TUNGSTEN IN YUKON

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INTRODUCTION

In 1959, the Geological Survey of Canada published Economic Geology Series No. 17, "Tungsten in Canada", by H.W. Little, an excellent summary of known occurrences in Canada up to the end of 1953. The fact that this publication is now badly out of date, only 15 years after it was written, is an indication of how rapidly tungsten exploration has been moving. It is noteworthy that 73% of the cumulative Canadian production to the end of 1968 has been recorded since 1953. Since most of the new developments have been in Yukon, this paper will provide an updating of the Canadian tungsten position as well. In this discussion, "Yukon" includes those adjacent areas of the Northwest Territories and Northern B.C. which are only accessible through Yukon (Figure 2).

Economic Geology Series No. 17 lists only eight tungsten occurrences in Yukon and Northern B.C., two of which were placer occurrences. The present report discusses 30 lode and one placer occurrence, including Cantung, North America's leading straight tungsten mine. These new developments are all the more significant when one considers that the erratic and recently depressed world tungsten market has discouraged exploration and almost all of the new discoveries were made accidentally in the course of exploration for other metals.

From information now available it is possible to draw some general conclusions concerning the best techniques and most favourable geological areas for tungsten exploration, and speculate on the growth potential of the Canadian industry. A comprehensive introductory section on the marketing, metallurgy and uses of tungsten has been included because the references are not readily available.

THE METAL

Tungsten (or wolfram, as it is sometimes called) is unique because it has the highest melting point (3370°C), highest boiling point (5900°C) and highest tensile strength (590,000 lbs) of all the metallic elements. Its specific gravity, 19.3, is equal to that of gold. In addition, it possesses great hardness, elasticity, ductility, and resistance to corrosion. Its only drawbacks - excessive oxidation at high temperatures and reduced ductility at low temperatures - cause problems in fabrication. Its main uses - in steel and non-ferrous alloys, carbide and stellite - reflect its hardness and resistance to ear, and in particular, its ability to retain these properties at high temperatures. The main alloy products are tool steels, armour, cutting edges and hard surfacing. Tungsten also has smaller, but strategic, uses in the electrical, chemical, and space industries.

Tungsten is marketed as a mineral concentrate (rather than as a metal) for which the price is quoted in dollars per short-ton unit (stu) of WO_3 (one short-ton unit is 20 pounds of WO_3 and contains 15.862 pounds of W). The quotation is for concentrates containing a minimum of 65% WO_3; concentrates grading higher sell at a premium price while those grading below 65% sell at a discount, if they can be sold at all. The term "tungsten concentrate" covers a wide variety of quality, each mineral deposit producing a concentrate with slightly different metallurgical properties. The particular needs of the consumer and the design of his treatment plant govern the type of concentrate he prefers and the premium he will pay above the average market price. In 1968, U.S. consumption was allocated as follows: in alloys (23%), in carbides (45%), as metal (20%), and miscellaneous (12%). Nearly every use of tungsten requires a product low in molybdenum (less than 0.4%), although scheelite concentrate grading over 70% WO_3 and containing up to 0.8% molybdenum is suitable for direct addition to steel melts. Manganiferous varieties of wolframite are unsatisfactory for steel alloy production. Copper, arsenic, antimony, phosphorous, and sulfur are the other impurities which most often cause trouble in meeting alloy specifications. A low-molybdenum scheelite ore which concentrates well is a premium product and, fortunately, most Canadian ores fall within this category.

An important practical consideration for northern areas is that the high density and metal content of a tungsten concentrate results in a very valuable shipping product. At present metal prices, a 70% WO_3 concentrate is worth about $3000 per short ton or about ten times as much as an average lead or copper concentrate and about equal in value to a lead concentrate containing 1300 ounces per ton of silver. It can readily be seen that the cost of transporting a tungsten concentrate from a remote area represents only a minor part of its value.

THE WORLD MARKET

Tungsten is a minor metal in terms of quantity consumed, and yet its unique qualities and unusual distribution give it strategic importance out of all proportion to its production value. It has been more susceptible than most metals to wild price fluctuations. To give a recent example, world price dropped to $7.19 per stu in mid-1963, but then rose to $46.00 per stu in July, 1967. The graphs in Figure 1 show the variations in world price and production since 1903. The peaking of both during wartime is due to the critical location of most of the world's reserves and tungsten's special role in heavy industry. Unlike all other metals, the bulk of known world reserves, 80% at the time of the last published estimate in 1954 (Li & Wang, 1955) are located in the communist sector of Southeast Asia; mainly in China but also, to a lesser extent, in North Korea and Russia.

In addition to the Viet Nam War, factors affecting world price in the past decade have included the change in Russia's position from a net exporter to net importer, and development of new products, such as carbide tire studs. The most significant influence, however, has been the new stability resulting from the creation and management of the U.S. Government stockpile, now the largest single source of tungsten concentrates in the world. Between 1951 and 1958, the U.S. Government provided domestic exploration loans and contracted for concentrates from both domestic and foreign producers at prices between $56.00 and $63.00 per stu WO_3. In February, 1965, the U.S.

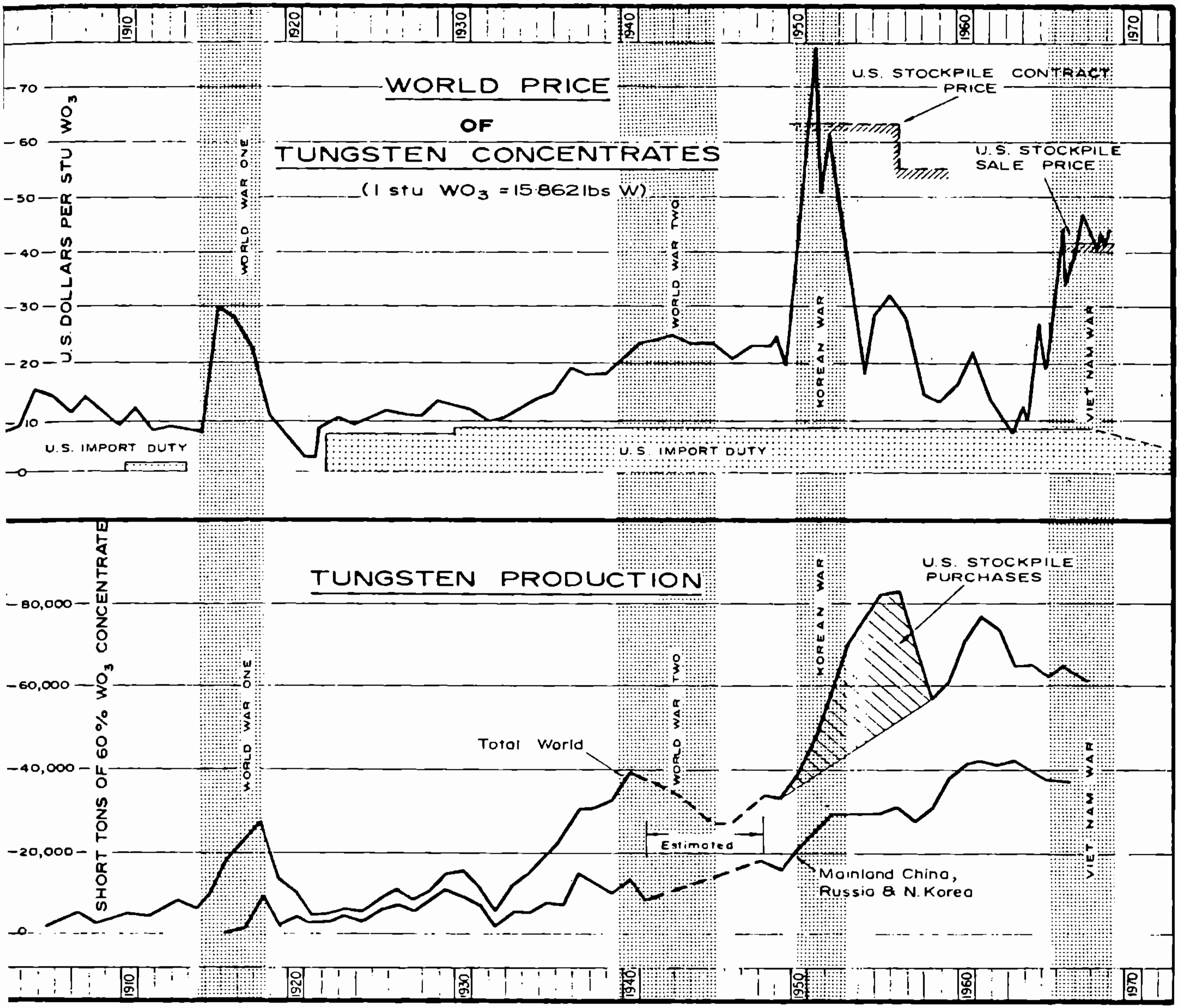

Figure 1 - Graph of World Tungsten Price and Production, 1903 - 1968. Source: Li and Wang, E&MJ, D.B.S., UNCTAD

commenced a long-range plan for the orderly disposal of surplus tungsten from the stockpile at a price of $43.00 per stu WO_3. At June 30, 1968, stockpile inventories totalled 180 million lbs W, of which one third was considered surplus.

These stockpile supplies which are available to all non-communist nations, have had the effect of:

(a) imposing price stability at a level which is almost double the historical average price, thereby

(b) encouraging the exploration needed to increase free world reserves and develop a strong free world industry.

In 1930, the United States imposed an import duty of 50 cents per pound of metallic tungsten contained in concentrates, equivalent to $7.93 per stu WO_3. As a result of the Kennedy Round of Tariff Negotiation, completed in 1967, the United States agreed to a 50% reduction in its tungsten tariff over a five-year period. When this reduction is completed on January 1, 1972, the duty will be 25 cents per pound of metal, or $3.97 per stu.

Preliminary 1968 figures indicate that China, Russia, and North Korea produced 55% of world production for the year, North America 19%, and the rest of the free world nations 26%. Canada, with only one small mine, ranked sixth with about 5% of the total.

CANADIAN DEVELOPMENTS

Tungsten generally occurs worldwide in or near acidic intrusive rocks of Mesozoic age within younger mountain belts. The bulk of the world reserves, particularly in Southeast Asia, occurs as wolframite in quartz veins in or near intrusive rocks . About 75% of U.S. production, and virtually all the Canadian production, has, in past years, come from contact metasomatic scheelite deposits. The most significant North American reserves that are now being found are in large, low-grade, porphyry-type deposits, usually associated with molybdenum.

At present, Canada has one producing mine and several deposits under active development. The Cantung Mine produced almost three million pounds of tungsten during 1968 and by the end of 1969 its cumulative output will be the highest in Canadian history, surpassing that of the Salmo area, B.C., where operations ceased in 1958 on completion of U.S. stockpile contracts. To the end of 1968, the Cantung Mine and the Salmo operations of Canadian Explorations Ltd. had accounted for 90% of the total Canadian production to date of 29,618,306 pounds (see Table 1).

TABLE 1 - CANADIAN TUNGSTEN PRODUCTION[1]

To December 31, 1968

Mine	Date	Mined Tons	% WO_3	Shipments lbs W	Recovery %
Scheelite & Others, Halifax Co., N.S.	1910-18			350,000[2]	
Outpost Island, Great Slave Lake, N.W.T.	1941-42		0.7 (approx)	23,340	10
Hollinger, Timmins, Ont	1942-43, 53-54	52,777	0.5	281,927 78,914 360,841[3]	70
Red Rose, Hazelton, B.C.	1942-43,) 52-54)	114,175	1.40 (approx)	1,836,950	70
Emerald, Feeney & Dodger, Salmo, B.C.	1942-58	1,089,929	0.98	14,402,395	85
Cantung, Tungsten, N.W.T.	1962-68	465,267	2.34	12,508,780	73
Miscellaneous				136,000	
GRAND TOTAL				29,618,306	

1 - compiled from Little, 1959; D.B.S., B.C. Dept. Mines and company records. Canadian production records prior to 1950 are very poor. Totals shown for some mines may include minor production from nearby properties.

2 - estimated by Little, 1959

3 - includes some ore from other Ontario gold mines custom milled by Hollinger.

During 1968 the tempo of Canadian tungsten exploration was greatly accelerated. At Salmo, B.C., Canadian Explorations Ltd. carried out further drill sampling on the Invincible deposit and is conducting a feasibility study. Ore reserves were reported in 1953 as 386,000 tons averaging 0.83% WO_3 (Canadian Minerals Yearbook). Shaft sinking began at Burnt Hill, N.B., on a wolframite-quartz vein deposit where reserves are quoted as 1,500,000 tons grading between 0.75% and 1.0% WO_3 (Northern Miner, Oct. 10, 1968). Within Yukon, the Harvey Creek and Fox Lake prospects were discovered and the Mactung deposit responded well to initial drilling.

The Glacier Gulch molybdenum deposit of Climax Molybdenum (B.C.) Ltd. at Smithers, B.C. has been explored by 120,000 feet of drilling and 9000 feet of tunnelling between 1957 and 1968. A small, but recoverable, amount of scheelite is present with molybdenite in quartz veins in a porphyry-type deposit. Reserves have not been published.

PROSPECTING

The only economically important tungsten minerals are scheelite and the wolframite family. Their main characteristics are:

Mineral	Formula	%WO_3	% W	S.G.	H	Magnetism	Cleavage
Scheelite	$CaWO_4$	80.6	63.9	5.4-6.1	4.5-5	None	4
Wolframite	$(Fe,Mn)WO_4$	76.3-76.6	60.5-60.7	7.1-7.5	5	Feeble or absent	1

Scheelite, the main tungsten mineral found in Yukon, is almost impossible to distinguish visually from common carbonates and rock forming silicates. Its only reliable diagnostic feature is a bright bluish-white fluorescence under ultraviolet light. It has a vitreous lustre and is usually colorless in Yukon although a wide range of pale colors are possible.

Wolframite is actually a family of minerals which comprise a solid solution series between the iron end member, ferberite, and the manganese end member, huebnerite. All varieties are dark colored with a submettalic to adamantine lustre. Where the term "wolframite" is used in this report, it refers to the solid solution series.

Wolframite and, to a lesser extent, scheelite concentrate well in stream gravels and can be detected by ordinary creek panning. Most Yukon scheelite deposits are found in the contact alteration aureole bordering granitic stocks that intrude rocks of Cambrian or older age. Scheelite is usually associated with a distinctive dark green diopside - garnet skarn and small amounts of pyrrhotite and chalcopyrite. Prospectors should concentrate their search in Cambrian or older rocks and use a combination of creek panning, stream geochemistry and an ultraviolet lamp. All iron gossans in these areas should be lamped as a matter of course. The Fox Lake occurrence, which is marked by a prominent gossan in a well travelled area only 30 miles from Ross River, remained undiscovered until 1968.

Tungsten minerals are commonly associated with molybdenite and, therefore, the occurrence of wolframite or scheelite may, in the propert environment, be an important indicator of porphyry-type molybdenum mineralization. The best known example of this association is the Climax Mine at Leadville, Colorado, the world's largest molybdenum mine. Here, four distinct intrusive pulses produced three separate molybdenum orebodies and an iron-tungsten "front" or umbrella occurs over each. Tungsten is present as huebnerite in very low (0.03 to 0.04%) amounts, associated with pyrite, topaz, fluorite, cassiterite and brannerite in quartz veins. The tungsten umbrella associated with one pulse has been fortunately superimposed on the molybdenum orebody from an earlier pulse, resulting in a huebnerite byproduct that is sufficiently large to make Climax one of the two largest U.S. tungsten producers.

Five Yukon wolframite occurrences - Mt. Fitton, Mt. Sedgwick, Old Crow, Clear Creek, and Fiddler - which are described in detail later, could be important indicators of undiscovered molybdenum. Two others, Canadian Creek and Black Diamond, lie beside molybdenum prospects which were discovered in 1968 and will be drilled in 1969.

YUKON OCCURRENCES

Thirty-one occurrences are described in this report and their locations are shown on Figure 2. The most important area lies in a broad arc extending almost 400 miles southeast from Mayo through Macmillan Pass and Cantung, generally paralleling the Selwyn Mountain Range. For discussion purposes, I have named this the Selwyn Tungsten Belt.

Southeast of the Canol Road, the Selwyn Tungsten Belt follows the Yukon - N.W.T. border and lies near the west extremity of Cambrian and Ordovician miogeosynclinal deposition. A pronounced facies change exists between shallow water carbonates on the east and fine clastics to the west. These miogeosynclinal rocks are underlain by a Proterozoic clastic-grit unit and overlain by Silurian to Mississippian shale, argillite, conglomerate and quartzite. Limestone is only well developed and extensive in the Cambrian units. A series of generally small, discordant quartz monzonite and granodiorite stocks, of middle to late Cretaceous age, occur in the Selwyn Mountains. The intrusions are surrounded by contact aureoles up to a mile in width and up to the hornfels facies in metamorphic grade. Where the intrusive rocks cut calcareous units, prominent and economically important scheelite deposits have formed in dark green skarn zones. These are typical contact metasomatic deposits - relatively small in tonnage and often erratic in shape and rich in grade. The skarn is composed mainly of green diopside and red garnet with lesser amounts of tremolite, actinolite, epidote, feldspar, calcite and a number of rarer silicates. The skarn is often partially replaced by pyrrhotite, chalcopyrite and scheelite and is cut by quartz-scheelite veins. The mineralization is usually confined to within several thousand feet of the intrusive contact. Because the skarns only develop in limestone and impure limy rocks, most tungsten occurrences are in Cambrian rocks.

DESCRIPTION OF OCCURRENCES

(1) Cantung Mine*, Tungsten, N.W.T. (61°57'N, 128°15'W); 43 P 61-23, 68 P 67-40°. Although only 15 years have passed since this deposit was discovered in 1954 by Northwestern Exploration Ltd., a Kennecott subsidiary, it has had more than its share of misfortune. Scheelite was not recognized at first in the chalcopyrite-pyrrhotite deposit, and, as the copper grade was quite low, the claims were allowed to lapse in 1958. The Mackenzie Syndicate recognized the scheelite and restaked the property immediately.

Canada Tungsten Mining Corp. Ltd. was formed in 1959 to develop the deposit. By the commencement of production in November 1962, it was known to contain 1, 176,400 tons of open pit ore grading 2.47% WO_3 and 0.45% copper, one of the richest tungsten deposits in the world. Production financing was provided by American Metal Climax, Inc., Falconbridge Nickel Mines Ltd., and Dome Mines Ltd. By mid-1963, the world price had dropped to its lowest level in 40 years and operations had to

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* numbers refer to localities plotted on the Index Map (Figure 2)

° the most useful or recent, readily available references are noted with each property. References of comprehensive interest are listed at the end of the report. 36 EG 17 refers to page 36, Economic Geology Series No. 17; B - Bulletin, M - Memoir, P - Paper, all published by Geological Survey of Canada.

be suspended for a year. Then, after 2 1/2 years of continuous operation, disaster struck again in December 1966 in the form of a fire which destroyed the mill and crusher. Production resumed in late 1967 and has continued uninterrupted to the present. To the end of 1968, total production was 12,508,780 pounds of tungsten metal (788,700 stu WO_3) from 465,267 tons of ore averaging 2.34% WO_3. Ore reserves at the end of 1968 were given at 814,000 tons grading 1.70% WO_3, indicating another 5 1/2 years life at the present mining rate. American Metal Climax and Dome presently hold some 49% of the issued capital stock.

The Cantung deposit is a lens shaped body 600 feet long, up to 300 feet wide and 80 feet thick. It is situated within a complex structural setting, occuring in the lower, gently dipping limb of a small, doubly plunging, overturned syncline which, in turn, is superimposed on the limb of a major syncline. A local, gentle dome occurs in the vicinity of the mine. Small stocks of biotite granite outcrop 4000 feet northwest and 3000 feet southeast of the orebody and probably underlie it at shallow depth. Intense local faulting and narrow dikes of porphyritic rhyolite cut the orebody.

The host rock is a lower Cambrian, massive crystalline limestone bed up to 250 feet thick, called the "ore" limestone. This is the purest limestone in the region and it is restricted to the synclinal structure near the mine. It becomes slightly dolomitic towards the top and the orebody is confined to the base of the unit, immediately above the sharp contact with underlying "swiss-cheese" limestone. This unit was originally a thin bedded, calcareous siltstone containing small limy pods, which has altered near the mine to dense, well bedded, light green calc-silicate rock.

Economic concentrations of scheelite are confined to dark green skarn, which is composed mainly of diopside, garnet, quartz, orthoclase and pyrrhotite. Minor constituents are epidote, actinolite, chalcopyrite and sphalerite.

The Baker Prospect, located three miles southeast of the mine, is similar in minerology, grade and mode of occurrence, although smaller in size. The skarn zone has a maximum thickness of ten feet. Several minor showings also exist between the Baker and Cantung deposits, all of limited extent and most confined to the base of the "ore" limestone.

(2) MB Showing, (61°49'N, 127°50'W); 28 P 64-52. This occurrence, 18 miles southeast of Cantung on the northeast side of Flat River, is owned by Canada Tungsten Mining Corp.

Unlike the Cantung deposit, this scheelite occurs in a weak skarn which has developed in a Cambro-Ordovician silty limestone, over 5000 feet stratigraphically higher in the section. The mineralized zone is only a few feet thick, several hundred feet long and averages less than 0.5% WO_3.

(3) BUS Group, (61°50'N, 128°03'W); 46 P 61-23. This showing also lies along the N.W.T. border, about 13 miles southeast of Cantung and across the Flat River valley from the MB group. It has been idle since Mackenzie Syndicate examined it in 1960. Small amounts of scheelite and chalcopyrite occur in a pyrrhotite-bearing skarn zone.

(4) BG Group, (61°33'N, 127°28'W); 46 P 61-23. This deposit is situated four miles west of Lucky Lake and 40 miles southeast of Cantung, along the N.W.T. border. It was investigated by Northwestern Expl. Ltd. in 1954, Mackenzie Syndicate in 1960, and Cyprus Expl. Corp. Ltd. in 1967 and 1968.

Mineralization consists of lead-zinc-copper sulfides in pyroxene-rich skarn which has developed in Cambrian rocks. The showings are situated along the contacts of porphyry dikes, which are, in turn, related to a quartz diorite stock. Early reports indicated that scheelite was associated with the sulfides, but recent work by Cyprus indicates that the tungsten content is very low.

(5) Broten River, (61°48'N, 129°05'W); Map 6-1966. Several tungsten bearing diopside skarn zones were found in 1965 by the Yukon Pacific Prospecting Group and Mount Billings Venture syndicate. The showings are located about six miles east of Tustles Lake on the north side of a small glacier, near the headwaters of Broten River. An adjacent area was investigated by Spartan Explorations Ltd. in 1966 and 1967 for its molybdenum potential but the tungsten has had little attention.

Skarn is developed in limy beds within micaceous schist, gneiss and quartzite, which have been tentatively dated as Cambrian or older. Skarn widths up to thirty feet are found. Mineralization is poorly exposed and no estimate of grade is available. The showings all lie close to the margin of a large Cretaceous batholith.

(6) Lened Group, (62°22'N, 128°35'W); 47 P 61-23. This deposit, located 32 miles northwest of Cantung, was discovered in 1960 by Canex Aerial Exploration Ltd. Two tungsten zones exist, one on either side of a narrow, highly altered granitic dike. The footwall zone contains considerable massive pyrrhotite and some chalcopyrite and surface sampling indicated a grade of from 0.75% and 2.50% WO_3 and 0.1 and 0.7% Cu over widths up to 22 feet. The hangingwall zone contains less sulfide and

assays from 2.2% to 7.6% WO_3 and 0.1 to 0.2% Cu across an 8 foot width on surface. The showing occurs at the base of the lower Cambrian carbonate unit, close to the contact with a biotite granite stock.

Canex drilled two holes in 1961, totalling about 450 feet. This drilling indicated that the tungsten mineralization had little depth continuity. Atlas Explorations Ltd. restaked the showing in 1967 as the NIP claims and conducted geochemical and geophysical surveys in 1968.

(7) Hi-Min Groups, (62°48'N, 129°50'W); Map 8-1967. Two showings, about a mile apart, were discovered by Hudson Bay Exploration and Development Ltd. in 1967 and explored during 1968. The property is situated about ten miles southwest of Mt. Wilson and 80 miles northwest of Cantung. Scheelite occurs in interbedded argillite and limestone of Devonian-Mississippian age, near the contact of a quartz monzonite stock 1200 feet in diameter. One showing, on the Hi claims, is within 3000-4000 feet of the intrusion and is in a typical diopside-garnet-scheelite-pyrrhotite skarn. The other, on the Min claims, consists of a siliceous skarn well mineralized with pyrrhotite and minor chalcopyrite. Assays have not been published but tungsten values are believed to be low.

(8) Dragon Lake, (62°37'N, 131°32'W); 43 P 61-23. Scheelite is present with chalcopyrite in a pyrrhotite-rich diopside-garnet skarn zone on the margin of a small stock. Skarn has developed in thin limestone bands in Cambrian or older metasediments. The showing was first explored by Kennecott in 1960 and has only been sporadically prospected since.

(9) Mactung, (63°17'N, 130°09'W); 48 P 65-19. This property is located along the N.W.T. border, seven miles north of Macmillan Pass on the abandoned section of the Canol Road. It lies 110 miles northwest of Cantung and was discovered in 1962 by James F. Allan of AMAX Exploration, Inc., a subsidiary of American Metal Climax, Inc. AMAX carried out preliminary assessment work in 1963, 1964 and 1967 and, in 1968, drilled 4647 feet in five holes.

Scheelite occurs in skarn adjacent to a small discordant quartz-monzonite stock of probable Cretaceous age. The stock intrudes a 1200 foot thick Cambrian formation which, before alteration, was composed of argillite, siltstone, limestone and dolomite, together with minor quartzite and volcanic conglomerate. The argillaceous sediments have been altered to pyrite-rich, medium grade hornfelses and the calcareous sediments have been altered to three distinct lithologies - marble, light colored skarn and dark colored skarn. The light colored skarn is fine grained, hard, and grey to pale green in color. Diopside is the principal component and occurs together with quartz, plagioclase and wollastonite. The dark colored skarn is medium grained, heavy and dark green in color. Iron-rich diopside is the principal constituent and together with one or more of the minerals garnet, hornblende, plagioclase and quartz forms most of the rock. Calcite, scheelite and sulphides are normally present as minor constituents together with other silicates.

Significant concentrations of scheelite are confined to the dark colored skarn, in which it is disseminated as subhedral grains 0.5-1.0 mm across. Pyrrhotite and chalcopyrite form 3-10% of the skarn, although chalcopyrite is normally present only in minor amounts. The mineralization is confined to two stratigraphic units within the Cambrian formation. It is developed along a strike length of 3000 feet and at least 1000 foot downdip from the intrusive contact. These two units are 80 and 400 feet thick. The 80 foot unit is of higher grade, but the 400 foot unit has, by virtue of its thickness, a greater tonnage potential and occurs in a more favourable mining situation. Mactung has a lower grade but a much higher tonnage potential than the Cantung deposit.

(10) Emerald Lake, (63°36'N, 131°18'W); 40 P 53-7. The showing is situated about four miles northwest of Emerald Lake, on the north contact of the intrusive stock of the same name, and about 42 miles northwest of Mactung. Minor amounts of scheelite are present in: a) carbonate veins cutting the porphyritic trachytoid syenite of the stock, b) disseminations in the syenite near the veins, and c) quartz veins associated with pyrrhotite, chalcopyrite, pyrite, arsenopyrite and molybdenite. The intrusion cuts Ordovician or Silurian clastic rocks low in carbonate.

(11) Mt. Armstrong, (63°12'N, 133°16'W). Scheelite is rumoured to have been recovered from a minor gold placer on Russell Creek. The placer is on the flank of the Mt. Armstrong intrusion and the area probably warrants careful prospecting.

(12) Mayo Lake, (63°50'N, 134°40'W); 36 EG 17. The G.S.C. investigated this area in 1943 because of the similarity of the small stock northeast of Mayo Lake to those found at Potato Hills and Scheelite Dome (described below). In spite of poor exposures, scheelite was found at two locations near Roop Lakes. It occurs in metasediments of the Yukon Group, of Cambrian or earlier age, near the contact of the stock, and in quartz veins cutting both the intrusive and the host rocks. Scheelite was also found in minor amounts in a

gold placer on Ledge Creek nearby. No subsequent work is reported from the Mayo Lake area.

(13) Potato Hills, (64°02'N, 135°45'W); 21 EG 17, 82 B 111, Map 52-1965. The sampled portions of this deposit are quite low in grade. However, because of its unique geology and obviously great size it is one of the more interesting occurrences in Yukon. Tungsten has been known in this area since 1904 when scheelite was recognized in gold placers on Haggart Creek and its tributary, Dublin Gulch. Prospectors investigated the bedrock source during both World Wars but it was not seriously sampled or evaluated until 1968. A low-grade skarn deposit occurs on the southeast side of the Potato stock but most of the tungsten is finely disseminated in a quartz stockwork within the intrusion. Thus, this occurrence could be classified as a "porphyry-tungsten" deposit.

Except for a few gold-bearing arsenopyrite veins, silver bearing galena-jamesonite veins and one tin occurrence on the fringes, scheelite is the only economic mineral found in the stock. It is disseminated mainly within a well-developed quartz-filled fracture system, and to a lesser extent in the immediate walls of the quartz veins. Associated vein minerals are muscovite and feldspar. The intrusion, about 3.5 miles long and up to one mile wide, ranges in composition from granodiorite to quartz monzonite, with a locally porphyritic texture. Magnetite is scarce and the intrusive has no magnetic expression. The stock intrudes the Yukon Group, of Cambrian or earlier age, which in this area comprises a structurally complex sequence of foliated quartzite and schist, composed mainly of chlorite, sericite, graphite and quartz. On the east side of the stock a limy horizon in the schists contains moderately intense diopside skarn, and tremolite skarn float was found downhill in Ray Gulch. Samples of this float, the source of which was never found, contained 2.7% to 3.3% scheelite. Sampling by the writer during 1968 of a 50 foot bed of diopside skarn near the headwaters of Ray Gulch assayed less than 0.10% WO_3.

The richest placer deposits, grading as high as 0.035% WO_3, occur in the headwaters of Dublin Gulch and its tributaries, Bawn Boy Gulch and Cascallan Gulch. Total production to date has been about 20 tons of WO_3 concentrate, mostly from gold placer operations. Bostock estimated the average placer grade at 0.008% WO_3 (64 ppm W). A small amount of cassiterite is found with the scheelite.

The first extensive investigation of the lode potential of this area was undertaken during 1968 by Great Plain Development Co. of Canada Ltd. on claims staked earlier in the year by Conrad A. Provencher of Whitehorse. Twenty-four bulldozer trenches were dug through the thin residual overburden cover into bedrock. This trenching covered an area about 1000 feet square near the head of Dublin Gulch. The average grade of 56 samples was 0.042% WO_3, a gross value of about $1.80 per ton. The reserves of this type of material are probably enormous and it is possible that a more extensive sampling program might outline a richer zone elsewhere within the stock.

It is interesting to note that the highest placer grade reported by the G.S.C., 0.035% WO_3, is about the same as that found in bedrock by Great Plains, 0.042%, suggesting that fine scheelite is being taken into solution or washed away at the same rate as the coarse fraction is being concentrated in the stream. Geochemical sampling by the Geological Survey shows that silt assaying between 50 ppm and 200 ppm W (0.006 and 0.025%), which was derived from Dublin Gulch, has been carried as far as ten miles downstream by the placer activities. This silt grades higher than the average placer gravel measured by Bostock, and is half as rich as the best gravel tested.

Bostock reported that small amounts of scheelite were found in minor gold placers or in heavy mineral concentrates collected by the G.S.C. from a number of nearby creeks, including Secret, Rodin, Goodman, Lynx, Snowshoe, Arizona and Gem. No bedrock sources have been found but the placer scheelite could be derived from minor quartz veins or small intrusive plugs.

(14) Scheelite Dome, (63°47'N, 136°14'W); 30 EG 17. This occurrence is quite similar in many ways to that on Potato Hills. A granodiorite stock intrudes Yukon Group metasediments and is surrounded by small lode occurrences of gold, antimony and copper. Scheelite has been found in diopside skarn developed in limy beds on the north side of the intrusion at the head of Castnor Creek, and in a quartz stockwork within the intrusion. In addition, scheelite was found with gold and some cassiterite in placer gravel in Johnson Creek and its tributaries, Sabbath and Scheelite Creeks, and in Highet Creek and its tributary, Rudolph Creek, all of which drain Scheelite Dome. Two other nearby creeks, Boulder and Canyon, also contain minor amounts of scheelite.

(15) Clear Creek, (63°46'N, 137°22'W); 19 EG 17. This placer occurrence of scheelite with gold and cassiterite has been well described by the G.S.C. No recent activity has been reported and no bedrock source has been found.

(16) Ash Mountain, (59°17'N, 130°31'W). The first report of tungsten mineralization in this portion of northern B.C. is contained in B.C. Dept. Mines Bulletin 19, by K. DeP. Watson and W.H. Matthews, 1943. Scheelite was found at two locations on the north and south sides of Ash Mountain, associated with light colored garnet-idocrase-diopside skarn. Cassiterite is occasionally present. Several other barren skarn localities were found nearby, all close to the Parallel Creek Batholith. The host rock consists of metasediments with some limestone beds and is probably late Paleozoic in age.

(17) Blue Light, (59°42'N, 130°30'W). This deposit was discovered in 1962 by prospector Andrew Zborovszky for Chapman, Wood and Griswold, Consulting Engineers. It was later optioned to Rancheria Mines Ltd. and Union Carbide Exploration Corp., which drilled 1265 feet in six holes during 1966. The property was then returned to Zborovszky, who reoptioned it to Spartan Explorations Ltd. late in 1968. It is situated about eight miles northeast of the southern tip of Jennings Lake, about

28 miles north of Ash Mountain.

The showing occurs in a metasedimentary roof pendant along the western edge of the Cassiar Batholith. Rock types consist of pelitic hornfels, augen gneiss, gneissic granite, migmatite and minor skarn, cut by coarse-grained irregular pegmatite bodies. A 25-foot band of augen gneiss contains four distinct skarn layers, ranging in thickness from 0.7 to 5.0 feet. Samples taken by Chapman, Wood and Griswold of three zones, each averaging two feet wide, within an 18 foot thick stratigraphic section, and over an exposed length of 105 feet, assayed 3.0% WO_3 by channel methods and 5.9% by bulk methods. An arbitrary average of 4.45% WO_3 over a six foot width is equivalent to a grade of 1.48% across the entire 18 foot thickness. Although poorly exposed, the zone can be traced intermittently on surface for over 200 feet in either directon. Diamond drilling indicated that the zone is more complex structurally than originally thought. Small amounts of beryllium and tin are reported to be present.

(18) Fiddler, (60°08'N, 130°26'W); 80 P 66-31. Discovered in 1943 and originally held by Cominco, this property was actively explored beteen 1951 and 1953 by Yukon Tungsten Corp. Ltd. It is five miles north of Mile 701 on the Alaska Highway and

is now held by Native Minerals Ltd. Underground development consisted of some 530 feet of drifting and 235 feet of raising. There was no production although a small mill was installed.

Country rock consists of limy phyllites of lower Paleozoic age. Wolframite occurs in quartz veins with minor amounts of scheelite, muscovite, fluorite and cassiterite.

(19) Stormy Mountain, (61°29'N, 132°48'W); 41 P 61-23. This mineralized area was first discovered by prospector Arnold Racicot for Conwest Exploration Ltd. in 1955. Conwest dropped the property the next year and Canol Metal Mines Ltd. was formed in 1958 to explore the showing. During 1959, 1050 feet of drifting and 3460 feet of underground diamond drilling (36 holes) were completed. The property lay idle until 1967 and 1968 when bulldozer trenching was conducted by Jason Explorers Ltd.

Molybdenite is the most abundant mineral in this deposit, with scheelite present almost everywhere in small amounts. It occurs within a narrow contact aureole between the Rose Lake stock and metasediments of the Yukon Group. The Metamorphic rocks are probably middle-upper CAmbrian or older in age and consist of massive, crystalline limestone and micaceous schist. Near the intrusive contact, these rocks have been thermally metamorphosed to impure marble, andalusite-cordierite schist, and diopside-actinolite-garnet skarn. The stock is composed of biotite granite and, where it cuts limestone, is rimmed by a 10-20 foot thick layer of diorite, probably formed from the assimilation of limestone by granite. Granite-diorite and diorite-skarn contacts are sharp.

The skarn zone is also about 10-20 feet thick and lies above a very gently dipping intrusive contact. The skarn is gently domed on a larger scale over the intrusion. The economic minerals occur as moderately heavy disseminations, mainly in the diorite rim but to a lesser extent in skarn and granite. The mineralized body is an elongated, wedge-shaped mass up to 350 feet in longest dimension and averaging 7-8 feet in thickness. Company engineer W.E. Field estimated a probably reserve of 15,000 tons grading 0.73% Mo, or 17,000 tons grading 1.05% WO_3. The molybdenum and tungsten zones do not completely coincide and no combined grade calculation was made.

(20) Fox Lake, (61°52'N, 133°17'W); Map 7-1960. This property was discovered in June, 1968 by prospector Peter Risby of Ross River and staked as the CAB claims. It is located about 30 miles southwest of Ross River, at the headwaters of Fox Creek, approximately midway between the summits of Fox Mountain and Twin Mountain.

Atlas Explorations Ltd. optioned the property late in the summer and conducted a preliminary sampling and mapping program. It is a typical scheelite-pyrrhotite-diopside skarn occurrence, developed in limy horizons in metasediments near the contact of a small quartz monzonite stock. The metamorphic rocks consist of micaceous schist, gneiss and quartzite, probably of Cambrian or older age.

Two separate zones are present, striking almost at right angles. The structural relationship between them is not yet clear. The largest zone, the No. 2, consists of two separate skarn bands, each about fifteen feet thick, separated by a ten foot granitic sill. This zone is intermittently exposed along a strike length of over half a mile and lies conformably above the main intrusive contact. The No. 1 zone is smaller and contains considerable pyrrhotite and a little chalcopyrite, whereas the No. 2 zone has a very low sulfide content.

Initial surface sampling was difficult because of rugged topography and poor exposures. Assay results are conflicting and the grade is still uncertain, although it will be within the 0.5 to 1.0% WO_3 range. A good tonnage potential is indicated because of a fortunate parallel attitude between the rather narrow limestone horizon and the intrusive contact over a considerable strike length.

(21) Little Salmon, (62°12'N, 134°09'W); 38 P 65-19. This property was first described by the G.S.C. in 1928. It is situated seven miles east of Little Salmon Lake and just north of the Carmacks-Ross River Highway. It has been surveyed and drilled over the years by a number of companies.

Two showings are present. The Cliff showing is a silver-lead-zinc vein occurrence. The Lake showing consists of a magnetite-pyrrhotite-pyrite alteration zone along the contact of a small quartz-feldspar porphyry body. The zone is about twenty feet thick and locally contains galena, sphalerite and chalcopyrite. One drill hole intersected a calcite-garnet skarn containing minor amounts of chlorite and scheelite. The host rock is composed of feldspar and diopside and may be derived from a limy tuff.

(22) Harvey Creek, (62°35'N, 134°48'W); 74 M 352. This discovery was made in a new area on the southwest side of the Pelly River valley by Union Carbide Exploration Corp. in 1968. Staked as the Bull claims, it is an occurrence of scheelite in alternating layers of diopside-garnet skarn and hornfels. The alteration is developed in limy and argillaceous rocks of the middle Cambrian Harvey Group, about 500 feet from the

contact of a leuco-quartz monzonite dike. The thickest mineralized bed seen is about seven feet and the associated sulfide content is negligible.

(23) Canadian Creek, (62°43'N, 138°49'W); 444 M 284, 16 EG 17. Ferberite occurs on the claims of Casino Silver Mines Ltd., in a gold placer at the headwaters of Canadian Creek, which drains to the north into the Yukon River. Between Canadian Creek and the headwaters of Casino Creek, a copper and molybdenum zone was outlined on Patton Hill during 1968. Because of the unglaciated terrain and deep weathering, the mineralization does not outcrop and the nature of this deposit will not be known until it is diamond drilled this summer.

Tungsten was first noted in the placer concentrate by the G.S.C. in 1915. Its potential was investigated in 1941 by Yukon Tungsten Ltd. and Hollinger Exploration Ltd., in 1942 by Bralorne Gold Mines Ltd. and Yuba Consolidated Gold Fields and in 1953 by Tecumseh Petroleums. Only minor amounts of tungsten were recovered during gold operations.

A black sand concentrate is intimately associated with the gold. The habit of the gold suggests that it has not travelled far from its source. Magnetite comprises 40% of the black sand and most of the remainder is ferberite, generally minus 10 mesh in size. Also present are minor amounts of hematite, scheelite, molybdenite, cassiterite, ilmenite and monazite.

The black sand was reported to contain 14.8% WO_3 by the G.S.C. and 17.0% WO_3 by Hollinger. Estimates of the black sand content of the gravels range from 0.5% (Hollinger) to 1.0% (Casino Silver). Bostock judged that the ferberite content of the gravel varied from 0.1 to 0.75 pounds per cubic yard. These figures indicate that the placer deposit would grade between 0.007 and 0.015% WO_3. All investigations have been directed primarily towards the gold content and the extent of the tungsten placer reserves is not known.

(24) Kluane River, (61°49'N, 139°30'W); 42 M 267. Small quantities of scheelite are reported to have been found directly north of the Alaska Highway between Kluane and Donjek Rivers. The occurrence is associated with garnet and other skarn minerals along contacts between limestone of the Yukon Group and granitic rocks. Very little is known about this showing as the area has not been explored to any extent.

(25) Alaskite Creek, (61°29'N, 138°10'W); 112 M 340. This is a rather small occurrence of wolframite, chalcopyrite and fluorite, occurring in quartz veinlets within a Mesozoic alaskite and granodiorite stock. No significant development work has been carried out.

(26) Giltana Lake, (61°12'N, 136°57'W); 568 M 284, Inf. Circ. 5-1961. Northwest of the lake, narrow lenses of quartz and sulfides occur at granite-limestone contacts. To the north-east, beds of mica schist, quartzite and limestone contain magnetite, chalcopyrite and molybdenite. Scheelite was reported to occur with the sulfides at the first location by the G.S.C. in 1961. The Giltana Lake mineralization occurs in Yukon Group metasediments.

(27) Whitehorse Copper Belt, P 63-41. Scheelite is present in small amounts with gold, silver and gallium in the copper-iron contact metamorphic deposits of New Imperial Mines Ltd. The scheelite occurs in quartz veins which cut the orebodies and associated Cretaceous intrusives and upper Triassic limy sediments. At the Scheelite deposit (60°44'N, 135°10'W), the tungsten is associated with molybdenite and chalcopyrite in a four foot wide vein assaying 0.38% WO_3. Another vein three feet wide at the nearby Pueblo Tungsten deposit assayed 2.96% WO_3 and 2.04% Cu. Minor amounts of scheelite are also reported from the Carlisle and Copper King (60°44'N, 135°07'W), Empress of India (60°41'N, 135°08'W), Grafter (60°40'N, 135°07'W) and Cowley Creek (60°34'N, 134°53'W) deposits. These occurrences extend along the contact of the Whitehorse Stock for a length of 15 miles.

(28) <u>Black Diamond</u>, (59°41'N, 133°23'W); 39 EG 17, 72 M 307. This occurrence is located twelve miles northeast of Atlin, B.C., at the headwaters of Boulder Creek on the south slope of Mt. Leonard. Tungsten was recognized in the placer gravel early in this century but the first recorded development was by Cominco in 1939. Black Diamond Tungsten Ltd., a subsidiary of Transcontinental Resources Ltd., acquired the claims in 1950 and, by the time work was suspended in late 1952, had driven a 400 foot adit and diamond drilled on surface. The property was idle until 1968 when Adanac Mining and Exploration Ltd. and Canadian Johns-Manville Co. Ltd. began molybdenum exploration nearby.

Tungsten is present as wolframite, associated with sericite in quartz veins. Small amounts of arsenopyrite, molybdenite, cassiterite and zeunerite (a secondary uranium mineral) are also present, carrying low values in gold and silver. A black sand concentrate from Boulder Creek assayed 48.5% WO_3 and 10.0% Sn. A hand cobbed shipment from the veins assayed 15.2% WO_3 and 0.18% Sn. Tungsten occurs in six main veins which cut alaskite phases of the Cretaceous Surprise Lake Stock. The stock intrudes rocks of the Permian Cache Creek Group. The veins are probably of little economic interest but the tungsten may prove to have an interesting spatial relationship to the molybdenum zone, which is presently under investigation.

(29-31) British Mountains, P 63-32, Map 10-1963. Intriguing occurrences of wolframite and scheelite, mostly in placer form, have been found along the Arctic slope. There are three principal areas of interest which can be related to a bedrock source - (29) Mt. Fitton, (68°27'N, 138°00'W), (30) Mt. Sedgwick, (68°51'N, 139°00'W), and (31) Old Crow, (67°28'N, 149°40'W), plus several more scattered placer localities. The first two lode occurrences are within 30 miles of the Arctic Coast, less than fifty miles west from the mouth of the Mackenzie River, while the third is about 25 miles southwest of the village of Old Crow.

Wolframite, pyrite, arsenopyrite and molybdenite were found by prospector Anker Hoidahl prior to 1952 in metamorphic rocks west of Mt. Fitton and placer gold occurs nearby. The area was mapped by the G.S.C. during Operation Porcupine in 1962, at which time heavy mineral samples were collected from the drainage system. Tungsten mineralization appears to be related to small porphyritic granite stocks at Mt. Fitton and Mt. Sedgwick, and a larger body near Old Crow. The showings are associated with Jurrasic clastic rocks at Mt. Fitton, Carboniferous limestone at Mt. Sedgwick and Cambrian or older clastics at Old Crow. The tungsten associated with these intrusions, which may be as old as Devonian-Carboniferous, could be an important indicator of molybdenum.

CONCLUSIONS

Within the past fifteen years, Yukon has emerged as a major tungsten province even though exploration for tungsten has had relatively low priority. The most important deposits found to date, Cantung and Mactung, occur in contact metasomatic skarn zones. The potential that more deposits of this type will be found appears to be excellent.

Although deposits of this type tend to be small and erratic, their grade is often high. Their richness, together with the high metal content of the mill concentrate, offsets to a large extent the extra costs imposed by a remote location. Yukon scheelite deposits are usually low in impurities and will produce an easily marketed concentrate.

The uncertain marketing conditions which have always made tungsten mining so risky have recently been stabilized by the creation and management of the U.S. Government Stockpile. World price since 1966 has been close to $43.00 U.S. per stu, approximately double the historic average price.

The future health of the free world tungsten industry depends both on stable, strong price (to encourage the discovery of large reserves) and on research into new markets. The presence of large reserves of a useful metal has historically resulted in a major research effort leading to a strong industry, as demonstrated by nickel, aluminum and molybdenum.

The rapid change in mining economics towards bulk-handling methods applies to tungsten as much as it does to other metals. The trend is away from erratic, small deposits, which often have to be recovered by underground methods, except where grade is unusually high or labour is very cheap. Looking into the future, the tungsten occurrences of greatest economic interest are those in the porphyry classification. Examples of this type, in which tungsten is usually a minor byproduct, are molybdenite-huebnerite at Climax, Colorado, molybdenite-scheelite at Smithers, B.C. and scheelite alone at Potato Hills, Yukon.

A large area in the Potato Stock has been found to average over $1.50 per ton gross value in tungsten at current prices. The possibility of discovering a richer occurrence in an open-pit setting in Yukon justifies a thorough study of this type of tungsten occurrence and a careful investigation of all intrusions within the tungsten province. Open pit reserves grading $4.00 per ton in copper or molybdenum are now of economic interest. In the case of tungsten, however, cut-off grade might have to be a little higher because the limited size of the market would make it difficult to develop a mine at a sufficiently large rate. For example, a deposit grading 0.1% WO_3 being mined at the rate of 35,000 tons per day would produce about 17,000 short tons of 70% WO_3 concentrate annually. This is approximately one quarter of current world production and over half of free world output.

Yukon tungsten occurrences have a strong genetic relationship to intrusions and occur mainly in areas of Cambrian or older strata. This stratigraphic association is probably a function of carbonate content (which is lower in younger rocks) rather than origin because the widespread pattern of scheelite-bearing quartz veins cutting granitic rocks indicates that the intrusions were the direct source of the tungsten. On the other hand, the close empirical relationship between lead-zinc-silver deposits and these same strata has been well summarized by Gabrielse (1969). He believes that these Cambrian and older rocks originally contained higher than average quantities of metals that have subsequently been localized into significant concentrations by plutonic activity.

Not all intrusions that cut limestone within the Yukon tungsten province, or even within the Selwyn Tungsten Belt, have associated tungsten occurrences. It is possible that in some cases tungsten is present but has not yet been discovered. It is more likely, however, that tungsten is related to a particular phase of a complex intrusive event which extended from mid-Cretaceous to early Tertiary time. This question will be answered when more dating is done on individual intrusions.

Crawford (1963) speculated that a possible control on the location of the Cantung deposit was the position of suitable limestone at a high elevation relative to the intrusion. Most of the significant occurrences in Yukon are associated with small intrusions which have not been extensively unroofed and further study may show that tungsten is only found in or near the top of the intrusion.

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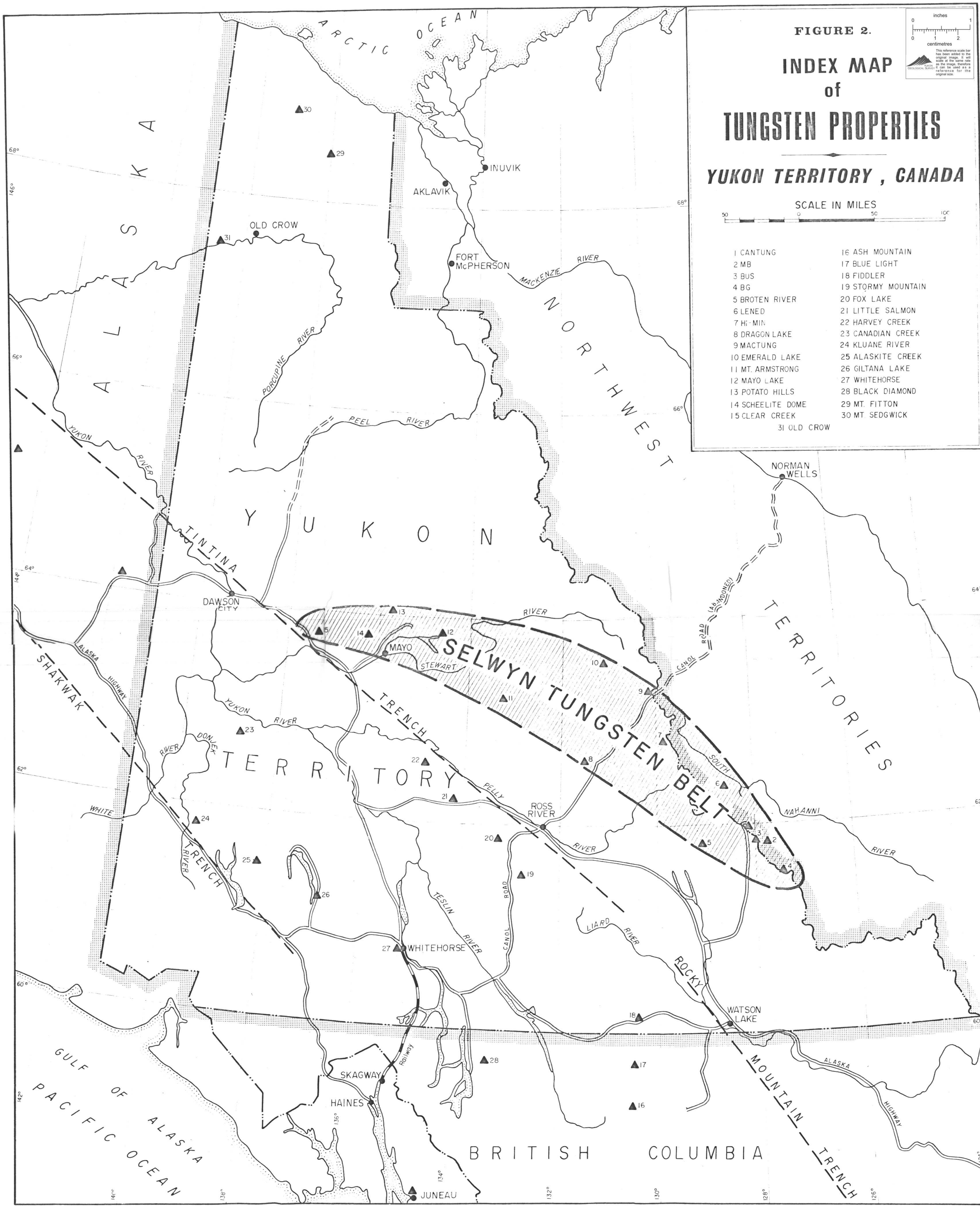
FIGURE 2.
INDEX MAP
of
TUNGSTEN PROPERTIES
YUKON TERRITORY , CANADA
SCALE IN MILES
50 0 50 100
1 CANTUNG
2 MB
3 BUS
4 BG
5 BROTEN RIVER
6 LENED
7 HI-MIN
8 DRAGON LAKE
9 MACTUNG
10 EMERALD LAKE
11 MT. ARMSTRONG
12 MAYO LAKE
13 POTATO HILLS
14 SCHEELITE DOME
15 CLEAR CREEK
16 ASH MOUNTAIN
17 BLUE LIGHT
18 FIDDLER
19 STORMY MOUNTAIN
20 FOX LAKE
21 LITTLE SALMON
22 HARVEY CREEK
23 CANADIAN CREEK
24 KLUANE RIVER
25 ALASKITE CREEK
26 GILTANA LAKE
27 WHITEHORSE
28 BLACK DIAMOND
29 MT. FITTON
30 MT. SEDGWICK
31 OLD CROW
inches
centimetres
ARCTIC OCEAN
ALASKA
YUKON TERRITORY
NORTHWEST TERRITORIES
BRITISH COLUMBIA
GULF OF ALASKA
PACIFIC OCEAN
SELWYN TUNGSTEN BELT
TINTINA TRENCH
SHAKWAK TRENCH
ROCKY MOUNTAIN TRENCH
INUVIK
AKLAVIK
OLD CROW
FORT McPHERSON
NORMAN WELLS
DAWSON CITY
MAYO
ROSS RIVER
WHITEHORSE
WATSON LAKE
SKAGWAY
HAINES
JUNEAU
MACKENZIE RIVER
PORCUPINE RIVER
PEEL RIVER
YUKON RIVER
STEWART RIVER
PELLY RIVER
WHITE RIVER
DONJEK RIVER
TESLIN RIVER
LIARD RIVER
SOUTH NAHANNI RIVER
CANOL ROAD
ALASKA HIGHWAY
Railway
68°
66°
64°
62°
60°
146°
142°
141°
138°
136°
134°
132°
130°
128°
126°
124°