-grade which was included in a shipment of ore sent to Ottawa from the Tungsten Queen.

BRALORNE — Scheelite is found at this gold mine on Cadwallader Creek. The property is owned by Bralorne Mines Limited (N. P. L), Bralorne, B. C.

A short shoot of tungsten ore was found in 551 Drift East. Part of this shoot has been mined and concentrated in a small plant recently built at the mine by the company.

PIONEER — Small amounts of scheelite have been found in the gold-quartz veins on this property. The mine is 2 miles from Bralorne. It is owned by Pioneer Gold Mines of B. C. Ltd., Pioneer P. O.

B. R. X. — Scheelite is found in small quantities in the California vein on this property. The mineral occurs as narrow stringers and widely scattered grains. The property is near Gold Bridge and is owned by the B. R. X. Consolidated Mines Ltd., Gold Bridge.

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* Egil H. Lorntzsen, personal communication.

BRISTOL* A small shoot of gold-scheelite ore has been discovered at this property on Tommy Creek. The property is reached by 3 1/2 miles of branch road which leaves the main Bridge River highway about 12 miles easterly from Minto mine. The owners, the Bristol Mines Ltd., are represented by J. C. Adam, 572 Howe Street, Vancouver, B. C.

The underground workings, consisting of 3 adits, in January 1942, explore a shear-zone, ranging in width from 15 inches to 20 feet, which cuts cherty quartzite and argillite. It has been exposed underground for a length of 600 feet. The shear-zone consists of fractured quartzite, numerous calcite veinlets, a lesser number of quartz veinlets, and gouge seams.

In general the shear is very sparsely mineralized with pyrite, arsenopyrite, and widely disseminated grains of scheelite.

Moderate amounts of scheelite have so far been found only in the intermediate level. This level consists of a cross-cut driven south-easterly for 250 feet and a drift driven 50 feet south-westerly and 90 feet north-easterly from the cross-cut. Where the main cross-cut joins the drift, scheelite is found over a width of 30 inches in the footwall-side of the main shear-zone. A sample taken across this width assayed: Tungstic oxide (WO_3), 0.6 per cent; gold, 0.41 oz. per ton; silver, nil. At 43 feet north-easterly from the cross-cut, scheelite is found as scattered grains over a width of 15 inches, in quartz stringers in the footwall-rock next to the shear. A sample taken across this width assayed: Tungstic oxide (WO_3), 6.5 per cent; gold, 0.26 oz. per ton; silver 0.1 oz. per ton. Between 48 feet and 57 feet north-easterly from the cross-cut, scheelite is found in association with higher than average amounts of gold, across the full shear-width of 7 feet. A winze has been sunk for 25 feet on this ore-shoot. A 50-pound sample from a pile of stored muck taken from the winze assayed: Tungstic oxide (WO_3), 0.16 per cent; gold, 1.40 oz. per ton; silver, 0.6 oz. per ton.

At the time of the examination, January 1942, the owners were raising from the lower level to connect with the winze.

SQUAMISH AREA

ASHLOO Small amounts of scheelite have been reported** from this gold property on Ashloo Creek, 28 miles by road and trail northerly from Squamish, at the head of Howe sound. This mind is owned by Ashloo Gold Mines Ltd., with offices at 602 Hastings Street West, Vancouver, B. C.

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* Report on Bristol Mine by R. J. Maconachie, formerly with the British Columbia Department of Mines.

** H. V. Smitheringale, personal communication.

SWAKUM MOUNTAIN — Scheelite is reported from showings on Swakum Mountain, 12 miles by truck road northerly from Nicola.

CONSOLIDATED NICOLA GOLDFIELDS LTD.*

References

1. Reports of the British Columbia Minister of Mines.
2. Dawson, G. M., Report on the Area of the Kamloops Sheet. Geol. Surv. Canada, Ann. Rept. Vol. VII, 1899, pp. 333-335B.

This property was fully described by Hedley (1,1936) and the reader is referred to that report for a complete description of the property. Since the date of that report a considerable amount of work has been done opening up the Enterprise vein on the 320, 550, 675, 800 and 900 levels, and the King William vein has been opened up on the 550, 675, and 900 levels.

In 1941, W. E. Cockfield of the Geological Survey investigated the scheelite occurrences at the property and the following account is a summary of his unpublished report.

"The property consists of upwards of 210 claims and fractions having an area in excess of 5,500 acres and is a consolidation of a number of groups of claims. It is situated about midway between Merritt and Kamloops.

"The rocks in the general vicinity of the property consist of fine-grained lavas together with tuffs and breccias and narrow bands of sediments which have yielded upper Triassic fossils. To the southeast and to the north-east these are underlain by upper Palaeozoic sediments. Large bodies of granitic rocks, chiefly quartz diorite, invade both groups three miles to the west and about eight miles to the north-east. The entire assemblage is overlain by Tertiary volcanics. At the mine itself, only Triassic volcanic rocks and basaltic dykes younger than the veins and probably related to the Tertiary volcanics, appear. The Triassic volcanics are for the most part massive but occasional attitudes on the bands of tuff indicate that the major structure is a syncline with the axis trending slightly west of north. It is probable that local folding occurs.

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* Report by W. E. Cockfield of the Geological Survey of Canada and published with the permission of the Director.

"The mineral deposits consist of veins following fracture zones that trend generally north to northwest and dip easterly at angles of 50 to 80 degrees. Individual veins vary in width from mere fractures to 9 feet and some of them have been traced continuously for distances of nearly 1500 feet. They are filled with quartz and minor amounts of calcite and carry pyrite, galena, sphalerite, tetrahedrite, chalcopyrite, bornite, and small amounts of arsenopyrite, pyrrhotite, and free gold.* Scheelite is present in small grains and short narrow bands and in some places forms aggregates of nearly pure mineral up to 5 inches in diameter. The scheelite content of the veins is generally low but small concentrations in which scheelite occurs plentifully have been found. Gold and silver values occur in shoots, with low grade or narrow unminable parts of the veins between, and the shoots themselves vary greatly in size and contained values. The present report is, however, concerned only with the tungsten content. There is no evidence to show that scheelite is present in greater quantities in the richer parts of the veins, and, as much of the gold ore developed by the workings has been mined out, there is probably insufficient evidence to justify any conclusion in this regard.

"During the examination, the veins were cleaned off at reasonably regular intervals, having regard to the positions of stopes, chutes, and timbering, and examined in ultra-violet light. As many intermediate points as possible were also examined. In the initial work, a number of samples were taken where groups of positive readings indicated possible ore shoots. Assays, therefore, with the exceptions to be noted below, were taken only at points where fluorescence indicated the presence of scheelite and, in computing average values of the veins, the many negative readings with the lamp have to be considered. The early work on the Joshua vein gave such low results that in subsequent work only the better showings were sampled.

"Preliminary investigation appeared to indicate that scheelite was probably more prevalent in the Joshua, King William, and Jenny Long veins than in the other veins of the property and attention was later devoted largely to them.

The main working of the property is the 320 adit level driven to intersect in turn the Enterprise, Tubal Cain

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* The presence of arsenopyrite, pyrrhotite, and free gold was determined in microscopic studies of the ore at the University of British Columbia.

and Joshua veins. A shaft has been sunk, from the point where this adit intersects the Enterprise vein, to the 900 level, and workings have been driven on the 320, 440, 550, 675, 800, and 900 foot levels. The King William vein, which branches from the Enterprise, has workings on all these levels except the 800. The workings of the Enterprise vein above the 320 level, from which the developed ore is largely stoped out, were not examined. For a description of these, the reader is referred to Hedley (1, 1936).

"The Joshua vein is developed by a shaft to a depth of 755 feet on the dip. Drifts have been run at the 100, 200, 300, 400, 550, and 750 foot levels. The 320 adit level of the Enterprise mine was continued to crosscut this vein, and drifts run north and south of the adit. The north drift was continued to the shaft which was encountered just above the 400-foot level. For convenience in this report, it will be referred to as the 320 level. The shaft is filled with water to within a few feet of this level.

"On the dump at the Joshua shaft, some specimens with high grade scheelite mineralization were found. Although much of the quartz here carries no scheelite, some of it carries small grains and masses and a number of specimens with dark brown masses of scheelite ranging up to 4 or 5 inches in diameter were seen. No statement can be made of the percentage of quartz carrying scheelite, and because of the difficulty of securing average samples of the dump, no samples were taken for assay.

"The 100 level has been drifted out for approximately 115 feet south and 130 feet north of the shaft. The vein has been stoped out over a length of 60 feet south of the shaft and a stope from below has taken out part of the floor of the level. No scheelite was found on this level.

"The 200 level is blocked north of the shaft. It has been driven 160 feet south of the shaft and the vein has been stoped out above the level for roughly half of its length. Scheelite was observed at only one point, but no samples were taken.

The 300 level is a drift for 140 feet north and 340 feet south of the shaft, with a stope above the southern drift for nearly half its length. A short stope from below comes up to the level. In the north drift, grains of scheelite were observed at three places and in the south drift at six places. Two samples cut at what were considered the best showings in the south drift assayed 0.02 per cent and a trace of WO_3 respectively.

"In the drift on the 320 level, between the cross-cut adit and the shaft, a number of positive readings with the lamp indicated the possibility of an ore shoot, 320 feet long. Sixteen samples were cut at points where fluorescence was shown. Of these, 12 assayed nil; one assayed 0.01 per cent; one assayed 0.04 per cent; and one assayed 0.08 per cent WO_3. A check sample on the last assayed 0.07 per cent WO_3. Taken in conjunction with a number of negative readings with the lamp, the writer's samples indicate an average content of WO_3 of 0.01 per cent over a width of 10.3 inches.

"In the south drift (320 level), scheelite was observed at a few places but was not sampled as it obviously was not present in greater quantities than in the north drift.

"No mineralization comparable to the heavy scheelite masses that occur on the dump were seen, and it is concluded that these came from parts of the mine that the writer was unable to inspect.

Tubal Cain Vein

"Only a few grains of scheelite were found in the Tubal Cain vein, which lies between the Joshua and the Enterprise veins. No samples were taken. The upper workings on the vein were not visited but examination by the mine officers revealed little scheelite.

Enterprise Vein

"The Enterprise vein has been one of the most productive of the property and a considerable part of it has been stoped out in the upper levels.

"An examination of the Enterprise vein indicated, on the whole, little scheelite. One small concentration on the 320 level, 88 feet south of the intersection with the King William vein, was sampled by Hedley.* This assayed 0.16 per cent WO_3 across 4 inches. Elsewhere the vein carries grains and small masses of scheelite but in quantities that were judged to be considerably less than in some of the concentrations sampled on the King William vein. These showings consequently were not sampled.

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* Hedley, M. S., British Columbia Department of Mines, Personal Communication.

King William Vein

"The King William vein branches from the Enterprise vein south of the point where the latter is intersected by the adit. Drifts have been run on the 320, 440, 550, 675, and 900 levels. In addition, a winze has been carried down from the 675 level to the 800 and a little drifting done, but these workings are inaccessible.

"At the surface, a shaft has been sunk on the King William vein to a depth of 170 feet, with levels at 40 and 170 feet. These workings are inaccessible. Open-cuts on the No Surrender claim, about 800 feet to the north, apparently trace the same vein where it underlies heavy drift cover. There is a gap of some hundreds of feet between these and the southermost exposures in the underground workings on this vein at the Enterprise mine.

"At the King William shaft some of the quartz in the dump showed grains of scheelite. Owing to the difficulty in securing a representative sample, no samples were taken. In an open cut at the shaft, scheelite appears in a shell of quartz adhering to the country rock, but as the vein has been mined out no samples were taken. The cuts on the No Surrender claim showed only a few grains of scheelite.

"In the underground workings of the Enterprise mine, the King William vein has been drifted out for distances up to 900 feet southerly from its point of intersection with the Enterprise vein on the various levels except the 800.

"On the 320 level scheelite occurred in a short stretch about 180 feet southerly from the intersection with the Enterprise vein. This stretch is about 10 feet long and is well mineralized with grains and masses of scheelite. Two samples across widths of 36 inches and 24 inches assayed 0.52 per cent and 0.29 per cent of WO_3 respectively. Both channels cut fair-sized masses of scheelite and undoubtedly represent the best material present. The vein on either side of this short stretch contained little scheelite. Scheelite was observed at roughly half the stations examined on this level, but at none of these was it deemed to be present in quantities sufficient to warrant sampling, having regard to the results obtained elsewhere.

"A raise between the 550 level and the 440, about 120 feet from the face of the 550 level, encountered masses of scheelite about the size of a man's fist. Fluorescent material appeared prevalent in the raise and on the 440 level immediately above. As the occurrence appeared to indicate an ore shoot, a number of samples were cut. As work was in progress in the raise, these samples were cut more or less at random and not necessarily at points of maximum fluorescence. The samples on the 440 level above were, however, cut at what were considered the best showings. Of five samples in the raise, one assayed 0.02 per cent and one assayed 0.03 per cent WO_3; the other three assayed nil. These samples were located 18, 26, 33, 39 and 55 feet above the manhole. Of the four samples grouped about the top of the raise on the 440 level, taken where fluorescence was at a maximum, one assayed 0.15 per cent WO_3 and the other three assayed nil. The King William vein has been drifted out for 630 feet beyond the point encountered in a cross-cut from the enterprise vein on the 440 level, and for 900 feet southerly from its intersection with the Enterprise vein on the 550 level. No concentrations of tungsten similar to those found in the raise were observed elsewhere on these levels.

"On the 675 level, the King William vein has been drifted out for 780 feet from its intersection with the Enterprise vein. For part of this distance it is disturbed by one of the basaltic dykes referred to. A wide part of the vein begins 330 feet from the intersection and continues for 240 feet. Here the vein attains a maximum width of 9 feet. A winze has been sunk to the 800 level in this section but is now inaccessible. The whole vein could not be examined in this section because of timbering but groupings of positive readings with the lamp indicated two sections which might be considered ore shoots. From one section which is approximately 75 feet long, 4 samples were taken; these assayed 0.04 per cent, nil, 0.02 per cent, and nil of WO_3. From the other section which is about 45 feet long, two samples were taken. These both assayed 0.02 per cent WO_3. In each case the average is 0.02 per cent, in one across 27 inches and in the other across 24 inches. In both cases only part of the vein was sampled; the remainder appeared to carry less scheelite.

"Some drifting has been done on a vein which has been tentatively correlated with the King William on the 900 level. In part the vein as exposed was little more than a fracture; the remainder of the vein showed fluorescence in places, but no samples were taken as the quantity of scheelite was judged no greater than at localities sampled elsewhere. A cross vein between this and the Enterprise vein has an indicated length of 200 feet but only about

90 feet of this is actually drifted out. At a point roughly 30 feet from the intersection of this with the King William vein a short shoot of high grade scheelite appeared in the breast of the drift and was cut down slightly below the level of the floor. In the back and on either side, disseminated scheelite appeared in the vein, and fluorescent material appeared in the drift at intervals in either direction. The high-grade itself appeared limited to 8 or 10 feet in length. Two samples were cut of the vein immediately adjacent to it at points where the fluorescence was marked. At one of these some grains of scheelite could be detected with the naked eye. One of these assayed 0.01 per cent WO_3 across 12 inches; the other assayed nil. A sample across 6 inches of highly fluorescent material near the southwest face (December, 1941) also assayed nil.

Jenny Long Mine

"The Jenny Long mine is situated some 13,000 feet southeast of the Enterprise mine. So far as is known the last work on the property was done in 1936 and the plant and machinery were partly dismantled. The mine is now inaccessible.

"Examination of the dump showed that some of the quartz carried scheelite. Narrow bands of fluorescent material appear in the quartz although the scheelite which appears to be greyish white is not readily visible. The fines on the dump carry many fluorescent chips and particles. A grab sample by the writer of the fines only, taken at points where these showed fluorescence, assayed 0.06 per cent WO_3. Hedley* also took several samples from the dump. A sample of wholly fluorescent chips assayed 3.5 per cent WO_3. A selected sample of partly fluorescent material assayed 0.06 per cent WO_3. Four other grab samples from different parts of the dump each assayed nil although fluorescent chips and particles were common. These results should not be construed as a sampling of the dump.

Johannesburg Mine

"The main showing is at a shaft on the Azela claim about 16,000 feet southeast of the Enterprise camp. This shaft which is 78 feet deep is filled with water to within 20 feet of the collar. The occurrence apparently consists of a shatter zone 6 to 8 feet wide with very little quartz near the collar of the shaft; judging from the dump, veins

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* Hedley, M. S., British Columbia Department of Mines, Personal Communication.

of quartz were encountered in the zone below. The quartz carries grains and narrow bands of scheelite and the latter mineral also occurs with narrow seams of quartz in the country rock. No samples were taken for assay.

"A number of other cuts exposing veins and bunches of quartz north-east of this shaft were not examined under ultra-violet light.

"A shaft known as the Johannesburg shaft, about 3000 feet north-east of the Azela shaft, is reported to be 212 feet deep, and is filled with water to within 60 feet of the collar. The upper part of the shaft is tightly lagged. Only a small amount of quartz appears on the dump, which was not examined under ultra-violet light.

Emulator

"The Emulator workings are situated about 3,000 feet slightly east of south of the Joshua shaft. The vein is shown on the surface by a line of cuts and trenches in one of which the vein attains a width of nearly 8 feet. In other cuts, the vein is expressed by a number of stringers of quartz. An adit has been driven to crosscut the vein and continued as a drift on the vein for about 90 feet. A short section of the back is lagged but beyond this, a wide part of the vein shows considerable fluorescent material. In the section near the face, scattered grains of brown scheelite appear in the quartz. Six samples were cut across parts of the vein. Three samples of the wide fluorescent part of the vein each assayed nil, and three samples nearer the face each assayed 0.02 per cent WO_3 across 48, 39, and 3 inches respectively. Two samples by Hedley,* one across the vein near the face, assayed nil, and the other across the strongly fluorescent material assayed a trace. The writer's samples, taking into account the nils obtained by use of the lamp, would indicate a stretch of the vein about 30 feet long which would average 0.01 per cent WO_3 across a width of 34 inches.

Moon Claim

"Two cuts about 50 feet apart appear on the Moon claim to the north-west of the Jenny Long mine. At one of these cuts, three parallel quartz stringers each two or three inches wide, in a fracture zone about 6 feet wide, are very well impregnated with scheelite. This scheelite

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* Hedley, M. S., British Columbia Department of Mines, Personal Communication.

mineralization was as heavy as any seen on the property. The quartz carried practically no sulphide and the intervening country rock showed no scheelite. The second cut exposed a quartz vein with very little sulphide and only a grain or two of scheelite. As the attitude of this second exposure could not be obtained, there remains some doubt whether it represents the same zone as the first. No samples were taken from these exposures.

"Most of the other veins of the property were given a preliminary examination but these showed very little or no scheelite at the points where exposed or on the dumps from the workings.

Conclusions

"It will be recalled that a very large part of the samples cut were taken at points where there was considerable fluorescence and the many nils obtained upon assay would either indicate that this fluorescence, while strongly simulating scheelite, may be due to some other mineral, or if due to the presence of scheelite, that this mineral in such cases is present in very minute amounts. It is therefore considered that fluorescence itself is not a wholly reliable guide to the amount of scheelite present. The tungsten content of the places sampled proved to be very low, and when the many points tested with the lamp with negative results are considered, it must be concluded that the average tungsten content of the veins is very low indeed. While the number of samples taken was limited, an effort was made, except in the instances noted, to sample what were deemed to be the better showings. A few small concentrations of good grade scheelite ore were found in the workings, but these appear to be somewhat widely scattered.

Don Group

"This group is situated on the crest of the ridge overlooking the valley of Stump Lake. The owners are W. McMaster, Murray Doyle et al, of Stump Lake, B. C.

Scheelite was found at only one location on the property. At this point, an incline shaft has been carried down 50 feet on a fracture zone which is about 5 1/2 feet wide. Stringers and veins of quartz appear in the zone; the amount of quartz varies considerably from place to place. Scheelite appears disseminated in the quartz from the foot of the lagging which extends about one-quarter of the way down the shaft to the bottom of the shaft. The zone carries more or less calcite but very little sulphide. Two samples were cut across the zone,

one across 35 inches near the bottom of the shaft assayed 0.05 per cent WO_3, and the other across 34 inches, 20 feet from the bottom of the shaft, assayed 0.25 per cent WO_3.

"Other workings a considerable distance to the south were examined but no scheelite was found."

SIMILKAMEEN - TULAMEEN AREA

GRANITE* Eight claims covering ground on the upper slopes of Granite Mountain, in the Similkameen Mining Division, were recorded in August, 1942, in the names of Stanley Cunningham, Robert Jameson, Louis Marcotte and A. A. Price, all of Coalmont. The property can be reached from the end of the Whipsaw Creek road (elevation 4,750 feet, 22 1/2 miles from Princeton) by following a pack trail which continues up Whipsaw Creek, almost to Hope Pass, and thence a branch trail westerly and northerly, to a total distance of about 10 miles from the end of the Whipsaw Creek road. The property can also be reached by trail from Blakeburn, a reported distance of 18 miles.

Bed-rock exposures consist of granodiorite, and andesitic gneiss. The granodiorite has a gneissic character and contains abundant biotite and hornblende. It is continuous with granodiorite exposed on upper Whipsaw Creek, mapped by Cairnes as Eagle Granodiorite. (Geol. Surv. Canada, Summary Report 1922, Part A, Page 114A and Fig. 11). Near the workings the andesitic gneiss is cut by dykes and sills of granodiorite.

Three old open-cuts, at elevations from 5,850 to 5,950 feet, spaced at intervals in a distance of 700 feet, exposed a vein (or veins), at the southern end following the contact between andesite and granodiorite and at the northern end entirely in granodiorite. In these exposures quartz, with some partly replaced wall-rock, ranges from a few inches to 3 1/2 feet in width. The vein filling contains small amounts of pyrite, galena, sphalerite and scheelite. Assays of samples representing vein exposures at the time of examination ranged from: Tungstic oxide (WO_3), nil or trace to 0.05 per cent. Some grains of greenish scheelite up to 1/4 - inch long were seen in pieces of quartz near the workings.

SKAGIT RIVER AREA

Scheelite has been reported from the Skagit River area by Cairnes (VII, 1920, p. F-9). It occurs on the Mammoth group in the old Twenty-three mile camp, at the junction of the Skagit and Sumallo Rivers, a point approximately 23 miles by an old road that extends south-easterly from the village of Hope.

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* Report by H. Sargent, British Columbia Department of Mines.

The scheelite occurs in a vein about 3 feet wide that follows the west wall of a calcic-silicate zone about 50 feet wide. It is associated with various calcic-silicates which include abundant anorthite, feldspar and actinolite and with the sulphides nickeliferous pyrrhotite and sphalerite. Very little work appears to have been done on this property.

HEDLEY AREA

Scheelite has been reported from lime-silicate rocks at various places between Hedley and Olalla.

It has been reported by George H. Lyons, of Hedley, and C. D. Collen of Oliver, from the headwaters of Eighteen-mile Creek, north of Hedley and by Williams from showings near Olalla.

VERNON AREA

Tungsten reported from this area is from the White Elephant group, (Precambrian Gold Mines, Ltd.) a gold property, 2 miles west of Okanagan Lake and about 36 miles south-westerly from Vernon. Concerning this reported occurrence, Cairnes says (VII, 1931, p. 87-A, foot-note): "The writer was informed that some scheelite had been associated with the quartz in the outcrop." The showing on the White Elephant group consists of a large quartz lens 60 feet long by 50 feet wide at the surface, but longer underground, that has been mineralized by small amounts of pyrrhotite, pyrite, chalcopyrite and locally, a moderate amount of the gold-bearing bismuth telluride, tetradymite. Cairnes does not mention scheelite underground. The country rock is granite.

BEAVERDELL AREA

The Beaverdell area is in south central British Columbia and centres around Beaverdell, a village on the Kettle Valley branch of the Canadian Pacific Railway, 261 miles east of Vancouver, or 93 miles by road east of the town of Penticton. It may be reached by motor-road easterly from the town of Kelowna, 46 miles distant. Kelowna is on the Okanagan Highway route No. 5, 328 miles easterly from Vancouver.

Scheelite in small quantities occurs in several of the calcic-silicate zones in the Beaverdell area, but development in August, 1940, had not exposed economical amounts.

ELITE — This prospect consists of the Elite mineral claim staked in July, 1940, and owned by Victor F. Locke, of Kelowna.

The claim is on the west side of Arlington Mountain, approximately 5 miles north of Carmi. Carmi is on the Beaverdell-Kelowna road 5 miles north of Beaverdell. The workings are 1 1/2 miles west of the highway.

The workings, at an elevation of 3,500 feet, may be reached by following a compass-line on a bearing (astronomic) of north 30 degrees west for 1 1/2 miles from a point, elevation 2,900 feet, on the Carmi-Kelowna road that is 5 miles north of Carmi.

The hillside in the vicinity of the showings is the gentle westerly slope of Arlington Mountain. It is densely wooded and although covered by only a foot or two of overburden in many places, outcrops in the vicinity of the workings are scarce.

The scheelite showing consists of an area approximately 15 feet in diameter of calcic-silicate rock that contains scattered grains of scheelite. Quartz-diorite occurs 50 feet northerly from the workings.

The calcic-silicate rock consists of light green, dense diopside, granular, brown garnet and some granular calcite and epidote and quartz.

The scheelite occurs as grains disseminated throughout the rock, showing a preference for areas of quartz and, occasionally, as short-hair-like veinlets in quartz. The amount of scheelite is so small that samples of selected specimens in excess of 5 pounds are usually too low in scheelite to give a recordable assay in tungstic oxide, WO_3.

All the workings are old, apparently antedating the year 1915, the date of publication of a report by Reinecke (VII, 1915, pp. 142-143) in which he mentions the scheelite occurrence. No recent work other than sampling of the small dumps has been done on the showings.

The workings consist of three pits. An upper one 6 feet in diameter by 6 feet deep; a second one 5 feet lower and 15 feet westerly from the first and 5 feet in diameter by 4 feet deep, and a third one, 10 feet below the second and 40 feet in a direction south 20 degrees west from it. All these pits show small amounts of scheelite.

OTHER OCCURRENCES IN THE BEAVERDELL AREA

Mr. Victor Locke, owner of the <u>Elite</u> mineral claim, showed the writer two other occurrences of scheelite. One was on the east bank of the Westkettle River opposite a point on the Beaverdell-Kelowna road, 5 miles north of Carmi. The other showing was on Knob Hill, approximately 7 miles north-east from Beaverdell up Beaverdell Creek.

<u>Kettle River</u>. The Kettle River occurrence is in a band of garnetiferous limestone that extends south-easterly from the east bank of the river for 500 feet over an outcrop width of approximately 100 feet.

The outcrops are in an area that consists of low knolls, 20 to 40 feet high, in a badly burnt-over area.

The mineralization, as seen in the outcrops and surface pits, consists of a few grains of scheelite scattered indiscriminately through garnetiferous limestone. Garnet, the brown andradite variety, occurs in small irregular patches throughout white, crystalline limestone; the scheelite present favours the garnet areas. The amount of scheelite in these showings is negligible.

The only working on these outcrops consists of one open-cut 3 feet deep on the west slope of a knoll 40 feet high and 120 feet from the river-bank.

Knob Hill. The Knob Hill showings may be reached from Beaverdell by following the road north-easterly up Beaverdell Creek for a distance of 7 miles, then by a westerly route through open pine-woods of the hillside to an elevation of 4,300 feet. The hillside in the vicinity of the workings is relatively open, covered with range-grass and pine trees and slopes gently north-westerly.

The occurrence consists of minute grains of scheelite sparsely disseminated through calcic-silicate rock that is composed of diopside, brown garnet, calcite and quartz. A 4-foot granite dyke cuts the calcic-silicate rock.

No structural control of the scheelite mineralization by faults or favourable zones is apparent.

The workings consist of an old vertical shaft, 25 feet deep, a pit 8 feet in diameter by 4 feet at a point 5 feet north-easterly, from the shaft and a trench 3 feet wide that extends for 40 feet in a north-westerly direction from the pit. From a point 20 feet south-easterly from the end of the trench a branch-trench extends south-easterly for 15 feet towards the shaft.

Calcic-silicate rocks sparsely mineralized with scheelite occur in all the workings. Much of the mineralized rock was examined in ultra-violet light and that showing the best scheelite was assayed for tungstic oxide, WO_3. However, the amount of scheelite even in the best specimens was too small to give a recordable assay in tungstic oxide. The showings, as they existed when examined by the writer, do not expose any mineable ore.

The Beaverdell scheelite showings were examined by the writer in August, 1940.

BIG BEND AREA

Scheelite has been found in this area on the Ole Bull and Orphan Boy properties 54 miles north of Revelstoke. No other occurrences of the mineral have been reported from the general area except in placer.

OLE BULL and ORPHAN BOY Small amounts of scheelite have been found in these properties which were prospected for gold in the 1890's. The area is reached by following an old packhorse trail which leaves the Big Bend highway 54 miles north of Revelstoke. From the highway the trail follows the north side of Goldstream River for 4 3/4 miles to McCulloch Creek, thence north-easterly up the creek for 5 3/4 miles to the Ole Bull cabin, elevation 6,100 feet.

The rocks on the property include quartzite and mica schist. These rocks are cut by a number of prominent quartz veins.

Several of the quartz veins on the property contain small amounts of scheelite. The veins are lenticular and range in width from a knife edge up to 7 inches within a few feet. The scheelite is found usually as pin-points, occasionally in grains the size of rice, and, in one place, in patches 2 inches in diameter.

Specks and small patches of scheelite have been found in quartz veins and lenses cut by the adit on the Orphan Boy claim, adjacent to the Ole Bull.

None of the veins so far exposed on these properties contain sufficient scheelite to be mined.

REVELSTOKE AREA

The Regal Silver, near Albert Canyon, is the only property known to contain scheelite in the Revelstoke area. The general geology of this section is given in the following report.

REGAL SILVER The Regal Silver property, comprising the Crown-granted mineral claims Joy, Alice, Helena, Bee, May, Cora, Emily, Annie, Nestoria, Francis, Hilda and Big Ledge No. 2, owned by Mrs. Emily Woolsey, is under option to W. S. Campbell and associates of Edmonton, Alberta, as of October, 1940.

The property is on the west side of Clabon Creek, a southerly-flowing tributary to Woolsey (Silver) Creek. Woolsey Creek flows south-easterly into Illecillewaet River at a point approximately 1 1/2 miles down-stream from Albert Canyon, a flag-stop on the Canadian Pacific Railway 20.9 miles east of Revelstoke. The camp is at an elevation of 4,455 feet, and the workings (Fig. 7), all underground, are between elevations of 4,455 and 5,550 feet. The Snowflake property adjoins the Regal Silver on the west.

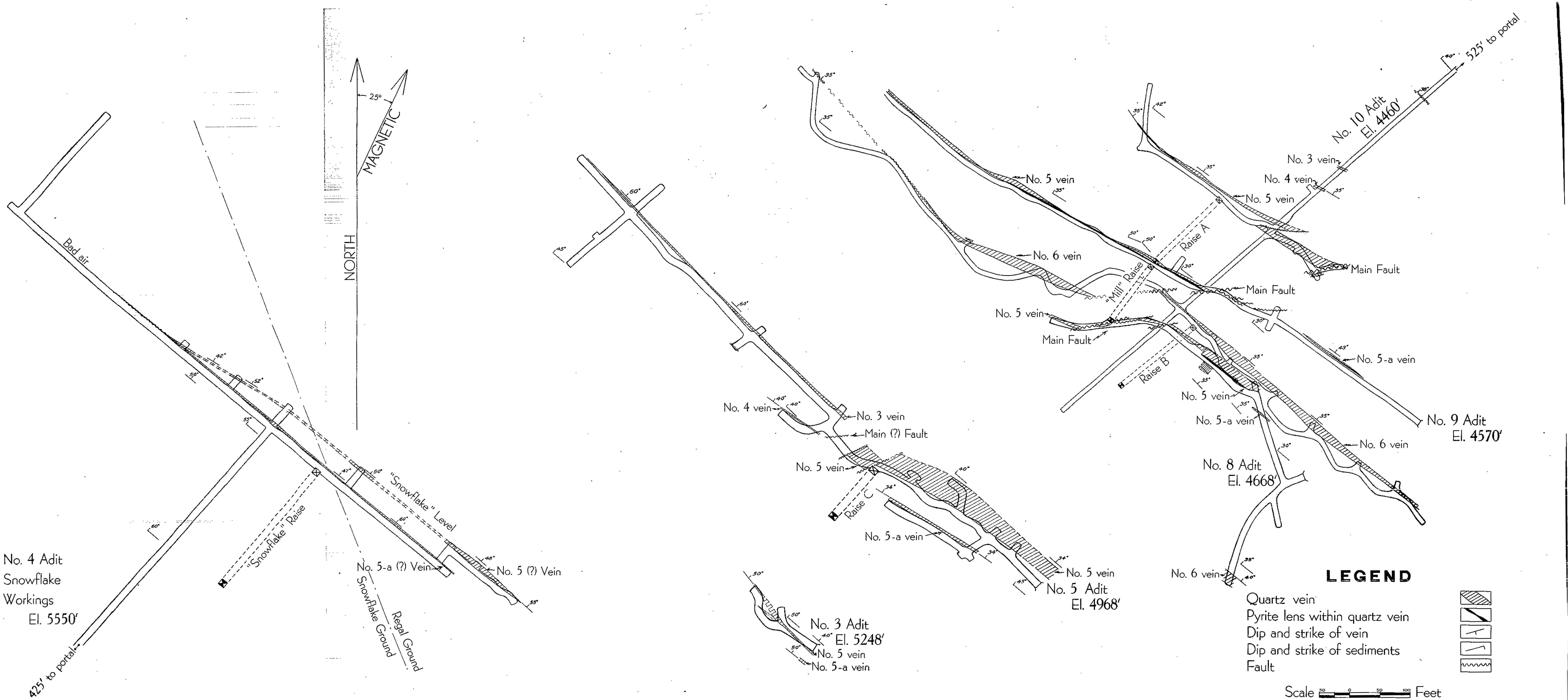

Fig. 7. Regal Silver. Plan of underground workings (after Company's plan) showing distribution of veins and faults.

History

This property in 1918 consisted of seven claims. The original group of four claims, staked by C. E. Kennedy in 1918, was acquired by David Woolsey, who added these claims to the group during that year when the property became known as the Woolsey group. It is believed that Woolsey did the first surface and underground work, presumably in No. 3 adit, in 1918. The following year the property was bonded to a company represented by C. V. Brennan and the present No. 5 adit was commenced and driven 120 feet. In 1920 development work is reported to have been done by David Woolsey and his two sons.

In 1925 the property was acquired by the Bernier Metals Corporation of Vancouver, who made considerable surface improvements and started the present No. 10 adit. In 1926 further surface work was done and the No. 10 adit driven for approximately 200 feet. This work, including additional development in No. 5 adit, was continued by the company until 1927.

In December, 1927, the Bernier Metals Corporation ceased to function and was succeeded by the Morton-Woolsey Mines, Limited,* which in turn gave an option to the Buck and MacCulloch Syndicate in March, 1928; this syndicate incorporated the Regal Silver Mines, Limited**. During 1928, No. 10 adit was extended to cross-cut the Nos. 5 and 6 veins along which drifting was done. In 1929, No. 10 adit was extended and an intermediate level, now No. 9 adit, was started. In 1930, considerable underground work was done consisting of exploration on Nos. 9 and 10 adits, the starting of No. 8 adit and the extension of the No. 4 adit of the <u>Snowflake</u> workings from <u>Snowflake</u> ground into the adjacent <u>Regal</u> ground.

In 1939 the property was operated by A. S. MacCulloch and associates. Ore tests were made with the object of producing a scheelite concentrate suitable for marketing. A small underground mill of approximately 25 tons rated capacity was installed. It is reported that this mill only ran two weeks and that no concentrates were shipped.

In August, 1940, Edmonton and Vancouver interests, headed by W. S. Campbell of Edmonton, re-opened the property, tore out most of the machinery composing the 1939 underground mill and commenced the installation of equipment for a small pilot mill. This work was being done at the time of the writer's examination in October.

Access and Topography

The property is reached by caterpillar road from Silver Creek siding on the Canadian Pacific Railway, approximately 1 3/4 miles

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* Company dissolved February, 1941.

** Company struck off August, 1940.

west of Albert Canyon. The caterpillar road climbs approximately 2,300 feet in a distance of 7 miles from the siding to the mine-camp.

The workings, all underground, are on a steep hillside that slopes with an average angle of 26 degrees into the bed of Clabon Creek. Slide rock and low bush characterize the adjacent hillside. Rock bluffs, though not present in the vicinity of the workings, are numerous and extensive a few hundred feet above. The bluffs are the starting points for many snow slides during the winter season. As a result, care must be observed in the choice of building sites in order that places free from snow slides may be chosen. This is not easy.

Geology.

The deposit consists of scheelite in bedded quartz-sulphide veins which lie within black to grey slates. No igneous rocks were noted on the property.

The slates are part of a belt of slightly metamorphosed Pre-cambrian sediments which strike north-westerly and dip eastward. This belt is approximately 14 miles wide and extends for several miles north-westerly and south-easterly. The Regal-Silver lies approximately 3 miles within the south-westerly boundary of the belt.

To the south-west, across the strike, this belt of slightly metamorphosed sediments is succeeded by a short discontinuous belt, approximately 2 miles wide, of more highly metamorphosed sediments, consisting chiefly of quartzites and schists. These rocks are in contact to the south-west with a large area of schists, gneisses, gneissic granites and pegmatites (VII, Gunning, 1928, p. 149), a lithological group of rocks to which Daly (VII, 1913, p. 35) gave the name "sill-sediment complex."

Granitic rocks do not occur on the property. The nearest areas of granite are two stocks, one of which outcrops 7 miles north-east of the workings in the vicinity of Fang Rock (see map No. 237A in report by Gunning, 1928) and the other outcrops 8 miles to the south-east on Albert Creek south of Illecillewaet River. (Idem. 1928, pp. 144-148).

The granitic tongues in the complex immediately to the south-west indicate the presence of an underlying mass of granite. This inferred mass of granite, extending north-westerly would underlie the Regal scheelite occurrence and serve as a source for the mineralizing solutions responsible for the veins on the property.

The rocks on the property are black to grey, graphitic slates or slaty argillites, some of which are slightly limy. They are fairly uniform in attitude, varying in strike from north 40 degrees to 50 degrees west and in dip from 30 degrees to 60 degrees north-eastward. Other sedimentary types and igneous rocks are absent from the vicinity of the workings.

Folds.

Folding on a small scale has not occurred within the limits of the underground workings; the rocks strike north-westerly and dip south-eastward with no reversals of dip. This corresponds to the regional structure of the area which has been described by Gunning (VII, 1938, p. 151), as follows:

> "The major geologic structure is a broad synclinal trough whose axis trends north-west-south-east through the centre of the mapped area. Within this major syncline the rocks are complexly folded into a series of synclines and anticlines whose axes, on the whole, parallel the regional strike of the sedimentary formations and plunge towards the south-east."

Although the strike of the rocks in the workings is fairly constant, the dips show a progressive and general flattening as from the uppermost to the lowermost levels. In general, the dips in the uppermost or Snowflake level are between 60 and 55 degrees, this figure changes through 50 and 45 degrees in No. 5 adit to 40 and 35 degrees in Nos. 9 and 10 adits. This tendency for the rocks to flatten in a north-easterly direction suggests the presence of a synclinal trough in that direction. Without more field data it is impossible to predict how far north-east the axis of this fold would lie.

Faults.

Post-vein faults are widespread. The faults are of two main types: (1) transverse, inter-vein faults that cross-cut the veins and offset them across their strike, and (2) Parallel, intra-vein faults that parallel the veins, lie within them and displace the walls of the vein by unmeasurable amounts. The inter-vein faults can be seen in (Fig. 7), but because of difficulty in clear representation the intra-vein faults have only been occasionally shown.

The main transverse inter-vein fault is one that strikes east and dips steeply northward. It has been cut on all levels but No. 3 and the Snowflake level. The fault-zone consists of abundant crushed graphitic slate (Plate IV-A). Numerous curved slips follow the crushed slate and some branch into the wall rock. Depending on the abundance and compactness of these slips, the main crush-zone ranges from 1 foot to 10 feet in width. Crushing within the zone appears to have been intermittent and interrupted by one main period of quartz mineralization. In many places the zone contains slightly deformed stringers and small lenticular bodies of quartz (Plate IV-A) lying within the sheared graphitic slate and roughly parallel the main direction of the fault-zone; no minerals other than quartz appear to have been formed at this time. Because of the deformation and fracturing of these quartz veins and stringers, faulting within the zone was apparently continued after the deposition of the quartz. The formation of quartz in the fault-zone no doubt completely post-dates that of the main quartz-sulphide veins.

Displacements within the plane of the main fault, as measured in the drifts and as calculated from vein offsets, are as follows: dip-slip, 55 feet; strike-slip, 100 feet; net slip 115 in a direction inclined at 30 degrees below the horizontal in a north-easterly direction. Because of variations in the dip of the fault, the figures for heave and throw of the faulted vein vary slightly from place to place; however, the figures are close to those pertaining to the displacement on No. 8 level, namely, a heave of 20 feet and a throw of 50 feet. Other faults of much smaller size occur at other places underground, (Fig. 7). Displacement along these has amounted to only a few feet and has not caused any trouble in locating the faulted segments of the vein.

Veins.

At least five separate quartz-sulphide veins have been cut in the underground workings. These veins are all more or less parallel to one another and to the enclosing slates, although occasionally cutting the slates at small angles, and may be classed as bedded veins. They range in strike from north 45 to north 65 degrees west, in dip from 34 degrees to 60 degrees north-eastward and range in width from a few inches in places where the vein-matter disappears along a fault to as much as 30 feet; however, widths between 2 and 8 feet are more common. The maximum length of any one vein is not known, but 1,000 feet of vein-matter is exposed in No. 6 vein on No. 10 level (see Fig. 7).

A distinct ribbon-texture (Plate Iv-B) is characteristic of much of the vein-matter. This texture is manifested by bands and ribbons of either unreplaced slate or of pyrite which has favoured deposition along these ribbons. Even where sulphides are abundant the vein is definitely banded. This banding is disconnected and irregular and is therefore considered to be inherited from an earlier ribbon-texture rather than caused by repeated re-openings by fissuring within the vein. In extreme cases slate forms the bulk of the vein-matter, and vein-quartz tends to form stringers along the slate, finally ending as a few veinlets of quartz.

The intra-vein faults are not so conspicuous as the transverse, inter-vein faults, inasmuch as they follow the vein and are usually plainly evident only where they follow pyrite lenses or leave the veins along their strike. These faults are commonly marked only by thin clay slips in either the hanging- or foot-wall of the vein. Where they follow pyrite lenses the slips widen to crush-zones up to 1 foot in thickness; usually, however, they are marked by 1/2 - inch to 6 inches of crushed pyrite. Abundant slickensiding, expressed by mirror-like surfaces on the pyrite along slip-walls and occasional superposition of the vein, indicate that considerable movement has occurred along these intra-vein faults. However, there are no markers either within the vein or in the vein-walls to determine relative movements within the plane of the fault.

Determinations of relative movement along the faults and the direction of movements are of importance in, (1) attempting to correlate the various scheelite-bearing pyrite lenses cut in the drifts and (2) in trying to determine the extent of any lens up and down the dip of the vein. With such extensive intra-vein faulting present and no information concerning the displacement along these faults, prospecting for the extension of these pyrite lenses beyond their apparent termination, is difficult without definite working clues.

Mineralogy.

The mineralogy of the veins consists of scheelite and pyrite, sphalerite, galena and small amounts of stannite, all in a quartz gangue. In addition to these, Gunning (VII, 1931, p. 217) mentions microscopic amounts of tetrahedrite, ruby silver, native silver and chalcopyrite from the Snowflake ores. The writer has not studied the Regal ores under the microscope, but considers it probable that these minerals are present in similar amounts. In most places quartz is the more abundant constituent, the combined sulphides and scheelite generally amounting to less than 1 per cent of the vein-matter.

The scheelite occurs (1) in small amounts indiscriminately scattered at wide intervals throughout the quartz veins, and (2) in relatively larger amounts confined to four thin pyrite lenses or ribbons which lie within Nos. 5 and 5A veins. In the first mode of occurrence, scheelite is found either as thin, microscopic films that usually parallel the ribbon-structure of the veins, or as occasional grains which range from microscopic size to 1/4-inch in diameter and are usually associated with small pyrite clusters. The scheelite is at first only recognizable by its fluorescence in ultra-violet light. In the second mode of occurrence scheelite is within pyrite lenses. These lenses range in length from a few feet to 250 feet, and in thickness from 1 inch to 18 inches, although 6 inches is a more common width. The amount of scheelite in these lenses is very variable, ranging from a few microscopic specks to one kidney of relatively pure scheelite measuring 2 feet long by 4 inches wide (Plate III-B). In general, the scheelite occurs either as short thin kidneys (Plate V-A) or as ribbons that parallel the walls of the pyrite lenses. The ribbons range from 1/32 to 3/4 of an inch in thickness and from 1 inch to several feet in length. They commonly consist of disconnected grains and small patches of scheelite (Plate V-B) and less rarely of a solid band of the mineral.

To a large extent, pyrite and quartz replace the scheelite in the ribbons and accounts for much of its discontinuity along the strike.

Pyrite is the most common sulphide in the quartz veins and is abundant at many places in the slate wall-rock. Like the scheelite pyrite occurs either scattered in small amounts throughout the quartz veins, or concentrated into scheelite-pyrite lenses described above. The pyrite lenses are commonly the locus of extensive intra-vein faulting. As a result, pyrite grains are commonly broken and in the faults the grains are crushed to material of gouge-like consistency. Many of the pyrite grains in the vicinity of the faults are coated by films of graphite. This graphite has probably resulted from the extreme crushing of pyrite-bearing, graphitic slate adjacent to the veins.

Galena and sphalerite, found together in widely scattered areas throughout the quartz veins, usually occur as small walnut-sized patches within the quartz. In a few places a few hundred pounds have been mined from rich pockets. The galena is the usual steel grey, cubic-cleaved variety. The sphalerite is noticeably light brown in colour and is almost a resin-jack.

Stannite occurs in small quantities associated with the pyrite. Excepting in No. 5A vein in the Snowflake adit, it is seldom recognizable in a hand specimen. In this vein stannite is found in the drift in the vicinity of the raise and in the lower 50 feet of the raise in patches up to 2 feet in diameter, that consist roughly of one-third stannite, one-third pyrite and one-third quartz gangue. Small segregations of scheelite were seen associated with the stannite.

Excepting for slate partings, gangue in all the veins is entirely milky quartz. The only carbonate seen was a 2-foot pocket of calcite lying within the main fault-zone on No. 10 level. Inasmuch as the fault post-dates the quartz veins, the formation of this calcite must also post-date them.

Individual Description of the Veins.

For purposes of description, these veins have been numbered as from the hangingwall-side to the footwall-side; numbered thus they are Nos. 3, 4, 5, 5A and 6 (Fig. 7). Of these, No. 5 is the most important as far as scheelite-bearing vein-matter is concerned.

No. 3 vein has been found on level Nos. 5 and 10, (Fig. 7). Its usual width is approximately 2 feet, but it widens to a maximum of 5 feet in No. 5 adit, then narrows towards the northwest end of the same adit to a 5-inch ribbon of crushed material in an intra-vein fault.

No. 4 vein has been found on adits Nos. 5 and 10. Measured across the dip it is 25 feet below No. 3 vein. It is similar in range of widths to No. 3 vein.

No. 5 vein, the only one in which scheelite occurs in appreciable amounts, has been found in the following adits: Snowflake level and Nos. 3, 5, 8, 9 and 10, (Fig. 7). Measured across the dip it is 50 feet below No. 4 vein. Seen in short sections the vein appears to be tabular and of a uniform width. However, because of discontinuous ribboning that is manifested by dying out and coming in of quartz bands within the general boundaries of the veins, the actual width of vein-matter is variable along drift-sections. This variation in width is noticeable on all levels, but particularly so on No. 9. On the Snowflake level, No. 5 vein ranges from 2 to 11 feet wide, but towards the north-west end of the drift it disappears in sheared rock and crushed vein-quartz along an intra-vein fault (Fig. 7). On No. 3 level it ranges from 6 inches to 4 feet. This vein reaches its maximum width of 30 feet in the side drift on No. 5 level, but decreases to 11 feet on its strike north-west towards the main fault. In general, however, the widths are much less and within the wider sections of the veins, bands of slate are common. On No. 8 level the range in width is from 3 to 11 feet, on No. 9 from 1 to 6 feet and on No. 10 from 1 1/2 to 12 feet of quartz and towards the extreme north-west end of the drift on this level the vein narrows to 3 inches of pyrite. Although No. 5 vein is similar to the other veins inasmuch as it generally consists of abundant quartz with patchy sulphides, it differs in that it contains three narrow, well-defined lenses of nearly solid pyrite. These lenses are found on Nos. 8, 9 and 10 levels, but they are absent as well-defined lenses on the Snowflake as well as on the Nos. 3 and 5 levels. On the Snowflake level a considerable amount of galena was discovered, particularly in the cross-cut 90 feet back from the face at the south-east end of the drift on No. 5 vein.

No. 5A vein lies in the foot-wall from No. 5; measured across the dip it is 25 feet below that vein. It has been found in the Snowflake level and in Nos. 3, 5, 8 and 9 levels. On the Snowflake level it ranges from 2 to 4 feet 4 inches in width, at No. 3 level the short section exposed is 4 feet wide. On No. 5 level it ranges from 3 to 5 feet in width, on No. 8 level the short section cut is 1 foot wide and on No. 9 level the vein ranges from 1 foot to 1 foot 6 inches wide. On Nos. 3, 5 and 8 levels this vein is similar to the other veins in consisting of abundant, ribboned quartz with patchy sulphides, but on No. 9 level it contains a foot-wall lens of crushed pyrite. This lens (Fig. 7) is approximately 45 feet long and ranges from 1 inch to 10 inches in width. It contains a few short sections of ribbon-scheelite. It may be mentioned that on the Snowflake level a few pockets of stannite and pyrite up to 2 feet in diameter were found, particularly in the Snowflake raise. Scheelite occurs in the Snowflake level to the same extent that it does on the other levels, except for concentration in pyrite lenses on levels 8, 9 and 10.

No. 6 vein is found on Nos. 8 and 10 levels; measured across the dip it is 110 feet below No. 5 vein. On No. 8 level the short section cut is 15 feet wide. On No. 10 level it is extremely variable in width ranging from a maximum of 18 feet on the south-east to a few disconnected stringers of quartz along an intra-vein fault to the north-west (Fig. 7). The vein consists chiefly of ribboned quartz, with patchy sulphides and traces of scheelite.

Scheelite-bearing Pyrite Lenses.

Assayable amounts of scheelite occur mainly in the pyrite lenses that lie within the quartz veins. Elsewhere in the veins exposed in development the amount of scheelite is so small and so erratic in distribution that it can be considered of mineralogical interest only. Scheelite-bearing pyrite lenses occur in Nos. 5 vein on Nos. 8, 9 and 10 levels and in No. 5A on No. 9 level. They range from 1 inch to 18 inches thick, in general averaging about 6 inches, and from 25 feet to approximately 350 feet in length. Because of extensive intra-vein faulting the continuity of these lenses on the dip of the vein may be obscure and their correlation one with the other is practically impossible in the absence of connecting winzes and raises. Intra-vein faulting, combined with the originally disseminated nature of the mineralization, has further increased their erratic distribution in the plane of the parent quartz vein. The vertical extent of these lenses in the plane of veins is indicated in only one place, namely in the "Mill" raise above level 8. Here abundant sulphide extends more or less continuously to a point 120 feet up the raise from level 8. However, down the dip below level No. 8 in raise A, sulphide lenses are absent from the vein. Although definite data concerning the extent of this mineralization on the dip of the vein are not available, the sections as cut by the drifts indicate that it is probably less than the slope distance between the levels Nos. 8, to 9, i.e., less than 190 feet. In view of the relatively small size and number of the pyrite lenses so far found in the extensive drifting done on this vein, it is not to be expected that any increase will be found with further drifting. More exploration up and down the dip of the vein would delimit those lenses already found and encounter any smaller lenses that may lie between the levels.

Estimates of Amount of Scheelite in the Pyrite Lenses.

Because of (1) the irregular shape and erratic distribution of the scheelite-bearing pyrite lenses and (2) the erratic distribution of scheelite within those lenses, it is well-nigh impossible to make a reliable estimate of either grade of mineralized material or amount of tungstic oxide (WO_3) that could be reasonably expected. Despite this, however, the writer has attempted to estimate the amount of scheelite present in the drift sections. A portable ultra-violet light was used to outline the scheelite streaks and lenses in the drift-backs by fluorescence. The data obtained were checked by taking a number of samples across the full widths of the lenses at different places where widths of scheelite varied. The summarized results of this work are given in the following paragraphs.

The longest drift-section of scheelite-bearing material occurs on level No. 9, both east and west of raise A. The easterly section begins at a point 10 feet east of the raise and extends to a point 110 feet east where the lens is cut off by the main fault. The extent up and down the dip of the vein is unknown. Comparable sections do not occur either above in levels No. 8 or below in No. 10. Scheelite-bearing pyrite is found in the "Mill" raise for a dip-length of approximately 25 feet, but no similarly mineralized lenses occur in raise A below No. 9 level. It is probable, therefore, that the dip-length of this lens would be less than 50 feet. Based on the above method the calculated amount of scheelite in this 100-foot section is 200 lbs. of tungstic oxide (WO_3) per foot of depth for a sulphide width of 6 inches.

The westerly section on level 9 extends from a point 40 feet west of raise A to a point 225 feet west, a distance of 185 feet. The extent up and down the dip of this section is unknown. Inasmuch as it does not appear above or below on No. 8 or No. 10 levels, its extent on the dip is less than 195 feet; the slope distance on the vein between Nos. 8 and 9 levels. No information is available concerning the direction or amount of rake for any of the pyrite lenses. The dip-length is probably less than 50 feet. Based on the above described procedure, the writer has calculated that the 185-foot drift-section of this westerly lens might contain 176 pounds of tungstic oxide (WO_3) per foot of depth over a 6-inch average width of pyrite lens.

On level No. 8 a drift-section of the vein beginning at a point 150 feet east of raise A and extending to a point 250 feet east of the raise, a total distance of 100 feet, contains several disconnected short ribbons and one large kidney of scheelite. The kidney as exposed at the time of the writer's examination, measured 2 1/2 feet in length by 4 inches in width and consisted of massive scheelite cut by a few stringers of quartz; the scheelite amounts to approximately 90 per cent of the mass, the veinlet quartz accounting for the rest. Applying the same reasoning used for the west lens on No. 9 level, the extent of the scheelite-bearing pyrite lens on the dip of the vein is probably less than 50 feet. The various sections of scheelite seen in this 100-foot drift length, when averaged over the full length, may yield 48 pounds of tungstic oxide (WO_3) per foot of depth across an average width of 6 inches of pyrite lens.

A lens of scheelite-bearing pyrite on No. 10 level in No. 5 vein at its north-western end exposes a length of 17 feet, and an average of width 7 1/2 inches. The minimum value for the dip-length of this lens is 20 feet and the maximum is unknown, though probably less than 50 feet. The samples taken indicate that 400 pounds of tungstic oxide (WO_3) per foot of depth over 7 1/2 inches may be expected for the 17-foot length.

Suggested Development.

The writer submits the following suggestions for further work, should any be contemplated on the property, namely that:

(1) Efforts should be directed towards the exploration of only the scheelite-bearing pyrite lenses. Although it is doubtful if these will carry any large amounts of economically mineable ore, still a small tonnage of scheelite could be obtained from them.

(2) The pyrite lens in the west end of No. 5 vein on No. 10 level be drifted on to the north-west.

(3) The cross-cut that extends north-easterly on No. 9 level from a point 220 feet east of raise A, be extended north-easterly to intersect the south-easterly extension of No. 5 vein across the main fault. To pick up a point corresponding to one on the north side of the fault at this level it would be necessary to go down the dip of the fault for 50 feet on the south side of the fault.

(4) In general, raising and sinking could be done from the drift-sections of the scheelite-bearing pyrite lenses to their extremities.

LARDEAU AREA

Scheelite has been found at two properties in the Lardeau, one at a new prospect, the United Victory, on the Incomappleux (Fish) River and the other on a silver-lead property, the Lucky Boy, near Trout Lake.

UNITED VICTORY The United Victory group is 17 miles up the Incomappleux (Fish) River between Boyd and Kelly Creeks at an elevation of about 3,000 feet. It is reached from Beaton by road for 12 miles, thence by trail for 5 miles to the property.

The claims were located in 1942 on showings of scheelite by Bert Oakey and Henry Gunterman, both of Beaton. The ground is being prospected and the showings developed by Bralorne Mines Ltd., 555 Burrard Street, Vancouver.

The scheelite is found in a bed of lime-silicate or skarn rock* which is 5 feet wide and is exposed by a few natural outcrops for

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* For usage in this bulletin see pp. 11-12.

1,000 feet. A sill of granite rock lies in the foot-wall and limey schist and limestone lie in the hanging-wall.*

In the summer of 1942 scheelite and tin were found by a Department of Mine's Engineer, in Incomappleux River, at the mouth of McDougall Creek and also at the junction of the 3rd creek flowing into McDougall Creek from the west. Bert Oakey accompanied this engineer.

LUCKY BOY** This group consists of a number of Crown-granted and located claims held by C. H. Tillen of Trout Lake and Lethbridge. Six Crown-granted claims and two located claims constituting the original Lucky Boy group are held by Tillen on lease and bond from George Yuill of Trout Lake. The <u>Horseshoe</u> adjoins the <u>Lucky Boy</u> on the west and is owned by Lance Hillman of Ashcroft.

The property, due west of Trout Lake, is reached by 3 1/2 miles of pack-horse trail on an easy grade. It is at an elevation of 4,500 feet on the north-westerly facing slope of Trout Mountain. The mountain slope is deeply covered with overburden and supports a heavy growth of timber. Camp consists of three buildings adequate for 6 men. Water is obtained from a small spring 1,000 feet away.

The property was worked originally for silver-lead ore. Prior to 1906, 400 tons of sorted ore was shipped assaying: silver, 200 to 300 oz. per ton; lead, 20 to 35 per cent. In 1912, after six years of inactivity, 28 tons, assaying about the same, was shipped.

The vein strikes slightly north of east, dips 20 to 30 degrees southward and crosses the steeply north-dipping formation almost at right angles. The host rock is predominantly schist, but on the lowest level a bed of limestone forms the walls. The vein ranges from 6 inches to 6 feet in width and throughout probably averages between 1 foot and 2 feet. The gangue is white drusy quartz; sulphide mineralization consists of galena, tetrahedrite, sphalerite, chalcopyrite and pyrite; a little native silver occurs locally. Scheelite is present in the vein in small grains and masses up to several square inches in area.

The vein was traced on the surface for about 500 feet by several open cuts and two old caved adits. The underground working on the <u>Lucky Boy</u> is an incline shaft close to the <u>Horseshoe</u> line sunk on the dip of the vein for 190 feet. From it three levels have been driven as drifts on the vein at distances of 65, 85 and 155 feet respectively from the collar of the shaft.

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* H. L. Hill, personal communication

** Report by S. S. Holland, British Columbia Department of Mines.

The highest, No. 1, level is driven westerly from the shaft and a small stope put in above it. The vein as exposed is narrow and contains little sulphide. There is little or no scheelite in the vein on this level.

The No. 2 level was driven east and west from the shaft; the east drift, for a distance of 230 feet with several short raises up the dip; the west drift for 120 feet and most of the ground up to No. 1 level was stoped. At 57 feet from the shaft scheelite mineralization is present in the remaining pillars along the drift and extends westerly for about 40 feet. It shows in the backfill in a raise 85 feet west, and on the west side of a second raise 100 feet west of the shaft. The scheelite mineralization makes an attractive display on the west side of this raise from 5 to 14 feet up from the level. Four samples in this section averaged 3.67 per cent tungstic oxide across an average width of 29 inches.

On the lowest level, No. 3, a drift has been driven east for 130 feet and a raise put through to No. 2 level but most of the vein remains unmined. At the corner of the shaft and the No. 3 level scheelite mineralization extends 23 feet east on both walls of the drift on the No. 3 level and extends 30 feet up the shaft from the bottom level. Six samples from the No. 3 level east of the corner averaged 0.41 per cent tungstic oxide across 33 inches and seven samples up the shaft on the east wall for 30 feet averaged 0.63 per cent tungstic oxide across 35 inches.

No. 3 level is driven 140 feet west of the shaft and most of the vein up to No. 2 level has been explored or mined. Scheelite occurs in the vein in a raise 70 feet west of the shaft as well as in pillars and unmined vein between No. 2 and No. 3 levels. There is no scheelite in No. 3 level in the west end.

Scheelite also occurs in the same vein on the Horseshoe claim in a surface exposure between the two shafts, also along the wall of the eastermost shaft and for a length of 12 feet in a drift driven east from the same shaft.

The distribution of the scheelite mineralization falls within the limits of a shoot raking eastward from the surface exposure on the Horseshoe through the raise on the west end of No. 2 level to the area between No. 2 and No. 3 levels. The exposure of scheelite on the east side at the intersection of the shaft and No. 3 level appears to be separated by a barren section suggesting that it is the apex of another shoot. No faulting was observed that would displace the vein were it part of the same shoot.

There is no development below the No. 3 level. At that depth the vein fracture crosses a limestone bed but its persistence through, and mineralization within the limestone are not proven by the present workings.

Most of the scheelite-bearing shoot was mined in the course of the earlier work. There is about 4,000 tons of material on the dump which at the time of examination (September 20, 1942) was being sorted at night under an ultra-violet light for scheelite. Up to that time 25 tons of ore had been sorted and sacked for shipment. A grab sample of the rough sorted ore assayed 1.41 per cent tungstic oxide and 0.63 per cent phosphorous. In spite of the fact that much of the scheelite-bearing vein has been mined it is estimated that above the third level there is possibly 200 tons in pillars and unmined sections of the vein, an unknown but small amount of broken material as backfill in stopes, and an unknown tonnage (possibly 100 tons or more) in the section west of the high-grade spot on the westermost raise on the second level and extending to the Horseshoe workings.

The complete extraction of the underground material is probably impossible owing to the poor condition of the workings and not economic owing to the amount of rehabilitation work necessary. However, several underground sections which could be reached easily and safely could produce a small tonnage of scheelite ore.

For further references to this property see The Annual Report, Minister of Mines, British Columbia, 1914, p. 317, 1933, p. 216; and Geol. Surv. of Canada, Mem. 161, p. 83.

NELSON AREA*

The Nelson area as used in this report includes the region between Kootenay Lake and the Arrow Lakes, north of the International Boundary. It includes the Slocan, Sheep Creek, Nelson, Rossland mining areas, and is well served by roads and by the Kettle Valley Branch of the Canadian Pacific Railway.

There has been no tungsten production from the area to date but the Emerald mine, discovered in 1942, will be in production in the spring of 1943 and other recent discoveries are in process of development. Scheelite has been known for years to occur in many of the gold-quartz veins but there has been no production, either as scheelite ore or as a by-product from gold-mining. In addition to scheelite, tungstite was encountered in gold ore from the Reno mine during the course of early milling operations and small quantities of wolframite occur in other gold-quartz properties in the Sheep Creek camp.

Scheelite occurs in the quartz veins as scattered grains and in stringers, lenses and pods. The largest known shoot, in the Venango vein, is reported to have contained an estimated several tons of relatively massive scheelite, but this was shipped as gold

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* Report on the Nelson area, excepting section on minor occurrences, by M. S. Hedley, British Columbia Department of Mines.

ore and the tungsten was not recovered. Elsewhere one or two attempts were made to produce a cobbed concentrate, but the scheelite was too dispersed to make a product of sufficiently high grade to withstand labour and shipping charges. Scheelite-bearing shoots in the operating gold mines have been so scattered or so low in grade that they have not warranted selective mining or the erection of a special plant for scheelite recovery. However, a production from quartz veins in the area could be expected if some central plant were available that would obviate the necessity for shipping cobbed or other low grade concentrates to eastern markets.

Scheelite-bearing quartz veins are known in the Sheep Creek Camp, Toad Mountain near Nelson, Bayonne, Rossland camp, Meteor in the Slocan, and at other scattered points. They occur in all rock types of the district, are of varied size and attitude, and possess a varied mineralogy. In most veins the scheelite is readily detectable with the naked eye, owing to its characteristically pale buff colour and its frequent occurrence in masses as much as 1/2 - inch or more in diameter. There appears to be no general rule for the finding and development of such deposits.

The outlook for production improved considerably with the finding, in 1942, of scheelite in a type of deposit hitherto unknown in the area, namely in the bodies of skarn produced by the high-temperature replacement of limestone.* The Emerald mine, which is in this category, is expected to be in production within a year of its discovery. Production from other deposits of this type is to be expected although it is too early to tell what that production might be or from which properties.

High-temperature replacement deposits in skarn have been found principally along the Salmo River Valley, but there is no known reason why they should be more abundant in that section. The same condition of stocks, dykes and batholiths of granite cutting limestone is found in many other parts of the general Nelson area. Certain theoretical factors have already been discussed (pp. 11-12) but some additional considerations may be dealt with here. The scheelite in this type of deposit occurs as small disseminated grains of a nondescript whitish colour that are not readily detectable except with the aid of an ultra-violet lamp. It is of wide distribution in minute amounts and a few grains are to be found in most occurrences of skarn. However, concentrations of mineable grade ore are rare, and these furthermore are apt to be streaky and discontinuous. Such concentrations have in some instances been proved to have a short vertical range, even though they may be extensive along their strike; an important example of this is given by the main Emerald ore-zone in which a substantial tonnage is represented by shoots many of which are so short that they do not reach the surface but which extend for 2,000 feet along

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* See pp. 11-12 for some general theoretical considerations.

their strike. Although in most deposits of this type the original composition of the limestone probably played an important part in the alteration, yet, given the presence of limestone cut by granite, structural conditions far outweigh chemical, serving as they have done to localize the course of rising mineral-bearing solutions. Full attention should be paid to the geological structure at all stages, from prospecting to actual mining.

EMERALD The Emerald property of 45 claims and fractions was formerly owned by The Iron Mountain Limited, Nelson, and is now owned by the Dominion Government. It is 6 miles southeast of Salmo and extends across the height of land between Sheep and Lost Creeks.

Salmo, a station on the Great Northern Railway running between Nelson and Spokane, is also on the Nelson-Nelway highway 25 miles from Nelson. A branch road to the mine 4 miles in length leaves the highway at the mouth of Sheep Creek which is 4 miles south of Salmo. This road, the main part of which has recently been improved, continues through to the Jersey claim near the southern end of the property. The millsite is on the highway 3 1/2 miles below the mouth of Sheep Creek, on the east side of Salmo River.

The mine camp and power plant are on a small flat at the head of Lime Creek, a small tributary of Lost Creek, at an elevation of about 4,100 feet. A steep and rugged hillside rises to the east above the camp for an additional 1,000 feet in elevation. Most of the timber in this section has been destroyed by fires, but sufficient green timber remains on the property for all or most mining needs.

History

Ground now included in the Emerald property was prospected many years ago for gold as well as for lead ore. The first report, however was in 1907, and from that year until 1925 the property was a small but steady producer of lead ore. A small mill was erected in 1919, but since has burned down.

In 1939, following some years of inactivity the owners, The Iron Mountain Limited, increased their holdings from 17 to 41 Crown-granted claims and fractions. A small amount of development work was carried on by hand mining for 3 years, under the direction of Harold Lakes of Nelson. Four additional claims were located in 1942.

In the winter of 1941-42 scheelite was found in the laboratory of the Department of Mines in molybdenite-bearing skarn which had been submitted for molybdenum assay. Some stripping was done on this skarn as soon as snow melted, in the hope that a commercial grade of scheelite might be found. On May 20th, 1942, Harold Lakes discovered scheelite on the north side of the Jersey Road in an old adit and in a series of open-cuts that had been driven many years ago in a search for gold, and had long been forgotten. This discovery, now termed the Emerald ore-zone, had promise of production and exploration was therefore concentrated upon it. Nothing more was done on the skarn.

Work was pressed on the Emerald ore-zone with a small crew and a limited amount of diamond-drilling was done. Later the property was brought to the attention of the Metals Controller for Canada, with the ultimate result that on August 17th the Iron Mountain Limited turned the property over to the Dominion Government.

From that day the rate of development was accelerated, and plans were laid for bringing the property into production. The work is being carried out by Wartime Metals Corporation of Montreal, with E. E. Mason as manager of the Emerald Tungsten Project. At the time of writing, January, 1942, a tram line is being constructed and plans are being drawn for a concentrator with a capacity of 300 tons per day.

General Geology

The property is underlain by lower members of the Pend d'Oreille series, intruded by three bodies of Nelson granite (see Geology and Mineral deposits of Salmo Map-area, by J. F. Walker, Geological Survey of Canada, Memoir 172). The sediments are on the eastern limb of an anticline that underlies the ridge west of Lime Creek. They strike north 10 to 20 degrees east and dip eastward into the hillside with local minor folds and contortions; there is an average plunge of about 15 degrees southward.

The Pend d'Oreille series is composed dominantly of argillites but in the section from the level of the road to the Jersey claim, elevation 4,050 feet, to the summit of the ridge above there is much limestone. Lead-zinc mineralization, on which there are two series of old workings, occurs in the limestone in local rolls in the structure. Most of the limestone is relatively pure, is strongly recrystallized and blue-grey or white in colour. Three or more bands have been strongly and continuously altered to skarn* (locally garnetite) but for the most part the content of silicate minerals is low or absent.

The rocks immediately west of the bed of Lime Creek are siliceous argillites and quartz-mica schists; one band of limestone occurs on the ridge west of the creek. Between Lime Creek and the Emerald ore-zone the section includes soft, dark-coloured argillites as well as siliceous bands. A prominent band of limestone outcrops at the level of the Jersey road, and from that level to the top of the ridge there are alternate bands of limestone and thin-bedded, siliceous argillite, all dipping eastward at an average angle of about 55 degrees.

There are three stocks of granite. The main stock in the

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* For definition of skarn see p. 11.

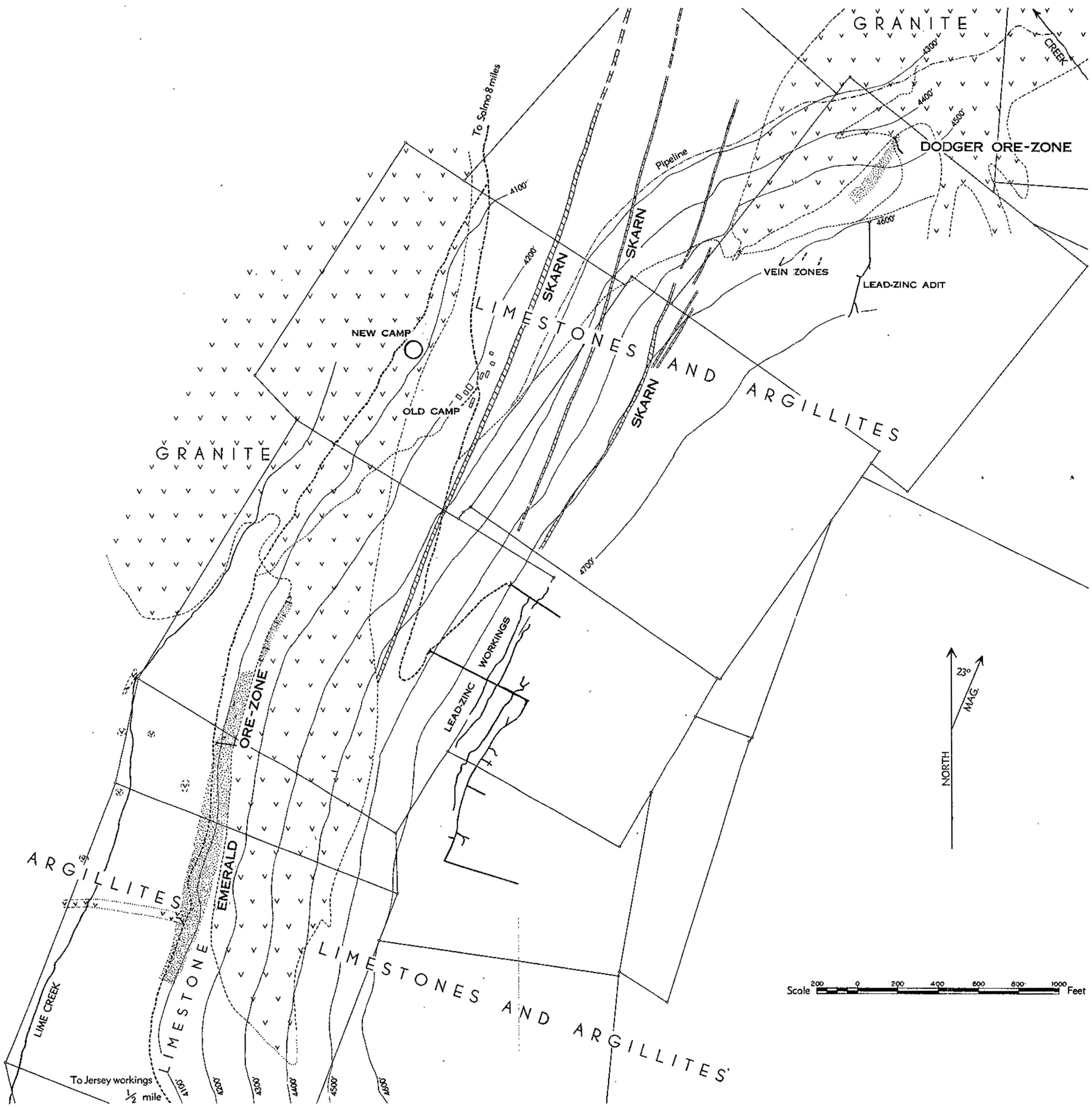

Fig. 8. Emerald Mine. Geological sketch-plan of part of property.

central part of the property, is about 1 mile long (see Fig. 7), and is a quarter of a mile wide near the drift-covered northern end. The southern end, south of a sharply defined embayment in the contact, is 400 to 700 feet wide and ends in a point to the south. There are associated dykes near the south end, trending both easterly and northerly. The western margin of the southern part of the stock is cut by many quartz stringers and contains many small, irregular masses of quartz. The Emerald ore-zone is adjacent to this margin.

The second stock occurs on the Jersey claim and is an elongated body a quarter of a mile south of the first. It has not been mapped in detail since mineralization adjacent to it is chiefly lead and zinc, but locally there is evidence of small amounts of scheelite.

The third or northern stock is about 1 mile in length, only the southern end of which is mapped in detail (see Fig. 7). The southern end consists of granite and granodiorite and the northern end of monzonite. Dyke-like offshoots near the southern end produce an irregular outline, and the Dodger showing lies within an embayment in the contact.

Alteration of high-temperature replacement type (commonly referred to as contact-metamorphic) is of widespread but local development and is not restricted to actual granite contacts. Three prominent bands of limestone lying between the central and northern bodies of granite are completely altered to skarn, a greenish to brownish rock which locally is garnetite. The bands are made up of thin-bedded limestone which was presumably of such a composition as to permit the wholesale formation of calcium-bearing silicates and other minerals throughout its length, whereas other limestone bands are not altered.

The lower skarn band is from about 20 to more than 50 feet thick, and has been traced for a distance of nearly 4,000 feet. The two upper bands are 5 to 15 or 20 feet thick, and about half a mile long, apparently disappearing to the south. There are additional shorter skarn bands near the south end of the northern stock and others are present in the Dodger embayment. Skarn is also developed between the Emerald and Jersey claims. Sulphide minerals are almost everywhere present in varying amounts, from a fine scattering to locally massive concentrations, as in the Dodger ore-zone. All or nearly all of the skarn contains disseminated scheelite, commonly low in grade.

The mineralogy of the skarn has not been extensively studied but the rock is the product of an intense alteration of limestone characterized by massive green diopside and brown garnet. It is a banded rock, the individual bands of which are mottled and streaky and contain a few small patches of residual limestone. The minerals include the following in variable proportions: diopside, garnet, vesuvianite, calcite, feldspar, augite, amphibole and others, the sulphides pyrrhotite, pyrite, molybdenite, chalcopyrite and, in addition, scheelite and powellite.

A somewhat different type of alteration, characteristic of the Emerald ore-zone and formed locally in relatively pure limestone by replacement, consists of closely associated silicate and sulphide minerals. It differs from the common, garnetiferous skarn in that the silicates include augite, probably actinolite, some epidote and biotite and other minerals in minor amounts; pyrrhotite and pyrite are developed in abundance, together with small amounts of chalcopyrite and rare specks of molybdenite. A little wolframite has been detected. Some silicified limestone is associated with this mineral assemblage. It is perhaps confusing to refer to this rock, which constitutes the tungsten ore in the Emerald zone, as skarn, but there is no other name which is at present acceptable. The chief difference between this Emerald skarn and the above-noted skarn bands lies in the fact that the former contains no easily recognizable garnet and no diopside, both of which are characteristic of the skarn bands, and in the fact that sulphides are abundant. The intimate association of sulphides and pyroxene (and locally biotite) is also found in parts of the Dodger ore-zone where the two types of skarn intergrade.

Scheelite Mineralization

Scheelite occurs in garnet-diopside skarn, in concentrations of sulphides in such rock, in the Emerald type of skarn, in silicified limestone, in quartz veins and replacements, and in hydrothermally altered granite. It is of widespread occurrence even though concentrations in excess of 0.25 per cent tungstic oxide are relatively rare. All of the scheelite occurs as fine, disseminated grains.

There are three main occurrences: (1) the skarn bands, (2) the Dodger ore-zone, (3) the Emerald ore-zone. These are separate and are for the most part geologically distinct. They will be dealt with separately and later certain common factors will be discussed.

Skarn Bands

The Skarn Bands are of least immediate importance, having been only partly explored. The content of tungstic oxide is low and the only possibility of mining more than local sections depends upon a large tonnage operation. There is a molybdenum content that is even lower than the tungsten, and it is only in certain sections of one or more of the upper bands that the metal seems possibly of economic value.

The scheelite occurs as scattered grains or in trains of grains that follow individual beds. Certain beds or groups of beds appear to have been more favourable than others in any given section but there is no apparent reason why this is so; at least there seems to be no textural or mineralogical feature to explain this fact. Much of the scheelite seems to be merely a constituent of the rock but some is clearly related to narrow quartz-filled fractures. These stringers of quartz traverse the beds at right angles and locally branch out and penetrate between the bedding planes; some contain scheelite but most of them are barren. The rock adjacent to some stringers is enriched with scheelite and certain beds may be enriched for distances as great as 20 feet from a stringer which has apparently acted as a feeder. It is inferred that there are two generations of scheelite, but there is no other supporting evidence.

Certain sections as much as several feet wide and as much as 30 or 40 feet long may assay a large fraction of 1 per cent tungstic oxide, but much of the skarn assays less than 0.10 per cent tungstic oxide. Visual examination of the grade of the skarn band is difficult owing to the fact that there is commonly some powellite present, the fluorescent colour of small grains of which is not easily distinguishable from that of scheelite.

The skarn bands dip eastward towards the northern granite stock and must terminate against granite at some distance down the dip. It is possible that richer concentrations of scheelite may occur farther down the dip and closer to the contact. Some preliminary surface sampling and near-surface diamond-drilling has been done on the lower band and further investigation is contemplated.

Dodger Ore-Zone

The Dodger ore-zone is only partly explored. It lies in the fork between the south end of the northern granite stock and an easterly projection from it. The granite basin so formed is shallow and interbedded argillites and limestones dip eastward within it. One band of limestone, locally containing lead and zinc mineralization, was drifted on in the upper Dodger adit and has been exposed at intervals by open-cuts. This band is unaltered, but the section beneath it contains much skarn.

An old adit was driven 80 feet southerly from the granite contact on a showing of sulphides. From a point near the portal for a distance of 36 feet there is much skarn of both garnetiferous and Emerald type containing much sulphide, chiefly pyrrhotite. This appears to be a bedded deposit dipping at 50 degrees, and if so is about 17 feet wide; a composite sample across the full width assayed: tungstic oxide; 1.7 per cent. Stripping farther to the south showed skarn with varied amounts of scheelite but for the most part rather low in grade. Diamond-drilling from two stations 100 feet apart showed in section a very complex structure with some drag-folding the details of which could not be worked out. Economic mineralization was indicated but the lateness of the season forbade further work.

Certain general conclusions may be drawn, even though the structure is not completely understood. The alteration is to skarn of the garnet-diopside type but there is much associated sulphide intergrown with silicates after the Emerald type of skarn. Mineralization apparently follows the bedding in an intricate structure, pointing to the conclusion that there has been a selective replacement of certain beds in the section. The amount of scheelite is variable and may or may not occur with the heaviest concentrations of sulphides; it may occur in skarn alone but not as a rule when garnet is most prominent. The better grade of scheelite does not persist to the granite contact but is separated from it by from 5 to 30 feet of relatively barren rock.

This zone is deepening to the south and approximately the same conditions may be expected for a strike length of 1,000 feet unless the granite trough should disappear with a sharply steepening contact. Just east of the end of the granite there are three sulphide-bearing vein-zones, the strike of which leads them towards the Dodger zone beneath intervening overburden; these zones contain very little scheelite, but they are composed of massive sulphides rather than of skarn. There is a possibility that they are connected in some way with an extension of the Dodger zone.

Emerald Ore-zone

The Emerald ore-zone is the largest and the highest in grade at the present stage of development. It is on the south side of the central granite stock at about the level of the Jersey road (see Fig. 9).

The only underground work at the time of examination was an old adit and the following description of the ore bodies is based on surface work and diamond-drilling.

The Emerald ore-zone is naturally divisable into two sections, a northern and a southern, on either side of a postulated fault that has dropped the southern section about 50 feet relatively to the northern. The two sections are distinct and will be mined separately.

The northern section is the smaller but is on the average higher in grade. It is 450 feet long, up to 50 feet in horizontal width, and bottoms at shallow depth. The ore is in strongly altered granite in contact with argillites. The ore-body has been outlined by several trenches put through deep overburden, and is not completely exposed. It narrows abruptly near the north end to an extremely shallow "tail" and tapers to the south to a zone a few feet wide. The surface area is estimated to be 9,000 square feet and the depth, as proved in two diamond-drilled sections, is about 15 feet beneath the overburden of boulder clay.

Mineralization is in strongly altered granite and quartz. The quartz is highly irregular and occurs as replacement bodies rather

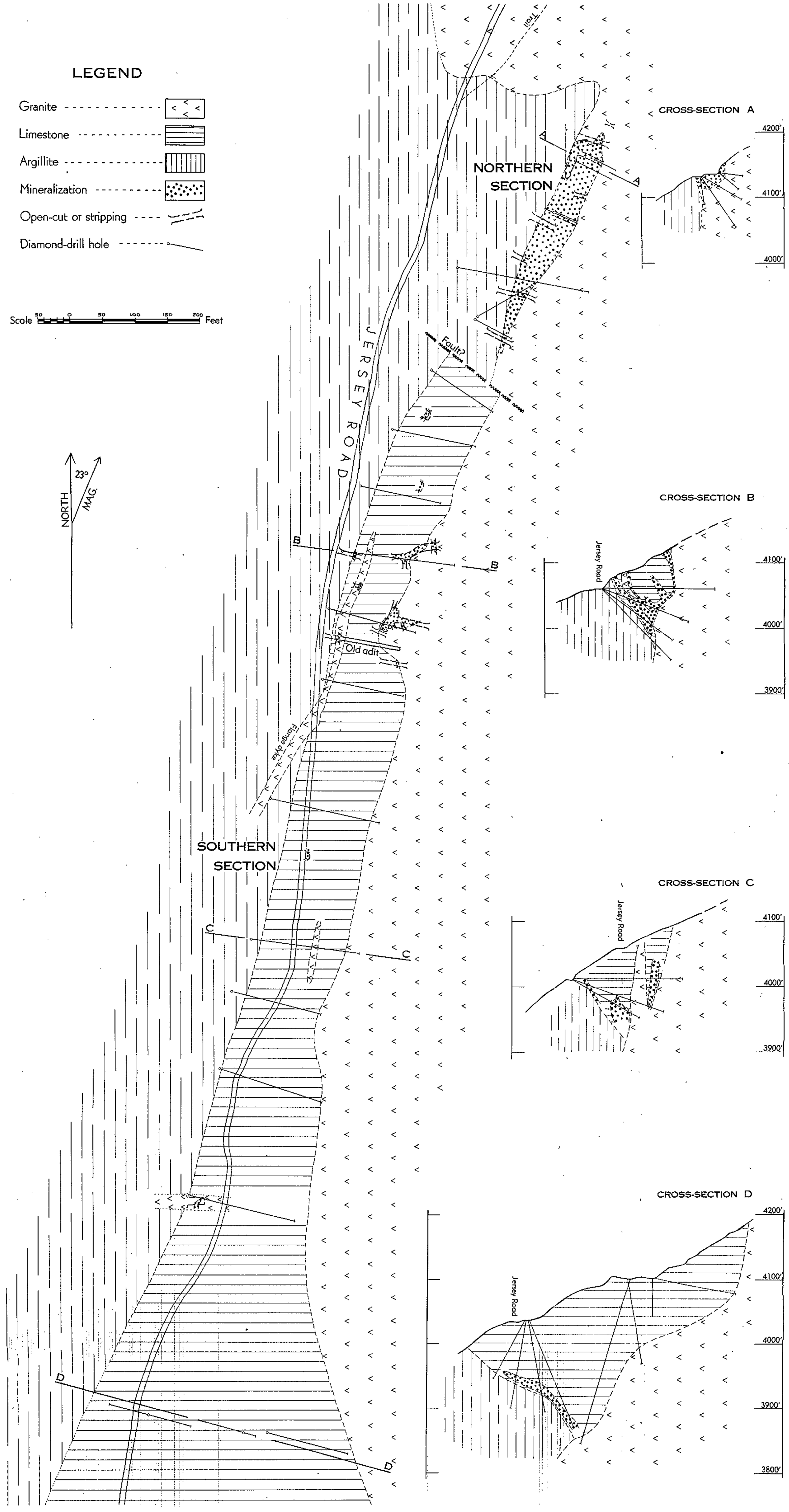

Fig. 9. Emerald Ore-zone. Plan and selected cross-sections as outlined by diamond-drilling.

than veins. The amount of sulphides, including pyrite, pyrrhotite, chalcopyrite and molybdenite is generally low, but there are two ribs of heavy sulphide associated with pyroxene which are identical with the Emerald type of skarn characteristic of the southern section. Much of the ore is in almost completely silicified granite, material that is largely quartz but showing vestiges of granitic texture. There is locally a secondary development of mica, which is particularly noticeable in a 2 1/2 - foot section in one trench that assayed 21 per cent tungstic oxide. The scheelite is all fine-grained and is disseminated through the three types of host rock; the grains appear to be larger and more scattered on the eastern margin where there is less silicification of the altered granite.

Oxidation is intense in parts of the ore-body. The silicified and altered granite is porous and oxidation has penetrated it to the bottom of the mineralization. The more massive concentrations of sulphides, however, are not oxidized except at the surface where detached blocks disintegrate rapidly with the production of a white coating of ferrous sulphate. It is a matter of interest to note that massive pyrrhotite does not oxidize rapidly but rather the intergrowth of pyrrhotite, pyroxene and biotite.

Diamond-drill cores were fragmentary and no good section of the ore-body was obtained but there appears to be a sharply defined boundary between ore and unmineralized rock underneath. A wholesale alteration of the granite beneath the ore-body has been proved to extend to a depth of at least 120 feet. This alteration has produced a soft, incoherent, bleached product in which the granitic texture is in large part destroyed. This is dominantly a sericitic alteration, accompanied by stringers, grains and irregular masses of quartz. Locally a fine, black quartzose breccia occurs beneath the ore but not in it; it is seen also in irregular veins in the granite north of the ore-body. The black material is tourmaline, and it is not known what relation this quartz-tourmaline breccia bears to the ore, if any.

It is believed that this section represents the roots of a once larger ore-body that occurred at the base of the limestone.

The southern section of the Emerald ore-zone is now being developed for mining on a 300 tons per day basis. It is 1,725 feet long between the northern bounding fault and the southermost diamond-drill station. The maximum width of the zone is about 140 feet horizontally within which the ore occurs in several laterally well-defined bodies as well as in irregular shoots against the granite.

Limestone, stratigraphically the lowest on the property, dips eastward towards the steep granite contact and lies conformably above argillite. There is thus a triangular wedge of limestone, the apex of which is at the line of contact of argillite with granite. Mineralizing solutions have risen through the granite and have produced ore-bodies in and near the base of the limestone wedge.

The argillite-limestone contact is relatively straight and follows the general course of the Jersey road. Dips in the northern part are about 50 degrees eastward and in the southern part are about 70 degrees eastwards. There is some local contortion recorded in the drill cores that probably signifies drag folding. The granite-limestone contact at the surface is quite regular, except at one place east of the old adit where there are two small outward bulges in the granite, around which the limestone beds are flexed and broken. The granite contact has a steep westward dip.

The outline of the granite is complicated in cross-section in the north-central part of the zone by an eastward dipping, flange-like offshoot or dyke. This flange dyke is from 10 to 30 feet wide and is irregular. It lies near the argillite-limestone contact, and the granite trough formed between it and the stock coincides in general with the base of the limestone wedge and also with that of the ore. A further complication, in the neighbourhood of the old adit, consists of a broad cross-flange of granite which does not completely reach the surface but which effectively divides the limestone wedge into two parts.

A second, cross-cutting dyke about 20 feet wide has been traced from the Jersey road across Lime Creek to the west. Other small outcrops of granite in the basin of Lime Creek may represent either dykes or small bosses.

The wedge of limestone is about 75 feet deep at the northern end and rakes to the south at an angle of about 7 degrees. At the southern explored end of the section the granite swings easterly and as a result the basin was expected to deepen rapidly. A cross-section established by diamond-drilling, however, disclosed a buried shoulder of granite that meets the limestone-argillite contact on the same line as though the limestone-granite contact at the surface were straight. The limestone wedge is 200 feet deep at this southernmost cross-section.

Most of the ore in the southern section of the Emerald ore-zone is that particular type of skarn already referred to, namely an intimate mixture of pyroxene and sulphides. Much of the remainder consists of silicified limestone containing sparse sulphides and a minor amount of greenish silicate minerals. Some ore occurs in granite and in quartz bodies within or adjacent to the granite, but this is of minor importance so far as known; there is a distinct possibility, however, that more ore of granitic type will be found than has so far been indicated by diamond-drilling.

Three or more tabular ore-bodies are known, as well as some irregular pods and masses. The ore-bodies are for the most part parallel with the average attitude of the bedding and are apparently controlled in general by the bedding planes, although there has been local transgression of them. The ore-bodies are known at the time of writing only from diamond-drilling at north-south intervals of 100 feet or more.

The ore-bodies include sheets of unmineralized limestone that apparently represent unreplaced beds. In most cross-sections the ore obviously plays out up the dip; in some it merely wedges out and in others it passes into a series of sheets of skarn containing less scheelite and separated by increasing widths of intervening limestone. The same thing happens to a lesser extent in depth, with the ore playing out down the dip into unaltered or silicified limestone, masses of silica or, less commonly, into unmineralized skarn. In certain sections, on the other hand, mineralization occurs across greater widths at or close to the granite contact and locally follows the contact and penetrates the granite for short distances. In one cross-section the flange dyke is completely replaced by skarn, so much so that no evidence of the dyke was seen in one drill-hole that crossed it.

The ground is for the most part deeply covered with glacial drift so it is not known how much mineralization reaches the surface. Strong local mineralization is exposed by trenching at the bulge in the granite contact; some of which is bedded and some follows the contact without regard to bedding. Much of the ore does not reach the surface, however, particularly in the deeper part of the basin, and some in the northern or shallower end is weaker at the surface than it is at depth. Both skarn and scheelite are confined to a short vertical range and the worth of the mine is due to the fact that although the ore bodies are shallow there are good average widths for the known length of 1,725 feet.

The evidence points to the fact that scheelite mineralization is streaky, but it is not known how continuous individual streaks may be. In the core intersections many widths assaying 5 per cent or more tungstic oxide are bounded sharply with similar-appearing material that assays a fraction of 1 per cent.

It is an interesting fact, and one possibly of value to prospecting in general, that scheelite tends to occur within the western rather than the eastern side of the limestone basin. In other words, the scheelite tends to follow the limestone-argillite contact rather than the limestone-granite contact. This is particularly apparent in the southernmost cross-section.

Disseminated scheelite occurs in sheet-like zones from a few inches to 12 feet in width. In one section ore will be mined across a horizontal width of 30 feet including beds of limestone too narrow to be left as pillars, whereas in other sections the ore bands are widely enough separated that the intervening limestone may be left. Local coalescence of ore-bodies across intervening limestone, the occurrence of local pods and sheets at and near the granite, and variations in intensity of mineralization all contribute to difficulties in mining and preclude the making of precise statements regarding widths and lengths of ore-bodies at the present time.

Until mining is well advanced it is impossible to do more than hint at the probable interrelation of different types of ore and to outline some of the possible factors that have influenced the deposition of ore. The following statements deal with observed facts the relative importance of which is not known.

The granite abreast of and beneath the wedge of limestone is strongly altered to a bleached and somewhat incoherent mass containing sericite and much quartz. It is plain that the mineralizing solutions rose from depth within the granite and produced this alteration, but no mineral was deposited in it. Diamond-drill cores disclose a very small amount of sulphides including rare grains of molybdenite.

There tends to be more quartz within the granite close to the contact and this quartz, either as replacement masses or as ramifying stringers, locally contains scheelite but not many sulphides. Mineralization of this type, in places constituting ore, is seen particularly in that complex area in and near the old adit, where the flange-dyke is to a high degree replaced by quartz. This concentration of quartz in granite may merge upwards into skarn but there is a tendency for it to pass rather into relatively massive silica, which presumably has replaced limestone, and which in turn passes into silicified and mineralized limestone and thence into skarn. The sulphides, particularly pyrrhotite, are largely confined to the skarn but scheelite with or without sulphides, may occur also in silicified limestone or in quartz-invaded granite. Massive silica is not as a rule mineralized and may form the bottom of an ore-body.

The foregoing sequence is an idealized one and is not everywhere developed. It indicates that uprising solutions sericitized and deposited some silica within the granite, deposited more silica at the limestone contact and finally produced the sulphide-bearing skarn still farther away from the source, within the wedge of limestone. Almost all of the skarn contains scheelite, as does much of the partly silicified limestone, particularly when it contains an appreciable amount of sulphides; the quartz-invaded granite only locally contains scheelite.

The process of alteration and mineralization appears to have been a continuous one, whether or not it was protracted. There is a hint, however, that some scheelite may have been introduced with a later influx of quartz. The evidence for this is found within the old adit where a rib of mineralized quartz appears to be different in character from that which has silicified the granite, and may be younger. This is entirely logical, in view of the cited evidence of secondary introduction of scheelite in the skarn bands elsewhere on the property. The importance of this secondary introduction in the Emerald ore-zone, if it is indeed a fact, is not known.

There appear to have been several factors that localized the alteration and mineralization. Bedding was the most important.

Not all of the ore is bounded by bedding planes, but there is a strong tendency for it to be so bounded. Some slight difference in original composition or texture seems to have made certain beds more amenable to replacement, and this appears to have been so whether or not the original limestone was folded. Drag-folds in some instance served to localize the alteration, and it may be that these might have formed a locus of least pressure resistance to the invading solutions. The bedding is not everywhere followed, however, and it is clear that fractures in some places helped to introduce and to guide the solutions. The vertical range of the Emerald ore-bodies is so short that it is assumed that replacement and mineralization were governed by a fine balance of conditions among which temperature and pressure were probably important.

General Remarks

The foregoing discussion has been somewhat generalized. Actually the various types of alteration and of mineralization integrade locally, but it is a general fact that they are separate and distinct. The picture is not of course complete, and much exploration remains to be done.

The lower Skarn Band was bulk-sampled where exposed east of the old camp (see Fig. 8), and also diamond-drilled to test the values near the line of exposure. Some long holes are contemplated to investigate values farther down the dip and closer to the granite basin which is presumed to underlie the region between the central and northern stocks. It is quite conceivable that in this location mineralization may be found in other beds than those seen to be mineralized at the surface.

The Dodger ore-zone is to be developed as soon as snow is off the ground. There is no ore yet blocked out, strictly speaking, but there is every indication of an important ore-body in this section. Development from the present showings and extending farther to the south may establish a connection between the Dodger mineralization and that of the upper skarn bands.

The Emerald ore-zone is outlined and is in process of being completely developed. The southern end is "open" and the last established cross-section is better than the average. Further exploration to the south is contemplated.

There are no gold values. It is alleged that early prospectors obtained some high gold assays, but this has not been substantiated.

There is no recoverable molybdenum in the Emerald ore-zone and apparently none in the Dodger, but there may be a recovery of this metal from the skarn bands if these or sections of them, can be brought into production.

No worthwhile scheelite has been found about the southern granite stock on the Jersey claim. There are, however, indications of scheelite and prospecting in that general area is to be recommended, particularly as knowledge of the factors governing mineralization expands. In the language of the prospector this is scheelite country, and finding and outlining of favourable structures should be systematically undertaken, rather than the more ordinary procedure of searching merely for mineralized outcrops. As in exploring any deposit of this general type the employment of detailed geological mapping is important.

Progress of Mining

At the time of examination and up to November 1st there were no underground workings other than the Dodger adit and the old adit on the Jersey road. Some trenching and stripping had been done on the Emerald ore-zone and a minor amount on the Dodger ore-zone, but no complete, systematic trenching had been attempted. Some bulk sampling had been done on exposures of the lower Skarn Band, and several thousand feet of diamond-drilling had been done on the Emerald and Dodger zones, chiefly on the Emerald.

During January 1943, two adits were being driven at an elevation of 4,025 feet and a third is projected at an elevation of 3,950 feet to tap the southern section of the Emerald ore-zone. A tramline is being constructed from the lower adit to the millsite which is about 1 1/2 miles distant to the west, in the valley bottom of the Salmo River. Plans are being drawn for the mill and excavation for foundations has been started.

An adequate supply of water for camp and mine use was obtained, partly from a stream half a mile to the north and partly from the old lead-zinc workings. A new camp was built to replace the collection of small and old buildings already on the property. The new camp has been completed, and there are about 200 men on the payroll. The existing road from the mouth of Sheep Creek was widened and in part relocated and no difficulty is expected in winter travel.

The mill is being built on contract by Consolidated Mining and Smelting Co. of Canada, Limited, with a view to early completion. Work at the mine is being pressed vigorously by the manager, E. E. Mason.

MOLLY

This property, owned by Consolidated Mining and Smelting Company of Canada, Limited, is on Lost Creek, 4 miles from Salmo River. It was staked originally as a molybdenite property from which a small shipment was made during the war of 1914-18. In June, 1942, Joe Gallo of Nelson discovered scheelite mineralization on the Molly 4, quite apart from the molybdenite workings, and a considerable amount of surface work was done on it by the Company during the balance of the season.

A branch road leaves the highway 8 miles south of Salmo and follows easterly up Lost Creek to an old logging camp immediately east of the property. The showings are on a steep mountainside which faces north at an elevation of 4,200 feet, or 1,200 feet in elevation above the creek: they are reached by a steep trail from an old mine camp on the creek.

The rocks are argillites and limestones of the Pend d'Oreille series, intruded by a large mass of Nelson granite. Mineralization is in skarn within light grey limestone adjacent to the granite and in a slight embayment in the contact. Sharply defined areas in the limestone are altered to skarn* which contains abundant garnet. Sulphide minerals include pyrrhotite, pyrite, chalcopyrite, molybdenite and rarely sphalerite.

Scheelite occurs as small, disseminated grains in skarn and none is found in limestone. It is associated generally but not exclusively with sulphide minerals. Sulphides are most abundant in the main showing at the granite contact, but the scheelite content is lower at the contact than it is at a distance of 30 feet or more from it. At several points a better than average grade of scheelite was observed associated with relatively massive garnet.

The main or eastermost showing has been completely stripped for a strike length of 200 feet and a width of 20 to 40 feet along a northwesterly trending contact. Limestone beds dip flatly south, at an average angle of about 15 degrees, and are displaced by one or two minor faults. Small areas of granite are discernible on the stripped area, suggesting that the upper surface of the granite is here highly irregular. Skarn is developed as two bedded replacement bodies, one of which is 3 1/2 to a local maximum of 10 feet thick, is 80 feet long, and is seen to extend down the dip for about 20 feet. This skarn band extends from the main granite on the east to, apparently, a small granite mass on the west, although the alteration may cease short of this granite. The second skarn band is about 10 feet stratigraphically above the first and outcrops 15 feet to the south; the two bands barely overlap in plan. The second body of skarn is 50 feet long, 6 to 8 feet thick, and extends about 15 feet down the dip; farther down the dip it is, at least locally, succeeded by limestone. Fifteen feet farther west, past a small aplite dike, the stripping is in argillaceous rocks.

The grade of mineralization was estimated only. A maximum grade of possibly 2.0 per cent tungstic oxide was only locally seen. A tungstic oxide content of 0.5 per cent or somewhat less seems to be a fair estimate over the widths and lengths indicated.

Northwest of this showing, along the trail, at distances of 80 and 200 feet, are two local occurrences of skarn in limestone. These are lenticular and are close to the granite contact.

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* For definition of Skarn see p. 11.

An additional 130 feet still farther to the north-west an old open-cut discloses skarn of a slightly different manner of occurrence. The open-cut at the time of examination was not cleaned out, but the southern face showed a mass of skarn 10 feet or more high and 6 to 10 feet wide, developed diagonally across the bedding of the limestone; two small masses of skarn were seen on the west wall of the open-cut. A few vaguely defined slips could be seen, and these might have served to introduce or to control the formation of the skarn, or else it formed along the axis of a roll in the structure. Mineralization here is somewhat stronger than the average of that in the main showing.

The property was examined in October, 1942.

JUMBO

This group, consisting of three Crown-granted and several located claims, is owned by Herb. Gretchfield and associates of Salmo. It was under option to Kelowna Exploration Company Limited who did some exploratory work during the latter half of 1942.

It is on the north side of Lost Creek, opposite and adjoining the Molly at an elevation of 5,100 feet, 1 mile north of the old logging camp, from which it is reached by trail. It may also be conveniently reached by 1 1/2 miles of trail from the Emerald mine. The showings are in a band of Pend d'Oreille limestone at the western contact of a large body of Nelson granite.

The principal working is an adit driven 85 feet north-westerly in granite to a contact with argillite. A northern branch of the adit also reaches argillite and a second branch, the face of which is 110 feet north of the portal, encounters a quartz vein as much as 5 feet wide, which follows a granite-skarn contact. The skarn is exposed on the west side of the vein for a distance of 20 feet and is of unknown width. Disseminated scheelite occurs in the skarn for a vertical distance of nearly 20 feet, as seen in a shallow winze at the face of the drift; the skarn contains much watery quartz and some sulphides, principally pyrite. The grade of this material, as exposed, was estimated to be a little more than 0.5 per cent tungstic oxide.

Some open-cuts have been put in on the contact at intervals, from 100 feet south of the adit to 750 feet north. A band of limestone, as much as 15 feet thick, follows the contact and dips away from it beneath argillites. Skarn is developed locally in this limestone and contains small amounts of scheelite. At the northernmost end of the open-cuts float containing worthwhile scheelite was discovered just before snow fell. Other old workings extend along this contact, but were not seen at the time of examination in late October, 1942.

CLUBINE This property, staked by L. R. Clubine in 1942, was optioned by Consolidated Mining and Smelting Company of Canada, Limited. It is on Lost Creek and includes all ground south of the Emerald and west of the Molly on the north side of the creek. The ground is heavily covered with overburden.

Scheelite mineralization was found in a small outcrop of skarn 150 feet from the road and a 120-foot trench was put in across the strike. A second trench, 50 feet long, was put in about 500 feet up the hillside to the north. Skarn, limestone and argillites are exposed in these trenches, but there is doubt whether the two are on the same horizon. The strike is north-westerly but, at least in the lower trench, there is minor folding, including two flat rolls with a low southerly plunge. Scheelite is disseminated in the skarn, some sections of which contain an interesting amount of scheelite.

This prospect has promise inasmuch as scheelite occurs nearly half a mile from the outcrop of any known intrusive body. The ground should be carefully studied to find all outcrops and to determine the structure and the factor or factors that influence the deposition of scheelite. Further stripping operations and some diamond-drilling began late in 1942.

LITTLE KEEN This group of recorded claims is owned by J. Sapples of Salmo and, together with additional claims staked by Joe Gallo, was optioned in 1942 by Bralorne Mines Ltd. It is on the west side of Bennet (Bear) Creek, a tributary of Sheep Creek 3 1/4 miles from its mouth. It is 7 miles south of Salmo by road. The principal showings are 1,500 feet south of and 400 feet in elevation above the Sheep Creek road. The group was originally staked as a molybdenite prospect.

The moderately steep hillside is for the most part heavily covered by drift. A few outcrops of argillite are seen, dipping in general northward with the slope of the ground. A small area of outcrop shows granite cutting argillite and limestone and some surface work has been done on it. Mineralization is in a band of altered limestone that appears to be about 20 feet thick; molybdenite and scheelite occur in it within the same small area but are not otherwise closely related. The structure appears to be anticlinal in general, with a northward plunge flatter than the hillside, but complex minor folding and some faulting obscure continuity; alteration to skarn* is not complete and does not rigidly follow the bedding.

Disseminations of scheelite and molybdenite occur in the skarn, and the latter mineral is also found in the granite. Associated sulphides are chiefly pyrrhotite and pyrite. Molybdenite-bearing patches have been found assaying up to 5 per cent MoS_2 and short

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* For definition of skarn see p. 11.

scheelite-bearing bands assaying about 1 per cent tungstic oxide and, in addition, a few stringers assaying several times the latter figure.

A winze was sunk 15 feet with a dip of 20 degrees on the granite-limestone contact. This encountered some faulting and some evidence of mineralization. Current work (December 1st, 1942) is reported to include driving an adit at a slightly lower level.

The rather intricate structure and the small area (100 by 200 feet), only imperfectly exposed, make initial exploration difficult, but the showings warrant examination. The scheelite and molybdenite are not intimately associated, but probably would have to be mined together; it is too early to state which mineral is likely to be the more important, although if alteration of the limestone band extends far up the dip the scheelite is almost certain to predominate. The possibility of the existence of bays or troughs in the upper surface of the granite should be investigated.

A second showing, 1,000 feet in elevation above is in skarn at the contact of another granite stock. Early work disclosed only small amounts of scheelite but an additional discovery is reported to have been made just before snow fell. Bralorne relinquished their option in January, 1943. The property was examined in late October, 1942.

BALSAM

This group of 5 claims was staked in July, 1942, by Ed Haukendahl and partners of Ymir. It is half a mile east of the Hunter V mine, at an elevation of about 6,000 feet on the ridge between Hidden and Porcupine Creeks. It is reached by 3 1/2 miles of trail from the Porcupine Creek road 1 1/2 miles south of Ymir.

The northern margin of a large mass of granite is in contact with Pend d'Oreille limestone along the east-west ridge already mentioned. The limestone is altered to skarn in a strip along the contact from a few inches to a few feet wide, as exposed in a series of old and new open-cuts and trenches along a length of 800 feet. Scheelite occurs as scattered grains in the skarn, together with variable amounts of chalcopyrite, pyrrhotite and pyrite. An estimated maximum content of 1.5 per cent tungstic oxide was seen in one small area, but the average exposed in the several workings was estimated to be a small fraction of one per cent.

Alteration and mineralization both seem to be restricted to the actual contact, with little penetration of the limestone.

Further work was being done at the time of examination, late October, 1942.

STEWART

This group was staked in May, 1942, by Ed Haukendahl and partners of Ymir. It was optioned in June of the same year by Premier Gold Mining Company Limited, who carried out a considerable amount of surface work between August 10th and October 31st, 1942. The property was later optioned by Consolidated Mining and Smelting Company of Canada, Limited.

The claims are on Stewart Creek which flows into Salmo River 1 1/2 miles north of Ymir. A pack trail 3 miles in length leads westerly from the river, elevation 2,500 feet, to a campsite on the creek, elevation 4,000 feet. The showings are above the campsite on a heavily timbered, northward sloping hillside between elevations of 4,500 and 4,850 feet.

Scheelite mineralization is confined to one or more bands of skarn,* which are interbedded with argillites and other fine-grained sediments of the Rossland Volcanic group. These rocks dip steeply west. The showings are north of a wide bay in a body of granite porphyry. The mineralization is not closely related to the granite, the best showings being about 300 to 1,200 feet north of the contact.

The scheelite occurs as fine grains disseminated through the skarn which is a greenish rock composed of secondary silicates, chiefly diopside, among which garnet is present but is only locally abundant. The rock is patchy owing to variations in the relative proportions of the silicate minerals but there is no apparent association between scheelite and any one of the silicate minerals or grouping of them; where garnet is most abundant there is in general less scheelite. Sulphide minerals are present in small amounts of molybdenite, and rarely chalcopyrite and galena.

Mineralization may occur across the full width of a band of skarn or as one or more narrower bands within it. Shoots pass into stringers rather than terminate abruptly. In no instance was mineralization seen in the argillaceous walls. The best indicator of scheelite is sphalerite, although not in proportion to the amount of the latter mineral. Scheelite is closely associated with the formation of skarn, but the presence of some flat-lying quartz stringers points to the possibility that some scheelite was introduced at a later date; this may account for a better than average concentration in an old 15-foot long adit, but definite proof is lacking.

The best mineralized section is about 500 feet in length. It is nearly 600 feet north of the granite and is 150 feet south of the old adit which was the site of the original discovery. The northern part of this section is a single band of skarn, from 3 to 8 feet wide, which has been completely stripped for a length of 225 feet and which is mineralized across an average width of 2.8 feet. There is some evidence of faulting, but with no apparent offset. In the southern part of the section, 180 feet long, there is a second band of skarn 2 to 15 feet wide and 40 to 50 feet west of the main band. The highest grade section on the property, and also the widest, is

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* For definition of skarn see p. 11.

on the west band, the extensions of which are unknown. Farther north, towards a small creek, and farther south to the granite contact mineralization is weak and erratic in skarn that has been uncovered in a number of trenches along the same general north-south line.

There appears to be one long band of skarn and one shorter one which lies to the west in the best mineralized section but there are offsets and discontinuities that obscure the relationship between them. It may be that (1) the original limestone was lenticular, (2) faulting has offset the shorter band so that it has not been picked up by trenching, in which case the longer band is not continuous but is in reality two or possibly more bands faulted into line or, (3) there has been close folding that has produced a local repetition or has squeezed out some of the original limestone.

All showings have been carefully sampled by Premier Gold Mining Company, Limited. Assays range from a trace to 4.6 per cent tungstic oxide, with some sections below mining grade. Certain definite shoots are indicated, but their rake is not known.

The structure is not understood. It is not known for certain how many skarn bands there are nor what the effect of the faulting has been. Overburden is not deep for the most part, but the timber cover is heavy and stripping has been carried to the limit of its feasibility. Underground work, supplemented by diamond-drilling, is needed to give necessary information regarding continuity and control of mineralization.

The property was examined in late October, 1942.

GROUNDHOG

This group of 5 claims was staked by Joe Gallo of Nelson in 1942, and was optioned by Bralorne Mines Ltd. who relinquished the option after doing a small amount of stripping. It is on the east side of Arrow Lake, 6 miles from Deer Park by logging road and 2,000 feet in elevation above the lake.

Sedimentary rocks, possibly including some greenstone, dip northwestward and are intruded by diorite. The contact trends northerly and appears to truncate the formation at a small angle, but the scarcity of exposures makes this point obscure. The mineralized zone lies about 100 feet west of the diorite and about 50 feet south, in a vague embayment in the contact.

The mineralized zone consists of skarn* and a little garnetiferous limestone, and is bounded laterally by blocky argillites. The zone is imperfectly exposed but appears to be about 60 feet wide and can be seen for a length (strike north-east) of 125 feet, to the

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* For definition of skarn see p. 11.

south side of a small knoll. The skarn contains much garnet and sulphides, including chiefly chalcopyrite and pyrrhotite, which are locally plentiful. Scheelite occurs as disseminated grains, some of which are very small, in the skarn and particularly where sulphides are abundant.

An old 30-foot shaft on the small knoll passes vertically through 20 feet of skarn and 10 feet into diorite. An open-cut 35 feet north of the shaft and 40 feet long is driven across the strike and shows scheelite throughout its length, but most is within the eastern 25 feet of length. Light stripping north-east of the trench and south of the shaft shows skarn at a few points. Systematic stripping was attempted by bulldozer but, except on the knoll, the over-burden proved to be too deep.

Distribution of scheelite within the zone cannot be clearly seen owing both to imperfect exposure and to heavy oxidation. Many specimens on the shaft dump would assay nearly 1 per cent tungstic oxide, and a few specimens from the open-cut could assay about 2 per cent, whereas some exposed parts of the zone contain very little scheelite. The shallow depth to unmineralized diorite in the shaft, although it does not prove that the exposed section bottoms at a depth of 20 feet, does make the available tonnage limited in this section.

Stripping already referred to at the southern base of the knoll imperfectly exposes skarn, not all of which is mineralized. Completion of this stripping should prove whether or not interesting mineralization persists to any distance south of the shaft; overburden farther to the south-west is deep, and systematic stripping or trenching would be expensive.

The property was examined in October, 1942.

BUNKER HILL

This property, consisting of two Crown-granted and a number of located claims, is owned by Waneta Gold Mines, Limited, of Nelson. It was a small gold producer in the past. It is on the east side of Limpid Creek, a tributary of the Pend d'Oreille River, and is 8 miles by road either from Nelway or Columbia Gardens. The property was under lease during the latter part of 1942 to Harry Lefevre, of Rossland, who discovered scheelite in two old pits some distance from the main workings.

The showing, elevation 4,000 feet, is about 1,000 feet easterly from the portal of No. 3 adit, close to the western contact of a granite stock. The intruded rocks are argillites, limestones and quartzites of the Reno formation, which locally dip towards the granite in a small embayment in the contact.

Scheelite occurs as disseminated grains in a banded gneiss which appears to have been derived from argillaceous sediments. It is closely associated with fine-grained, lacy-textured pyrite that weathers to a yellow iron oxide. Distribution within the two pits appeared to be quite uniform, and two samples of representative material assayed 0.29 and 0.22 per cent tungstic oxide. The band of gneiss, not all of which is mineralized, dips eastward towards the granite and appears to be between 75 and 150 feet wide, and may be several hundred feet long between the granite and a band of skarn.* The skarn contains only a negligible amount of scheelite.

Overburden is not deep, and some effort should be made to outline the mineralization, which is evidently related to the granite contact. The dip of the contact should also be determined because if it dips flatly under the mineralization, there may be little tonnage represented.

ST. ELMO

The St. Elmo claim is 1 mile north-west of Rossland, at an elevation of 4,400 feet. It was under examination late in 1942 by Consolidated Mining and Smelting Company of Canada, Limited.

Scheelite was found in the old workings early in the year and later, in the adjoining claims to the east, the <u>Consolidated St. Elmo</u> and the <u>Cliff</u>.

Three drifts in the lower adit-level of the <u>St. Elmo</u> follow weak shear-zones in "greenstone" of the Rossland Volcanics. These strike east and dip about 70 degrees north. They are mineralized erratically with pyrrhotite, pyrite, and chalcopyrite; there is some calcite and some local silicification, but no true vein quartz. Scheelite occurs in these shear-zones in shoots of which the longest is 70 feet. The maximum width is 5 feet, and most shoots are 1 1/2 to 2 1/2 feet wide. The scheelite occurs as fine disseminations and clusters of grains and locally forms tiny discontinuous stringers in the rock. It is in many cases closely associated with sulphide minerals, but may be distributed through the rock or in silicified patches regardless of the presence of sulphides.

The occurrence is somewhat erratic, and continuity of widths and grades could best be determined by raising or even stoping on one or more of the most promising shoots.

BLUE EYES

In September, 1942, scheelite was found on the Blue Eyes claims about 3 1/2 miles north of Rossland. The ground is being prospected at the present time by Bayonne Gold Mines Limited.

VELVET

Small amounts of scheelite have been seen in the dump and in the underground workings on this property. The Velvet mine is on the Cascade Highway, 13 miles west of Rossland and is owned by the Velgo Mining Inc. of Seattle, Washington.

* For definition of skarn see p. 11.

MINOR OCCURRENCES OF SCHEELITE IN THE NELSON AREA

Buff-coloured scheelite has been found occasionally in the quartz veins on the Venango, on the west side of Eagle Creek near Blewett about 5 miles west of Nelson. It occurs in scattered grains and in nodules of massive mineral. One specimen seen by the writer measured approximately 5 inches in maximum dimension. No recovery of the scheelite has so far been made.

Scheelite in the Poorman mine, across Eagle Creek from the Venango, has been mentioned by LeRoy (VII, 1911, p. 147) and is described as being of rare occurrence in the veins on the property. Scheelite has also been reported (H. C. Hughes, personal communication) from the adjoining Royal Canadian and Nevada groups on 49 Creek.

Scheelite has also been found on the gravels of 49 Creek on the Acorn group, downstream from the Royal Canadian and the Nevada groups.

At the Euphrates mine, being worked by the Gold-Silver-Tungsten Mining and Milling Company, at Hall Siding, about 10 miles south of Nelson, scheelite occurs in small amounts in the gold-quartz veins. The installation of a 100-ton flotation mill to treat gold ore was completed in 1941. It was originally planned to save the scheelite as a by-product, but, since no scheelite has been produced, these plans were apparently not completed.

At the Porto Rico, approximately 5 miles northwesterly from Ymir, tungstite was reported to Walker (VI, 1909, p. 38) to have been found on the concentrating tables. It has also been reported (H. C. Hughes, personal communication) from the Spotted Horse approximately 1 mile north-easterly from the Porto Rico.

From near Ymir, scheelite has been reported from the Old Timer mine.

In the Kootenay Belle mine, on Sheep Creek, Brock (VII, 1908, p. 19) described wolframite and scheelite as occurring in bunches or kidneys, occasionally in masses weighing about 30 lbs., in the quartz. It was reported to Walker, (VI, 1909, p. 38) that during the earlier operations at the Queen mine, near the Kootenay Belle, tungstite was seen on the Wilfley table when operating on oxidized ore. Mining operations have been carried on fairly continuously from that time to this, but no increase has been found in the amount of scheelite. Tungsten has been recovered from tables in the old Reno mill.

North-westerly from Nelson the occurrence of scheelite on the Meteor, near Slocan City, has been described by Cairnes (VII, 1935, p. 180) as follows:

"Scheelite was also discovered in the Meteor vein. It is stated to have formed a mass of about 500 pounds on No. 2 level where it occurred as a wedge-shaped body about 12 feet long and 4 inches thick at the base. A small kidney of scheelite, amounting to about 25 pounds, was also found on No. 4 level."

North-easterly from Nelson, scheelite has been reported (H. C. Hughes, personal communication) from the Alpine mine, near the head of Sitkum Creek and from the Scranton, near the head of Woodbury Creek.

HINTS TO PROSPECTORS*

The tungsten minerals have a high specific gravity and are easily concentrated in a gold pan. Wolframite has almost as high a specific gravity as galena. Scheelite has a specific gravity not as high as wolframite but higher than either "black sand" or iron sulphide and will tail behind these minerals in a pan.

Prospecting with a gold pan is recommended. Scheelite is very brittle and pieces even the size of a matchhead do not travel far but fine grains of scheelite, some as fine as dust, will travel many miles, like fine colours of gold, and will be caught in a pan. A few specks or colours of scheelite to the pan will be found in almost any creek and can generally be disregarded. Panning does not indicate an interesting amount until there are perhaps 50 colours to the pan. The pan tailing should be examined under ultraviolet light because even the smallest colours fluoresce. Zircon is another common fluorescent mineral retained in the pan, but its fluorescent colour is orange and the mineral grains will scratch the sides of the pan and will even scratch glass. A beginner should not try to pan too cleanly because it is hard to distinguish the scheelite grains with the naked eye. Until a man is experienced he should examine the heavy tail frequently in ultraviolet light to see how far it is safe to pan down or how far he must pan down to see the colours.

There are two main types of scheelite occurrence, namely in quartz veins and in highly altered rock at or near a granite contact. Wolframite in important amounts occurs only in quartz veins but this mineral is rare in British Columbia. Scheelite occurs in quartz veins as grains, veinlets, pods or irregular masses, but in a rock gangue it occurs as disseminated or scattered grains the size of rice and usually very much smaller. In a pan there is no distinguishing feature between scheelite from either type of occurrence.

Scheelite in most quartz veins can be detected with the naked

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* By M. S. Hedley, British Columbia Department of Mines.

eye, but scheelite that occurs as fine grains scattered through skarn* or any other type of rock can be seen and prospected only in ultra-violet light. The prospector must carry an ultra-violet lamp outfit with him and provide himself with a light-proof black cloth or hood. For examining large surfaces it should measure at least 7 by 7 feet, but for examining specimens or the contents of a gold pan a smaller and lighter hood can be used--a coat or hat is not good enough. A particular, small area may be combed at night but all initial prospecting must be done in the day time.

Scheelite is so widespread that a few specks may be found in any quartz vein or in any body of highly altered limestone. These small amounts certainly indicate the presence of tungsten-bearing solutions but they are worthy of attention only insofar as they may indicate a promising area. Commercial amounts of scheelite, when seen in ultra-violet light, make a vivid display and an ore assaying one-half of one per cent tungstic oxide (WO_3) is easily mistaken by the inexperienced for a much higher grade.

Estimates of grade of coarse scheelite in quartz veins may be made by estimating areas (see p. 122). An experienced man, when accustomed to one deposit, is able to tell on sight the approximate grade of disseminated scheelite, but on a new deposit he may often be mistaken. It is recommended, however, that a prospector acquaint himself with the appearance of various grades of scheelite from various properties, as this knowledge will help him to tell commercial from non-commercial grades.

One type of scheelite occurrence in quartz is apt to be misleading. This scheelite is in very small grains, so fine and scattered that fluorescence is imparted to the quartz itself and a large area may glow in ultra-violet light even when the individual grains of scheelite are invisible to the naked eye. The grade of such material is much lower than the individual is likely to estimate and, what is more serious, a relatively high percentage of the scheelite present may not be recoverable in ordinary milling practice because of its fineness.

Tungsten-bearing quartz veins, whether the mineral is wolframite or scheelite, occur in all sorts of rock. There is no rule for finding them. The tungsten minerals occur characteristically in shoots in the veins, with or without other metallic minerals, and in many instances the structural control of the shoots is not evident.

High temperature replacement deposits occur typically in skarn.* Skarn is strongly altered limestone characterized by garnet and by the hard greenish mineral diopside. It may contain sulphide minerals, and in most cases, these are considered to be

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* See p. 11 for a general discussion.

favourable to the occurrence of scheelite. Any area in which there is some limestone that is cut by or that is close to granite (or granodiorite or even diorite) may be favourable prospecting ground.

In general a favourable site for the occurrence of skarn and of mineralization is not so much adjacent to a straight contact of a batholith as next to some irregularity in a contact, whether the body of granite is large or small. More precisely, a bay or angle in the line of contact is favourable, particularly if it is underlain by a trough in the upper surface of the granite. A good geological condition is illustrated by an area containing a number of small masses of granite which can usually be considered to represent the projecting, higher points of a larger body that lies beneath the surface of the ground.

Gneiss, or coarse-grained banded rock of a somewhat similar appearance to skarn, may also contain scheelite. This gneiss is formed locally and directly by some stock or batholith in contrast to regional or widespread gneisses such as those found in the Shuswap formation east of the Okanagan valley.

Granite itself may contain scheelite in quartz veins or in networks of quartz stringers. Areas of granite are known that contain scheelite in silicified and otherwise altered rock. The presence of much silica (irregular masses of quartz) and of sulphides is the best indication, but in some places the sulphide content is so low that little oxide is formed by weathering.

Generally speaking, no gossan or iron cap at or near a granite contact should be overlooked, particularly where the sedimentary rocks contain some limestone. This does not refer to rusty areas in which the sediments are dark-coloured argillites, a situation very common in British Columbia.

Pyrrhotite is a common associate of scheelite, particularly when it is closely intergrown with green silicate minerals, but not necessarily when it occurs as solid veins and masses containing no silicate minerals.

In some cases scheelite is related to quartz stringers, even in skarn, but generally speaking it can be considered as merely one of the skarn minerals. Prospecting therefore, at least in early stages, consists in tracing skarn and it should be remembered that the skarn is closely controlled by the original bedding of the sedimentary rocks. Skarn may form along a contact without regard to bedding or may form along fissures, but in the majority of cases it forms along a bed or series of beds that have proved to be more favourable than others. A knowledge of the local structure is consequently invaluable in the task of stripping and opening up a deposit, no matter whether this structure is simple or complex. In particular it may be mentioned that ore shoots may follow some particular fold or roll in the structure and an early recognition of this fact may save a great deal of work.

The bedding of limestone may be obscured or destroyed by the alteration to skarn, and consequently it may be difficult to project the skarn mass beyond an outcrop, or in other words to determine the strike and dip and to estimate the probable depth and extent of the skarn. If, however, careful study is made of the surrounding and nearby rocks it is often possible to work out the local structure in some detail. A study of the unaltered rocks may indicate whether the skarn is bedded or not and whether it is localized along certain folds or contacts between limestone and some other sedimentary rock. In short, the study of geological structure is invaluable in sizing up and developing a scheelite deposit of this type.

Ore shoots are apt to be streaky and many are known that have little depth. In other words an ore shoot may not go down indefinitely but almost certainly terminates against granite. Some shoots are known that terminate before they reach underlying granite and also die out up the dip or away from the granite. In the main ore-zone at the Emerald some ore-shoots do not reach the surface (see p. 142) although the underlying granite is only 100 feet down the dip. In such cases a poor surface showing above favourable structure is worth investigating whereas if the underlying structure is not favourable such a surface showing may be taken at its face value and ignored.

Tungstite, the soft, yellow oxidation product of primary tungsten minerals, is not common but it may be present and enrich surface samples. It does not fluoresce and it is hard to detect in some instances. Surface sampling should therefore be done on the freshest possible material.

The commonest minerals that may be mistaken for scheelite owing to their similar colour of fluorescence are calcite, hydrozincite and powellite. The common fluorescence of calcite is red but some drip or scale is white; scratching, or treatment with acid is sufficient to prove that it is merely a scale and that it is a carbonate. Hydrozincite is a hydrous zinc carbonate that forms as a whitish to yellowish coating on zinc blende. The fluorescence is a brilliant white in colour, easily mistaken for that of scheelite; the manner of occurrence and the fact that it is readily soluble in acids suffice to distinguish it from scheelite.

Powellite is a calcium molybdate, common in skarn and particularly when molybdenite is present. It is usually an oxidation product but may in some instances be primary. It is a soft, yellowish or whitish mineral that may be crystalline or earthy. The fluorescent colour varies from yellowish-white to orange, whereas that of scheelite varies from blue-white to yellow, and the two minerals may appear identical in ultra-violet light. Powellite may be distinguished by the fact that it occurs as a crust on molybdenite or, if the grains are large, it can be easily scratched with the finger nail and the powder adheres to the skin. Scheelite on the other hand cannot properly be scratched, although the finger nail may break it down to a powder; the powder is easily rubbed off the skin. Tiny grains of powellite cannot be distinguished with certainty from scheelite except by chemical tests (see p. 3).

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Plate I A Red Rose. Scheelite (s) in a gangue of quartz (qtz) and orthoclase feldspar (or). Twice natural size.

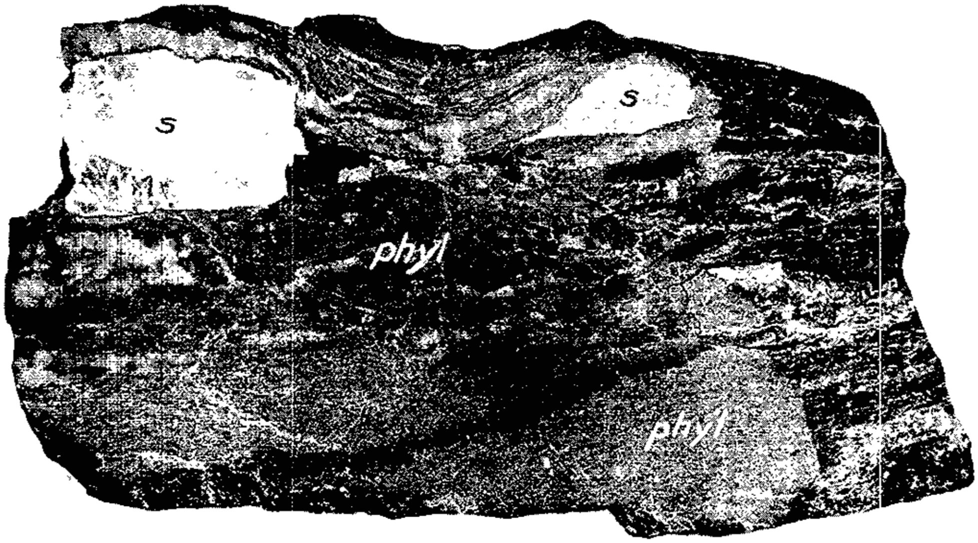

Plate I B Columbia Tungstens Company, Limited (Hard-scrabble). Nodules of solid scheelite (s) in phyllite (phyl). Natural size.

Plate II A Columbia Tungstens Company, Limited (Hardscrabble
Disconnected patches and thin irregular streaks of
scheelite (s) in quartz-carbonate gangue
(qtz & cb). Natural size.

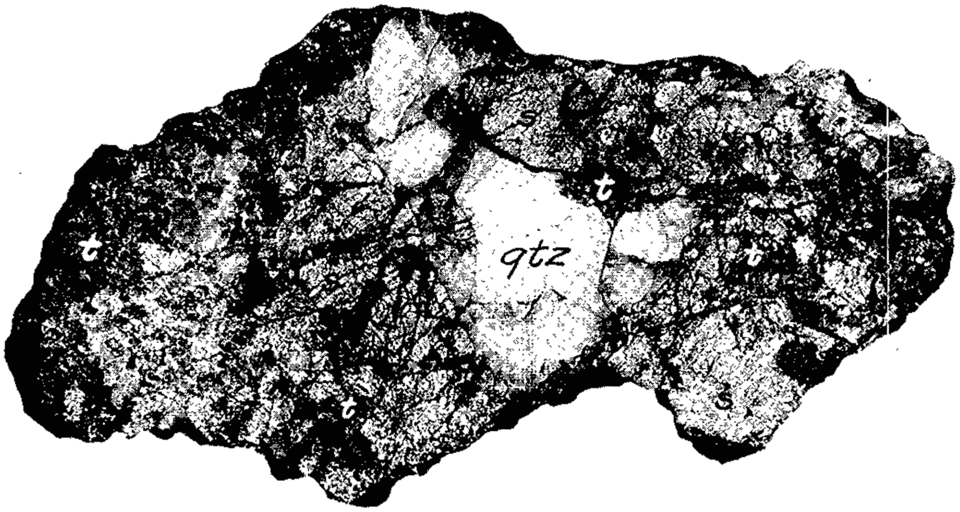

Plate II B Taylor property. Vein-matter showing scheelite
(s) being replaced by tungstite (t). Quartz (qtz).
Twice natural size.

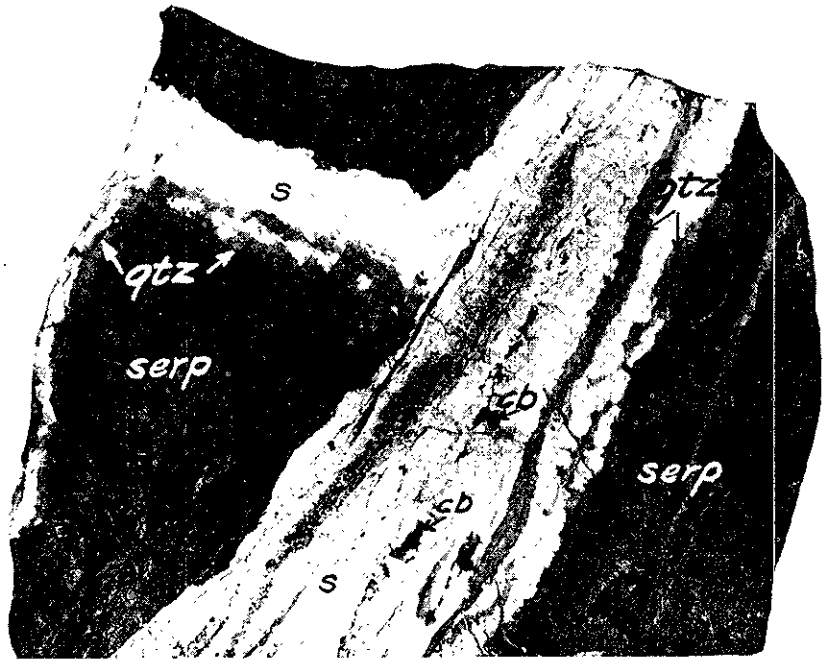

Plate III A Tungsten Queen.   Vein of scheelite (s) containing chalcedonic quartz (qtz) and ankeritic carbonate (cb) in carbonatized serpentine (serp). Natural size.

Plate III B Regal Silver. Relatively pure scheelite (s) in a pyrite lens (py) of No. 5 vein, as seen in the floor of No. 8 adit at a point 240 feet west of Raise A. Wall rock (rk) is slaty argillite. One-seventh natural size.

Plate IV A Regal Silver. Crushed graphitic slate and lenticular quartz in main fault-zone as seen in No. 8 adit.

Plate IV B Regal Silver. Ribbon texture as seen in quartz vein in back of Raise B, No. 10 adit. Vein 4 feet wide.

Plate V A Regal Silver. Fractured scheelite (s) with quartz (qtz) and pyrite (py). The distribution of the scheelite is approximately parallel to wall of enclosing pyrite lens. Natural size.

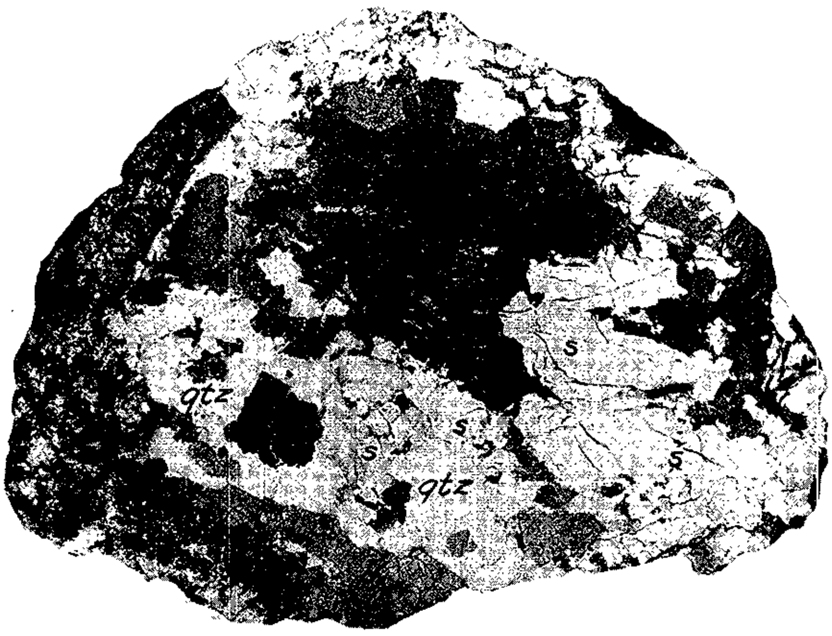

Plate V B Regal Silver. Disconnected patches of scheelite (s) and quartz (qtz) in pyrite (py) of a pyrite lens. Natural size.