Geological Survey of Canada
Commission géologique du Canada

ECONOMIC GEOLOGY
REPORT 32

GEOLOGY OF CANADIAN TUNGSTEN OCCURRENCES

ROBERT MULLIGAN

1984

Canada

ECONOMIC GEOLOGY REPORT 32

GEOLOGY OF CANADIAN TUNGSTEN OCCURRENCES

ROBERT MULLIGAN

1983

Available in Canada through

authorized bookstore agents
and other bookstores

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Ontario, Canada K1A 0S9

and from

Geological Survey of Canada
601 Booth Street
Ottawa, Ontario, Canada K1A 0E8

A deposit copy of this publication is also available
for reference in public libraries across Canada

Cat. No. M43-32/1984 Canada: $10.00
ISBN 0-660-11486-0 Other countries: $12.00

Price subject to change without notice

Critical Readers

K.M. Dawson
G.B. Leech

Original manuscript received: 30 – 01 – 78
Final approved for publication: 74 – 11 – 78

Preface

One of the objectives of the Geological Survey of Canada is to develop a national data base concerning mineral occurrences from which evaluations of the distribution and nature of our non-hydrocarbon mineral resources can be made. The results of detailed studies on metallic and nonmetallic elements of economic importance to Canada are published by the Survey in the Economic Geology Report series, which in the past decade has included reports on titanium, vanadium, tin and tantalum.

The physical characteristics of tungsten make it an important industrial mineral. It is very hard and dense, and has a higher melting point than any other metal. It is ductile and even very fine tungsten wires have high tensile strength. Tungsten is used for filaments in electric light bulbs and electric tubes. Tungsten carbide is one of the hardest materials known and is widely used in machine tools. Tungsten is also an important constituent of many superalloys and nonferrous alloys because of its high melting point and resistance to corrosion and oxidation. Because of tungsten's industrial importance, Canada requires an adequate and secure supply.

In this report Dr. Mulligan discusses the world distribution, geochemistry, mineralogy and classification of tungsten deposits. He lists all known Canadian occurrences and describes the geology and metallurgy of the most important of these.

D.J. McLaren
Director General
Geological Survey of Canada

Ottawa, March 1980

Préface

L'une des préoccupations majeures de la Commission géologique du Canada est l'amélioration constante d'une base de données nationale des venues minérales qui permet de juger d'une façon rationnelle la distribution spatiale et la nature des ressources minérales autres que les hydrocarbures. Les résultats détaillés d'études sur les éléments métalliques et non métalliques qui revêtent une importance économique pour le Canada ont été publiés par la Commission dans la Série géologie économique où, il y a une dizaine d'années, on pouvait y voir en bonne place, des études, notamment sur le titanium, le vanadium et le tantal.

Les caractéristiques physiques du tungstène le haussent à un niveau important dans l'industrie minérale; de fait, c'est un métal qui possède une dureté et une densité élevées, il a le plus haut point de fusion des métaux, il est, de plus, très ductile, propriété qui conserve même à des câbles très fins une haute résistance à la traction; il est utilisé aussi, comme filaments d'ampoules et de tubes électriques. Un dérivé, le carbure de tungstène, s'avère un des matériaux les plus résistants d'où son emploi en grande quantité dans les machines-outils. Il faut signaler aussi que le tungstène entre d'une façon très significative dans les superalliages et dans les alliages non ferreux à cause de son haut point de fusion et de sa résistance à la corrosion et à l'oxidation. Étant donné son importance marqué dans l'industrie minérale, le Canada en a besoin pour son marché actuel et futur.

Dans ce rapport, M.R. Mulligan étudie les gisements de tungstène du point de vue géochimique et minéralogique, il en donne une classification et en indique la distribution planétaire. L'auteur à catalogué toutes les venues connues au Canada et il donne, pour les plus importantes d'entre elles, des descriptions géologiques et métallurgiques.

Le directeur général de la
Commission géologique du Canada
D.J. McLaren

Ottawa, mars 1980

CONTENTS

Part 1. World distribution and production, geochemistry, mineralogy and general geology of tungsten deposits

Part 2. Description of Canadian tungsten occurrences

Tables

Plates

Figures

GEOLOGY OF CANADIAN TUNGSTEN DEPOSITS

Abstract

Tungsten occurrences are numerous and widely distributed in the Cordilleran and Appalachian orogenic belts and in the Archean provinces of the Canadian Shield. Most are closely associated with granitic rocks or porphyries but some are apparently unrelated to any exposed intrusions.

The most important deposits, including major past and present producers, are scheelite skarn deposits in the Cordillera. These are associated with granitic rocks of late Mesozoic age in a miogeosyncline belt that extends along the east fringe of the main Cordilleran eugeosyncline. They include the Emerald and associated deposits in the south, now abandoned, and the Canada Tungsten and MacTung (AMAX Northern) deposits near the Yukon – Northwest Territories boundary. The Canada Tungsten deposit, just east of the boundary, has been the only Canadian producer since 1973 and the main producer since its inception in 1962. Straddling the boundary about 160 km farther northwest, the MacTung (AMAX Northern) deposit is potentially economic, with substantial reserves of moderately high-grade ore.

A vein-type deposit in the Cordillera, the Red Rose mine near Hazelton, was a significant producer of scheelite concentrate, mainly during World War II. Other scheelite skarn and vein deposits and two wolframite-quartz greisen deposits in the Cordillera produced small amounts of tungsten concentrates.

In the Archean Slave and Superior provinces of the Precambrian Shield, scheelite is associated mostly with gold in quartz veins in volcanic or sedimentary rocks of 'greenstone belts'. Substantial amounts of scheelite were recovered from the Porcupine gold camp near Timmins, Ontario, mainly during World War II. Most of the tungsten was apparently related to felsic porphyry bodies. The only wolframite-quartz greisen deposit known in the Shield is the Fox Group at Great Slave Lake, where some wolframite and scheelite were recovered together with gold in 1941 and 1942.

In the Appalachian Region, whose orogenic history culminated in Devonian granitic intrusions, three wolframite-quartz greisen deposits have some economic potential. The Mount Pleasant deposit of Brunswick Tin Mines, Ltd., has sizeable but rather low-grade orebodies of wolframite together with molybdenite and bismuth minerals, and tin and base metals in some zones. The Burnt Hill mine, also in New Brunswick, has been worked intermittently for many years but no substantial production has been recorded. A deposit at Grey River, on the south coast of Newfoundland contains wolframite and scheelite ore of fairly good grade but limited proven tonnage. Minor amounts of scheelite have been produced from quartz veins in or near gold-quartz deposits in Nova Scotia.

Résumé

Les venues de tungstène sont nombreuses et largement répandues dans les zones orogéniques de la Cordillère et des Appalaches, ainsi que dans les provinces archéennes du Bouclier canadien. La plupart sont étroitement associées à des roches granitiques ou à des porphyres, mais certaines n'ont apparemment de rapport avec aucune des intrusions exposées.

Les gîtes les plus importants, comprenant à la fois les principaux gîtes productifs anciens et actuels, sont les amas de skarn à scheelite dans la Cordillère. Ces derniers sont associés à des roches granitiques datant du Mésozoique supérieur, situées dans une zone miogéosynclinale, qui s'étend le long du rebord est du principal eugéosynclinal de la Cordillère. Ils comprennent le gite d'Emerald et des gîtes associés situés au sud et maintenant abandonnés, ainsi que ceux de Canada Tungsten et de MacTung (AMAX Northern), proches de la frontière entre le Yukon et les Territoires du Nord-Ouest. Le gisement de Canada Tungsten, situé immédiatement à l'est de cette frontière, est le seul producteur canadien depuis 1973, et le principal producteur depuis son début d'exploitation en 1962. Le gîte de MacTung (AMAX Northern), chevauchant la frontière environ 160 km plus au nord-ouest, pourrait présenter un intérêt économique, grâce à des réserves substantielles de minerai de bonne qualité.

Un gîte de type filonien situé dans la Cordillère, soit la mine de Red Rose près de Hazelton, a produit des quantités importantes de concentré de scheelite, surtout au cours de la Deuxième Guerre mondiale. D'autres gîtes de scheelite de type skarn et filonien et deux gîtes de greisen à wolframite et quartz situés dans la Cordillère, ont produit de petits volumes de concentré de tungstène.

Dans les provinces archéennes du lac des Esclaves et du lac Supérieur, dans le Bouclier précambrien, la scheelite est généralement associée à l'or dans des filons de quartz, à l'intérieur des roches volcaniques ou sédimentaires des "zones de roches vertes". On a extrait des quantités substantielles de scheelite au chantier aurifère de Porcupine près de Timmins (Ontario), surtout au cours de la Deuxième Guerre mondiale. Apparemment, le minerai de tungstène était très souvent associé à des corps de porphyre felsique. Le seul gisement de greisen à quartz et wolframite que l'on connaisse dans le Bouclier canadien est le groupe de Fox sur le Grand lac des Esclaves, où l'on a extrait de la wolframite et de la scheelite en même temps que de l'or en 1941 et 1942.

Dans la région appalachienne, où les intrusions granitiques datant du Dévonien ont marqué la culmination de l'orogénèse, trois gisements de greisen à wolframite et quartz présentent un certain intérêt économique. Le gite de Mount Pleasant appartenant à la Brunswick Tin Mines Ltd., contient des amas de wolframite de dimensions appréciables, mais faiblement minéralisés auquels sont associés de la molybdénite et des minerais de bismuth, et dans certaines zones, de l'étain et des métaux communs. La mine de Burnt Hill, aussi située au Nouveau-Brunswick, a été exploitée de façon intermittente pendant de nombreuses années, mais sa production n'a jamais été importante. A Grey River, un gisement situé sur la côte sud de Terre-Neuve contient des concentrations de wolframite et de scheelite d'assez bonne qualité, mais dont le tonnage prouvé est limité. On a aussi extrait de petites quantités de scheelite de filons de quartz, à l'intérieur ou à proximité de gisements aurifères quartzeux en Nouvelle-Ecosse.

Frontispiece. *Strongly banded scheelite-bearing skarn (in foreground) and contact with granite (right) on the North Face of the MacTung tungsten deposit, Yukon-Northwest Territories boundary, near Macmillan Pass.*

INTRODUCTION

This report[1] was originally intended to supplement rather than to supersede Geological Survey of Canada Economic Geology Report 17 by H.W. Little (1959), which is now out of print. Part 1 deals in general with various aspects of the geology of tungsten deposits, including world distribution, geochemistry, mineralogy, classification, metallogenic characteristics and geological environment. It contains references to Canadian examples and generalizations derived from information contained in Part 2, which is a description of Canadian occurrences and their geological setting.

Since Little's report was written, many new occurrences have been found. Several of these are of major or potentially major economic importance, including the only mine presently producing. New information has also become available on some of the previously known deposits, and new descriptions of these are included together with descriptions of the newly found deposits of significant economic or metallogenic importance. The emphasis in these descriptions is on the geological environment and metallogenic aspects of the deposits, partly at the expense of physical details. For minor occurrences that are not considered to warrant separate description, the data have been summarized as much as possible in the Appendix, which lists all occurrences, together with specific references to Little's report and to others. The occurrences are plotted on Map 1556A, and identified by numbers corresponding to those in the Appendix and referred to in the text.

Special acknowledgment is due the Mineral Policy Sector, Department of Energy, Mines and Resources, for access to their files, and also K.M. Dawson for critically reading the manuscript and especially for providing information on recent developments in exploration and geological studies of the northern part of the Cordilleran Region.

---

[1] The manuscript for this report was completed early in 1978 after the author's retirement from the Geological Survey of Canada. More recent information on "World and Canadian Production and Prices" was contributed by the Mineral Policy Sector, E.M.R.

PART 1

WORLD DISTRIBUTION AND PRODUCTION, GEOCHEMISTRY, MINERALOGY AND GENERAL GEOLOGY OF TUNGSTEN DEPOSITS

WORLD AND CANADIAN PRODUCTION AND PRICES

Canada has been a middle-rank producer and a net exporter of tungsten for more than a decade, and at intervals during and since World War II. Exports are all in the form of mill concentrates, and virtually all tungsten in industrially usable form is imported. Reserves are adequate for more than a decade at current rates of production, prices and demand.

Recorded production of tungsten by all countries in recent years is shown in Table 1A, and Canadian production and consumption in Table 1B.

The price of tungsten has fluctuated widely in the past (see Fig. 1). A major factor has been the export policies of the People's Republic of China. In 1976 a meeting of the working group of the United Nations Conference on Trade and Development (UNCTAD) Committee on Tungsten was convened to discuss means of price stabilization. Buying and selling of tungsten concentrates and products by the U.S. General Services Administration have a generally stabilizing influence. The price of tungsten concentrates rose fairly steadily through 1976 and early 1977, to about $180 U.S./metric ton unit by early summer. It fell to $155 in September 1977, then rose to between $175 and 180 in November 1977 but closed the year on a downward trend at about $165.

From 1977 Canadian tungsten production increased gradually to a maximum of 4007 t in 1980. Production fell sharply to about 1750 t in 1981 as a result of a six month strike against Canada Tungsten Ltd. which effectively reduced their annual output by 30 per cent.

Development continued in 1982 on the Mount Pleasant tungsten-molybdenum deposit in New Brunswick. This deposit, jointly owned by the Sullivan Mining Group and Billiton Canada Limited, is scheduled for production by the end of 1982 with an annual output estimated at 1800 t of tungsten trioxide. Presently indicated reserves are 9.135 Mt of 0.393 per cent tungsten trioxide.

Evaluation of the MacTung tungsten deposit owned by Amax Northwest Mining Company Limited continued during 1981. The deposit, which is located on the Yukon-Northwest Territories border, has calculated reserves of 57 Mt of 0.95 per cent tungsten trioxide including 12 Mt of 1.02 per cent tungsten trioxide that could be mined underground. A production decision has been deferred pending discussions between Amax and Cantung regarding development of the property.

Prevailing instability in the global market has caused rapid and broad fluctuations in the price of tungsten in recent years. The record price level of $185 per metric ton unit established in 1977 gradually declined to about $140 per

Table 1A. World production of tungsten ores and concentrates

	1974	1975	1976
	(tonnes, tungsten content)		
North America			
Canada	1 280	1 172	1 719
Guatemala	6	1	-
Mexico	245	220	188
United States	3 554	2 535	2 644
South America			
Argentina	87	(56)	59
Bolivia	2 044	2 693	3 039
Brazil	993	950	974
Peru	682	602	521
Europe			
Austria	-	362	365
Czechoslovakia	(80)	(80)	(80)
France	593	867	756
Netherlands	485	646	-
Portugal	1 478	1 467	1 285
Spain	347	351	328
Sweden	166	151	183
U.S.S.R.	(7 600)	(7 800)	(8 000)
United Kingdom	16	10	10
Africa			
Burundi	1	1	2
Nambia	-	7	(140)
Nigeria	(1)	-	-
Rwanda	251	307	432
Tanzania	-	1	-
Uganda	(109)	(109)	(110)
Zaire	198	255	240
Zimbabwe	91	38	(59)
Asia			
Burma	502	330	174
China, People's Republic of	(8 500)	(8 980)	(9 000)
Hong Kong	(5)	(5)	(5)
India	12	19	23
Japan	769	732	755
Korea, North	(2 150)	(2 150)	(2 150)
Korea, Republic of	2 180	2 533	2 423
Malaysia	131	106	64
Thailand	2 204	1 773	2 055
Turkey	-	(5)	(5)
Oceania			
Australia	1 125	1 497	1 935
New Zealand	4	(5)	-
Total	37 889	38 816	39 723

Source: UNCTAD Tungsten Statistics, Jan. 1980, Oct. 1980, Oct. 1981.
( ) Estimate. - Nil or negligible.

Table 1B. Canadian tungsten production, trade and consumption, 1966-76

	Production* WO_3 Content	Imports Tungsten Ore**	 Ferrotungsten†	Consumption Tungsten Content
	(kilograms)			
1966	1 934 084	237 501	87 090	426 924
1967	121 381	105 959	87 090	404 337
1968	1 626 092	59 738	53 524	535 938
1969	1 843 167	193 457	95 254	476 646
1970	1 690 448	82 645	90 718	446 687
1971	2 097 505	69 536	100 697	290 192
1972	2 017 268	108 817	115 212	533 680
1973	2 104 850	5 443	78 018	462 531
1974	1 613 700	-	185 973	534 958
1975	1 477 731	1 000	45 359	451 336
1976	2 168 153	-	77 111	337 345

Source: Statistics Canada.
*Producers' shipments of scheelite. **W content. †Gross weight.
-Nil.

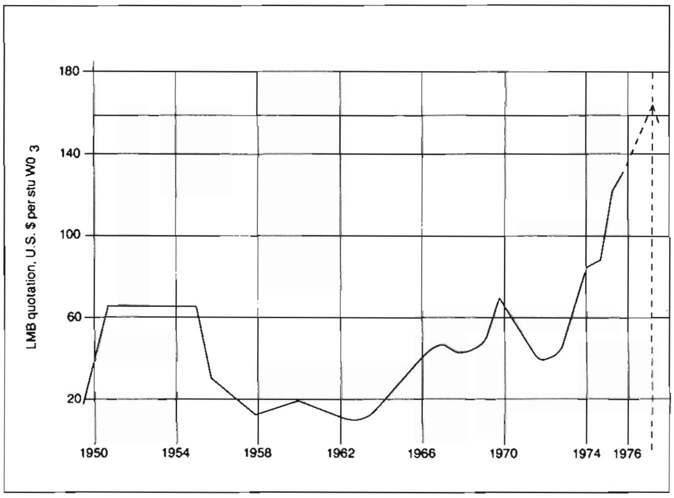


Figure 1. *Tungsten concentrate prices, 1950-1976.*

metric ton unit at the end of 1981 reflecting weakening demand among major consumers. The sharp decline in mineral and fuels exploration activity that began in 1981 has continued, further depressing the price of tungsten to about $100 per metric ton unit by mid-1982. This represents a 43 per cent decrease in price from the peak level established in 1977.

The continued downturn in demand for drill and other speciality steels, coupled with increased production capacity both in Canada and abroad, does little to improve the market prospects for tungsten in the near future. Continuing efforts by the UN Committee on Tungsten and its Preparatory Working Group aimed at price stabilization have failed to produce any real agreement between producing and consuming countries. A compromise solution proposed by the French would establish a commodity agreement between producers and consumers free of the economic provisions normally associated with this sort of agreement although such provisions could be added at a later date. However, even this compromise agreement was opposed most strongly by producing countries and discussions re-opened at the end of 1981.

GEOCHEMISTRY OF TUNGSTEN

Chemistry and Theoretical Geochemistry

The chemistry of tungsten is very complex. It may have any valence from +1 to +6. The lower oxidation states, in which tungsten has basic properties, are unstable; monovalent and bivalent tungsten occurs only as halides (Barabanov, 1970). In the higher oxidation states tungsten has acidic properties. It forms many complexes, mainly with oxygen but also with halides and other elements, which have been described by Li and Wang (1943). The complexes of hexavalent tungsten form various tungstic acids and salts, of which only a few of the monotungstates and tungstic acid itself occur as minerals. However, the existence and behaviour of some other compounds are pertinent to the transportation of tungsten and its concentration into deposits.

Something of the geochemical behaviour and associations of tungsten may be visualized with reference to the periodic table (Table 2). As a 'lithophile' element of Group VI, tungsten is bonded predominantly to oxygen, forming predominantly ionic bonds with oxygen and also with fluorine and chlorine (Ahrens, 1964, 1966). It is one of those minor metals, like lithium, beryllium and tin, which for various reasons involving mainly ionic radii, electronegativity and electronic configuration, are unable to substitute appreciably for the major elements in the early formed aluminosilicates of crystallizing granitoid rocks. These metals are therefore concentrated in late products and residual fluids, and are often found together in various combinations in the same geological environment.

In its dominant and most stable hexavalent state tungsten is an anion-forming element. It does not participate as an essential element in aluminosilicate structures but occurs almost entirely as a wolframate of calcium, iron or manganese, or much more rarely as a hydrated tungstic oxide. Hexavalent tungsten has about the same ionic radius (.062 nm) and the same valence as molybdenum, and molybdenum substitutes for tungsten to some extent in scheelite. Although their chemical properties are similar, the metals are separated by the lanthanide elements, so that their atomic numbers (42 for Mo and 74 for W) are very different. As a result of the differences in their electronic configurations, the valence electrons of tungsten are better screened than those of molybdenum and the ionization

Table 2. Valence and ionic radii of tungsten and some associated elements (approximately) according to their arrangement in the Periodic Table

	Valance State					
	+1	+2	+3	4	+5	+6
	Li	Be	B			
Ionic radius (nm)	.068	.035	.023			
Co-ordination number	6	4	3			
	Na	Mg	Al	Si		
Ionic radius (nm)	.097	.066	.051	.042		
Co-ordination number	6-8		4-6	4		
	K	Ca	Fe	Ti		
Ionic radius (nm)	.135	.099	.064	.068		
Co-ordination number	10-12			6		
				Zr	Nb	Mo
Ionic radius (nm)				.079	.069	.062
Co-ordination number				6	6	6
				Sn		
Ionic radius (nm)				.071		
Co-ordination number				6		
					Ta	W
Ionic radius (nm)					.068	.062
Co-ordination number					6	6

Some of horizontal groups omitted (double horizontal lines).
Fe does not belong in this position; shown here (as Fe^{+3}) for compactness.
Vertical lines denote boundary between dominantly cationic and dominantly anionic elements.

potentials are lower. The weakening of bonding of the valence electrons from molybdenum to tungsten increases the stability of the higher oxidation states of tungsten and its tendency to form oxygen compounds (Barabanov, 1970). Partly because of its higher electronegativity, covalent bonding of tungsten to sulphur is much weaker, and whereas molybdenum occurs predominantly as the sulphide MoS$_2$, the analagous tungsten sulphide, tungstenite, is rare. Furthermore, the polarizing properties of molybdenum are somewhat stronger than those of tungsten, promoting combination with the strongly polarized S^{-2} anion to form molybdenite (Shcherbina et al., 1971).

Tungsten enters isomorphously into niobium-tantalum minerals (Rankama and Sahama, 1950), probably substituting for pentavalent niobium or tantalum. Up to 0.2 per cent of tungsten is found in cassiterite from greisen deposits (Hosking, 1973), suggesting that tungsten substitutes for tetravalent tin. Some wolframite contains considerable amounts of tin. These and other isomorphous admixtures, as with titanium in rutile and sphene, presumably are examples of coupled substitution involving coparticipation of lower valence ions having similar ionic radii, Fe^{3+} for example. In Li$_2$Zr(WO$_3$)$_3$, the univalent and tetravalent cations are randomly arranged in the divalent cation sites of the wolframite-type lattice (Chang, 1967).

Abundance of Tungsten in Rocks

Information on the tungsten content of rocks is scarce and debatable. This is partly because analyzing for tungsten in low concentration is difficult. The detection limit, about 1 to 2 ppm by the most sensitive methods commonly used (mainly colorimetric), is about the same as its concentration in rocks and the margin of error is probably higher. More sensitive methods of analysis, notably neutron activation, are coming into use but require sophisticated equipment and techniques. Hamaguchi et al. (1962) obtained their data by neutron activation (Table 3).

The data of Table 3 generally indicate a slight increase in tungsten content from basic to acidic igneous rocks, but are not consistent and some of the data suggest otherwise. The implication that basic and even ultramafic rocks may contain as much or more tungsten than granitic rocks must be seriously considered since some occurrences are associated with these rocks.

With reference to granites in Transbaikalia, U.S.S.R., Ivanova (1963) reported that biotite granite from two areas without tungsten mineralization contains the same amount of tungsten (1.2 to 2 ppm) as unaltered granite from areas with mineralization. However, biotite-muscovite granite associated with mineralization contains up to 32 ppm and greisenized muscovite granite up to 250 ppm. Kozlov et al. (1974) reported similar but smaller variations between

Table 3. Geochemical abundance of tungsten in rocks

Igneous	Ultra-mafic	Basalt, Gabbro	Diorite, Andesite	Granite	Shale	Sand-stone	Carbo-nate	Reference
			(ppm)					
	0.77	0.7		1.3 (high Ca) 2.2 (low Ca)	1.8	1.6	0.6	Turekian, 1972
1.4					1.9	1.6	0.6	Horn and Adams, 1966
	0.1	0.1	1.0	1.5	2.0			Vinogradov, 1962 (mostly U.S.S.R.?)
				1.4			0.6	Jeffery, 1959 (Uganda)
			1.2	1.4				Sandell, 1946 (mainly N. America)
	0.2	0.2	1.0	0.7	1.3			Hamaguchi et al., 1962 (mainly Japanese?)
			1.0	2.0				Taylor, 1964
			2.0	2.8 2.0		1.9		Rub et al., 1969

Region	Number of Samples or Areas	Range	Mean	Reference
		(ppm)		
Other Granitic Rocks				
North Caucasus		1.7 - 2.2		
Altai			2.0	Shcherbina et al., 1971
E. Transbaikalia		1.0 - 2.95		
Transbaikalia	5	1.2 - 2.0	1.6	Ivanova, 1963
N. Caucasus (Granodi)				Shcherbina et al., 1971
granodiorite	5	<2.0 - 3.3		
biotite granite	3	<2.0 - 8.5		
two-mica	2	<2.0 - 8.3		
muscovitic	3	1.1 - 6.0		
Sierra Nevada	34	0.065 - 11.3	0.74	USGS, 1976, Prof. Paper 1000
Carrock Fell				Shepherd et al., 1977
granite	6		< 1	
greisenized	4		2	
greisen	1		15	

Region	Number of Samples or Areas	Range	Arith. Mean	Std. Dev.	Geom. Mean	Reference
				(ppm)		
Canadian Granitoid Rocks						
Appalachian	42	1.0 - 16.0	2.71	2.94	1.94	
Superior	54	0.2 - 4.0	1.29	0.69	1.17	Mulligan, 1980
Cordillera	96	1.0 - 25.0	3.3	4.6	1.99	
Yukon – N.W.T.	1516	1.0 - 480.0	2.9		1.16	Garrett, 1971a, b, unpubl. (average of 102 plutons)

Region	Number of Samples or Areas	Range	W (av. ppm)	Reference
Other Basic Rocks				
Uganda				Jeffery, 1959
dolerite	6	0.9 - 14.5	6.5	
amphibolite	5	2.7 - 6.3	4.0	
Sikhote Alin, U.S.S.R.				Levashev et al., 1974
alkaline olivine basalt	110	1.6 - 6.8	3.6	
olivine basalt and tholeiite	104	0.4 - 3.2	1.7	
diabase and spilite	151	0.4 - 10.0	1.6	
andesite-basalt-dacite	140	0.8 - 4.4	2.3	
trachyandesite	21	1.6 - 20.0	3.9	
rhyolite, felsite, etc.	82	0.8 - 4.0	2.5	
Mid-Atlantic Ridge?				Barsukov and Dmitreyev, 1975
lherzolite			2.8	
harzburgite			0.8	
dunite			1.2	
garnet pyroxenite			1.2	
North Caucasus				Shcherbina et al., 1971
andesite-dacite	25		1.0	
diorite and quartz diorite	17		1.6	
India				Dekate (quoted by Shcherbina et al., 1971)
basalt	40		1.0	
diabase	16		2.3	
gabbro-anorthosite	12		1.9	
basic and ultrabasic	78		1.6	
ultrabasic	10		2.6	

palingenetic granite and "plumasitic" rare metal granites with a maximum of 15 ppm in muscovite "apical facies" granite.

My data (1980) in Table 3 on Canadian granitoid rocks are composites from areas in parts of the Appalachian Region (Devonian orogeny), Superior Province (the main Archean province of the Shield) and the Cordilleran Region (mainly Mesozoic orogeny). The regions are discussed in that order in Part 2.

The analyses were made using colorimetric methods in the Geological Survey of Canada geochemical laboratory. Estimated limits of detection varied from 1 to 2 ppm in different batches. Values of less than 2 ppm were recorded as 1 ppm. The values for the Appalachian Region and the Cordillera may be unrealistically high because most were taken in areas where tungsten, tin or beryllium were known to exist. This bias was reduced somewhat by combining results from such areas into a single, average value that counted as a single sample in the data of Table 3. Furthermore, some isolated high values suspected of contamination by nearby mineralization were omitted. It may be more than a coincidence that the values for the regions and provinces are in the same order as the importance of deposits in them. However, the average for the Cordilleran Region, where most of the samples are from the 'main tungsten belt', seems too high when compared with Garrett's data in Table 3 from the east Yukon-Northwest Territories belt (part of the Cordillera), which contains numerous tungsten occurrences including two of the three largest deposits in Canada. His data are also the result of a much more intensive and systematic survey. My data for Superior Province (Canadian Shield) mostly represent a random collection along roads from Abitibi County, Quebec, to eastern Manitoba. The typical rocks sampled are more or less gneissic mesocratic rocks probably of granodiorite composition cut by reddish leucocratic granitoid rocks and pegmatite. However, the data include some samples from areas of tin-bearing massive sulphide deposits and of lithium and beryllium pegmatites, which tend to be a little higher in tungsten than the average for the province.

I have found that granitic rocks associated with most tungsten deposits have only sporadically anomalous tungsten contents, whether they are muscovite-bearing or not. Muscovite-bearing granites in general are not enriched in tungsten, although they commonly are enriched in tin and lithium. Granites near most, but not all, tungsten deposits are enriched in these elements. Beryllium seems to be more consistently anomalous near the large Canadian scheelite skarn deposits. Detailed analyses for particular areas are listed in the descriptions of areas and occurrences in Part 2.

Some of my data and Garrett's data (see Part 2, "Cordilleran Region, east Yukon – Northwest Territories belt") indicate a broad statistical correlation between tungsten abundance in granitic intrusions and associated tungsten deposits. However, the correlation is not apparent everywhere for particular deposits, and other data indicate that the tungsten content of granitic rocks is not a reliable indicator of proximity to deposits. More data and more precise analytical methods may prove otherwise. On the other hand, the data in Table 3 for granitic rocks of the Sierra Nevada (USGS, 1976) were obtained by neutron activation analysis, and the average value (0.74 ppm) is about half that reported for granitic rocks of the world. The conclusion is that the tungsten abundance in rocks is not related to the occurrence of tungsten deposits. It may be significant that the data of Hamaguchi et al. (1962) in Table 3, also by neutron activation analysis, yielded about the same average for granite (0.7 ppm) as the average for the Sierra Nevada.

For alkaline rocks, the few data available suggest that tungsten is about as abundant in syenites as in granitic rocks. Nepheline syenites from the North Caucasus contain about 2 ppm, and similar rocks from India have some higher but erratic contents, according to data cited by Shcherbina et al. (1971). Jeffery (1959) also reported generally higher but very erratic values for nephelinites, phonolites and tinguaites from Uganda. The average tungsten content was 10 ppm, but the 17 determinations were considered too few to be significant. I found that a composite sample of fluorite-bearing syenite from the Rock Candy fluorite mine, British Columbia contained 50 ppm of tungsten. Berylliferous fenitized rocks of a syenite complex at Letitia Lake in Labrador (54°20', 61°57') yielded from 0.028 to 0.098 per cent of tungsten in three composite samples. No other syenite bodies sampled, fluorite-bearing or otherwise, were significantly anomalous in tungsten.

The high tungsten contents reported by Jeffery (ibid., Table 3) for basic rocks were not considered broadly enough based for statistical significance. However, the data of Levashev et al. (1974) and Barsukov and Dmitreyev (1975) also suggest that some intermediate and basic volcanic and ultramafic rocks contain as much tungsten or more than granitic rocks. According to Barsukov and Dmitreyev, "whereas Sn, Cu, Zn, and Hg are higher in harzburgite than in dunite, the opposite is the case for W, Mo, Pb, and Ag". The source of their data, described as "amount of ore elements in rocks of the earth's mantle", is not clear. The context is a discussion of rocks in the Iceland sector of the Mid-Atlantic Ridge, where certain ash layers are said to contain up to 6 ppm of tungsten, 20 ppm of tin, 12 ppm of molybdenum and 100 ppm of copper, but it also refers to island arcs.

The implications of these data must be seriously considered in view of the association of some occurrences with basic and ultramafic rocks (see "General Geology---Host rocks and tectonic environment"). On the other hand, Helsen (1975), using neutron activation analysis, reported tungsten contents from less than 0.01 ppm to more than 2.5 ppm in over 100 rocks, mostly basalts and andesites. The rocks were from oceanic islands and floor, island arcs and continental areas. The values found for island arc basalts and andesites are well below suggested world values.

Data on the abundance of tungsten in sedimentary rocks are even scarcer than for igneous rocks. The average values (Table 3) are 2 ppm or less, about the same as for granitic rocks. Jeffery (1959) found considerably higher, though erratic, contents in Ugandan shale, phyllite and schist. The average of 60 samples, excluding those from mineralized areas, was 3.9 ppm. Much higher values were found in graphitic phyllites, which are hosts to the tungsten deposits (ibid.; Reedman, 1973). Jeffery's data for carbonate rocks include carbonatites as well as sedimentary limestones, of which the eight samples all contained less than 1 ppm and averaged 0.5 ppm.

The very few data for Canadian sedimentary rocks are from widely separated sources. Six samples of greywacke and schist from the Precambrian Yellowknife Supergroup were found to contain 1 ppm or less of tungsten, although they are strongly anomalous in tin and slightly so in molybdenum. Potter (1969) reported an average 4 ppm in the pelitic rocks around the Burnt Hill mine in New Brunswick. McDougall (1977, personal communication) found less than the detection limit (about 1 or 2 ppm by the method used) in most of the sedimentary rocks in the general area of the Canada Tungsten mine, in the Northwest Territories). Iron formations of the Canadian Shield have been analyzed by neutron activation methods (Harmon et al., 1975). Of 51 samples of oxide, carbonate and sulphide facies, most values range from 0.1 to 1.0 ppm, with some in the 1 to 14 ppm range and one value of 51 ppm.

Deep-water sediments from various parts of the northwest Pacific Ocean have been reported to average 1.6 to 3.6 ppm of tungsten (Levashev et al., 1974). Those from the Sea of Japan contain 3.2 to 4.6 ppm and from the Amur Gulf 2.7 to 5.3 ppm. Levashev et al. stated that tungsten is particularly abundant in the sediments of that part of the Pacific. Sediments accumulating in the Sea of Okhotsk contain 15 to 30 ppm (Hosking, 1973). Sediments of the Black Sea also are reported to be strongly anomalous in tungsten. The brines of Searles Lake, California, an alkali evaporate deposit, contain 85 ppm and alkali lakes in arid regions of the U.S.S.R. are strongly enriched in tungsten (ibid.).

Coal may contain much more tungsten than inorganic sediments. According to data quoted by Eskenazy (1977), the mean content is about 10 ppm. Russian coals average 20 ppm with a maximum of 129 ppm, and Bulgarian coals contain up to 200 ppm. Eskenazy suggested that tungsten is bound in coal because hydroxy-cationic forms of tungsten are present in solutions capable of forming organometallic complexes. Admakin (1974) reported 1.2 to 51.1 ppm of tungsten in different types of coal from Transbaikalia, U.S.S.R. The highest contents were in collinite and postcollinite types, formed from plant remains in oxygenated deltaic environments. The formation of organic compounds from dissolved tungsten has also been suggested as the means of concentration in tungsten-rich black shale (Hosking, 1973). Apparently tungsten is not generally concentrated in plants but up to 300 ppm of tungsten was found in leaf ash of **Erectites hieracifolia** in northern Thailand. Hosking noted also that the ash of the brown alga **Fucus ceranoides** growing in some creeks in Cornwall that drain areas of tungsten mineralization contained 8 ppm of tungsten, whereas in creeks that drained barren areas the ash contained 4 ppm or less.

Tungsten in Rock-forming Minerals and Accessories

The main concentrators of tungsten in igneous rocks appear to be the micas and accessory minerals, although the bulk of the tungsten is evidently dispersed among the major minerals. Biotite is reported to contain up to 18 ppm but is more commonly in the 5 to 10 ppm range, and lower values have been reported (Shcherbina et al., 1971). Muscovite may contain 30 to 36 ppm or more, and is the main carrier of tungsten in the two-mica granite (Kozlov et al., 1974). Il'in and Ivanova (1972) reported the tungsten content of two-mica granite, muscovite granite and greisen to be in a narrow range averaging 46 ppm, and found microinclusions of tungsten minerals in muscovite containing 100 ppm or more.

Titanium and iron minerals may contain appreciable amounts of tungsten. Contents of 7.4 - 78 ppm of tungsten in sphene, up to 24 ppm in ilmenite, and 21.9 ppm in magnetite have been recorded (Shcherbina et al., 1971; Jeffery, 1959), and contents of up to 2000 ppm in rutile have been reported by Jeffery. Apatite from tungsten-bearing complexes of eastern U.S.S.R. contains about 300 ppm, and apatite from "postmagmatic formations" (presumably skarns), up to 800 ppm (Rub et al., 1969). Niobium-tantalum minerals (presumably from pegmatites) have been found to contain up to 10 000 ppm of tungsten. Rutile may contain up to 2000 ppm. Manganese minerals, mainly pyrolusite, from certain strata in Uganda contain up to 12 ppm of tungsten, and pyrolusite from tungsten mines there contains 6000 to 8000 ppm (Jeffery, 1959). Hot spring deposits of manganese and iron minerals at Golconda, Nevada have been mined for tungsten. Deposits in Bolivia and elsewhere are known to be similar.

As accessory minerals form only a small part of ordinary igneous rocks, it is evident that tungsten is dispersed mainly in the major rock minerals, chiefly in plagioclase. Probably most of the tungsten in granitic rocks occurs as minute inclusions of tungsten minerals (Rub et al., 1969).

MINERALOGY OF TUNGSTEN MINERALS

Of the tungsten minerals, only the wolframite group and scheelite are of major economic importance. The following concise systematic summary of tungsten minerals is taken from Kerr (1946).

- Tungstates
  - Wolframite group (monoclinic)
    - Ferberite, $FeWO_4$
    - Wolframite $(Fe,Mn)WO_4$
    - Huebnerite, $MnWO_4$
  - Raspite, $PbWO_4$ (monoclinic)
  - Scheelite-powellite group (tetragonal)
    - Scheelite, $CaWO_4$
    - Seyrigite, $Ca(Mo,W)O_4$
    - Powellite, $CaMoO_4$
    - Wulfenite, $PbMoO_4$
    - Chillagite, $3PbWO_4 \cdot PbMoO_4$
    - Stolzite, $PbWO_4$

- Sulphides
  - Tungstenite WS_2 (monoclinic)

- Oxides
  - Russellite, $Bi_2O_3 \cdot WO_3$ (tetragonal)

- Hydrous compounds
  - Tungstite, $WO_3 \cdot H_2O$ (or H_2WO_4) (orthorhombic)
  - Hydrotungstite, $WO_3 \cdot 2H_2O$ (or $H_2WO_4 \cdot H_2O$) (monoclinic?)
  - Thorotungstite, $2WO_3 \cdot H_2O + (ThO_2, Ce_2O_3, ZrO_2) \cdot H_2O$ (orthorhombic)
  - Cuprotungstite, $WO_3 \cdot 2CuO \cdot H_2O$

- Iron and manganese minerals which may carry tungsten
  - Limonite $(Fe_2O_3)nWO_3(H_2O)n$
  - Ferritungstite, $Fe_2O_3 + WO_3 + SO_2$ (hexagonal)
  - Tungomelane (var. of psilomelane or cryptomelane) $Mn_2O_3 + BaO + WO_3 + H_2O$
  - Hollandite, $BaO + MnO_4 + WO_3 + H_2O$ (orthorhombic)

- Minerals with minor tungsten content
  - Yttrotantalite, hjelmite, samarskite, microlite, hatchettolite, columbite, tantalite, schetelgite, sipylite, germanite, yttrocrasite

- DOUBTFUL SPECIES
  - Alkinite, pseudomorph of wolframite after scheelite
  - Calcioscheelite, synonym of scheelite
  - Cuproscheelite, analogous to scheelite
  - Magnesioscheelite, hypothetical
  - Meymacite, impure tungstite
  - Reinite, pseudomorph after scheelite
  - Tammite, possibly an artificial alloy
  - Trimontite, a mineral proved to be scheelite

The wolframite group of minerals forms a complete solid solution series whose chemical and, in part, physical properties vary according to the proportions of the end members, ferberite and huebnerite. Members containing more than 80 per cent of the ferberite molecule are classed as ferberite; those with 80 to 20 per cent as wolframite, and those with less than 20 per cent as huebnerite. These minerals are brown to black in colour and in streak, ferberite generally being darker than huebnerite. They are commonly nearly opaque in thin section.

The minerals have a submetallic to resinous or adamantine lustre and generally occur as tabular crystals or masses, locally in radiating groups. They have perfect cleavage in one direction but an uneven fracture, and are rather brittle. The hardness is 4 to 4½ or up to 5 in ferberite. Specific gravity varies from 7.1 in huebnerite to 7.5 in ferberite. The more iron-rich members are appreciably magnetic.

The iron-rich members are more abundant than the manganese-rich ones, and the term 'ferberite' is frequently used in descriptions, but in general all members of the group are described indiscriminately as wolframite. They are so described, with a few exceptions, in this report.

Scheelite forms a partial solid solution with its molybdenum analogue powellite. Up to 20 per cent but rarely more than 2 or 3 per cent of MoO_3 may replace WO_3. Powellite in turn accepts up to 10 per cent of WO_3. The molybdenum-bearing varieties are described as molybdoscheelite or molybdian scheelite. They are yellowish – fluorescent in ultraviolet light, whereas pure scheelite has a bluish white fluorescence. Concentrates containing more than about 0.4 per cent of MoO_3 must be purified to avoid penalties on the market.

Scheelite may be colourless to white and may be difficult to distinguish from similar minerals, such as quartz, but it is commonly yellowish or buff or more rarely green, grey or nearly black. It is translucent in thin section and generally easy to recognize by its strong relief and moderate birefringence. The streak is nearly white. Cleavage is good in four directions. Hardness is 4½ to 5, the fracture uneven to conchoidal. The mineral is quite brittle and its friability is a major milling problem. Specific gravity is 6.1, decreasing to 5.5 in varieties high in molybdenum.

The following descriptions of minor and rare tungsten minerals are from Little (1959).

Minor minerals:

Powellite: Calcium molybdate, $CaMoO_4$, in which atomic substitution of W for Mo, up to 10 per cent occurs. Tetragonal. Lustre, greasy on fracture surfaces, subadamantine on crystal faces. Colour, straw yellow, brown, greenish yellow, pale greenish blue; also dirty white to grey, blue, and nearly black. Hardness, 3½ to 4. Cleavage, indistinct in one direction. Fracture, uneven. Specific gravity 4.2.

Stolzite: Lead tungstate, $PbWO_4$. Tetragonal. Lustre, resinous. Colour, reddish brown, brown, fawn, yellowish grey, straw yellow; also green, yellow-red, red. Streak, uncoloured. Hardness, 2½ to 3. Specific gravity 7.9 to 8.3.

Raspite: Lead tungstate, $PbWO_4$. Monoclinic. Lustre, adamantine. Colour, yellowish brown, light yellow, grey. Hardness, 2½ to 3. Cleavage, perfect in one direction. Specific gravity 8.5.

Cuprotungstite: Basic copper tungstate, $Cu_2(WO_4)(OH)_2$. Microcrystalline. Lustre, vitreous, waxy, or earthy. Colour, pistachio-green to olive-green and emerald green. Streak, greenish grey to greenish yellow.

Tungstite: Hydrous tungstite oxide, WO_3H_2O (?). Possibly orthorhombic. Lustre, resinous; on the cleavage faces, pearly. Colour, bright yellow, golden yellow, or yellowish green. It is an alteration product of wolframite, hübnerite, ferberite, and scheelite.

Meymacite: Variety of tungstite pseudomorphic after scheelite.

Ferritungstite: Hydrous, basic iron tungstate, probably $Fe_2(WO_4)(OH)_4 \cdot 4H_2O$. Forms earthy coatings composed of hexagonal plates. Colour, pale yellow to brownish yellow.

Rare and doubtful minerals:

Chillagite: Lead tungsto-molybdate, $Pb(Mo,W)O_4$, in which the ratio of Mo:W is 5:3 to 1:1. Tetragonal. Colour, straw yellow to ochre yellow. Known only at Chillagoe, Queensland, Australia.

Reinite: Formerly classed as a tetragonal modification of ferberite. Now known to be ferberite pseudomorphic after scheelite.

Sanmartite: Zinc, iron, calcium tungstate $(Zn,Fe,Ca)WO_4$. Monoclinic. Lustre, resinous. Colour, dark brown to brownish black. Cleavage, perfect in one direction. Specific gravity 6.7. Known only at San Martin, Argentina, where it is an alteration product of scheelite.

Cuproscheelite: Formerly classed as calcium, copper tungstate $(Ca,Cu)WO_4$, but since shown to be a mixture of a basic copper tungstate (cuprotungstite) and scheelite.

Russellite: Bismuth, tungsten oxide $(Bi_2,W)O_3$. Tetragonal. Colour, pale yellow to greenish. Hardness, 3½. Specific gravity 7.35. Known only at Castle-an-Dinas mine, Cornwall.

Thorotungstite: Basic tungstate or oxide with (Al,Fe):(Th,Ca,Ce,Zr):W - 1:1:3. Formula uncertain. Colour, yellow. Specific gravity 5.55. Alteration product of wolframite or scheelite. Known only in the Kintla district, Malay States [Malaysia].

Anthoinite: Hydrous, basic aluminum tungstate, $Al(WO_4)(OH)H_2O$. Isotropic (?). White, chalky masses resembling kaolin. Hardness, 1. Specific gravity about 4.6. Known only in the Belgian Congo [Zaire], at two localities.

Tungstenite: Tungsten sulphide, WS_2 (?). Hexagonal. Colour, dark lead-grey; soils the fingers. Known only at Emma mine, Salt Lake county, Utah.

Tungstenian Limonite: $(Fe_2O_3)n \; WO_3(H_2O)n$. According to Kerr (1946, pp. 76, 77), at Golconda, Nevada, limonite containing tungsten that is either adsorbed or is present as finely divided tungstic acid has been found in considerable quantity.

Hydrotungstite: $(H_2WO_4)H_2O$. Monoclinic (?). Name suggested by Kerr (1946, p. 75) for this mineral, which occurs as a greenish alteration of ferberite. Hardness, 2. Specific gravity 4.6. Known only at Calacalani, Bolivia.

Tungomelane: Name proposed by Kerr (1946, p. 78) for a tungstenian psilomelane (MnO_2) that occurs at Golconda, Nevada, and in other parts of the world. It is reported to contain up to 7 per cent WO_3.

Hollandite: According to Kerr (1946, p. 79) a small amount of tungsten was detected by Vaux in hollandite (probably $MnBaMn_6O_{14}$), but it is not known if the presence of tungsten in this mineral is widespread.

Mineral Identification and Analysis for Tungsten

Scheelite ordinarily is recognized by its characteristic fluorescence in short-wave ultraviolet radiation. The fluorescent colour is from brilliant white to bluish if pure and from yellowish white to yellow if molybdenum-bearing.

Powellite, the molybdenum-dominant analogue, is canary-yellow. Wavelengths of about 253.6 nm, as emitted from fused quartz mercury vapour lamps, are most effective. The fluorescence may be masked by coatings, including iron oxides, on weathered surfaces. Several other minerals, notably hydrozincite, fluoresce in white to bluish colours, as does mineral oil, and where any doubt exists, a chemical test such as described in standard texts should be made.

A simple and effective zinc/HCl streak test for scheelite is described by Hosking (1973) as follows:

> This test may be used to confirm the presence of tungsten in any species in which it is an essential component except members of the wolframite series. To carry out the test a heavy streak of the mineral is made on a small piece of unglazed tile. A small pile of zinc dust is placed on the streak and several drops of concentrated HCl are added to this by means of a teat pipette and in such a way as to ensure vigorous reaction between the acid and the powder. The powder is then washed off by a jet of water and the presence of tungsten is indicated by the treated streak appearing blue.
>
> A field alternative consists of adding a drop or so of the acid to the surface of the mineral under test and then rubbing the damped surface repeatedly with a zinc nail. A resulting blue solution indicates the presence of tungsten.

In my own experience, scratching the surface, wetted by HCl, with an ordinary steel knife blade or needle is usually sufficient to obtain the blue colour.

Identification of wolframite is more difficult. The acid treatment procedures described in standard texts do not work very well, as wolframite is scarcely affected by strong HCl or H_2SO_4. Even with aqua regia, reaction is very slow, but the yellow coating of tungstic acid develops overnight. Alkali fusion methods are preferable. If a crucible is used it should be of nickel or iron, not ceramic. The powdered mineral is added to a relatively large volume of molten NaOH (or sodium carbonate or bicarbonate) in the crucible and fused at low red heat for 10 to 15 minutes. The fusion is dissolved in water, and the solution acidified with dilute HCl, yielding a copious yellow precipitate of tungstic acid. The bulk of the dark solution is poured off the settled precipitate and the balance diluted with a little water. Then granulated zinc is added, and the characteristic blue should develop at the interface between zinc and precipitate (this may be only local and temporary).

Another fusion procedure, an ammonium hypophosphite test, is described by Hosking (ibid.) as follows:

> This test may be used as an aid to the identification of any tungsten mineral. Briefly, a little of the powdered substance to be tested is mixed with 3 or 4 volumes of ammonium hypophosphite in a silica crucible. The mixture is heated until a melt is obtained and there is a copious evolution of phosphides of hydrogen (which may ignite and which stink). A few drops of water are then added to the hot turbulent melt and if a product rather like blue ink is obtained tungsten is probably present. The reaction can be carried out in a silica crucible using a candle flame as a source of heat; alternatively a comparatively small quantity of the mixture may be placed in an open tube near one end and heated with the flame of a cigarette lighter or even a match. A few drops of water are finally added to the melt by means of a teat pipette and the product is allowed to run down the tube thus permitting its colour to be readily assessed.

Analytical methods for tungsten in low concentrations are generally unsatisfactory. Ordinary spectrographic procedures are unable to detect tungsten in the concentration ranges found in unmineralized rocks. The limit of detection of the quantitative method currently used in Geological Survey of Canada laboratories is 0.05 per cent (500 ppm). Limits as low as 15 ppm detected by emission spectrography have been reported, but this is far above normal rock contents. X-ray fluorescence methods are practical only down to 50 to 100 ppm (G. Lachance, personal communication).

For tungsten in low concentration the most sensitive methods in common use are colorimetric. The method used by the Geological Survey geochemical laboratory, as in the rock analyses reported herein, is by zinc dithiol after an alkaline fusion. The detection limit is given as 1 or 2 ppm but the margin of error is probably at least an order of magnitude.

Neutron activation methods of analyzing tungsten accurately at very low concentration have been developed in recent years. The data of Hamaguchi et al. (1962) and those of the U.S. Geological Survey (1976) on the Sierra Nevada granite (Table 3) are by these methods. The data of Harmon et al. (1975) for iron formation, quoted in the text, are by neutron activation. The methods are tedious and expensive and require sophisticated techniques and equipment. A procedure said to detect 0.005 ppm of tungsten in a 100 mg sample has been described by Simon and Rollinson (1975). A "Spark Source" technique giving a detection limit of 1 ppm within 5 per cent precision was mentioned by Dick (1977, App. III).

GENERAL GEOLOGY

World Distribution of Tungsten Deposits

Most of the major tungsten deposits of the world are in the "circum-Pacific" belt, which can be broadly considered to include New Zealand, eastern Australia, Indonesia, Malaysia-Thailand, Burma, China, Japan, eastern U.S.S.R., Alaska, the Cordillera of Canada and U.S.A., Mexico, Peru, Bolivia, and part of Argentina.

Important deposits exist also in various parts of Europe, especially the Iberian Peninsula, France, southwest Great Britain, Austria, Sweden, and the Erzgebirge district of Germany and Czechoslovakia. Among important areas of the U.S.S.R. apart from the Pacific regions are Transbaikalia, and the Altai and Kazakhstan areas.

In Africa, the most important recent producers have been Rwanda, Zaire, Zimbabwe and Uganda, but there are significant deposits in South Africa, Namibia, Nigeria and elsewhere.

In the Appalachian belt of North America, tungsten was produced in North Carolina, and small amounts in the Appalachian Region of Canada. In eastern South America, Brazilian deposits include at least one important producing area.

These descriptions give only a very general idea of tungsten distribution, which is remarkably widespread considering its low crustal abundance. Good descriptions, but dated, are contained in Li and Wang (1943) and Little (1959).

Host Rocks and Tectonic Environment

From the scanty information available, most of the major tungsten-bearing areas of the world, as in the Canadian Cordillera, appear to be in thick miogeosynclinal or shelf assemblages of predominantly sedimentary rocks in major orogenic zones near the margins of continents. In this they resemble the major tin belts of the world. Most of these are also important tungsten producers, though not everywhere from the same parts of the belts.

In the Malay Peninsula most tungsten and tin deposits are in a miogeosynclinal zone that occupies the western half of the peninsula and may extend northward through Thailand and east Burma into the Chinese province of Yunnan, and southward into Indonesia (Burton, 1972). In Peru, tungsten deposits are associated with the Cordillera Blanca Batholith, which lies in an interior miogeosynclinal belt, whereas gold, iron, copper and zinc are associated with the Coastal Batholith (Pitcher, 1974; Cobbing, 1974). The generalization seems to apply also to Bolivia (Ahlfeld, 1967), Australia (Solomon et al., 1972) and various parts of eastern U.S.S.R., mainly in the interior.

The tungsten belts are characterized by abundant, predominantly granitic intrusions, to which the deposits are generally closely related. These granitic intrusions are thought to have originated mainly by melting or granitization of the sedimentary 'continental crust' at depths where the temperatures were sufficiently high. In plate tectonic theory, these conditions are thought to have existed in deeply buried segments above subduction zones.

The tungsten of the deposits is commonly thought to have been derived primarily from the metamorphosed or granitized sediments, and either incorporated in or excluded from the resulting palingenetic granite (see "Relationship to granite" below). In view of the low abundance of tungsten in ordinary sedimentary rocks and the scarcity of deposits in batholithic belts, the source rocks of the deposits must have been exceptionally rich in tungsten. This could have resulted from mechanical (placer) concentration from older deposits. Some major tungsten belts are notably close to old cratons that contain tungsten concentrations. The East Yukon – Northwest Territories belt in the Canadian Cordillera is the closest part of the Cordillera to the Yellowknife-Beaulieu district of Slave Province. The Bolivian tin-tungsten belt is close to the Brazilian craton, where tin and tungsten deposits are widely distributed. Tweto (1960) suggested that the large, young tungsten deposits of Colorado Mineral Belt were derived from concentrations in the Precambrian gneisses of the belt.

Other special conditions, such as the existence of stagnant basins rich in organic carbon, might have resulted in unusual concentrations. In Uganda graphite schists consistently high in tungsten and containing nodules of ferberite are hosts to small tungsten deposits (see "Transportation and deposition" below). In central Sweden, bituminous alum shales presumably deposited in shallow marine basins have exceptionally high tungsten contents (Hubner, 1972). The graphitic, pyrite-rich pelitic rocks interbedded with the skarn zones at AMAX Northern on the Yukon – Northwest Territories border may be an analagous case, though their tungsten content is not known. In all such cases the sedimentary rocks acted as agents for deposition of tungsten. The outstanding examples of this function are the carbonate rocks that are hosts to the important class of scheelite skarn deposits.

It is widely held that the general increase in size and number of deposits in younger orogenic belts reflects an increase in concentration by recycling of older concentrations.

Although the miogeosynclinal environment appears to be the most favourable for tungsten deposits, many are found in eugeosynclinal facies of orogenic belts. These are dominated by basic volcanic rocks and thought to be underlain, at least in part, by oceanic crust. In this environment some tungsten deposits are associated with basic rocks as well as granitic rocks, and are commonly emplaced in a thick sequence of mafic volcanic rocks. This raises the possibility of a volcanogenic origin of the deposits, analogous to that assumed for some stratabound base metal deposits. The stratabound tungsten deposits in Austria and elsewhere in Europe are believed to be genetically related to the volcanic rocks interbedded with the sediments (Maucher, 1972; Höll and Maucher, 1976). The granites of eugeosynclinal belts may themselves be, at least in part, products of differentiation of mantle material. Furthermore, the tungsten content of some mafic rocks appears to be as high as, or higher than, that of normal granite.

According to the data of Levashev et al. (1974), some mantle-derived basic rocks contain as much tungsten as palingenetic granite, or more. Their interpretation is complex, involving different stages in the generation of different rock types. However, their final statement is: "The exceptionally high tungsten content of alkaline basalt and andesite shows that the mantle and melts generated in it are the primary source for the subsequent geochemical cycle of the element". Barsukov and Dmitreyev (1975) likewise emphasized the role of differentiation products of mantle material in concentrating metals, including tungsten. Shatkov (1975) discussed the relatively high fluorine content of some basalts and andesites, especially alkaline ones. He suggested that it reflects the local intensity of gas liberation from the upper mantle in zones of deep structural dislocation, and that fluorine may have been instrumental in the transference of lithophile elements like tungsten from the mantle. Discussions of these possibilities generally refer to tin rather than tungsten, but as tungsten occurrences are more common than tin occurrences in the eugeosynclinal environment, the possibilities should apply to tungsten as well.

Tungsten appears to be associated with ultramafic rocks in a few places but the relationship is vague. In North Carolina, soapstone bodies contain scheelite disseminated and in stringers, but they are thought to be of metamorphic origin (Bentzen and Wiener, 1973). Scheelite occurs in serpentinized dolomite skarn at Ristaus Mine, Pitkaaranta, Finland (Eskola, 1952). Some tungsten-bearing gold deposits are more or less closely associated with ultramafic rocks in the Canadian Shield and in the Cordillera. In the Cordilleran areas they also are closely associated with felsitic porphyries, apparently rhyolitic but much sheared and altered, and unlike any of the normal intrusions of the areas. This invites speculation that these peculiar porphyries are related to the ultramafic rocks as cognate products of differentiation of parent (mantle?) material. Possibly the porphyries to which scheelite is related in the Porcupine Camp in the Shield are also similarly related to ultramafic rocks. In any case, it is axiomatic that all tungsten was derived in the first instance from igneous primary crustal material.

Metallogenic Epochs

Most tungsten deposits fall into one of several distinct age groups, which can be described as metallogenic epochs and correspond to major orogenic disturbances. The most important of these corresponds to a protracted but mainly late Mesozoic orogeny that chiefly affected the circum-Pacific tungsten belt, including the Canadian Cordillera.

The Hercynian (Variscan) orogeny, of late Paleozoic age, is represented mainly by the important European deposits of Portugal, western Spain, France, southwest England and the Erzgebirge area of Czechoslovakia and Germany. In various areas of tungsten deposits, notably eastern and southeastern Europe and Transbaikalia, older tungsten concentrations have been reconcentrated during the Variscan and, in places, Alpine orogenies.

The Caledonian (Devonian) orogeny is represented by deposits in some parts of the circum-Pacific belt, including the southernmost part of eastern Australia, some of the U.S.S.R. tungsten areas, and the northernmost Yukon occurrences of the Canadian Cordillera. In Europe tungsten deposits occur in the Caledonian belt of Scandinavia and Great Britain. Some deposits in Bulgaria and Yugoslavia are

Table 4. Types of tungsten deposits

Type	Typical Host Rock	Tungsten Minerals	Associated Gangue Mineral	Associated Metals or Minerals	Canadian Examples	Foreign Examples	References
Magmatic dissemination in granite		wolframite, scheelite			Ross Lake, N.W.T.(?)	Oreana, Nevada(?) Burma(?)	Kerr, 1946 Li and Wang, 1943 Fortier, 1947
Pegmatite		wolframite, scheelite?	feldspar, quartz, muscovite, fluorite	Li, Be, Ta, Mo, Sn	Dublin Gulch (114e)* Scheelite Dome (114f)	Namibia Zaire China Adoria, Portugal Oreana, Nevada	Haughton et al., 1939 Frommurze et al., 1942 Varlamoff, 1972 Li and Wang, 1943 Cotelo Neiva, 1972 Kerr, 1946
Greisen, quartz greisen vein	Granite, argillite, etc.	wolframite (scheelite)	muscovite, topaz, fluorite, tourmaline?	arsenopyrite, Mo, Bi, Sn, Be, Li, Cu, Zn	Mt. Pleasant (17a) Fox Group (142) Black Diamond (101c)	China, Burma, Europe, U.S.S.R., Australia, and numerous others	
Porphyry	Granite, etc.	wolframite (scheelite)	fluorite, topaz (at Climax)	Mo, Cu	Glacier Gulch (85) B.C. Moly (89c) Adera (101c)(?)	Climax, Colorado	Wallace et al., 1968
Skarn (contact metamorphic)	Calcareous limestone	scheelite	diopside-hedenbergite, garnet, epidote, vesuvianite, tremolite-actinolite, plagioclase, biotite, quartz	pyrrhotite, Cu, Mo, Cu, Bi (Zn)	Canada Tungsten (107g) Emerald, etc. (46b) MacTung (111a)	Pine Creek, California Sangdong, Korea Brejui, Brazil	Gray, 1968 Klepper, 1947 Johnston and de Vasconcellos, 1945 Ferreira and Albuquerque, 1969
Feldspathic (pegmatitic) quartz vein		scheelite wolframite	orthoclase, albite, micas	Mo, Cu, etc., Be, F rare	Red Rose (86b) East Malartic (25d) Canada Tungst (?)(107g)		
Quartz vein		scheelite	quartz, carbonates	pyrite, arsenopyrite, Au	Moose River (9) Porcupine (30) Cariboo (76d,e)	Southern Africa (widespread)	Foster, 1977
Quartz-carbonate vein	ultramafic, mafic, etc.	scheelite	carbonate, quartz, chrome-mica	Sb, Hg (rare), Te (rare), Au?	Bridge River (73a,b)	Colorado (Te)	Tweto, 1968
Stratabound	sediment and volcanic	scheelite (wolframite)		Sb, Hg (Austria)		Kleinartal, Felbertal, Austria Bindal, Norway Uganda-Burundi Colorado(?)	Holl and Maucher, 1972 Skaarup, 1974 Reedman, 1973 Tweto, 1960
Hot springs, brines,	Mn-Fe tufa deposits	Mn, Fe complex?				Golconda, Nevada Uncia, Bolivia	White, 1955
Placer		wolframite, scheelite		Au (Canada)	Canadian Creek (123) Boulder Cr. (101) Dublin Gulch and Haggart Cr. (114e)	China Nigeria Zaire, Burma, and others	Li and Wang, 1943 Hosking, 1973

*Locality numbers from Map 1556A and Appendix.

said to be associated with Caledonian granitic rocks. The deposits of the Canadian Appalachian Region (and parts of the U.S. Appalachian belt) belong to this age group, although the Mount Pleasant deposit in New Brunswick is apparently slightly younger.

Precambrian deposits occur in all the major Shield areas of the world, including Canada, South America, Africa, Fennoscandia, India and western Australia. The Precambrian deposits of Africa and Brazil are of various ages and they perhaps range into the Paleozoic and later. The deposits in parts of Brazil and Nigeria are widely believed to belong to a single epoch-province prior to continental separation. Those of the Canadian Shield are mainly related to the Kenoran Orogeny, dated at about 2500 Ma, and very few are known in the younger Precambrian provinces.

Relationship to Structure

Within the major tungsten-tin belts of the world, many deposits are disposed along linear or arcuate features that controlled the emplacement of major granitoid intrusions. These are known in some places, and assumed in others, to mark deep fault zones of regional extent. Tweto (1960) speculated that the Tertiary granitic stocks with which tungsten deposits are associated in the Colorado Mineral Belt were intruded along a deep-seated fault. However, in the western United States as a whole, tungsten deposits are concentrated in three broad subparallel linear belts that transcend the regional geological pattern. In Kerr's view (1946), "Regional structural correlation of tungsten deposits must assume a control that passes beneath even the most deep-seated structures that may be identified by surface mapping... the features responsible for the broad control of tungsten deposits appear to correspond to those features responsible for emplacement of the igneous intrusions."

According to plate tectonic theory, such belts of igneous intrusions are now melting above subduction zones. However, the existence of multiple belts that are characteristically of different ages seems to call for a shifting locus of subduction, with attendant development of island arcs, geosynclines and orogenic evolution. In the Tasman metallogenic province of eastern Australia, according to Solomon et al. (1972), potassic granites are concentrated near the foreland areas of successive Paleozoic continental margins.

Anticlinal structures are cited as controlling factors in the emplacement of tungsten deposits or of related granitic plutons in many tungsten-bearing regions. In southern Jiangxi, China, five subparallel anticlinoria mark the loci of granitic intrusions to which the tungsten deposits are related (Li and Wang, 1943). In Bolivia folding was followed by eruptions of acid magmas with associated tin and tungsten deposits along north-south fractures and in anticlines of Paleozoic sediments (Ahlfeld, 1936). In Lemhi Range, Idaho, tungsten deposits are in veins in fractures that follow and are typical of an anticlinal crest (Kerr, 1946). Kerr also referred to scheelite-fluorite deposits along anticlinal axes by replacement of limestone under schist at Kramat Pulai in Malaysia. In the southeast part of the Canadian Cordillera, an anticlinorium determines the outcrop pattern of the Proterozoic and early Paleozoic rocks that are the hosts of tungsten deposits.

Some deposits are thought to have been emplaced during and as a result of folding. These include the 'saddle-reef' veins of Moose River, Nova Scotia, and perhaps some of the veins in the Yellowknife-Beaulieu district and in the Cariboo district of the Cordillera. At the Brejui mine in Rio Grande do Norte, Brazil (Table 4), scheelite-bearing tactites occur principally as lenses in the crests and troughs of folds, where the enclosing schists are thicker than on the limbs (George Bedoya, personal communication).

Tungsten deposits are concentrated along the flanks of major batholithic belts in many places. In the western part of the Canadian Cordillera most deposits are scattered along the east flank of the Coast Plutonic Complex. In New Brunswick scattered occurrences of tungsten, tin and beryllium are associated with late-phase muscovitic granite bodies located along the inward-facing flanks of the major granitic belts. These presumably mark zones of crustal weakness that determined the boundaries of the major batholithic belts. The west contact of the Cassiar Batholith in northern British Columbia is marked by a fault zone that has been traced for 150 km.

Some occurrences in the East Kootenay district of southern British Columbia apparently are related to northeasterly trending transverse faults dating from Proterozoic time and may reflect the northeasterly grain of Precambrian basement rocks. Similarly, northeast-striking faults cut the oldest exposed Precambrian strata in the Mackenzie Mountains in the northern part of the East Tungsten Zone but no tungsten bodies are known to be associated with them. On a more local scale many deposits, such as Canada Tungsten and Red Rose, appear to be related to pre-mineral faults. The Emerald and adjoining deposits may be related to a major overthrust fault.

The outstanding structural feature of the major Canadian skarn deposits is their location on major 'bulge' structures, where the direction of fold axes changes markedly along strike. In the southern Cordillera the Emerald group of deposits is at the point of maximum curvature of the Kootenay Arc. In the northern part of the Cordillera, Canada Tungsten and MacTung are similarly situated with reference to the major arc structure of the Mackenzie Mountains. An analogous case is the Bolivian tin-tungsten belt, where the trend of fold axes is deflected around the westward bulge of the Brazilian Precambrian Shield (Ahlfeld, 1967).

Classification of Tungsten Deposits

The classification of tungsten deposits is a difficult problem involving arbitrary decisions, some of which may be controversial. The great majority of deposits belong to one of three main groups: skarn, quartz greisen, and vein deposits, but pegmatites traditionally have been considered important. Even disseminations in granite have been listed as a class, although their independent existence is doubtful. Several additional classes have been set up in Table 4 to illustrate special modes of origin or associations, including distinctions among varieties of vein deposits. The following explanatory notes are intended to clarify and supplement the information given in the table. The order of listing is in the general order of distance from associated intrusions.

Magmatic Disseminations in Granite

Although few, if any, examples of tungsten minerals disseminated in granite are of indisputably primary origin, the possibility of such segregations cannot be ruled out. The distribution of tungsten among the minerals of granitoid rocks (see "Geochemistry---Abundance in rocks") shows that the bulk of tungsten is contained in feldspars, chiefly plagioclase, and suggests that it is in the form of microinclusions of tungsten minerals.

At the Oreana mine, Nevada, abundant aplite is associated with the pegmatitic tungsten deposits. It commonly contains sparsely disseminated scheelite, even where it extends into granodiorite, although the granodiorite does not contain any (Kerr, 1946). Kerr appears to consider the disseminated scheelite as primary, since the aplites grade into ore-bearing pegmatites.

According to information quoted by Li and Wang (1943) with reference to the Machwi area of Burma, "although disseminated cassiterite is widespread throughout these granites, wolframite has not been detected... it does occur in certain segregations consisting of tourmaline and kaolinized feldspars together with cassiterite."

Wolframite and scheelite are widely disseminated in discontinuous quartz veinlets and segregations in many granitoid intrusions. Although these concentrations evidently reflect minor postmagmatic redistribution, in many places there is no good evidence that they are not derived from original magmatic disseminations.

Pegmatites

Tungsten is not a characteristic pegmatite element. Most of the recorded occurrences are in central and southwest Africa, and in most cases where tungsten is mentioned specifically (Haughton et al., 1939; Frommurze et al., 1942) it is in connection with associated greisen or quartz veining. However, some of these appear to be related to typical pegmatites with lithium, beryllium and tantalum minerals. At one locality in Omaruru, wolframite was found in the greisenized quartz core of a pegmatite. In the Maniema district of Zaire wolframite and cassiterite are mainly associated with quartz veins and greisens, less with pegmatites and albitization. In the Kivu region they are in albitized and greisenized rocks above the pegmatite contacts (Varlamoff, 1972).

The pegmatitic tungsten deposits of China referred to by Li and Wang (1943) and Davis (1961) appear to belong to the pegmatitic vein and greisen classes rather than to the true pegmatites. Cotelo Neiva (1972) referred to cassiterite and wolframite in pegmatites carrying beryllium, lithium and tantalum minerals in northern Portugal.

The Oreana mine in Nevada is one of the few pegmatitic tungsten occurrences in the United States (Kerr, 1946). The pegmatites contain potash feldspar, oligoclase, muscovite, beryl and fluorite in scheelite-bearing areas. In places pegmatite changes to a solid quartz vein. Both are associated with aplite and locally grade into aplite and both are at the contact between a granitic intrusion and limestone. Scheelite is found in traces in the aplites, in many places extending into the granite, but it has not been found in the granite. Wolframite is reported to occur in a mica pegmatite in Grafton County, New Hampshire, at Silver Hill near Spokane, Washington, and in the Black Hills, South Dakota (Kerr, 1946). In the last two it appears to belong to the beginning of the quartz vein stage.

The only pegmatite tungsten occurrences reported in Canada are insignificant or doubtful, being more in the nature of greisens or feldspathic quartz veins. The Lacorne molybdenite mine in Quebec is intermediate between a true pegmatite and a feldspathic vein deposit, but the tungsten content is negligible. No tungsten minerals have been reported in any of the numerous lithium- and beryllium-bearing pegmatites of the Canadian Shield, although some of them are in areas that also contain many tungsten occurrences.

Greisen and Quartz Greisen Veins

Greisen and related deposits make up one of the most important classes of tungsten deposits. In Canada they are fewer and less important than skarn deposits. The largest deposits are in the Appalachian Region. They are subordinate in the Cordillera, and only one occurrence in the Canadian Shield is known. The term 'greisen' refers to a metasomatic rock characterized by quartz and muscovite, with or without topaz, fluorite, tourmaline, feldspar or ore minerals. It forms characteristically in granitic or other aluminosilicate rocks, supposedly by reaction with fluorine-bearing fluids while the ore minerals were precipitated from fluoride complexes. Cassiterite and wolframite are the main ore minerals. In some places, as in Canada, wolframite greatly predominates. The scheelite in Canadian deposits appears to have replaced wolframite.

These deposits have been referred to as pneumatolytic, implying that the ore-bearing fluids were in a gaseous state, and the minerals deposited at somewhat higher temperature than in the subsequent hydrothermal stage. Extremely volatile tungsten hexafluoride possibly was present as a gas, at least momentarily when external pressure was reduced, but the compound hydrolyzes readily in contact with water vapour.

Greisen deposits everywhere are related closely to granitic intrusions, many of which contain muscovite as well as biotite. Characteristically they lie in and above cupolas or other protrusions surmounting batholiths but quartz greisen veins commonly extend some distance into the enclosing rocks. The origin of the ore-bearing fluids is discussed under "Relationship to granite".

Of the characteristic gangue minerals after quartz, muscovite and perhaps remnant or secondary feldspar, fluorite is present almost everywhere, implying that calcium was available from plagioclase or calcareous wall rocks. Topaz is most abundant where the deposits are in argillaceous rocks, as at the Burnt Hill mine in New Brunswick, but is common also in altered volcanic rocks at Mount Pleasant, N.B. Tourmaline apparently is a frequent and locally abundant constituent of greisen deposits generally but is absent or very scarce in Canadian wolframite deposits. Among Canadian deposits beryl is abundant only at the Burnt Hill mine, although it has been reported elsewhere. Lithium, another typical pegmatite element, is found as lithia mica in many places, especially the European Hercynian deposits, but is virtually absent from Canadian deposits.

Of the sulphide minerals, arsenopyrite is very common and predominates over pyrite in places, as at Mount Pleasant. Molybdenite generally is present but subordinate. Cassiterite is decidedly subordinate in Canadian deposits except at Mount Pleasant. Bismuth is an important minor constituent. Copper, zinc and lead sulphides usually are present in variable amounts.

Greisen deposits show considerable affinity to pegmatites in mineral composition and in some places, although not in Canada, they are closely related to pegmatites. They are also similarly related to the 'feldspathic quartz vein' type, which is often referred to as a pegmatitic vein. They also have many features in common with porphyry deposits, as discussed below, and some deposits here classed as greisens, as at Mount Pleasant, have been described as porphyry deposits (Parrish and Tully, 1977).

Porphyry Deposits

'Porphyry' deposits are very similar to greisen deposits, and some tungsten and tin deposits like Mount Pleasant, New Brunswick, have been described as porphyry tungsten deposits (Parrish and Tully, 1977). The Climax, Colorado, deposit, where tungsten is an important coproduct, is a classic example of a Porphyry Molybdenum deposit (Wallace et al., 1968).

The main points of similarity with greisens are their close association with granitic rocks, and their sericitic, feldspathic and argillic alteration aureoles. The main difference is that typical porphyry deposits are either copper-dominant or molybdenum-dominant, and the tungsten usually is confined mainly to upper zones or to crosscutting veins. Also, porphyry deposits generally lack fluorite, though not universally (at Climax, for example). In central Asia porphyry molybdenum deposits of three areas are all rich in chloride but only one contains a significant amount of fluorite (Berzina and Sotnikov, 1977). Although almost all tungsten deposits contain some molybdenite and some molybdenite porphyry deposits contain tungsten, apparently they rarely if ever occur in approximately equal amounts.

At Climax and Glacier Gulch in British Columbia tungsten is mainly confined to upper or outer zones of the molybdenum orebodies. At B.C. Moly tungsten is confined to quartz veins that cut the main molybdenum mineralization. At the Adera property, wolframite-bearing veins are mainly near the southern limit of the deposit, and the probably related Black Diamond wolframite deposit lies west of and above the Adera.

The relationship of tungsten and molybdenum is discussed in more detail below.

Skarns

The term 'skarn', as used in Canada, generally refers to a mineralized assemblage composed largely of silicate and aluminosilicate minerals that have developed in carbonate rocks near igneous intrusions. The term is roughly synonymous with tactite, contact metamorphic and pyrometasomatic. Mineral composition varies, depending on the composition of the carbonate and interbedded rocks affected by the primary thermal metamorphism, on the extent of metasomatic processes, and on the composition of introduced material. The relative importance of these processes is somewhat controversial but obviously tungsten, iron and other chalcophile metals, for the most part, were introduced.

Tungsten-bearing skarns typically are formed in calcite-rich carbonate rocks near contacts with subalkaline igneous rocks ranging from granite to quartz diorite. Scheelite is the only significant tungsten mineral, although traces of wolframite and rarer minerals have been reported in a few places and wolframite occurs in late quartz veins at Sangdong, South Korea (Klepper, 1947).

The preference of tungsten deposits for calcareous carbonates, notably at the Emerald and nearby deposits in British Columbia, appears to be general, although in some places the host rock is described as dolomite. In calcareous carbonates, according to accounts, the favoured locus of deposition is at the contact between calcareous and argillaceous rocks (Shimazaki, 1974; Johnston and de Vasconcellos, 1945). This preference is apparent at the Emerald and Dodger mines and perhaps at Canada Tungsten in the Northwest Territories, where much of the ore was found at the contact between the relatively pure ore limestone and the metasiltstone of the chert unit. It may reflect enhanced opportunity for chemical exchanges.

Many scheelite skarns are in carbonate units that overlie thick sequences of more or less metamorphosed clastic rocks. Some are remarkably distant from granitic contacts and their direct derivation from the granite appears doubtful. The Sangdong deposit in Korea is 4 km from the nearest exposed granitic intrusion. Like the Emerald and nearby deposits and the Canada Tungsten deposits in Canada, it is in Cambrian limestone that overlies Precambrian sedimentary rocks. The host limestone at MacTung on the Yukon – Northwest Territories border is probably Ordovician but lies unconformably on Precambrian metasediments. Sangdong has been compared with 'stratabound' deposits of Austria (Maucher, 1972). The inference is that in some skarns the mineralization may be derived not from the associated granite but from the underlying metasediments.

The mineral composition of skarns is important because it provides much information on the physical and chemical conditions under which scheelite was deposited. Table 5 gives some idea of the relative proportions of characteristic skarn minerals in Canadian and other skarns. The predominant silicate in nearly all Canadian skarns and many others is pyroxene, although Kerr (1946) considered garnet and epidote to be predominant in American deposits. Pyroxene appears generally to be close to hedenbergite, though commonly described as diopside. A few per cent of manganese is usually present. Garnet is almost ubiquitous but tends to be localized in Canadian deposits. It is usually described as grossularite but sometimes as andradite. Surprisingly scarce, wollastonite is confined mainly to the fringes of skarn zones. Plagioclase is a minor or localized constituent of most skarns but is abundant at the Blue Light deposit in British Columbia, where it is associated with clinozoisite and epidote. At the Canada Tungsten pit plagioclase, usually corroded and replaced by potassic feldspar and calcite, is often associated with scheelite. It occurs in retrograde skarn at MacTung but was considered primary at Seven Rila Lakes in Bulgaria.

The minerals pyroxene, garnet, wollastonite and plagioclase are anhydrous and are believed to have formed in the progressive stage of thermal metamorphism. Amphibole marks the beginning of the hydrous stage, usually considered retrograde, corresponding with large scale metasomatism. It is only locally abundant in most skarns, where it is associated with abundant pyrrhotite and is generally richer in scheelite than are the primary skarn assemblages. The amphibole is generally a tremolite-actinolite or ferrotremolite type, but hornblende is reported in some skarns. Hornblende is dominant in amphibole skarn at Pine Creek, California, but is commonly surrounded by actinolitic amphibole. It is thought to replace diopside-hedenbergite (Gray, 1968). Some apparently primary hornblende coexists with pyroxene in the Invincible skarn in British Columbia.

Biotite occurs only in retrograde skarn. It probably marks the culmination of metasomatic activity and is closely associated with quartz veins and scheelite and sulphide mineralization at Canada Tungsten and MacTung deposits and at Pine Creek, California. At Sangdong, South Korea, biotite is abundant in the high-grade ore of the main bed (Klepper, 1947). At Pine Creek it is closely associated with chalcopyrite (Gray, 1968). Muscovite in small amounts usually accompanies biotite in skarns but is common in greisen and greisenized granite dykes, as at the Canada Tungsten and Emerald deposits.

Clinozoisite-epidote group minerals were considered by Kerr (1946) to be the predominant constituents of scheelite skarns. They are not conspicuous in Canadian skarns except in the Blue Light deposit in British Columbia. Most of these minerals are associated with strongly corroded garnet and may be derived from garnet, but some epidote near the intrusive contact at Pine Creek may be primary. There, epidote tactite separates hornblende tactite from the intrusive, and rims the tactite in many places (Gray, 1968). Some epidote-rich Zn-Pb skarns with minor tungsten are, like the Blue Light, in relatively high grade rocks (K.M. Dawson, personal communication).

Vesuvianite, one of the predominant minerals of scheelite skarns, according to Kerr (1946), generally is scarce in Canadian skarns except for the Dodger deposit, where it

Table 5. Skarn minerals

	MacTung	Cantung	Emerald	Blue Light	Pine Creek	Sangdong	Seven Rila Lakes
	(111a)*	(107g)	(46b)	(98)	(Gray, 1968)	(Klepper, 1947)	(Zhelyaskova-Panajotova et al., 1972)
Pyroxene	major hedenbergite	major hedenbergite	major hedenbergite?	minor	major diopside-hedenbergite	major–local	stage 1
Garnet	major–local grossularite-almandine	major–local grossularite-almandine	major–local grossularite?	minor	major grossularite-andradite	major–local andradite	stage 1 andradite
Wollastonite	local	local			local		
Amphibole	major–minor	major–local	minor–local		major–local	major–local	stage 2
Biotite	local	minor–local	local	major	minor–local	major–local	stage 2
Clinozoisite-epidote	minor	local	local	major	major–local		stage 2
Plagioclase	local	local		major	minor–local		stage 1
Vesuvianite	local–scarce	scarce	local		local–scarce		stage 1
Pyrrhotite	minor	minor	minor		minor	minor	
Pyrite	scarce	scarce		scarce?	local		stage 4

*Locality numbers from Map 1556A and Appendix.

was seen in all thin sections. It is fairly common in the lower skarn near the east boundary fault at MacTung but apparently is scarce elsewhere (Dick, 1977). It is present at the Logjam Creek occurrence. Vesuvianite formed later than the main skarn minerals at Pine Creek, but it is listed as a stage 1 mineral at Seven Rila Lakes in Bulgaria.

Several other nonsulphide minerals, which occur in minor amounts, locally have considerable significance. Potassic feldspar is rare in typical skarn assemblages but is common in crosscutting quartz veins, as at Canada Tungsten. Fluorite is notably scarce in the major Canadian skarns but is abundant at the Baker prospect, near Canada Tungsten, and at the Blue Light. It is present at Pine Creek and at Barro Vermelho in Brazil, and in several Japanese skarns. At Sangdong it comprises up to 10 per cent of the ore. Another fluorine mineral, cuspidine $Ca_4Si_2O_7F_2$, occurs in some skarns (Burt, 1972). It is interesting that scapolite, one of the few chlorine-bearing minerals, is associated with fluorite at the Blue Light, Barro Vermelho, and Seven Rila Lakes deposits.

Apatite is so commonly and closely related to scheelite as to suggest that they were both derived from the same complex (see "Transportation and deposition"). Apatites from skarn deposits described by Rub et al. (1969) are fluorapatites and contain several hundred ppm of tungsten. The source is thought to be in the associated intrusions, but at the stratabound Tux deposit in the eastern Alps, scheelite, apatite and pyrite are mainly in the graphitic horizon (Holl and Maucher, 1976). At MacTung collophane is abundant in some horizons of the pelitic sediments. Collophane occurs also in the Cariboo district. Small amounts of sphene, also common in skarns, are thought to be derived from rutile in the sediments at MacTung. Graphite evidently is uncommon in skarns but has been reported at Fugigatani, Japan (Burt, 1971b; Shimazaki, 1974) and at Barro Vermelho (Johnston and de Vasconcellos, 1945). At MacTung it is rare in skarn but abundant in associated pelitic sediments (Dick, 1977).

Pyrrhotite greatly predominates over pyrite in typical scheelite skarns, as in Canada. At Pine Creek some pyrite is present, mostly replacing pyrrhotite, and pyrite at Seven Rila Lakes is listed as a stage 4 (late) mineral. Some early magnetite is present at both, and the associated garnet is at least partly andradite. Pyrite has been reported also in some skarn at the Emerald deposit. It is virtually confined to quartz veins at Cantung (Zaw, 1976) and MacTung (Dick, 1977). Dick suggested that the source of both iron and sulphur of the pyrrhotite at MacTung was in the interbedded graphitic hornfels, which contains abundant pyrite. Molybdenite is scarce in skarn at Canada Tungsten and MacTung but occurs together with molybdian scheelite at the Emerald and nearby properties. It is common in crosscutting veins at the Dodger deposit near the Emerald, and less so at MacTung and at Pine Creek. Bismuth is common in small amounts in most scheelite skarns. Copper as chalcopyrite is evidently the dominant base metal of scheelite skarns in general. It is dominant in the major Canadian tungsten skarns even though they are in a zinc-lead province. At the Dodger deposit, scheelite skarns in a calcareous horizon overlap zinc-lead deposits in a dolomitic horizon, and both types of deposit are mutually exclusive. However, sphalerite locally amounts to 5 per cent at Canada Tungsten, and sphalerite, galena and other sulphides and sulphosalts occur in some skarns elsewhere. Zinc-lead skarns in the northeastern part of the Canadian Cordillera commonly contain minor scheelite (Dawson and Dick, 1978).

The anhydrous minerals, pyroxene, garnet, plagioclase and wollastonite, are believed to have formed primarily as a result of thermal metamorphism. That they are commonly found at considerable distances from intrusive contacts may reflect the location of fractures by which carbon dioxide was able to escape from the system. However, major redistributions of material, including tungsten to form scheelite, have occurred and suggest that hydrous fluids were available even in this primary stage. Increasing pressure of hydrous fluids expelled from an associated intrusion during crystallization or from invaded or assimilated bedded rocks may have initiated the opening of fractures in the enclosing rocks. These fluids then replaced the escaping CO_2 and altered the primary assemblages. The hydrous minerals such as amphibole, micas and clinozoisite are thought to have formed mainly by retrograde metamorphism, but some may be primary. Fluorite, vesuvianite and scapolite indicate the presence of fluorine or chlorine, and apatite may contain significant amounts of fluorine, chlorine or CO_2. Silica was introduced on a major scale, and scheelite and apatite, mainly followed by pyrrhotite and other sulphides, were deposited in greatly increased amounts. Normal hydrothermal processes would prevail, although the solutions might be buffered by the skarn minerals and residual calcite.

The principles that govern the mineral assemblages in skarns are complex and are beyond the scope of this report. They have been discussed by Zaw (1976) with reference to the Canada Tungsten mine, and in detail by Dick (1977) in his interpretation of the MacTung deposit. One important factor that affects the skarn mineral assemblages is the oxidation state during the primary stage. Thus, according to Shimazaki (1977), the presence of Fe^{3+}-poor grossularite in Japanese skarns reflects oxygen fugacities lower than the pyrite-pyrrhotite-magnetite buffer. He suggested that this favoured the precipitation of scheelite. According to Burt (1971a), under reducing conditions only hedenbergite will form and under oxidizing conditions only andradite. The association of hedenbergite-diopside with grossularite-almandine at Canada Tungsten and MacTung presumably indicates an intermediate oxidation state. The presence of magnetite at Pine Creek in California and Seven Rila Lakes in Bulgaria evidently reflects a higher oxygen fugacity.

The temperature-dependence of some typical skarn mineral facies is given by Zharikov (1970) as follows:

750-800°C	wollastonite-plagioclase
550-750°C	pyroxene-garnet-wollastonite
500-550°C	pyroxene-garnet (most common)
450-500°C	pyroxene-garnet-epidote
350-400°C	pyroxene-epidote (nonaluminous garnet also stable)

Together with temperature, pressure is crucial because it determines the extent of dissociation of $CaCO_3$ and hence the potential activity of calcium. Figure 2 (after Dick, 1977) illustrates the temperature-H_2O-CO_2 relationships for typical skarn reactions, assuming total pressure (100 MPa) equal to the sum of CO_2 and hydrous partial pressures.

Feldspathic (Pegmatitic) Quartz Veins

Feldspathic quartz veins appear to be a valid separate group intermediate between pegmatites and normal quartz veins. The feldspars, orthoclase and albite, typically are in isolated masses in quartz. Muscovite and tourmaline are common and beryl and fluorite are occasionally present. In this they resemble quartz greisen veins. Pseudopegmatitic veins resulting from pervasive potassium metasomatism are not included in the class.

The best examples of the type are at the East Malartic and Canadian Malartic gold mines in the Val d'Or area of Quebec. The nearby Lacorne mine is closer to a true pegmatite but its tungsten content is negligible in any case. The only important Canadian deposit assigned to this class is the Red Rose mine, where 773 765 kg of WO_3 in concentrates

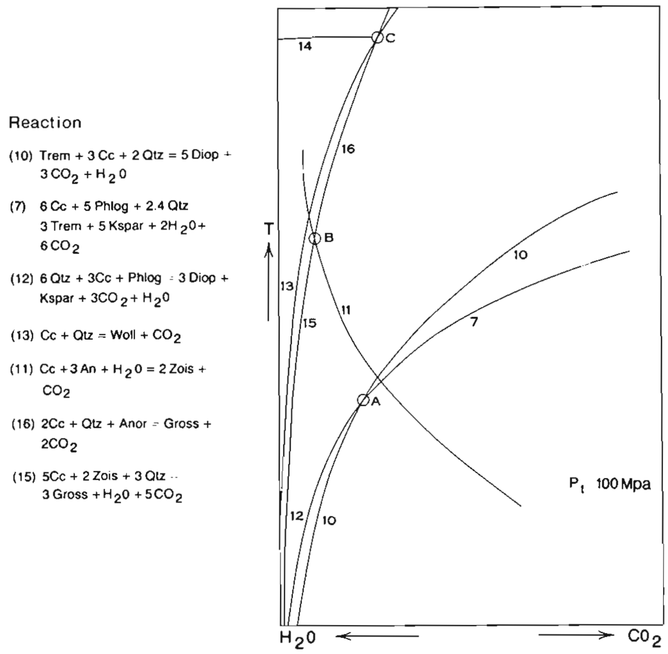


Figure 2. *Relationships of relative H_2O-CO_2 concentration to temperature for typical skarn reactions at 100 MPa total pressure. (Compiled from various sources by Dick, 1977, Fig. 24.)*

were produced between 1942 and 1953. Similar smaller deposits are nearby. These deposits contain some wolframite as well as scheelite, but otherwise are distinguishable from normal quartz veins mainly by their feldspar content. Many of the quartz veins cutting skarn at Canada Tungsten are also rich in feldspar.

Quartz and Quartz-carbonate Veins

Excluding the Red Rose deposit as a feldspathic quartz vein, only a few of the numerous and widespread deposits of this class have been of any economic importance. In the Appalachian Region the only significant producers were Moose River and Indian Path. In the Shield, deposits are nearly all in the Archean Superior and Slave provinces. At the Porcupine Camp important amounts of scheelite were recovered, mainly during wartime emergencies. In the Cordillera, scheelite concentrates were produced from veins in the Bridge River-Tyaughton Creek area, at Regal Silver, and in the Cariboo district. Some trial shipments of tungsten-bearing placer concentrates were made from the McQuesten-Mayo district.

Vein scheelite deposits are important in many parts of the world. Particularly interesting in their similarity to those of the Canadian Shield are the numerous deposits associated with gold in greenstone belts in southern Africa, which are described by Foster (1977).

The outstanding association is with gold, either in the same vein or in nearby veins. Arsenopyrite is widespread and stibnite and other antimony minerals are localized. Antimony-bearing tungsten vein deposits are zonally associated with mercury deposits in the Tyaughton Creek area, in some 'stratabound' deposits in Europe (see below), and in northeast U.S.S.R. (Nekrasov, 1973). Especially rich in carbonate, these veins evidently formed at low temperatures. However, carbonate minerals, particularly ankerite, are almost characteristic of scheelite-bearing quartz veins. If carbonate minerals are absent, it could be because the calcium was used up to form scheelite, or because it was introduced with tungsten in chloride solutions (see "Transportation and deposition"). Pyrite is the predominant iron sulphide; pyrrhotite, characteristic of skarns, is rare but arsenopyrite is common. Probably most vein deposits are associated with granitic rocks or acidic porphyries but many are associated with mafic intrusive or extrusive rocks, especially in greenstone belts, and a few with ultramafic rocks. Some apparently are not related to any intrusions. Although most veins are discordant, a remarkable degree of concordance has been noted in many places, in some of which the veins have been folded with the enclosing strata. Such veins may have been emplaced prior to associated granite or contemporaneously with it. Deposition from metamorphic pore fluids has been proposed for some of them, such as at Moose River in Nova Scotia.

Stratabound Deposits

This type of deposit, as defined here, excludes conventional skarn deposits like those at Sangdong (Klepper, 1947) and some Canadian deposits that are strongly controlled by bedding but are considered to be essentially epigenetic. On the other hand, many of the deposits described as stratabound have been formed by some degree of mobilization and reconcentration and the boundary between syngenetic and epigenetic deposits cannot be rigidly defined.

Some tungsten deposits in Uganda and Rwanda are confined to certain black schist horizons that are strongly anomalous in tungsten on a regional scale, as noted by Jeffery (1959), Reedman (1973) and others, and discussed by Hosking (1973). The graphitic schists contain nodules of ferberite that at the Nyamalilo mine are up to 4 cm long (Reedman, 1973). There also, ferberite, ferritungstite and anthoinite occur in veins, some of which follow the bedding and have been folded with the strata.

The Kleinartal and Felbertal deposits in the Austrian Alps are probably the best known of numerous strata- and time-bound tungsten deposits in lower Paleozoic metasedimentary and metavolcanic rocks (Höll and Maucher, 1976). According to Maucher (1972) small scheelite occurrences are distributed in certain rock units over more than 500 km, and most of them are far from granitic contacts. Some deposits are quartz-scheelite veins in gneisses and are attributed to palingenetic regeneration and granitization of stratabound concentrations during the Variscan orogeny (Höll and Maucher, 1976). The stratabound deposits are in black graphitic schist, in dolomite and in interbedded basic metavolcanic rocks. Some of the metavolcanic rocks are described as hornblendites. At Kleinartal the well preserved sedimentary fabric shows excellent examples of synsedimentary diagenetic scheelite mineralization (Höll and Maucher, 1972). The deposits are thought to be genetically related to underlying basic volcanic rocks as products of associated hydrothermal activity.

Stratabound antimony and mercury deposits also are considered to be related to the widespread basic volcanic activity of the early Paleozoic Era (Maucher, 1972). Höll and Maucher (1976) referred to ore mineralization of the "antimony-tungsten-mercury formation", and described deposits in which both scheelite and stibnite are present as well as mercury and numerous other trace metals, including gold.

In the Cévennes district of France scheelite occurs in quartz veins that are confined to clinozoisite gneisses at one stratigraphic level. Some occurs also in lenses concordant with the bedded rocks and folded with them (Routhier and Brouder, 1973). Antimony deposits also are numerous in the area.

Stratabound tungsten deposits have been reported in the Orsdalen and Bindal areas of Norway. In the latter area scheelite skarns occur in calcareous bands in gneisses and in the gneiss itself, but are absent between marbles and granite (Skaarup, 1974). They are thought to have formed during metamorphism by exchange of material between the marbles and the gneiss.

Scheelite is abundant in veins and bedrock bands in the Boliden Mine in Sweden, as well as in various other deposits in the Skellefte district (Grip, 1951). The Boliden massive sulphide deposit is now generally considered to be essentially stratabound. Tungsten is associated principally with pyrrhotite.

Tweto (1960) suggested that many small tungsten deposits in the Precambrian gneisses in Colorado are syngenetic. Possibly some small deposits in Canada, particularly in the Yellowknife-Beaulieu, East Kootenay, Cariboo and Moose River districts, are syngenetic. Some essentially stratabound zinc-lead (W, Cu, Ag) skarns in the northeastern part of the Canadian Cordillera contain minor scheelite (Dawson and Dick, 1978).

Hot Springs, Brines, and Evaporites

White (1955) reviewed data on tungsten-bearing manganiferous hot spring deposits. At the famous Golconda deposit in Nevada, tungsten-bearing manganiferous and ocherous layers up to 6 m thick underlie calcareous tufa. Beneath the blanket deposits are veins of similar mineralization, which are thought to be the source of the ores. They contain about 0.016 per cent of beryllium oxide as well as up to 6 per cent of tungsten. The tungsten is in colloidal form and was recovered by leaching. Similar, smaller deposits are known at East Range and Sodaville, Nevada, at Evans Lime Quarry, Utah, and at Salinas Valley, California. The deposits are in tungsten-bearing belts and might have been derived from bedrock deposits by circulating groundwater.

The Uncia hot spring deposit in Bolivia likewise contains up to several per cent of tungsten in lenses of manganese-rich material in flat-lying travertine. The deposit is in a valley below the Uncia tin mines in the eastern Cordillera of central Bolivia, and the tungsten was most probably derived from the tin ores above.

Tungsten-bearing brines and evaporites occur in arid regions of the U.S.S.R. and western United States. The Searles Lake deposit in California, a mass of evaporites about 90 km^2 in area, contains 70 ppm of tungsten. It has been a major source of lithium, which occurs in small concentration. The tungsten may have been leached from nearby primary deposits or from acid volcanic rocks, which are thought to be the source of the lithium.

Relationship to Granite

The almost universal and close spatial relationship of some ore deposits to granite has been interpreted according to two opposing theories. As applied to tungsten, they are:

1. In the classical magmatic-hydrothermal theory, tungsten is derived from the granite by concentration in residual fluids during crystallization and segregated with them by the consequent increase in fluid pressure.
2. Tungsten in bedded rocks assimilated by developing granitic magmas is concentrated in fluids also in the rocks, and both are excluded from the magmas because of their low solubility in magmas.

Both theories accept the premise that tungsten is concentrated in fluid fractions because it is unable to enter isomorphously into the main minerals, feldspar and quartz (see "Chemistry and theoretical geochemistry"). Both admit that the magma originated possibly from melting or granitization of bedded rocks, but the second theory is directly dependent on this mode of origin whereas the first is also compatible with an origin by differentiation of other 'primordial magmas'.

The first theory seems most appropriate for deposits of the quartz greisen type, which are commonly found in and above cupolas surmounting extensive granitic batholiths. They are predominantly wolframite-bearing and associated with abundant fluorine minerals. This suggests that an abundance of fluorine in the magma increased the initial solubility of tungsten in it. Experimental work by Smith (1947) and by Burnham (1967) indicates that fluorine, unlike chlorine, is strongly partitioned into the silicate melt during crystallization, rather than into immiscible aqueous fluids. It may be that tungsten becomes bound in hydroxyfluoride complexes and remains in the melt until the last stage of crystallization. The work of Štemprok (1974) and Štemprok and Urbanova (1976) also shows that tungsten as potassium tungstate is soluble up to several per cent in silicate melts at high temperatures, and that practically all of it is exsolved during crystallization.

The second mode of origin, exclusion from developing palingenetic magmas, seems most appropriate for scheelite-bearing veins and some skarns that are distant from intrusive contacts. Fluorine-bearing minerals usually are scarce in such deposits whereas fluid inclusions in minerals are moderately saline. Foster (1977) has shown that scheelite is soluble in alkali chloride brines at temperatures above 400°C. Therefore aqueous chloride solutions in pore spaces of clastic rocks undergoing granitization, especially in the absence of fluorine, would dissolve any available tungsten. These solutions would be largely immiscible in the silicate magma and available to enter any fractures.

The above discussion is simplistic and ignores many problems. For example, some otherwise normal skarns contain abundant fluorite, and fluid inclusions in some quartz greisen – wolframite deposits are about as saline as those in typical scheelite skarns. Some of the possibilities and complexities involved with the first theory have been reviewed by Burnham (1967). The implications of the second theory, to my knowledge, have not been critically analyzed. However, some such mechanism is implicit in the hypothetical derivation of some deposits from 'metamorphic pore fluids' or in other situations where the role of granite has been considered indirect. These include the 'heat-engine' role, with tungsten leached and redeposited by circulating groundwater.

Transportation and Deposition

The main forms that have been considered for transportation are: (i) as a form of tungstic acid, (ii) as an alkali tungstate, (iii) as a fluoride or fluoride complex, (iv) as a chloride or chloride complex, and (v) as a heteropoly acid of phosphorous, arsenic or other element.

The possible transport of tungsten as a form of tungstic acid was considered from a thermodynamic viewpoint by Ivanova and Khodakovskiy (1968) and by Naumov and Khodakovskiy (1972). They concluded that transport as undissociated tungstic acid or as HWO_4^- was possible. Temperatures higher than 350°C are more favourable for transport as undissociated tungstic acid. For the temperature range of formation of wolframite, transport as the hydrotungstate ion is more probable. The role of tungstate ion WO_4^{-2} is considered limited to temperatures below 300°C. Orthotungstic acid is only slightly soluble in near-neutral solutions at normal temperature, but can form colloidal solutions under certain conditions (Li and Wang, 1943). It is very soluble in alkaline conditions, yielding $(NaK)_2WO_4$.

Transport as an alkali tungstate has long been proposed because these compounds are soluble and generally stable. Štemprok (1974) and Štemprok and Urbanova (1976) found that a wide miscibility gap exists between sodium tungstate and silicate liquids but 3.5 per cent of WO_3 was dissolved at 1250°C and 2.5 per cent at 1100°C. During crystallization of the silicate melt, small globules of Na_2WO_4 formed at the surface of the silicate crystals. The most important conclusion appears to be that an alkali silicate melt can dissolve tungsten and that practically all of it separates as immiscible alkali tungstate during crystallization. The tungstate would presumably dissolve in any available hydrous fluid and be transported with it.

Because of the abundance of fluorine minerals in wolframite greisen deposits, transportation of tungsten as a fluoride complex had traditionally been assumed. The possibility has been discounted (Barabanov, 1970) because the hexafluoride hydrolyzes to tungstic acid in the presence of water. However, according to data cited by Foster (1977) WF_6 and WOF_4 hydrolyze to WO_2F_2, which apparently has a considerable stability range. Foster concluded that migration of tungsten as an oxyfluoride complex cannot be ruled out. Ivanova and Khodakovskiy (1968) considered that the stability of the complex HWO_3F "where HF reaches H_2O" (i.e., presumably where the concentrations are equal) will depend on the concentration of fluorine and, to a lesser extent, on the pH of the solution. They concluded that tungsten may be transported as a complex oxyfluorotungstate in hydrothermal solutions rich in fluorine. Ivanova (1974) reported that aqueous extracts from gas-liquid fluid inclusions of some wolframite greisen deposits of eastern Mongolia and U.S.S.R. contain fluorine, and concluded that tungsten was transported as hydroxy- and oxyfluoride complexes.

The very high volatility of WF_6 (a gas at normal temperature and pressure) suggests that it would be one of those gaseous or supercritical fluids that "must be present in high temperature ore fluids" (Krauskopf, 1964), and would separate from a fluorine-rich melt with any reduction of pressure. Even if the free compound is immediately hydrolyzed, this might be important in the initial separation of tungsten from the magma, and lead to the very low tungsten concentrations usually found in granites near deposits.

Transport of tungsten as a chloride or chloride complex is suggested by the chemical affinity of tungsten for chlorine, and by the presence of chlorides in fluid inclusions of tungsten deposits. The possibility has been dismissed (Barabanov, 1970, for example) because of the instability of tungsten chlorides, but is demonstrated by the work of Foster (1977). Foster measured scheelite solubility in KCl solutions at 100 MPa with P_{HCl} buffered by quartz, potassic feldspar and muscovite. In a 0.5 mole KCl solution, solubility increased regularly from 59 ppm at 350°C to 277 ppm at 560°C. In a 1 mole solution solubility rose rapidly above 400° to a maximum of 1075 ppm at 549°C. This rapid increase was accompanied by an almost exponential increase of HCl molarity, and Foster concluded that scheelite solubility is a function of P_{HCl}. The relationship between tungsten and chloride in the solution is unknown. According to data cited by Foster, gold shows a similar solubility dependence on P_{HCl} with increasing temperature. He attributed the common association of gold with scheelite in deposits in greenstone belts of southern Africa to their similar dissolution behaviour in chloride solutions. Migration of tungsten in chloride solutions may be applicable to the Canadian scheelite-gold vein deposits and also to skarns like those at Canada Tungsten, where fluid inclusions contain 5.5 to 7.6 per cent of NaCl equivalent (Zaw, 1976). This is about the same salinity as that found in some Japanese vein deposits (Takenouchi and Imai, 1971).

Even at some wolframite greisen deposits, such as Pasto Buena, Peru, where fluid inclusions of some stages are strongly saline (Landis and Rye, 1974), transport of tungsten by chloride solutions appears possible, although fluorite is also abundant. The high salinity of early stages decreased to 2 to 17 per cent of NaCl equivalent during the main wolframite deposition stage. The salinity of inclusions in the wolframite-bearing zones at Climax, Colorado, for comparison, is about 8 per cent, whereas that of molybdenum zones ranges up to 17 per cent (Hall et al., 1974). At Carrock Fell, in northwest England, where fluorite is apparently absent from the wolframite greisen deposits, fluid inclusions contain about 8.3 per cent of NaCl equivalent (Shepherd et al., 1977).

In the hypothetical mobilization of tungsten in marine sedimentary rocks, intergranular water, being saline, would provide the necessary alkali component. If fluorine were abundant some of it might enter the solutions. Thus alkali, fluorine and chlorine might all have contributed to the migration of tungsten, according to their relative concentrations and activities in the solutions.

The possibility of tungsten migration as a heteropoly acid, with various elements substituting for hydrogen in the acid tungstate radical, has been mentioned by Barabanov (1970). Of these $H_4[Si(W_3O_{10})_4]$, $H_3[P(W_3O_{10})_4]$ and $H_3[As(W_3O_{10})_4]$ seem especially significant. The silicatungstic acid obviously is an important possibility because quartz is so abundant in almost all types of tungsten deposits. Arsenotungstic acid may have been important in greisen deposits like those of Mount Pleasant, New Brunswick, where arsenopyrite is the dominant sulphide species and is intimately related to wolframite. Phosphorotungstic acid transport is plausible for deposits, particularly skarns, in which apatite is abundant and closely related paragenetically to scheelite. Outstanding among these is the MacTung (AMAX Northern) deposit on the Yukon – Northwest Territories border, where collophane is plentiful in some horizons of the skarn-bearing assemblage (Dick, 1977). Collophane is also locally abundant in one horizon in the Cariboo district. In some areas of eastern U.S.S.R. apatite is a leading mineral in greisens (10%) and quartz-scheelite veins (15%; Rub et al., 1969). The apatite of the greisens is fluorapatite and that of the veins is fluorocarbonate apatite. Apatite began to crystallize before scheelite, and continued to do so after it. The apatite of the tungsten-bearing magmatic complexes contains about 300 ppm of tungsten and that of the postmagmatic formations contains 700 to 880 ppm.

Tungsten may be deposited as a result of physical changes such as temperature and pressure in the system, or by chemical changes such as the reaction of ore-bearing solutions with the country rocks, or by combinations of both. In simple quartz veins remote from intrusions, temperature was probably the dominant factor and was undoubtedly important in all deposits, as the metamorphic grade of host rocks is generally low. In skarns or carbonate-bearing quartz veins with scheelite, a decrease in pressure, favouring dissociation of calcium carbonate and thus increasing calcium activity, was probably more important.

In carbonate rocks the frequent concentration of tungsten near contacts with argillaceous rocks may result from the damming effect of the more impervious clay rock, as well as opportunities for material exchange, perhaps involving semipermeable membrane effects.

Chemical changes are related to changes in pH, oxidation-reduction processes, and so forth, resulting from reaction with wall rocks, mixing of solutions from various sources, and relative activity of different components under different conditions.

In scheelite skarns, the dominant agent of deposition obviously was calcium, whether derived directly from calcite or derived indirectly from calcium-bearing skarn silicates. In quartz greisen deposits, which typically contain abundant fluorine minerals, deposition usually is thought to have resulted from the reaction of fluoride complexes with the country rocks. These are generally aluminosilicate rocks such as granite or argillaceous sediments. The typical products are fluorine-rich muscovite, topaz and fluorite. The fluorite implies availability of calcium from plagioclase or from calcareous wall rocks. Sericitization might also result from reactions involving deposition of tungsten from tungsten-bearing alkali chloride solutions (Foster, 1977).

Deposition of tungsten by reduction reactions may be involved in the development of stratabound deposits in graphitic schist, as in Rwanda and Uganda, where ferberite, scheelite, anthoinite and tungsten ochre are mined from quartz veins and breccia zones in graphitic schist. At the AMAX Northern deposit graphite-rich pelitic hornfels is interbedded with the skarn units and the graphite is leached from the peripheries of scheelite-bearing quartz veins (see Plate 12). At the Ada and Silver groups in British Columbia, the scheelite-bearing veins contain graphite, the only veins in the area that do.

At the Pasto Buena mine in Peru, wolframite deposition was associated with episodes in which influxes of meteoric water mixed with water of magmatic origin (Landis and Rye, 1974).

Scheelite-wolframite Relationship

The characteristic occurrence of minerals from the wolframite group in some types of deposit, and of scheelite in others has been noted above. The minerals belong to different crystallographic systems and to two different solid solution series. Thus the wolframite group is virtually confined to the iron and manganese tungstates, and never contains molybdenum. Scheelite is isostructural with analogous calcium molybdate, and accepts appreciable amounts of molybdenum. The corresponding lead tungstates and molybdates are also isostructural with scheelite and form limited solid solutions.

According to Oelsner (1966) the relative proportions of ferberite and huebnerite (the H/F ratio) are indications of the temperature range of formation. He considered wolframite with H/F ratio greater than 0.8 as pegmatitic, 0.8 to 0.1 as pneumatolytic and less than 0.1 as hydrothermal. Furthermore, "in the hydrothermal phase only the end members and scheelite are stable, and wolframite will tend to be replaced by scheelite wherever calcium is available, preferentially replacing huebnerite." The temperature dependence of the H/F ratio is not supported by experimental work (Hsu, 1976). The relative availability of iron and manganese must be a decisive factor. Scheelite does commonly replace wolframite, suggesting a lower temperature stability range for scheelite. The ferberite in low-temperature deposits, with tellurides in veins in Colorado (Tweto, 1968), for example, might be explained by Oelsner's idea that the pure end members are most stable, especially ferberite.

The occurrence of wolframite with fluorite in greisens and related veins, and of scheelite without fluorite in skarns and most veins has been explained by Burt (1972) as a function of F/CO_2 activity (Fig. 3). According to Burt, greisen indicates an environment relatively enriched in fluoride ion and depleted in CO_2, whereas skarns are relatively enriched in CO_2 and depleted in F^{-1}. However, fluorite is abundant in some scheelite skarns that contain no wolframite. Some others contain cuspidine, $Ca_4Si_2O_7F_2$ (ibid.). Wolframite likewise occurs in some quartz greisen veins that cut limy rocks but reaction with the country rock apparently was minimal. Wolframite probably will form only if more fluorine is present than is required to fix any calcium contained in the system*. As greisens usually are in aluminosilicate rocks and are typically associated with low-calcium granite, the amount of available calcium would normally be small in any case.

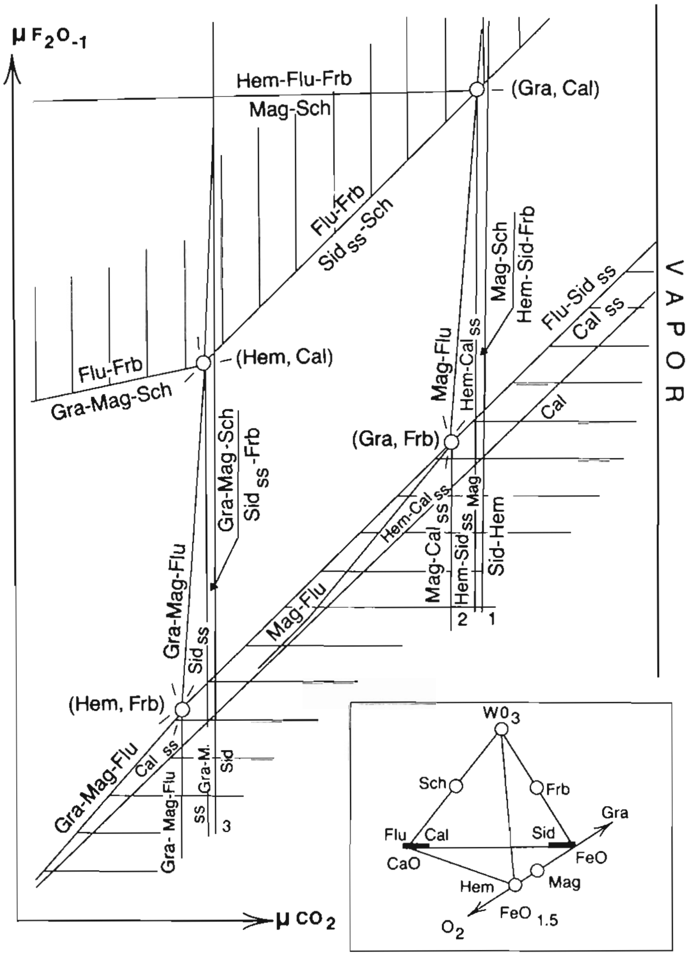


Figure 3. *Schematic μF_2O_{-1}-μCO_2 projection of the system Ca-Fe-W-C-O-F in skarns, veins and greisens. The assemblage fluorite-ferberite, characteristic of greisens and veins, is stable in the area with vertical hachures. The assemblage calcite-scheelite, characteristic of skarns, is stable in the area with horizontal hachures (after Burt, 1972).*

Association of Tungsten With Other Metals

Molybdenum

Most tungsten deposits contain some molybdenum as molybdenite or as molybdian scheelite, or both, in skarn deposits, and as molybdenite in most other types of deposit. Some molybdenum deposits, especially of the porphyry type, contain tungsten as wolframite or scheelite, or both, generally in certain zones or veins. Why tungsten occurs almost entirely as a tungstate, whereas molybdenum occurs primarily as the sulphide, is related to their different electronic configurations as discussed under "Chemistry and theoretical geochemistry", above.

---

* As the solubility of fluorite (0.016 g/l at N.T.P.) is much lower than that of scheelite (2 g/l) it should tend to form preferentially.

Some data suggest that a lower stability of molybdenum in hydrothermal solutions would lead to its early separation. Khitarov et al. (1967) concluded from fractionation experiments that the vapour phase of the solutions may contain geologically significant concentrations of molybdenum, and that the concentration will increase as the temperature and acidity of the solution increase. In experimental work cited by Burnham (1967) molybdenite was found to be soluble in chloride solutions below 525°C (the temperature range at which iron, zinc and copper were precipitated) and was fixed at higher temperatures, mainly above 600°C.

This high-temperature deposition of molybdenum from chloride solutions of appropriate composition may account for the observed zonal separation and later introduction of tungsten in porphyry molybdenum deposits, as well as the more pronounced zonal relationship to peripheral base metal deposits. How tungsten behaves under these conditions is not known but the experimental work of Foster (1977) (see "Transportation and deposition") suggested that tungsten would be precipitated from chloride solutions only at considerably lower temperatures than those inferred for molybdenum.

Tin and Beryllium

Tungsten and tin are found together in varying proportions in many parts of the world. Almost everywhere the deposits are greisen and quartz greisen vein types with wolframite as the predominant tungsten mineral (see "Scheelite-wolframite relationship"). Why scheelite deposits rarely contain important amounts of tin is not fully understood but involves modes of concentration and transportation in the different types of deposits. Aside from their similar geochemical behaviour, tungsten and tin may have concentrated together in sediments because of the high specific gravities and relative stability of their minerals.

Beryllium likewise is confined mainly to the greisen environment but is concentrated in the major Canadian skarn deposits to some extent.

Gold

Scheelite-bearing quartz and feldspathic quartz veins are closely associated with gold in parts of the Appalachian and Cordilleran regions, and very commonly in the Superior and Slave provinces of the Canadian Shield. Notably in Superior Province the deposits are in greenstone belts and are generally associated with mafic volcanic rocks. Foster (ibid.) noted a very similar association of tungsten with gold in greenstone belts of southern Africa. Gold and tungsten occur together also at the Yellow Pine mine, Idaho, and elsewhere in the western United States (Kerr, 1946), in some stratabound deposits of Austria (Maucher, 1972) and in parts of the eastern U.S.S.R. (Nekrasov, 1973).

Foster (1977) discussed the possibility that gold deposits with associated scheelite in the greenstone belts of southern Africa were derived from ultramafic source rocks by metamorphic processes. He concluded that "the ready mobility of gold and tungsten in chloride-rich hydrothermal solutions and similarity of dissociation behaviour with temperature variation clearly explain the geochemical compatibility of the two elements in greenstone-type deposits".

Antimony and Mercury

Tungsten is associated with antimony minerals in many places, and with mercury in a few. There is also some spatial relationship to gold deposits in some of these.

The outstanding Canadian example is in the Bridge River district in southwestern British Columbia, where scheelite-bearing gold veins, scheelite-stibnite veins and stibnite-mercury veins occur in an overlapping zonal arrangement. Scheelite is present in some members of all three groups. The scheelite-bearing stibnite and stibnite-mercury veins consist largely of carbonates, and appear to be low-temperature deposits. Scheelite also occurs in tetrahedrite-bearing veins associated with gold in the Manson Creek area of central British Columbia. In both areas the deposits apparently are related to highly altered porphyry intrusions that could be related to ultramafic rocks. Mercury is found in some tungsten- and gold-bearing stream sediments in McQuesten-Mayo district of the eastern Yukon Territory and in the Sixty Mile area of western Yukon. In the former, antimony minerals are common in the Ag-Pb-Zn vein deposits. Tungsten also is associated with tetrahedrite in a few gold deposits in the Canadian Shield, notably in the Yellowknife area.

Many stratabound tungsten deposits in Europe are spatially related to stratabound deposits of stibnite and stibnite-cinnabar (see "Classification of tungsten deposits – Stratabound deposits"). Stibnite and scheelite occur in the same deposits fairly commonly, and mercury occasionally. These deposits are thought to be derived from underlying mafic volcanic rocks by 'hydrothermal processes' (presumably volcanic exhalative). Associations of tungsten with stibnite and mercury deposits in northeastern U.S.S.R. were mentioned by Nekrasov (1973).

Other examples of scheelite-stibnite association are the Yellow Pine mine in Idaho and some veins in Bolivia (Kerr, 1946). Most deposits of this association are rich in carbonates and emplaced in rocks of low metamorphic grade. They appear to be low-temperature deposits but their environments differ considerably and no definite generalizations can be made.

Iron and Other Sulphides

Arsenopyrite is the predominant sulphide mineral and is intimately related to wolframite in the Mount Pleasant greisen deposit in New Brunswick, and is abundant at the Burnt Hill wolframite greisen deposit. It is the main sulphide in the Moose River scheelite-quartz veins in Nova Scotia and is abundant in many scheelite-bearing gold-quartz veins in the Shield and the Cordillera, including the Bridge River area. However, pyrite usually predominates in scheelite vein deposits, whereas pyrrhotite is characteristic of the major skarn scheelite deposits and pyrite is virtually confined to late siliceous veins in them. Chalcopyrite is the most common base metal sulphide in the major Canadian tungsten skarns and most greisen deposits and is generally so elsewhere. Sphalerite is found at MacTung and is locally abundant at Canada Tungsten in the Northwest Territories. It is present in most other tungsten-bearing skarns in the northern part of the Cordillera (Dawson and Dick, 1978) and is foremost in some, together with argentiferous galena. It predominates also in the Mount Pleasant greisen deposit. Sphalerite and galena are common and tetrahedrite, stibnite or other antimony minerals are localized in scheelite vein deposits. The molybdenum association is discussed above.

Minor metals include bismuth, mainly in greisen skarn and some vein deposits, and tellurium. The outstanding example of the tungsten-telluride association is in parts of the Colorado Mineral Belt (Tweto, 1968). The Canadian Shield contains scheelite and tellurides in some gold-quartz veins, notably at the McIntyre-Porcupine and Hollinger Consolidated mines in the Porcupine Camp.

PART 2

DESCRIPTION OF CANADIAN TUNGSTEN OCCURRENCES

Part 2 contains summary descriptions of the environment and character of tungsten deposits in the main geological regions of Canada, and more specific descriptions of subregions and less important areas. Following each of these are notes on individual occurrences considered to be economically important or geologically significant. The known Canadian occurrences are identified by numbers and letters corresponding to the locality numbers on Map 1556A and in the Appendix. The notes in Part 2 supplement the readily classifiable facts and descriptions given in the Appendix, which are not generally repeated in this section.

The descriptions follow the order of deposits as presented in the Appendix, which is governed by the natural order of geological regions and provinces: Appalachian, Canadian Shield and Cordilleran. Within this framework the order is generally east to west and south to north, but is inconsistent locally.

The most important Canadian tungsten deposits found so far are skarn (contact metamorphic) deposits in the Cordilleran Region. They comprise the Emerald and adjoining orebodies (46b) in southeastern British Columbia and the Canada Tungsten mine (107g) and MacTung (AMAX Northern) (111a) in the Selwyn Mountains near the Yukon – Northwest Territories border. The Emerald group of deposits was mined intermittently from 1943 to 1973. The Canada Tungsten mine was first operated in 1962, and currently is the only tungsten producer in Canada, though some high-grade ore was mined at the Max property (104) in 1977. The MacTung (AMAX Northern) deposit has been explored extensively by drilling and some underground work. It contains a large tonnage of potentially economic ore.

Another deposit in the Cordillera that produced large amounts of tungsten concentrates is the Red Rose mine (86b), which operated mainly during World War II. It is classed as a feldspathic quartz vein deposit. Minor amounts of tungsten in concentrates have been produced from several deposits of the quartz vein type and from two of the few wolframite-quartz greisen deposits in the Cordillera.

The Appalachian Region contains three wolframite-quartz greisen deposits of economic potential, including the Mount Pleasant polymetallic deposit (17a), which has been intensively explored and partly developed in recent years. Small amounts of tungsten as scheelite have been produced from vein-type occurrences that are closely associated with gold-quartz veins.

In the Canadian Shield practically all occurrences are of the quartz-scheelite vein type. They are mostly in or closely associated with gold-quartz veins. The Porcupine Camp (30a-d), particularly the Hollinger mine, was by far the most important producer. A unique wolframite-quartz greisen deposit, the Fox Group (142) at Great Slave Lake, was mined for a short time for its gold and tungsten content.

APPALACHIAN REGION

Tungsten occurrences in the Appalachian Region are confined to belts of Devonian granitic intrusions of the Acadian Orogeny, which marked the culmination of tectonic activity in the region. Excepting Mount Pleasant (17a), they are in predominantly clastic sedimentary rocks of Ordovician to perhaps Early Devonian age, or rarely in associated granitic intrusions. In Newfoundland, New Brunswick and Quebec, the sediments are associated with volcanic rocks in eugeosynclinal sequences but in southern Nova Scotia they are more shelflike, without volcanic components.

Unlike those of the Cordilleran Region and the Canadian Shield most of the Appalachian deposits are of the fluorite-bearing wolframite-quartz greisen type. They include the only large and potentially important deposits of this class in Canada. The wolframite deposit at Mount Pleasant is associated with a late or postorogenic subvolcanic phase of intrusion, apparently related to an Early Mississippian volcanic complex. The Burnt Hill (18), Square Lake (17) and New Ross (15a) occurrences are associated with muscovite-bearing granite that is either postorogenic or altered by postmagmatic processes.

Most of the scheelite deposits are very small, and virtually all are of the quartz vein type. They are more or less closely associated with granitic intrusions but the Moose River deposits (9), at least, were formed apparently during folding of the sediments and possibly prior to granitic intrusion. They are typically saddle-reef veins, like the gold deposits with which they are closely associated.

Newfoundland

The only documented tungsten deposits of Newfoundland are in the (broadly defined) "Central Mobile Belt" of mainly Ordovician to Lower Devonian sedimentary and volcanic rocks and metamorphic equivalents, intruded by mainly Devonian granite. The belt is symmetrical, bounded on the northwest and southeast by Precambrian rocks and overlying lower Paleozoic shelf deposits (Williams, 1964). The Gander Bay occurrence (1,2) is apparently a typical quartz-scheelite vein of no commercial importance. The Grey River deposit (3,4) is a typical fluorite-rich wolframite-quartz greisen vein deposit, and is one of the few of its class in Canada that are potentially important. Tungsten occurrences shown on Fogwill's (1965) map of Newfoundland mineral occurrences are unconfirmed (Fogwill, personal communication). According to E. Swanson, American Smelting and Refining, Ltd., Buchans (personal communication), small scheelite occurrences are known in the large belt of Ordovician-Devonian rocks north of Grey River, but no other wolframite deposit is known. In view of the geological environment and the presence of beryllium, molybdenum, fluorite and base metal deposits, it would be remarkable if there were not many more tungsten occurrences.

Grey River

The Grey River deposit (3,4) is one of the largest typical wolframite deposits in Canada. The property, just north of the Grey River settlement on the south coast, is held by American Smelting and Refining, Ltd., under the management of the Buchans Unit. A linear zone of quartz veins more than 1525 m long has been explored by surface trenching and drilling, and by a drift more than 1525 m long about 244 m below surface with 25 raises of various lengths above the adit. The central portion of the surface showings, about 610 m long, was estimated to contain about 1 per cent of WO_3 over a 0.9 m width (Northern Miner, Jan. 29, 1966). Results from underground work have not been published but, from the above figures, potential ore above the adit might amount to about 0.45 Mt.

Geology

The deposit (Fig. 4) is in an isolated assemblage of presumably Ordovician or Silurian metamorphic rocks and intruding granite. The regional geology has been described by Riley (1959), and the local geology by Bahyrycz (1957) and Gray (1958). The bedded rocks, considered metasedimentary except for a few lenses of metavolcanic(?) rocks outside the area of Figure 4, are mainly amphibolite and hornblende-plagioclase-quartz schist and gneiss, mica schist and gneiss, and impure quartzite and quartz-feldspar paragneiss (Nos. 1, 2 and 3, respectively, in Fig. 4). Gradations exist between these categories. Calcareous shale and calcite schist outcrop in a band 9 to 21 m wide along the northwest shore of Long Pond. The quartz content ranges from less than 10 per cent in massive amphibolite to 35 per cent in banded amphibolite. Biotite makes up 5 to 10 per cent of micaceous amphibolite. Muscovite, apatite, magnetite and sphene are common accessories. Mica schist and gneiss are composed essentially of quartz, biotite and muscovite, with rare amphibole and garnet. The quartzitic rocks contain 75 to 90 per cent quartz, with minor muscovite and biotite, and less than 3 per cent albite and oligoclase. The metamorphic grade is generally in the albite-epidote-amphibolite range. As contact effects are not mentioned, the grade is apparently quite uniform and the metamorphism regional in character.

Granitic rocks, as mapped, extend about 24 km north of the contact, 48 km east, and 80 km west of Grey River. Much of this is paragneiss (F. Anderson, personal communication). In the immediate area they include massive, porphyritic, gneissic and crushed varieties. They contain K-feldspar, quartz, albite-oligoclase and biotite, with accessory muscovite, apatite, sphene and magnetite. Pegmatites, both concordant and discordant, are widespread in the metasedimentary rocks. Apparently muscovite is the only mica and amounts to about 12 per cent. Accessories include rutile, magnetite, garnet and fluorite. Pink and grey varieties cut one another, according to Bahyrycz, but according to Gray the grey pegmatites are younger and are slightly mineralized. One is traceable into a wolframite veinlet, and beryl is mentioned in this context.

The bedded rocks strike uniformly east-west parallel to the foliation, and dip steeply to moderately north for the most part. Faults make up three prominent sets: an east-west set parallel to schistosity, a southeasterly striking set, and a north to northeasterly striking set. Faults of the last set, apparently tension fractures, are commonly occupied by quartz veins, including the wolframite-bearing ones. In addition, a strongly arcuate set is prominent in the granite area.

Mineralization

Wolframite-bearing veins are confined to a limited zone, mainly in the metamorphic rocks but partly in the granite (Fig. 4). The zone contains more than 300 veins and lenses, as mapped on the surface. The principal vein is 0.6 to 4.3 m wide, averaging 0.9 to 1.2 m, and possibly 760 m long. The average dip is about 85° west. The large veins have a laminated structure, with a sheeted and slickensided northwest contact and vugs throughout (Gray, 1958). Coarse muscovite often forms a layer at the vein contact; molybdenite is commonly intergrown with the mica; and fluorite, pyrite and some scheelite occur in silicified wall rock near the vein (Bahyrycz, 1957).

After quartz and mica, the main vein constituents are pyrite, wolframite and fluorite. In the main adit, wolframite appeared to me to be much scarcer than pyrite, which is coarse and plentiful, and scarcer than fluorite, which is quite conspicuous. The wolframite I saw was in small crystals, randomly oriented and apparently randomly distributed in the vein (Plate 1). Some may be concealed amongst pyrite, much of which is coated with dark brown oxidation products. A little copper stain was seen in places. Fluorite appears bluish purple underground but looks green in sunlight. It occurs in scattered patches 2.5 cm or so across, and in definite streaks or veinlets near the middle of the vein in the vicinity of some raises. The vein has a ribbon structure, because bands of quartz alternate with thin layers of dark country rock material, which suggests a composite origin or repeated dilation of the vein fracture. It winds somewhat, and swells and pinches out in places. Gouge appears to border the vein only locally. Near the portal the gneiss appears muscovitic and is cut by irregular and ptygmatic small veins and pegmatites.

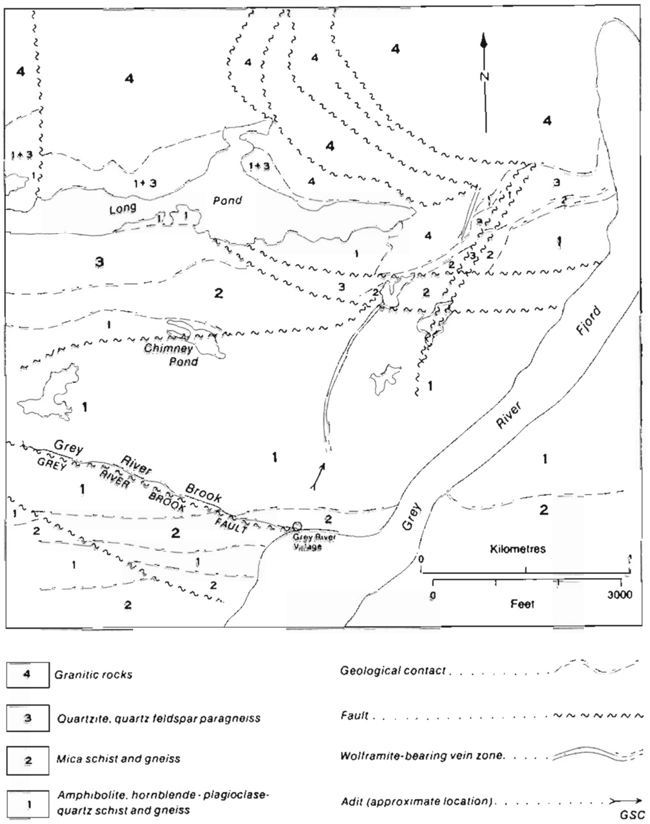


***Figure 4**. Grey River tungsten deposit, Newfoundland. (Geology after Bahyrycz, 1957, simplified.)*

Among other vein minerals reported in small amounts are molybdenite, scheelite, apatite, beryl, chalcopyrite, stibnite, sphalerite and galena. Molybdenite in the vein is associated mainly with mica near the vein contacts. It apparently is most abundant in the north (granite) area, and is more widely distributed in the area than tungsten. Scheelite is rare; some replaces wolframite along surfaces and cleavage planes (Plate 1). Some primary scheelite was reported in vugs in smaller veins. Beryl, like molybdenite, is associated with mica. Gray (1958) reported it "only in the south end of the vein, in crystals rarely 2½ inches long and ¼ inch across, associated with glassy quartz and large plates of white mica." I did not see it and it is apparently very scarce, judging from the analyses listed below. Chalcopyrite is sporadic and generally scarce in the main vein, but amounts to 1 to 3 per cent in the northern section at the surface (Bahyrycz, 1957) and is usually the most prominent ore mineral in the granite section (Gray, 1958). A little stibnite is present in the principal vein; it is more abundant in veins farther west (Chimney Gully Veins) but is not in the granite area. Some bismuth minerals occur, mainly with galena and scheelite (ibid.).

The deposits were found during a search for tin, as tin-bearing float had been reported from the area and tin was reported in "small amount" in the veins. It is apparently very

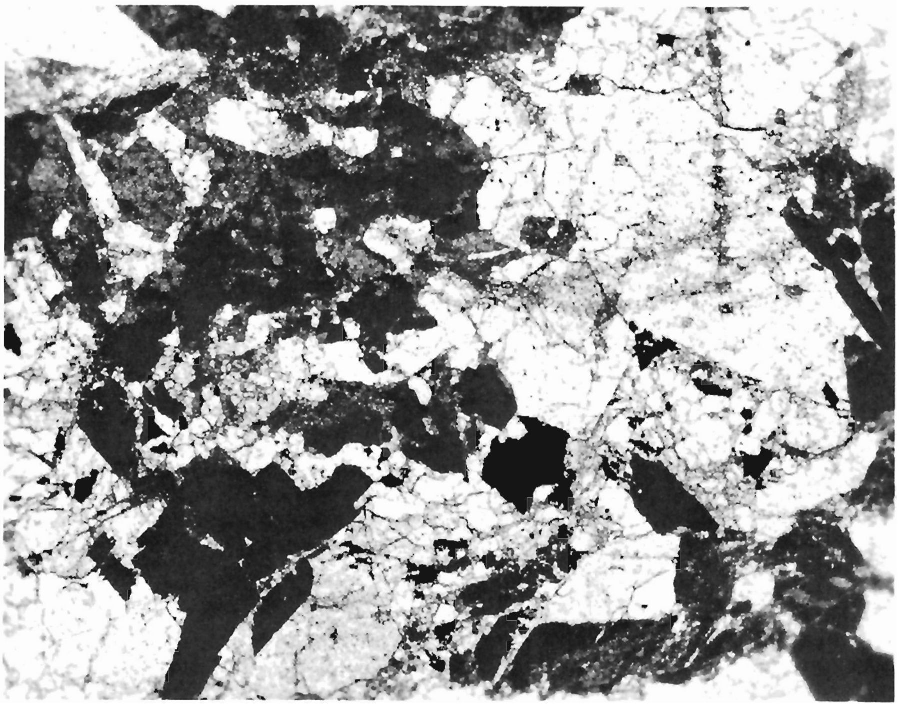


Plate 1

Thin section of wolframite-scheelite ore, Grey River (3), showing wolframite (black) veined and partly replaced by scheelite (grey) in quartz matrix with minor fluorite. (Plain light, X15; GSC 201964-T)

scarce, at least in the part traversed by the adit, judging from the following analyses of three composite samples that I took along the drift:

Sn	Be	Mo	Li	W	K	F
(ppm)				(%)		
31	2	10	16	-	0.4	0.10
10	-	26	16	0.06	0.3	0.25
17	-	31	16	> 0.1	0.3	0.21

Detection limit W 0.05%.

The potassium and lithium levels are appreciable for quartz veins and both they and the tin may be bound in contained mica. Tin may be more abundant in the granite area, which has something of a greisen character, according to Gray's description, but he reported only 20 ppm Sn in wolframite from both areas. Gray (ibid.) also reported 10 to 20 ppm of Sn, together with 2.5 per cent of F and 500 ppm of V in country rock amphibolite. If correct, this implies definitely anomalous tin in the environment, and an extremely high fluorine content. The wolframite in vein 10 (main vein) contains 26.3 per cent of $MnWO_4$ and the wolframite in vein 6 contains 35.4 per cent, according to Gray. It is therefore closer to ferberite than to huebnerite.

A zonal distribution of metals in the area was suggested by Bahyrycz (1957) but is not well defined. Gray pointed out that lead and zinc are more abundant north and south of the tungsten zone, that copper is most abundant in and near the granite area, and that stibnite occurs in veins some distance to the west.

Nova Scotia

The widespread tungsten occurrences of Nova Scotia include wolframite-bearing quartz greisen veins closely associated with muscovitic granite in the New Ross area (15a), and many quartz-scheelite veins. The latter are similar to and generally near or amongst gold-quartz veins of the saddle-reef type. Minor amounts of scheelite have been produced from some of these, especially the Moose River "Scheelite Mine" (9, see below) and the Indian Path mine (16).

The quartz-scheelite veins appear to be only casually related to granitic rocks. They apparently formed as the sediments were folding (Malcolm, 1976; Miller, 1974) and perhaps before granite intruded, but probably not before regional low-grade metamorphism that preceded intrusion (Taylor and Schiller, 1966). In the opinion of Miller et al. (1976), metamorphic pore fluids transported tungsten and other vein metals from the sediments into the veins.

The muscovite-bearing granite with which wolframite and cassiterite are associated in the New Ross area (15a) is high in lithium (av. 149 ppm), tin (av. 26 ppm) and fluorine (0.09%), and somewhat above average in tungsten (2-10 ppm), according to my analyses. Muscovitic granites at Purcells Cove and west of Melrose are also anomalous in lithium, tin and fluorine but not in tungsten, whereas biotite granite about 40 km west of New Ross is moderately enriched in tungsten (4-8 ppm).

Moose River Gold District

The "Scheelite Mine" in this district (9), although not important economically, exemplifies the saddle-reef variety of quartz-scheelite vein deposits and contributes to hypotheses for the stratabound origin of some tungsten deposits (Fig. 5).

The property is about 4 km west of the community of Moose River Gold Mines. The extensive old workings are not accessible now, and recent bulldozing has obscured most of the outcropping veins. The geology of the property was described by Faribeault (in Messervey, 1931), as follows:

> [The property] extends east of the Stillwater Brook about 750 feet, and west of the Stillwater Brook about 300 feet, and north and south across the formation about 200 feet.

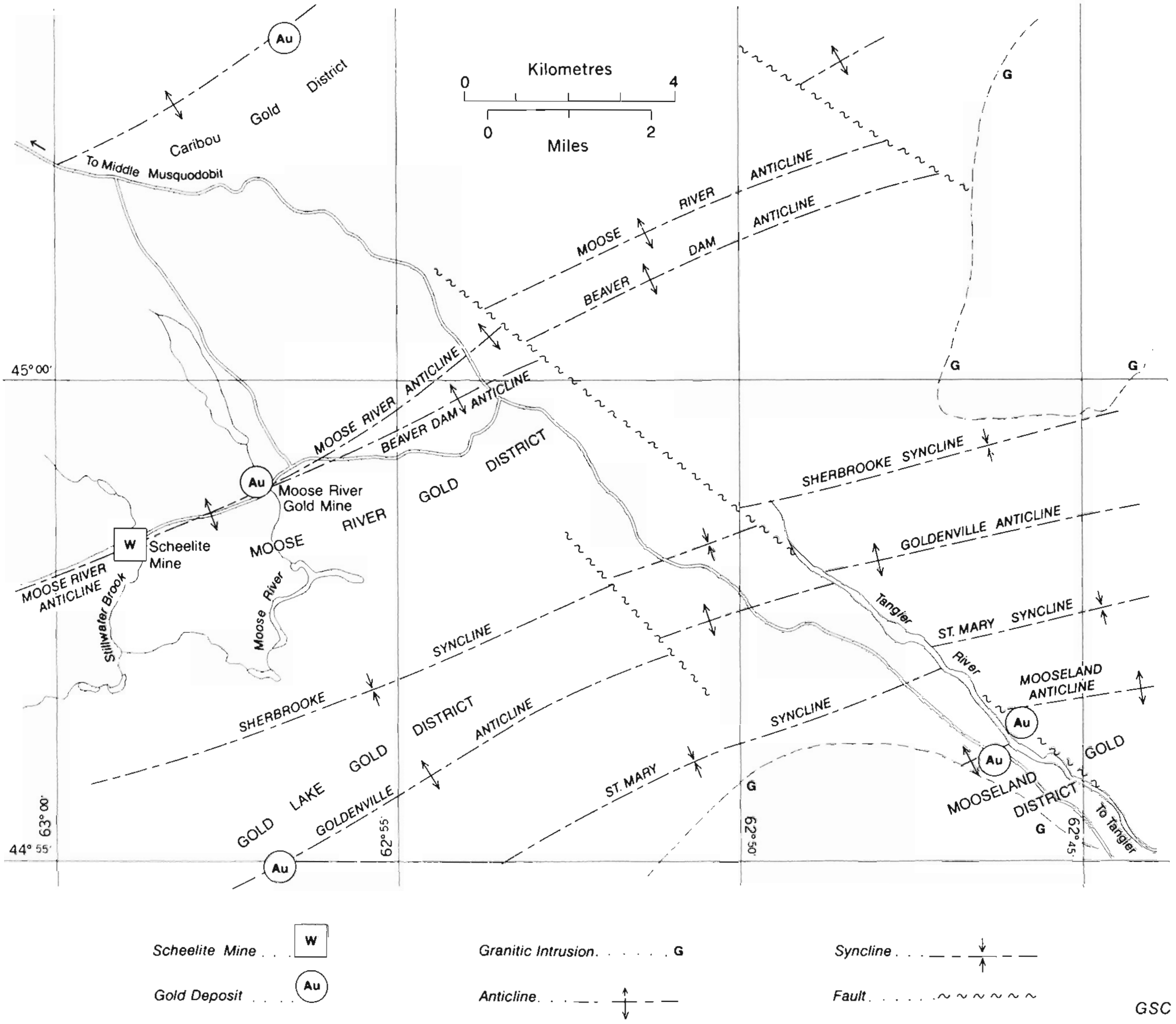


Figure 5. *Geological setting of Moose River "Scheelite Mine", Nova Scotia.*

The veins so far discovered are interbedded veins and coincide with the bedding planes and occur in thin layers of slate interstratified with beds of quartzite. Dr. Faribault in the summary report of the Geological Survey Branch of the Department of Mines for the year 1909, referring to this property states:

"The width of the veins vary from the fraction of an inch to 24 inches, but few of them, and this is particularly true of those showing the most scheelite, average more than four inches. They are generally quite uniform in width, though some of them show enlargements and rolls, so common in the gold bearing veins. These rolls plunge westward at low angles, which correspond with the pitch of the anticline, also approximately with the line of intersection of the cleavage and bedding planes, and may indicate, as in the case of gold veins the general pitch of the ore-shoots.

The vein matter consists essentially of quartz, scheelite, and mispickel in varying proportion. The quartz is mostly translucent, white and glassy, and quite different from the gold-bearing veins of the Province. The scheelite is honey yellow to pale reddish brown in colour, is coarsely crystalline, and shows distinct cleavage. It often constitutes a large part of the smaller veins; in some of which it occurs in a series of lenses or rolls. In the larger veins the scheelite is mainly confined to the outer part where it occurs in thin, irregular patches.

The mispickel is always massive and varies very much in quantity in the different veins. In one or two of the veins it is the predominant constituent; but generally it is less abundant than the scheelite, and sometimes is scarcely visible. It also occurs abundantly in the slate adjoining the veins, in very minute well formed crystals commonly surrounded by a narrow zone of white mica with scales at right angles to the surface of the mispickel.

The strata is folded in three main anticlines and two synclines, the distance from the axis of the north anticline to the axis of the south anticline being approximately 600 feet. The axis of the middle anticline has a general east and

> west course, and pitches west at a low angle. A short distance south of the axis of the middle anticline the formation is again folded making a small anticline, the axis of which is distant from the axis of the middle anticline, approximately 40 feet. On the west side of the Stillwater Brook, a horizontal fault has been located causing a displacement of approximately 170 feet. This fault crosses the formation roughly north 45 degrees east."

A conspicuous feature of scheelite-rich specimens that I found on dumps is an abundance of white mica with the optical character of muscovite. Thin scales lie parallel with the ribbon structure of the veins and the long axes of scheelite lenses, giving the ore something of the appearance of greisen. The muscovite was probably formed by low-grade progressive metamorphism of kaolin in argillaceous material incorporated in the veins.

Scheelite is in crystals and polycrystal masses up to 7.5 cm long. It is veined by strained quartz and is believed to be one of the earliest minerals in the veins (Miller, 1974). Ankerite, the main carbonate mineral, is also veined by quartz and, like scheelite, is mostly near the wall rock contacts. Large masses of arsenopyrite locally engulf scheelite (ibid.). Previously mistaken for tourmaline, rutile occurs in needles and clusters in milky quartz, scheelite and carbonate (ibid.).

The scheelite veins are similar structurally to the strongly folded and corrugated but dominantly concordant gold-quartz veins nearby. These locally contain some scheelite. Miller echoed the view of Faribault and other early workers (Malcolm, 1976) that vein formation was essentially contemporaneous with folding and preceded granite emplacement; furthermore, that proximity of the intrusions had no effect on how large or rich the veins were. From fluid inclusion studies, Miller (1974) estimated the temperature of vein formation to be 200° to 300°C. From these considerations, he and Miller et al. (1976) concluded that the tungsten was derived from the sediments, probably via metamorphic pore fluids. The low tungsten content of vein material that I sampled in the Mooseland gold district, close to the granite, and the low lithium and rubidium content of mica-rich samples of the Moose River tungsten deposit suggest that the mineralizing fluid did not originate in the granite. Where exposed along the road to Tangier, the granite is high in lithium (169 ppm) and caesium (17 ppm) but not in other lithophile elements.

New Brunswick Granitic Belts

In addition to the important wolframite-quartz greisen deposits at Mount Pleasant (17a) and Burnt Hill (18, see below), wolframite occurs in minor amount in quartz greisen veins at Square Lake (17), and minor scheelite in skarns adjoining the Nicholas Denys stock in the Bathurst area (18a).

The Mount Pleasant deposit is emplaced in probably Early Carboniferous volcanics associated with late-magmatic hypabyssal granite. It is on a line of muscovitic granite stocks just north of the southern granitic belt and probably is slightly younger. These satellites have various rhyolitic and porphyritic phases, and locally muscovitic and altered zones that are generally enriched in tin and occasionally in molybdenum but not tungsten. The Square Lake greisen veins lie within the main granite mass but may be significantly younger.

The Burnt Hill deposit is on the east flank of the central granite belt and the Nicholas Denys occurrence is at one of the northernmost satellites of that belt. Martin (1970) considered the granite of this belt to be a hypersolvus type, representing mesozonal emplacement, and that of the southern belt to be a subsolvus type, characterized by hypabyssal and volcanic equivalents and the presence of rapakivi granite. In the Burnt Hill area, however, some pegmatite is involved with the older granitoid rocks although not in the late-phase muscovitic granite stocks along the east fringe of the batholithic belt. Beryl in quartz veins is associated with some of these and they are probably hypabyssal.

Mount Pleasant

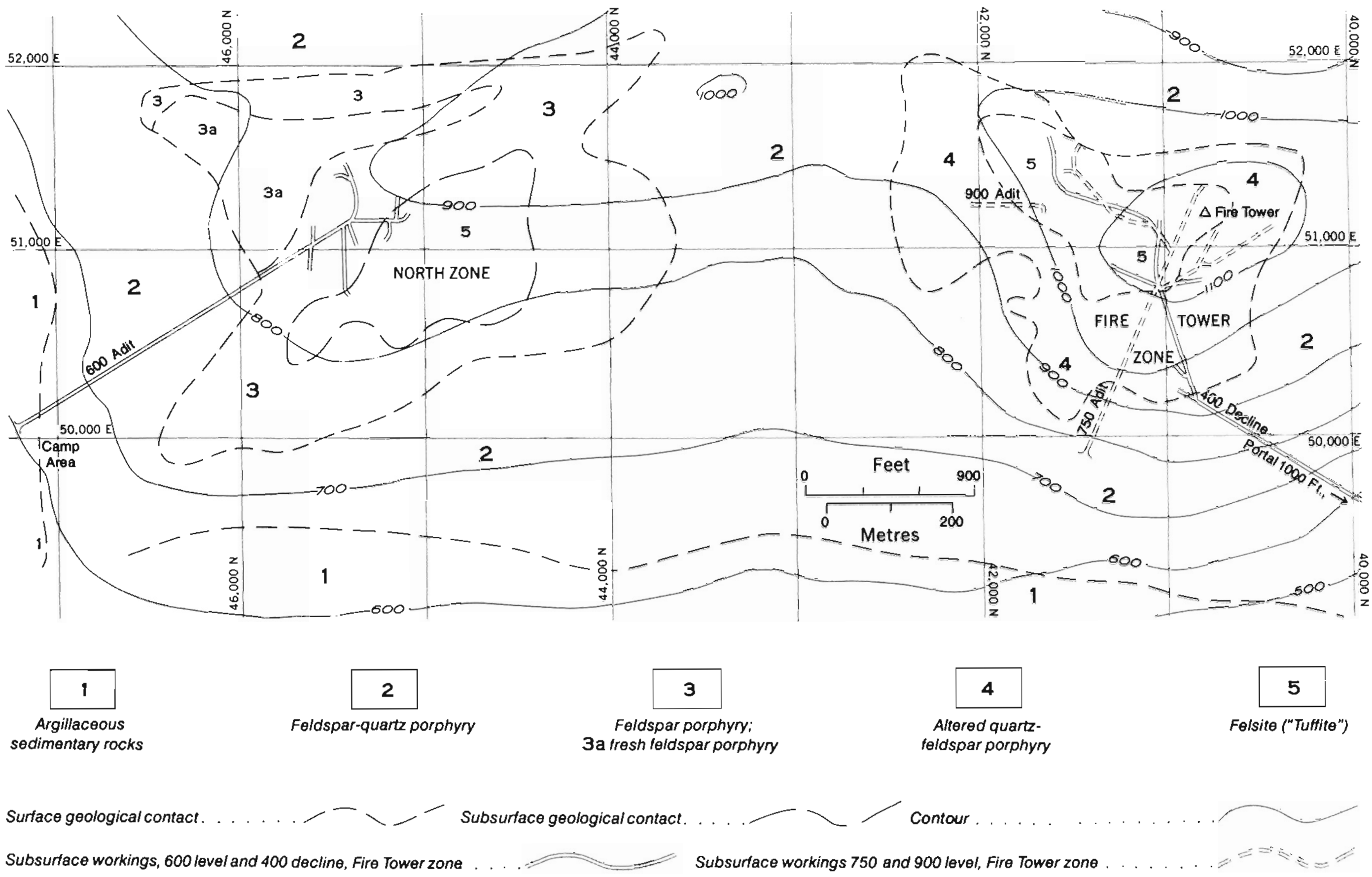
The tungsten-molybdenum-tin base metal deposit of Mount Pleasant (17a), a subvolcanic greisen type, is the largest wolframite deposit in Canada and the largest tungsten deposit in eastern Canada (Fig. 6A). It consists of two orebodies situated on a prominent ridge (Mount Pleasant), which is in Charlotte County, about 63 km south-southwest of Fredericton. The deposit has been explored by several companies since the discovery of geochemical anomalies in 1954 (Riddell, 1962). From 1961 to 1966 Mount Pleasant Mines Ltd. stripped and drilled extensively and drove an adit and exploratory drifts totalling 1464 m to explore tin concentrations in the North Zone. In 1967 Groupe Minière Sullivan, Ltd. acquired control of the property, which was then renamed Brunswick Tin Mines, Ltd.; they continued exploration and development until 1976. They directed the work mainly to the search for tungsten and molybdenum orebodies by drilling and driving three adits in the Fire Tower Zone. One adit 195 m long at 275 m elevation explored the northern part of this zone. Another, totalling 1335 m of workings, explored the central and southern parts at about 230 m elevation. The third, a decline collared at 130 m and totalling 1480 m of workings, confirmed the indicated depth extension of ore zones and provided bulk samples for metallurgical tests. The underground workings are shown in Figure 6A. Total drilling, including some in the North Zone, amounted to 74 290 m from surface and 28 542 m from underground stations (Parrish and Tully, 1977).

General Geology

The areal geology has been described by Tupper (1959), Van de Poll (1967), Ruitenberg (1967) and others. The main property descriptions are by Black (1961), Riddell (1962), Hosking (1963), Ruitenberg (1963, 1967), Dagger (1972) and Parrish and Tully (1971, 1977). The main mineralogical descriptions are by Petruk (1964, 1973) and Parrish (1977). Data regarding tin mineralization are summarized in Mulligan (1975).

The property lies near the western margin of a basin of acid volcanic rocks, which overlie lower Paleozoic sedimentary rocks to the west and are overlain by Mississippian redbeds and Pennsylvanian sandstones to the north. According to Tupper (1959), the volcanic rocks overlie the Devonian granitic rocks to the south unconformably, and according to Ruitenberg (1967), equivalent dykes cut the granite.

The volcanic rocks of the basin have been grouped by Van de Poll into the Rothea Formation and the Seelys Formation, which are separated by a disconformity. Both are dominantly extrusive pyroclastic quartz-feldspar porphyries but feldspar porphyry overlies quartz-feldspar porphyry in the Rothea Formation. Near Mount Pleasant similar porphyries, which Ruitenberg correlated with the Rothea and Seelys formations, have dominantly intrusive relationships although flow structures are locally distinguishable in the quartz-feldspar unit (unit 2, Fig. 6A). The Mississippian volcanic pile is more than 457 m thick on the east flank of Mount Pleasant (Parrish and Tully, 1977). The component porphyries surround felsite plugs in the north and south zones. These were mapped as "Seelys Formation" by Ruitenberg (1967) and



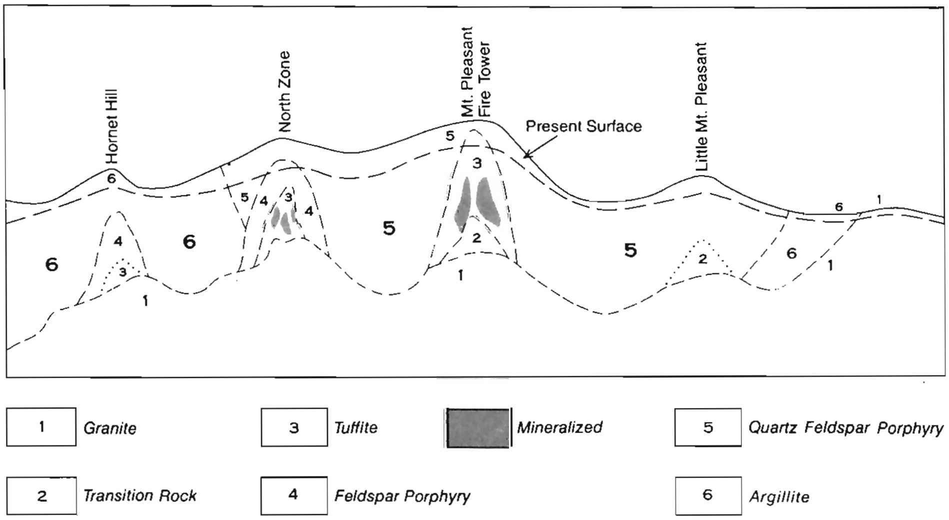


Figure 6A *(above)*

Geology plan, Mount Pleasant tungsten deposit, New Brunswick.

Figure 6B

Diagrammatic vertical section through North and Fire Tower zones, Mount Pleasant tungsten deposit, New Brunswick (after Parrish and Tully, 1977).

thought to represent volcanic necks. They grade downward into microgranite and were considered as hypabyssal intrusions by Parrish and Tully (1977 and personal communication). They are the main host rocks for tungsten and molybdenum mineralization and are intimately related to tin concentrations in both the North and the Fire Tower zones.

Description of Rock Units

Figure 6A is based on a surface geological map by J. Tully. Underground workings are superimposed. Also shown (after Parrish and Tully, 1971) is the felsite body in the North Zone (unit 5). There is some question of whether it outcrops or not, but it is shown because of its importance to mineralization. Parrish and Tully have emphasized the difficulty of distinguishing the volcanic units.

The argillaceous rocks (unit 1), of early Paleozoic age, are poorly banded and of low metamorphic grade. Contact with the Mississippian volcanic rocks is usually sharp and steep. According to Ruitenberg it is marked by a zone in which brecciated sediments are intruded by porphyry. Feldspar-quartz porphyry (unit 2) is the most extensive in the area. It is typically composed of pink feldspar phenocrysts about 0.5 cm long and smaller quartz eyes, in an aphanitic groundmass. It is generally altered, especially near the felsite plugs where it is commonly brecciated and locally mineralized. Feldspar porphyry (unit 3), which was described as latite or latite porphyry by Ruitenberg and by Dagger (1972), occupies a large area in the North Zone, where it is in gradational contact with quartz-feldspar porphyry. Near the mineralized zone the rock becomes progressively altered (unit 4), and light-coloured completely silicified phases alternate irregularly with green chloritic rocks in which the feldspar crystals have been destroyed, leaving small vugs. The vugs are lined with small quartz crystals and contain fine sericite, kaolin or chlorite and locally fluorite, arsenopyrite, sphalerite and cassiterite.

The term 'felsite', as applied here to the central plugs of the North and Fire Tower zones (unit 5), is one of the preferred alternatives to 'tuffite' listed by Parrish and Tully (1971). Felsite also forms the core of a feldspar porphyry body beneath Hornet Hill, about 1000 m north of the North Zone. The related "Transition Rock" forms a cusp beneath Little Mount Pleasant, about 1890 m south of the Fire Tower Zone (Parrish and Tully, 1977, Fig. 7). The felsite (Plate 2A) is a variegated rock, generally mottled or banded in light pink but varying to dark green or black where chloritized. It locally contains small feldspar phenocrysts and quartz eyes and is apparently of rhyolitic composition though much altered and silicified. The felsite is usually brecciated, especially in contact with other units, and it contains pipelike and dykelike bodies of similar rock locally cutting one another. Similar bodies occur in the surrounding porphyries. Downward, the unit passes through a "Transition Rock" into microgranite. Relatively unaltered, the transition rock appears more crystalline than typical felsite, but the contact is indefinite. The relationships of the units are depicted in Figure 6B (after Parrish and Tully, ibid., Fig. 7). Wherever holes have probed deep enough, microgranite has been found to underlie felsite. It is a fine crystalline aggregate of quartz and feldspar with about 10 per cent of biotite. It is thought to be related to the granitic plutons in the zone extending westward north of the St. George Batholith, and to be the source of the ore-forming solutions.

Structure

The northeast-trending fault passing near Mount Pleasant, as mapped by Ruitenberg (1967, 1968), has not been recognized in later work (Parrish and Tully, 1977). However, the alignment of felsite bodies from Little Mount Pleasant to Hornet Hill suggests some fundamental structural control. Ruitenberg also postulated a set of northeasterly trending fractures as a control of felsite dykes and tin lodes, especially in the North Zone. However, fracture patterns in the area are extremely complex and the way they relate to mineralization is obscure.

Breccias, apart from those in the felsite plugs, make up much of units 3 and 4 near the mineralized areas. They consist of angular to rounded fragments, chiefly of the porphyry units, in a matrix of finely comminuted material. They commonly have dykelike or pipelike forms and appear to be the locus of most intense alteration and mineralization. Some in the North Zone consist dominantly of kaolin, and have abundant fluorite along the walls and locally high tin concentrations. Breccias at Mount Pleasant were the subject of a thesis by Tait (1964).

Metasomatic Alteration

Silicification and chloritization are widespread in all the rocks of the North and Fire Tower zones. According to Parrish and Tully (1977), chloritization dominates outside the silicified area and silicification is strongest near and within the felsite plugs, where it is strongest above the ore and decreases sharply below the ore. Hematite appears as a halo about 100 metres from the plugs. Sericitic alteration in the vicinity of the plugs may be related to local potassic feldspar replacement in deep zones of the felsite bodies (Dagger, 1972).

More local alteration, chiefly associated with mineralization and characteristic of greisenization, has resulted in deposition of abundant fluorite and topaz. Topaz is especially conspicuous in the 600 adit where the North Zone is most enriched with tin. Kaolin, a common retrograde product of greisenization, is found throughout the ore zones and in dykelike and pipelike bodies especially in the North Zone.

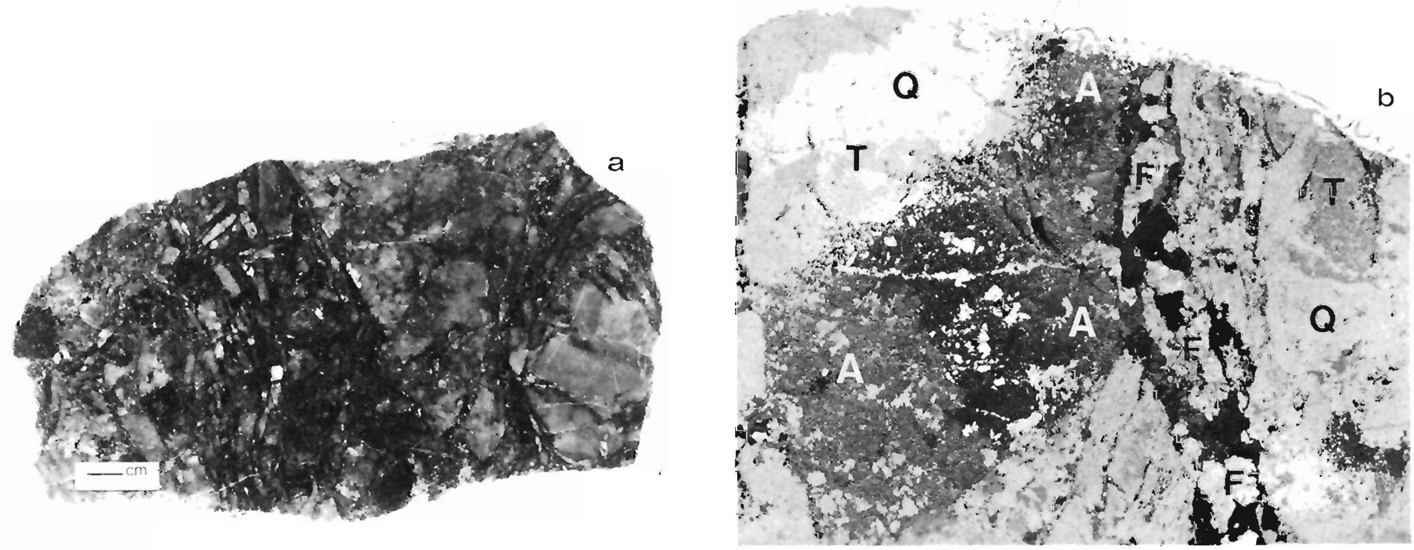


Plate 2. Felsite and ore from Mount Pleasant (17a). (a) Polished slab of felsite ore showing brecciation and arsenopyrite-wolframite-fluorite veinlets. (b) Thin section of a wolframite-fluorite veinlet in 2, showing wolframite (black) interspersed with fluorite (F). The dark grey area to the left is mostly arsenopyrite (A), light grey patches are topaz rock (T), and the remainder is mainly fine-grained quartz. (Partly reflected light, X4; (a) GSC 201964-D, (b) GSC 201964-Y)

Mineralogy

The mineralogy has been described in detail by Petruk (1964, 1973). The oxides include wolframite, cassiterite and rutile. The main sulphides are arsenopyrite, loellingite, sphalerite, chalcopyrite, galena, molybdenite, pyrite, stannite minerals and bismuth sulphides. Minor gangue minerals include ilmenite, apatite, tourmaline, zircon, columbite-tantalite and rare lepidolite.

Wolframite, which ranges mostly from 1 µm to 1 mm, is rarely visible in hand specimens. In some veinlets in the Fire Tower Zone grains several millimetres across are fairly common (Plate 2B) and aggregates several centimetres across have been found. The FeO content ranges from 12 to 22 per cent, and the MnO content from 1 to 11 per cent (Petruk, 1973). It contains about 77.5 per cent WO_3 and little or no Ti or Sn. Wolframite occurs chiefly in the felsite plugs or in nearby porphyry mainly in the Fire Tower Zone but locally in the North Zone. It is generally associated with molybdenite but more closely with arsenopyrite in wolframite-fluorite veinlets (Plate 2B). Fluorite is abundant in wolframite ore and topaz is common. Bismuth minerals are mostly in wolframite-molybdenite ore. Tungsten is present also in cassiterite, ranging from less than 0.2 to 1.7 per cent of WO_3, and in rutile, which contains up to 9.2 per cent of WO_3 (ibid.). Some scheelite is also present.

Sphalerite is widely distributed in the ore zones and is next in abundance to arsenopyrite, but is more concentrated in upper sulphide zones. Chalcopyrite is scarcer and restricted more to the upper parts of the Fire Tower Zone especially near the south and north contacts of the felsite plug and these contain the main tin concentrations. Galena is a minor component of sphalerite and chalcopyrite veins.

Molybdenite, like wolframite, is widely distributed in the deeper mineralized parts of the Fire Tower Zone. It also occurs at the surface on the north side of the Fire Tower hill and on the west side of the North Zone, both of which also contain tungsten.

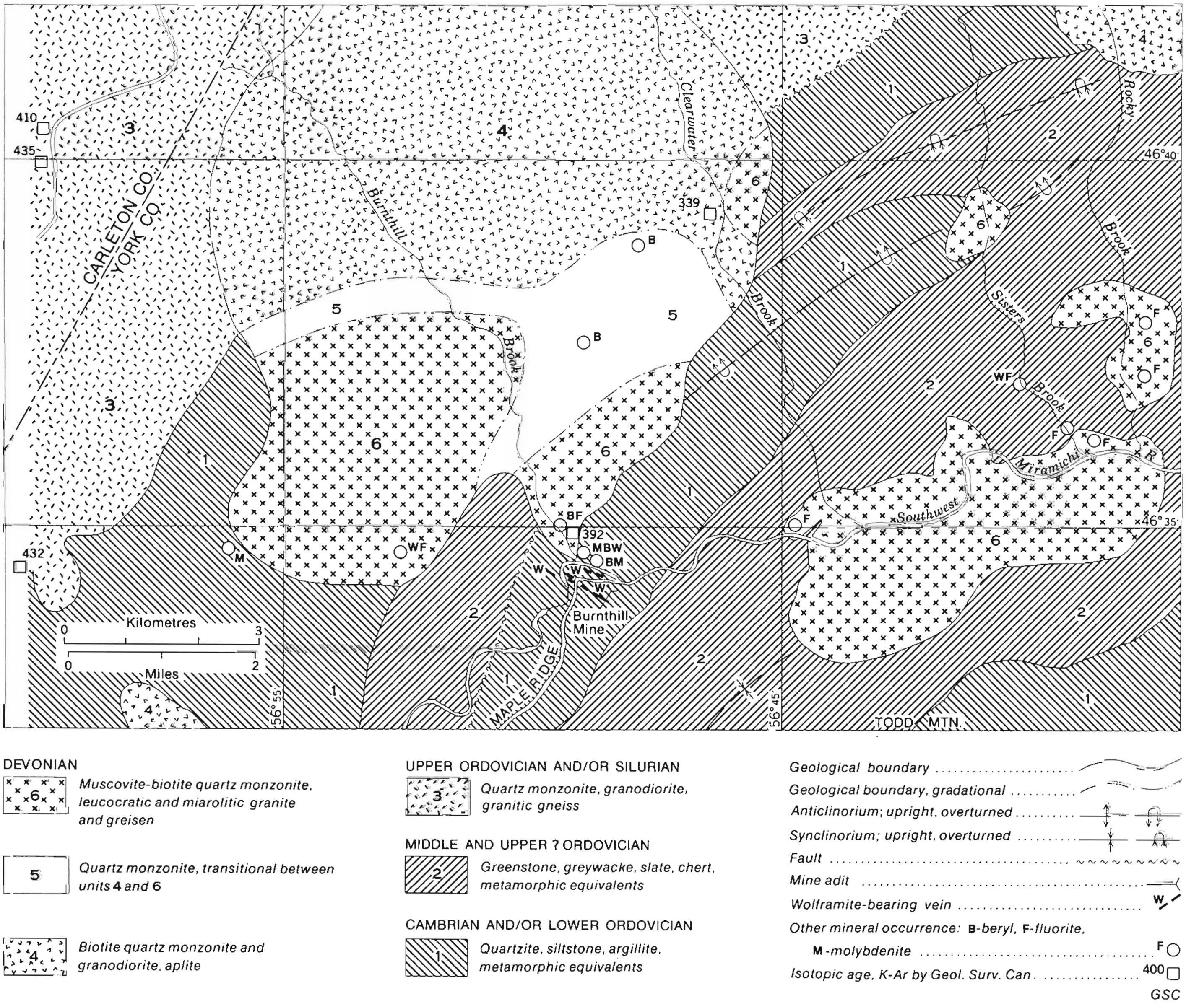


Figure 7. *Geological setting of Burnt Hill tungsten mine.*

Mineralized Zones and Ore Reserves

The largest tungsten concentrations are in and adjacent to the felsite plug in the Fire Tower Zone. Peripheral parts of the felsite plug in the North Zone contain smaller concentrations. The data given below are mainly from Parrish and Tully (1971, 1977).

The Fire Tower tungsten zone, broadly considered, occupies much of the felsite plug from about 275 m above to 60 m below sea level. It contains about 23 Mt of rock grading 0.2 per cent W, 0.1 per cent Mo, 0.1 per cent Bi, and 5 per cent fluorite. Within this broad zone at least two higher grade concentrations have been defined. The "Western Zone", about 150 m long and 60 m wide, extends from -30 m to just above 90 m, and contains 2.7 Mt grading 0.36 per cent tungsten, 0.15 per cent Mo and 0.11 per cent Bi. The "Northeast Zone" is about 365 m long and 12 to 18 m wide and extends from about -30 m to 120 m in elevation. It contains nearly 2.7 Mt grading 0.35 per cent W, 0.14 per cent Mo and 0.12 per cent Bi. Part of this zone is in feldspar-quartz porphyry outside the plug.

In the North Zone, tungsten concentrations form several poorly connected annular bodies, together forming a ring within and subparallel to the boundary of the felsite plug. They contain about 0.2 per cent of W, 0.06 per cent of Mo and 0.09 per cent of Bi, with a little tin.

Metal Zoning

Zonal relationships between tungsten-molybdenite and tin mineralizations, and between tin and base metal mineralizations are well established, although the zones overlap and are telescoped as in most subvolcanic deposits.

Tungsten-molybdenum mineralization is confined mainly to the interior of the felsite plugs and is limited in depth by its proximity to microgranite and transition rock.

Tin mineralization is concentrated mainly in the highly altered and fractured feldspar porphyry of the North Zone, on the north side of the felsite plug, and frequently is related to felsic dykes, which presumably are appendages of the plug. The mineralization is mainly cassiterite and the host rocks have been extensively replaced by fluorite, topaz and kaolinite typical of greisen deposits. Minor stannite is concentrated mainly in base metal sulphide deposits on the fringes of the tin-rich zones. Other tin concentrations are associated with the felsite of the Fire Tower Zone, mainly on the fringes and above the main tungsten-molybdenum zone and mainly in the zones rich in sphalerite and chalcopyrite.

Thus tin and base metal mineralizations are strongly telescoped and their zonal relationship is less distinct than that between tungsten-molybdenum and tin.

Geochemistry of Rocks and Ores

Petruk (1973) reported on the variation in metal content of ore samples. The data show good correlation among tin, copper and zinc but no correlation among tungsten, molybdenum, bismuth or tin.

Dagger (1972) reported on the concentrations of various elements, including molybdenum and tin, in mineralized and unmineralized rocks. Tungsten and bismuth were not detectable by the X-ray fluorescence method used.

Origin of Deposits

The tin and tungsten deposits have the typical mineral associations of greisen deposits, although in a subvolcanic environment. The source of the metals appears to be almost indisputably an underlying granite mass, of which the microgranite-felsite bodies are cupolas.

As tungsten mineralization is disseminated broadly in the 'intrusive' felsite bodies, the term 'porphyry tungsten' is admissible. However, there are pronounced differences from typical porphyry deposits, notably the dominance of fluorine metasomatism, the great predominance of arsenopyrite over iron sulphides, and the subordinate role of molybdenum and copper.

The affiliation of the felsite-microgranite with hypabyssal stocks north of the St. George Batholith was mentioned above (Description of rock units). Radiometric data have tended to support a younger age for these intrusions, and an age of 320 Ma has been determined for the Mount Pleasant felsite (A.A. Ruitenberg, personal communication). However, I understand from J. Tully (personal communication) that there is some doubt about the relative ages of granitic rocks in the area.

Burnt Hill Tungsten Mine

The Burnt Hill area (18) is the best example in Canada of a complex multimetal greisen deposit related to late-stage muscovitic granite. The deposit was known by 1870 and has been mined intermittently on a small scale since at least as early as 1917, when it was described by Young (1917). It also was described by Wright (1940a) and Potter (1969). The property was most recently reactivated about 1967 by Burnt Hill Tungsten Mine, and a considerable amount of exploration and new development has been carried out. The only recorded production was in 1916, when 180 t of ore containing 0.45 per cent of WO_3 were recovered, although some was produced in 1917. A new mill was built in 1953.

At the mine, subparallel fissure veins up to 2 m thick cut slightly schistose slate and quartzite near the southern tip of a body of pink alaskitic muscovite-bearing granite (Fig. 7). The granite extends beneath the mine area at a depth of about 180 m (ibid.). It is one of several similar bodies that are in part younger than but gradational into normal Devonian biotite-quartz monzonite and granodiorite. These Devonian intrusions are bordered on the west by, and are partly gradational into, partly gneissic and cataclastic quartz monzonite of Late Ordovician or Silurian age (Poole, 1960, 1963). The country rock at the mine is not appreciably metamorphosed but argillaceous members change to spotted schist as the granite contact is approached.

The veins form a northwesterly striking system, cutting across the bedding of the sedimentary rocks and paralleling a prominent system of joint planes and granitic dykes in these rocks. Individual veins are as much as 120 m long but they are commonly discontinuous and branching. They probably fill tension fractures. The walls are sharply defined by local silicification and sericitization of the wall rocks, but are generally without the muscovite-rich borders that characterize most greisen veins. However, topaz, another characteristic mineral of greisen deposits, is second in abundance only to quartz in the vein material.

Common vein minerals in addition to quartz, topaz and wolframite, include fluorite and beryl. Beryl, in radiating bursts of fine green needles, is found mainly near the walls. Molybdenite is fairly abundant although much less so than wolframite. Amounts of arsenopyrite, pyrrhotite, pyrite, chalcopyrite, sphalerite and galena are relatively minor. Cassiterite is widespread but scarce, and native bismuth has been identified.

The quartz is milky and generally massive but is in part euhedral. The veins are not distinctly banded but quartz, wolframite and beryl are commonly aligned perpendicular to the walls, and locally give rise to comb structure. Topaz is in crude crystals up to 2.5 cm long, generally in aggregates, and is dull green. Wolframite appears as brownish black tabular crystals up to 10 cm long. Cassiterite occurs sparingly in microscopic grains in wolframite (Victor, 1957, Fig. 7). A composite sample of wolframite was found by spectroscopic analysis to contain 0.03 per cent of tin, probably as inclusions of cassiterite. The minerals are essentially contemporaneous.

Wolframite is seen in veins between the mine area and the granite contact and also in greisen veins within muscovite granite on Burnthill Brook and Sisters Brook (Fig. 7). However, fluorite, molybdenite and beryl are more common in veins in the granites. Strongly anomalous tungsten (12 ppm) was found by colorimetric analysis in only one of five composite samples that I took of these granites. The tungsten-rich sample also contained anomalous beryllium, but all five were distinctly anomalous in tin (6-24 ppm). According to Poole (1963), close spatial relationship of tin and tungsten minerals to granitic rocks (units 5 and 6) and their metamorphic aureoles was confirmed by X-ray fluorescence analysis of treated pan concentrates from many streams in the area.

Potter (1969) reported that the Ordovician sediments of the area contain 4 ppm W, 1 ppm Mo and 2 ppm Sn, and their abundance in the granitic rocks in parts per million is as follows:

	W	Mo	Sn
Clearwater	3	1	20
Burnt Hill	25	14	2
	13	6	10
Mine (drill core)	3	1	2

My findings on the late leucogranites in the Burnt Hill mine area (Fig. 7) accord with these in a general way, except that my sample of mine granite from a deep drill section is strongly enriched in tin and beryllium. These findings confirm the thesis that these late muscovitic granites generally are anomalously high in lithophile elements.

The 4 ppm of tungsten reported by Potter for the Ordovician sediments is at least double the amount for average pelitic and arenaceous rocks. Potter suggested that the tungsten had been incorporated with the sediments in the Devonian orogenic batholith and concentrated into the late-phase differentiates.

Nicholas Denys

Small tungsten- and molybdenum-bearing skarns are associated with the Nicholas Denys granitic stock (18a), which adjoins the "Millstream Break", a fault zone separating the host Silurian sedimentary rocks from the predominantly Ordovician volcanic assemblages to the south. The latter contain tin-bearing massive Pb-Zn-Cu sulphide deposits, of which at least two are near a muscovitic granite stock that contains molybdenite and beryl occurrences. Molybdenite also occurs within the Nicholas Denys stock. No tungsten has been reported in the stock, but two of three composite samples that I took are strongly anomalous (12 and 16 ppm) in tungsten. A sample of porphyry at the Keymet property was found to contain 8 ppm of tungsten. Tungsten is anomalous in sediments of streams draining the area underlain by the Nicholas Denys stock and its aureole, and another stock about 8 km to the north (Boyle et al., 1968).

Quebec Appalachian Belt

Some small scheelite occurrences are associated with Devonian granitic intrusions. These lie in a belt of Silurian and Devonian sedimentary rocks southeast of a belt of Ordovician greenstone and associated rocks. The Ordovician belt contains some massive sulphide deposits and also ultramafic rocks and associated asbestos deposits related to the Ordovician Taconic Orogeny. Mine Hill (20a) is the locality where scheelite was first identified in Canada.

CANADIAN SHIELD

Tungsten is widespread in the Archean Superior and Slave provinces (radiometric age of culminating granitic intrusions about 2500 Ma). It is rare in the younger Churchill Province (1800 Ma) except in a fringe zone along the northwest border of Superior Province. One significant deposit (142) lies approximately at the Churchill-Slave border. The few deposits in the Southern Province, roughly contemporaneous with Churchill Province, include one (27a) of considerable geological significance. In the youngest province, Grenville, only two insignificant occurrences have been reported (21a,b).

Nearly all the occurrences in Superior Province and most of the others are scheelite-bearing quartz veins, very commonly associated with gold, and most of the scheelite produced has been as a byproduct or coproduct of gold production during wartime emergencies. Skarn scheelite occurrences, so far uneconomic, are sparingly represented in part of Slave Province, and the significant occurrence in Southern Province (27a) is a skarn type. The only wolframite-quartz greisen deposit known in the Shield is the Fox Group (142) at the Churchill-Slave border. There also, tungsten was a minor coproduct with gold. Wolframite is, however, a rare accessory at some tin-bearing massive sulphide deposits.

The broad distribution pattern described above corresponds approximately to that of tin and lithium, although tungsten is much more widespread, and the pattern reflects to some degree a worldwide association of metals. The tourmaline in many of the veins, especially where most scheelite has been recovered, further indicates affinity with the lithophile metal environment. The great majority of occurrences are in greenstone belts of residual volcanic or sedimentary rocks, separated by granitoid rocks and gneisses. These greenstone belts may have acted to some degree as repositories of small-cation lithophile metals like tungsten, tin and lithium, rejected and mobilized from granitoid rocks during granitization of the gneissic belts. Further information on the mode of occurrence and associations of tungsten deposits is given under "Superior Province".

Grenville Province

The Addington and Star mines (21a,b) are the only reported tungsten occurrences and are among the very few gold occurrences known in Grenville Province. They were the first gold mines operated in Ontario. It is noteworthy that these veins are tourmaliniferous (see above).

Southern Province

Foster Township, Ontario

This is the only significant occurrence (27a) in Proterozoic (Huronian) rocks and the only typical skarn deposit in the eastern Shield, particularly interesting in its implications for the stratabound origin of some tungsten deposits.

The area comprises northern parts of lots 7, 8 and 9, Concession III, and southern parts of these in Concession IV. It was described by Card (1976), as follows:

> Disseminated tungsten and sulphide mineralization occurs erratically over an area approximately 1,400 feet (430 m) wide and 4,800 feet (1,500 m) long on the faulted north limb of the St. Leonard Anticline. The mineralization occurs mainly in skarns in the Espanola Formation and in sandstone and argillite of the Mississagi Formation. Mineralization occurs near the faults of the St. Leonard System and the intensely altered gabbroic intrusions. Detailed mapping by Texas Gulf Sulphur Company Incorporated has defined six en echelon zones of mineralization which trend northeast-southwest and are generally parallel to the strike of the metasediments. These zones range in width from a few inches (cm) to about 30 feet (9 m) and in length from about 1,200 to 2,500 feet (370 to 760 m).
>
> Mineralization occurs as disseminated grains in the highly altered metasediments, and in quartz veins. Sulphides are generally present in minor (less than 5 percent) amounts, although small pods containing up to 20 percent sulphides occur locally. Minerals recognized include scheelite, powellite, pyrrhotite, pyrite, chalcopyrite, sphalerite, molybdenite, and arsenopyrite which are closely associated with skarn minerals such as idocrase, diopside, wollastonite, and garnet. Scheelite, the dominant tungsten mineral, and powellite, the other tungsten mineral identified, occur as ½ to 2 mm subhedral grains that are disseminated through the rock, and as small veinlets with quartz.
>
> The origin of the mineralization is not known, but there is apparently a close relationship between mineralization, gabbroic intrusion, faulting, and high grade metamorphism. The mineralization is stratabound for the most part, but this is probably caused by hydrothermal introduction of materials into chemically favourable beds. In the Sudbury region, there are several small deposits of scheelite in quartz-carbonate veins associated with Nipissing Diabase. Possibly the Foster Township deposit is of similar origin.

Analyses of chip samples was reported by Card as follows: W trace to 0.38, MoS_2 trace to 0.27, Bi trace to 0.11, Cu 0.01 to 0.29, Sn trace to 0.01, Zn trace to 0.18 per cent; and Ag trace to 0.36 oz./ton.

Composite samples that I took (S-1, S-2, etc., Fig. 8) yielded the following results (GSC Spectrographic Laboratory):

	W	Mo	Be	Sn	
		(%)		(ppm)	
S-1	NF	<0.005	<0.003	4.6	Quartz veins cutting quartzite
S-2	NF	<0.005	<0.003	34.0	Quartz stringers and pyritic argillite
S-3.1	0.7	0.010	0.0029	100.0	Old pit, skarny pyritic quartzite
S-3.2	0.5	0.023	0.029	27.0	
S-4.1	0.5	0.0058	0.0032		
S-4.2	NF	0.012	<0.0003	50.0	

Detection limit 0.05%.

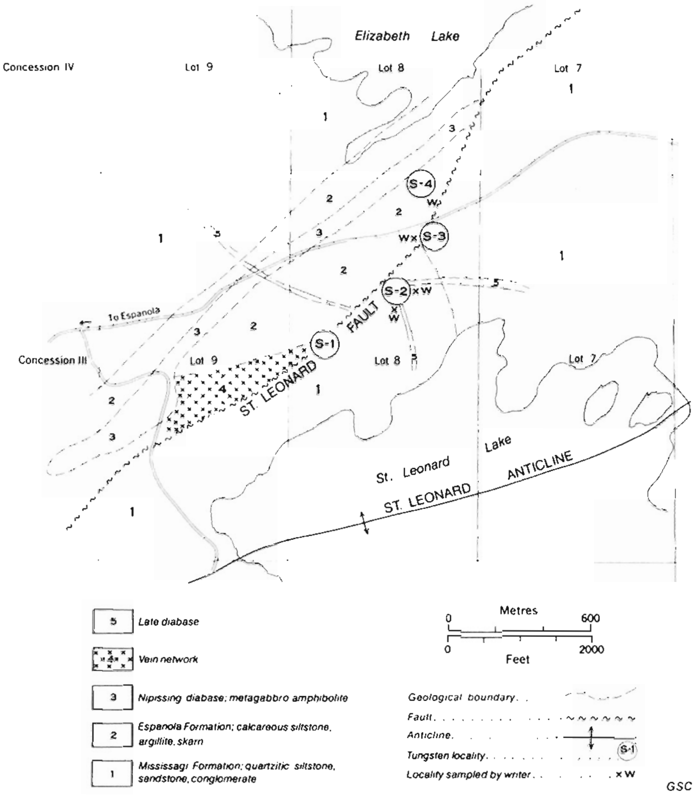


Figure 8. *Tungsten occurrences and geology in Foster Township, Ontario. (Geology after Card, 1968, 1976.)*

At S-1 scheelite was found in only one fragment from the numerous quartz veins cutting light quartzite. At S-2, in an area of old shallow trenches, a little was seen in two or three pieces from the borders of quartz-epidote veins cutting dark argillaceous quartzite with disseminated pyrite. At S-3, at an old pit beside the main road, 'powellite' (more probably molybdian scheelite) and lesser scheelite were quite abundant in pyritic garnetiferous skarny quartzite. At S-4, north of the road, 'powellite' and some scheelite were found in concordant skarn bands a few centimetres thick amongst dark argillaceous quartzite, also in a quartz vein (S-4.2), which occupies a small crossfault. Pyrrhotite is prominent in these skarns. This locality is fairly close to a mapped gabbroic intrusion.

In thin sections, the skarns were seen to consist chiefly of minerals of the zoisite-clinozoisite-epidote group, some diopsidic pyroxene, and garnet. There appears to be both zoisite and clinozoisite. Pinkish garnet forms subhedral grains full of inclusions of these minerals and of quartz, and most garnet is in formless shreds amongst these. Quartz is abundant. In one section that contained abundant pyrrhotite and iron-stain, quartz is pierced by numerous unidentified fine needles. No idocrase, feldspar or carbonate were seen. The original rock was evidently rich in quartz.

Since the nearest exposed granitic rock, the post-Huronian Killarney granite, is 29 km southeast, attributing the skarn formation to the nearby mafic intrusions seems logical. The tungsten mineralization might have originated in these but, as it does not seem to be closely related to them spatially, it was more probably remobilized from the bedded rocks and concentrated locally in the skarn bands, and occasionally in quartz veins. In this sense, this could properly be termed a stratabound deposit. Another possibility --- that a granitic intrusion lies beneath --- is suggested though not proved by the fairly high molybdenum, moderate tin and decidedly anomalous beryllium content of some samples.

Superior Province

Most tungsten occurrences in Superior Province are scheelite-bearing quartz veins in or near gold-quartz vein deposits. Of these, the Hollinger (30c) and nearby mines of the Porcupine Camp (30a-d, see below) are probably the best representatives as well as the largest. Pegmatitic feldspathic quartz veins with feldspar and other pegmatitic minerals are characteristic of the Val d'Or area (25d, e, g). Virtually all the occurrences are in or near the greenstone belts, although in some areas they are in sedimentary components and a few are in intrusive rocks.

Although information on many deposits is very scarce, some idea of their main characteristics can be gained from a rough count of specific features in different areas:

1. The majority of deposits are in volcanic rocks, mainly andesite or basalt. Iron formation is commonly a host in sedimentary rocks and occasionally in predominantly volcanic rock.
2. Porphyry, usually quartz-feldspar porphyry, is prominent in many areas, especially in the Porcupine district.
3. Carbonate, usually ankerite, is an important vein constituent in some areas, notably Porcupine and probably is in many more where it has not been specifically mentioned.
4. Tourmaline is common and is especially characteristic of the Porcupine and Val d'Or area occurrences.
5. Arsenopyrite is recorded at many localities and is probably at many others.
6. Molybdenum is a minor accessory in several places.

A spatial association with ultramafic rocks and diorite or gabbro also may be significant. This may follow from the association with gold but most tungsten-gold occurrences are in mafic volcanic rocks, whereas tin-bearing zinc-copper massive sulphide deposits are associated with rhyolitic phases of volcanic cycles.

An antipathetic relationship between scheelite and gold in specific veins frequently is mentioned; furthermore, scheelite is generally considered older than gold in veins where they occur together. Actually, the association with gold may be due partly to the more intensive and wider search for gold and the greater attention paid to gold occurrences.

Val d'Or Area, Quebec

The Canadian Malartic mine (25d), East Malartic mine (25d) and Lacorne mine (25g) are pegmatitic quartz veins characterized by feldspar, muscovite, tourmaline, molybdenite and beryl. The Lacorne mine, a definitely pegmatitic type, was the only important Canadian producer of molybdenum from 1944 until about 1963. Beryl was recovered for a short time. Scheelite was a minor accessory. The deposit is at the west contact of the Lacorne batholith, a late-phase muscovite-biotite granite to which numerous lithium and beryllium pegmatites and other molybdenum occurrences are related.

At Canadian Malartic the pegmatitic veins contain albite, mica, tourmaline, fluorite, scheelite, molybdenite and other sulphides. They cut a porphyry body and also replacement bodies of sulphides and gold in greywacke, and pass locally into ordinary quartz veins. At nearby East Malartic, similar pegmatitic veins with tourmaline, beryl, scheelite and other minerals traverse the sheared and silicified gold-bearing zones in volcanic and intrusive rock. These deposits are just south of the main Cadillac-Malartic Break. Syenite porphyry and diorite intrusions are common in the area. Several other beryl occurrences nearby are known. Small shipments of scheelite were made in 1942 from Canadian Malartic and other mines in the district.

Opemiska Mine, Chibougamau Area, Quebec

The Opemiska mine (26) is mainly a copper deposit, though gold and silver are important there. Several major quartz-chalcopyrite veins transect mainly gabbroid parts of a layered ultramafic complex that was folded with the enclosing volcanic rocks. Amounts of scheelite and molybdenite are significant, and the mineralization is thought to be related to the Opemiska Lake granodiorite pluton (McMillan, 1972). According to McMillan (personal communication), about 8 per cent of tungsten and 0.12 per cent of tin were found in a composite bulk sample.

Timmins Area, Ontario

Porcupine Camp

The Porcupine Camp (30a-d; Fig. 9) has been a major producer of gold since 1910. Production mainly from the Hollinger, McIntyre, Porcupine and Dome mines (Bright, 1972a, Fig. 17) was valued at $1.58 billion by the end of 1965. The camp has also been the largest producer of tungsten in the Shield, the great bulk having been recovered from the Hollinger mine during World War II. Traces of wolframite have been reported at the Kidd Creek mine nearby (30e, see below) and a scheelite-bearing vein occurs near the Kam Kotia mine (30f).

These properties are all in the "North Timmins Block", the part of the Abitibi volcanic-sedimentary greenstone belt lying north of the Destor-Porcupine Break, which is a major regional fault zone. This fault-bounded block contains the thickest and most felsic-rich parts of the Abitibi belt. The gold and associated tungsten deposits are in mainly mafic volcanic rocks a short distance north of the Destor-Porcupine Break. Iron formation is abundant in the volcanic rocks south of the break but not in the mine belt.

Together with interbedded felsic volcanic and sedimentary rocks, these rocks have been deformed into a series of complex plunging folds, intruded by mafic-ultramafic rocks and quartz-feldspar porphyries. The porphyry forms stocks and dykes, mostly in the western part of the gold belt. Their distribution and relative size closely parallel that of the tungsten producers and most of the scheelite-producing veins are in or adjoining the porphyry.

The porphyries, including nonporphyritic alaskite phases, are mostly grey, weathering to pink or buff. Dark carbonaceous varieties are generally along strike from beds of carbonaceous argillite. The phenocrysts are quartz and albite or oligoclase in a groundmass of the same minerals, with local small amounts of biotite, chlorite, amphibole, sericite, tourmaline, apatite, carbon, carbonate, scheelite and pyrite. Chemically they are equivalent to granodiorite, though most of the potassium is assumed to occur as sericite (Ferguson, 1968). According to Bright (1972a,b), subvolcanic quartz-feldspar porphyry bodies intrude volcanic strata, particularly near felsic pyroclastic accumulations, and the stocks may be intrusive equivalents of the Krist felsic tuff. However, some appear to postdate Temiskaming sedimentation, and would then be the first expression of Temiskaming igneous activity (Ferguson, 1968). Albitite dykes cut the porphyry in the Hollinger and McIntyre mines.

The gold-quartz veins of the camp characteristically contain ankerite, tourmaline, minor albite and sulphide minerals, with or without scheelite. Molybdenite and rutile have been reported from Porcupine Paymaster. Stratigraphic control of gold mineralization is suggested by the close association of ore with certain horizons. However, Ferguson (ibid.) noted that in the Hollinger-Coniarium section the plunge of the porphyries generally conforms to the plunge of the folds, so that the porphyries and the wallrocks tend to maintain a similar relationship along the plunge of the structure. Hence he inferred that the relationship to stratigraphy might be fortuitous.

The detailed relationship of scheelite to gold and other minerals and to porphyry bodies has been described only at the Hollinger mine by Allen and Folinsbee (1944), from whose description the following has been condensed.

At Hollinger (Fig. 9) the main ore zone is a highly altered area about 1525 m long and 365 m wide along the axis of an easterly plunging anticline. The Pearl Lake and Millerton porphyries are elliptical pipelike bodies intruded along the axis and extending at least 1220 m in depth. The porphyry outlines shown in Figure 9 are on an intermediate level and all major scheelite occurrences are projected along the pitch of the porphyry onto this plane.

Scheelite and gold show a semblance of zoning around the porphyries. In the veins most of the scheelite, but only a little gold, occurs within or at porphyry contacts. Scheelite is rare more than 150 m from contacts, whereas gold increases outside the porphyry and extends much farther. The scheelite is practically pure, containing no molybdenum or copper and only traces of iron.

Some differences are apparent between scheelite-bearing veins associated with the Millerton and Pearl Lake porphyries. The former are quartz-ankerite veins in which scheelite was one of the first minerals to crystallize. Probably later, more quartz and ankerite were introduced together with sparse sulphides and gold. The sandy-coloured scheelite is in continuous leads or in lenses up to 3 m long. It is coarse and fairly well crystallized. No replacement of scheelite took place. In the veins associated with the Pearl Lake porphyry, tourmaline is abundant. Scheelite is disseminated and is bright orange or reddish. Albite-oligoclase feldspar is common. Scheelite and apatite were followed and replaced in varying degrees by tourmaline. More quartz, and ankerite, pyrite and gold were introduced after fracturing. Gold occurs sometimes in late fractures in scheelite. Pyrite is the only common sulphide and is much more abundant than in the veins of the Millerton porphyry. The veins are typically narrow S-shaped gash veins, sometimes having a central shear. They are never found in the porphyry, though nearby, and the structural relation to the porphyry is less clear than in the Millerton porphyry.

Allen and Folinsbee (ibid.) concluded that the scheelite is genetically related to the porphyry intrusions. They attributed the scheelite-gold zoning to repeated fracturing and successive waves of mineralization, and the vein assemblage of the Pearl Lake porphyry to higher temperature of mineralization. However, they considered that the

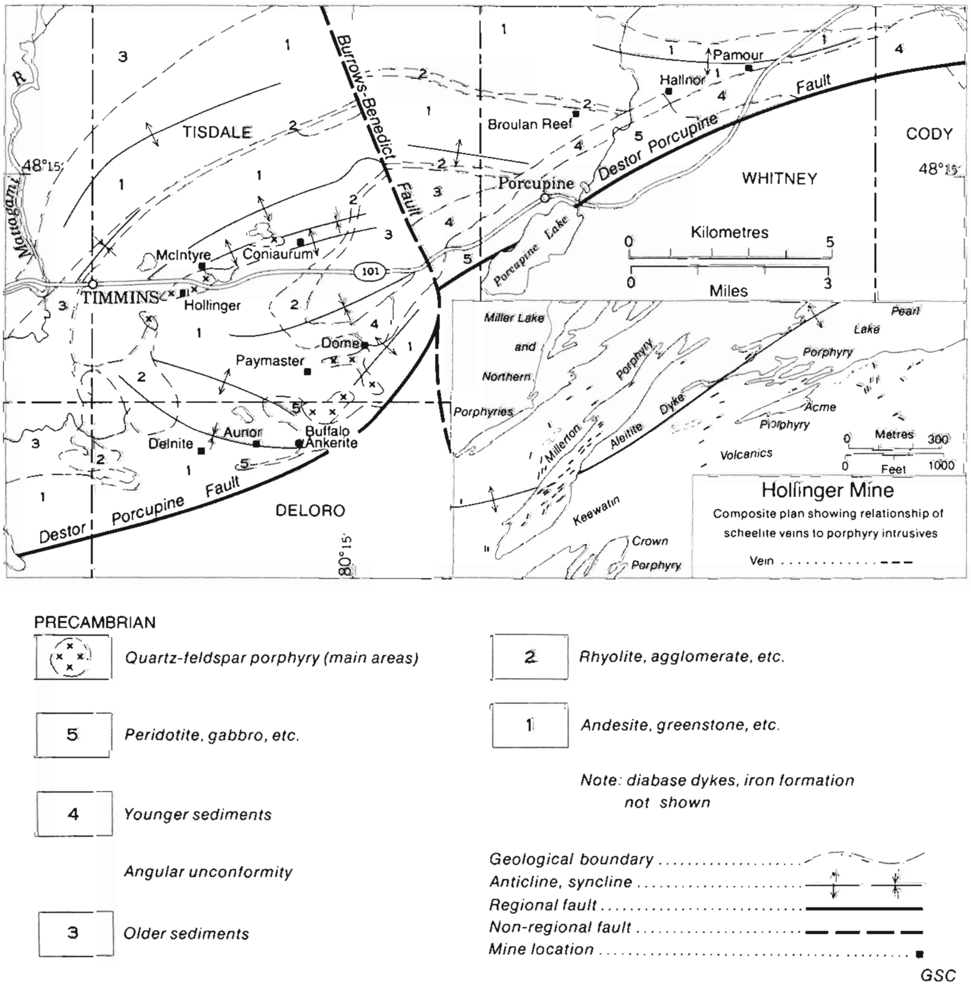


Figure 9

General geology of Porcupine Camp (after Ferguson, 1968). Inset: Hollinger mine plan showing scheelite veins and porphyry intrusions (after Allen and Folinsbee, 1944).

relationship to porphyry "points to the parent magma of the porphyry as the source of the mineralizing solutions." Traces of tin have been detected in gold from the Hollinger (Warren and Thompson, 1944), suggesting a geochemical link with the Kidd Creek deposit (30e). Perhaps these commonly related elements are inherently more abundant in this part of the Abitibi greenstone belt than elsewhere.

Scheelite was produced in 1940 and 1941 from ore shipped to the Bureau of Mines*, Ottawa. In 1942 Hollinger Consolidated established a scheelite concentrator, which produced a concentrate averaging 78 per cent WO_3 and a flotation concentrate with about 8 per cent. The average grade of mill-heads was 0.5 per cent WO_3 and 70 per cent was recovered. Some ore from Preston and other mines was milled on a custom basis. Based on Ferguson (1968) WO_3 production figures were:

	Hollinger	Preston	McIntyre	Dome	Coniarium
			(kilograms)		
1940	368				
1941	5 020	336	142	28	
1942	46 675		257	4.5	
1943	106 053	235			
1944	3 067				
1952	23 012	1 022			114
1953	22 126		106		94
	206 321	1 593	505	32.5	208

Other scheelite occurrences in the camp listed by Little (1959) are the Buffalo Ankerite, Broulan Reef, Pamour and Hallnor mines. Their tungsten content is considered negligible.

Kidd Creek Mine and South Bay Mine (Red Lake District)

The Kidd Creek mine (30e) and the South Bay mine (35c) are major stratabound Zn-Cu-Pb-Ag sulphide deposits containing appreciable amounts of tin and very minor amounts of wolframite and scheelite. They are in felsic-rich parts of greenstone belts (Kidd Creek in Abitibi, and South Bay in Birch-Uchi) that are somewhat richer in tin and other lithophile elements (Mulligan, 1975). The Kidd Creek mine is about 24 km north of and in the same structural block as the Porcupine Camp, where important scheelite-bearing gold-quartz veins are associated with mainly mafic volcanic rocks. The South Bay mine stands in similar relationship to the Uchi gold mine, which also bears scheelite and is associated with mafic volcanic and intrusive rocks. Up to 92 ppm of tungsten were found in composite samples of quartz-feldspar porphyry that I took at the South Bay mine.

Tribag (Briar Court Mines), Algoma District, Ontario

According to Blecha (1974), four breccia pipes form a cluster in highly faulted volcanic rocks near the north boundary of a greenstone belt (31a). They are composed of fragments of volcanic, granitic and other intrusive rocks in a matrix of quartz and carbonate, and are mineralized chiefly by chalcopyrite and molybdenite. Scheelite is locally abundant in one and rare in another. Wolframite occurs rarely in one. A porphyry body 6.4 km southwest is highly altered and mineralized with disseminated sulphides including chalcopyrite and molybdenite. Blecha compared the situation to porphyry copper deposits of the Cananea type.

Kenora District, Ontario

Sandy Beach Lake and Zealand Township

These quartz-vein occurrences (34a, 34b) are in mafic volcanic and sedimentary rocks, including iron formation, of the Wabigoon greenstone belt. Within about 26 km along the belt from the Zealand Township occurrence are numerous tourmaliniferous pegmatites, some of which contain beryl, lithium and caesium minerals, and a molybdenite-bearing pegmatitic vein deposit. They contain anomalous amounts of tin. A sample from the Zealand Township occurrence was found to contain 0.6 per cent of W and 250 ppm of Sn as well as anomalous Be and Li. This is a good example of the lithophile affinity of tungsten.

Redvers Lake

At this locality (34h), several pits have been sunk on narrow lenticular quartz veins that are strictly conformable with the enclosing augen gneisses and have rims and pods of probably secondary red feldspar. Fine molybdenite and pyrite are disseminated throughout the veins and also in the reddish altered gneisses. Scheelite is inconspicuous but fairly abundant throughout. A composite sample of mineralized quartz vein material was found to contain 620 ppm of W and 24 ppm of Mo. A sample of apparently normal gneiss contains 26 ppm of W and 80 ppm of Mo. No volcanic or sedimentary rocks are shown in the vicinity on the Ontario four-mile compilation maps.

Falcon Lake-West Hawk Lake Area, Manitoba

In this area (39) scheelite occurs in small amounts in several quartz veins, shear zones and silicified skarn zones in a narrow greenstone belt that passes along the north side of Falcon Lake. The band is bounded on the northwest by pink porphyritic granite. It encloses the Falcon Lake stock, a zoned gabbro-syenodiorite-granodiorite-quartz monzonite body (Davies, 1954). The skarn occurrences are in a conformable zone about 0.8 km northwest of Barren Lake, near the porphyritic granite contact. Small lenses of garnet, epidote and calcite-bearing quartz occupy shear zones in silicified amphibole-epidote-garnet rock. Small gold occurrences are associated with the Falcon Lake stock. Minor lithium occurrences were reported in the West Hawk Lake area, and sizeable lithium-bearing and beryllium-bearing pegmatites occur about 14.5 km southwest along the greenstone belt. The tungsten occurrences are unimportant, but their skarn affinity is exceptional in Superior Province.

Churchill Province

Many small scheelite-bearing quartz veins are scattered throughout the greenstone belt along the southern fringe of Churchill Province. The belt contains stratabound copper-zinc sulphide deposits from the Snow Lake area to Flin Flon. It also contains numerous gold-quartz veins and a lithium-beryllium pegmatite district. The metavolcanic rocks (Amisk) and metasedimentary rocks (Missi) of the belt have been considered Archean, but Bell et al. (1975) have presented evidence of a younger age. The intrusive granitoid rocks yield Hudsonian dates (Douglas, 1970). The lithium-beryllium pegmatites of Herb Lake area also indicate Hudsonian age (1800 Ma), although they are identical with nearby pegmatites in Superior Province that yield Archean ages.

---

* Now CANMET, Department of Energy, Mines and Resources.

As in Superior Province, the tungsten occurs mostly in veins bearing gold and minor scheelite. This includes occurrences in the Herb Lake camp, which are near the lithium-beryllium pegmatites. The only significant concentration, the Northern Tungsten, is apparently exceptional because gold has not been reported there.

Northern Tungsten, Manitoba

The Northern Tungsten (40d) scheelite-bearing quartz veins, 0.8 km up the creek at the west end of Snow Lake, are essentially parallel to the foliation of the enclosing hornblende-plagioclase-biotite-garnet gneisses. The vein system is exposed intermittently for about 120 m along the west bank of the creek, which marks a fault, and is about 1.5 m wide. It consists of small veins containing scattered lenses and patches of scheelite. Some open cutting has been done, and drifting from a short crosscut. These openings are now caved in. The remains of a mill stand on a large area of dumped material.

A bulk sample of 45 kg shipped to the Bureau of Mines, Ottawa, in 1949 assayed 25.35 per cent WO_3. A further shipment of 953 kg of concentrate, presumably after the mill was put in operation in 1951-1952, was reported to average 32.68 per cent WO_3. Two composite samples that I took, one from an open cut and one from an old ore bin, were found to contain less than 0.05 per cent of W and negligible tin and beryllium. No sulphide minerals or distinctive features were seen at exposed sections of veins.

Churchill and Slave Provinces

Fox Group, Northwest Territories

The Fox Group of 18 claims on Outpost Islands (142) was operated at various times between 1935 and 1951 by Slave Lake Gold Mines, International Tungsten Mines, Philmore-Yellowknife Gold Mines, and Tungsten Corporation of Canada. It was primarily a gold mine but much of the ore mined probably contained 0.5 to 0.75 per cent of WO_3. In 1941-42 tungsten concentrates containing 12 247 kg of WO_3 were recovered by tabling, together with 304 970 g of Au, 2332 g of Ag, and 51 193 kg of Cu. Grades of tungsten concentrates were about 50 per cent or less WO_3 and recovery was estimated to be only a little more than 10 per cent. A tin content of 0.2 per cent was reported in a 1937 shipment of 482 kg of ore from the 50-foot level of No. 1 shaft. No tin has been recovered. The last reported operation was late in 1951, when a 50-ton mill was supplied by material from the tailings dump. This was estimated to contain 9070 t carrying about 8 g/t of Au and 0.48 per cent of WO_3 (Lord, 1951).

Geologically, the deposit is of special interest as it is the only wolframite deposit known in the Shield. It has many of the attributes of a quartz-greisen vein deposit but is unusual in its gold content.

The deposit consists of sheared and silicified zones in quartz-mica schist and gneiss, in an area 2225 m long and 230 m wide covering parts of four islands and the intervening channels. The zones, up to 460 m long and 3 m wide, are in slightly fractured and brecciated rock, locally cut by quartz veins and partly replaced by quartz and metallic minerals (ibid.). Mineralization, which is mostly in micaceous quartzite (Hawley, 1939), consists of pyrite, and chalcopyrite with associated wolframite, magnetite, specularite, bornite, chalcocite and gold. The gangue is composed of quartz, sericite and chlorite. Molybdenite has been reported, as well as powellite replacing wolframite. Scheelite was not reported in place, but is common in the concentrate. Tin, probably as cassiterite, amounted to 0.2 per cent, together with 1.20 per cent of tungsten, in a bulk sample shipped to the Mines Branch in Ottawa. According to Hawley, quartz bodies with micaceous borders contain such minerals as tin, tungsten and molybdenum. Neither beryllium nor niobium was found in spectrographic analyses.

The attitude of the shear zones is about the same as that of the nearby strata. One main shoot was reported to "pitch about 70 degrees east, approximately parallel with the pitch of the drag fold immediately east of it" (Lord, 1951). From this it appears that there is an element of stratigraphic control, although structural control is evidently dominant.

The islands are underlain mainly by quartz-mica schist and gneiss, quartzite and conglomerate of the lower Aphebian Wilson Island Group (Douglas and Norris, 1974). Locally, knotted schists contain andalusite, staurolite and rare corundum. Crossbedding is common. Hornblendite dykes and one feldspathic pegmatite cut the rocks. The nearest exposed granite is 6.4 km north (Hawley, 1939). The nearest mapped granite is at Bute Island, about 9.6 km east, and is evidently part of the Archean Simpson Islands body.

Slave Province

Nearly all the tungsten occurrences of Slave Province are in or near the Yellowknife-Beaulieu River district. They are mainly in metasedimentary rocks of the Archean Yellowknife Supergroup, which underlies most of the district. However, the tungsten-bearing gold deposits of the Yellowknife area are in greenstone, which bounds the sedimentary assemblage on the west, and a few others are in interbedded volcanic rocks elsewhere in the area. They are essentially scheelite-quartz veins but some have pegmatitic characteristics and some have skarn characteristics.

Yellowknife-Beaulieu District, Northwest Territories

In this district (143, 144), except for the greenstones of the Yellowknife area west of Yellowknife Bay, the bedded rocks are chiefly greywacke and slate of the Yellowknife Supergroup (Fig. 10, in pocket). They are tightly folded and intruded by somewhat gneissic biotite granite, and by bodies of younger muscovitic and pegmatitic granite. Crossfolding on north-northwesterly trending axes of previously folded strata coincided with intrusion of the pegmatitic muscovite granite. Metamorphic aureoles surround the large granite bodies and are particularly conspicuous around the late intrusions. They are marked by development of cordierite-andalusite-staurolite nodules in the schists. Chiefly within these aureoles lie hundreds of pegmatite dykes, of which several hundred contain rare elements including lithium, beryllium, columbite-tantalite and occasionally tin. Some dykes are internally zoned with lithium and beryllium, and a lateral zoning of these elements is evident around some of the young granite bodies (Mulligan, 1965).

Mainly as scheelite-bearing quartz veins, most of the tungsten occurs in the less metamorphosed sediments outside the aureoles, though some occurs within them. The boundaries of the aureoles are generalized, however, and metamorphism is not uniform. Therefore, the general restriction of tungsten occurrences to the lower grade rocks may be valid. The same possibility applies to gold deposits, as three of the four mines in sediments are outside the metamorphic aureoles. Furthermore, the tungsten and gold deposits within the aureoles are generally in the lithium zone, farther from the intrusions than the beryllium pegmatites. The Tibbitt Lake occurrences, emplaced mostly in gabbroic sills (143r, see below), may be an exception. The distribution of tungsten occurrences may also reflect varying concentrations of tungsten (and gold) in different parts of the sedimentary basin, or a recurrence of a particular horizon by folding, rather than a metamorphic environment.

The association with gold is not as impressive as it is in Superior Province. However, the few former tungsten producers evidently were primarily gold producers. None is potentially economic as a tungsten deposit. All the occurrences are essentially of the scheelite-quartz vein type, but the carbonate in the veins and host rocks, and the contact metamorphic minerals like garnet, actinolite, and clinozoisite in some cases, suggest a transition to skarn-type mineralization. No scheelite was seen in samples of skarn from Turnback Lake, some of which contain a little tin and beryllian vesuvianite. A little scheelite is disseminated in granite and basic dykes at Upper Ross Lake (Little, 1959).

Many of the scheelite-bearing veins contain feldspar and tourmaline together with sulphides and a little gold. Tourmaline is common in the gold-bearing veins in the metamorphic belt, which are locally cut by pegmatite dykes, whereas it is lacking in most of the lithium and beryllium pegmatites of this district. This suggests that the scheelite veins, like the gold veins, are older than the pegmatites, which cut across the axes of late northwest-trending folds (Mulligan, 1975).

Structurally, the scheelite-bearing veins show no consistent relationship to regional structural patterns. According to Henderson and Jolliffe (1939), quartz bodies in the sediments have been emplaced along zones of structural weakness, which in most places clearly depend on folding. Some of the scheelite-bearing veins are involved in drag folds and are sheared parallel to the axes. Those veins may be older than the latest folding. The descriptions of many of the occurrences surprisingly emphasized the apparent concordance of the veins or mineralized zones with the sediments, although they did not imply any genetic significance. These features suggest a possible remobilized stratabound origin for the tungsten occurrences. No data are available on the tungsten content of nearby sediments. Samples of schist and greywacke taken between Thompson Lake and Sparrow Lake were found to be anomalously high in tin but not in tungsten (1 ppm in 4 of 6, maximum 2 ppm). Boyle (1961) reported less than 5 ppm of tungsten in tuffs and sediments of the Yellowknife area, but reported 5 ppm in epidote-amphibole facies rocks.

Gilmour Lake Area (143 k-p)

Many scheelite-bearing veins are concentrated in the small area between Gilmour Lake and Consolation Lake to the northeast. They have been prospected intensively. A mill was operated at the Storm Group in 1942. Some 27 t of scheelite ore were mined in 1941 from the Discovery vein at the Dot and Eva claims and about 18 t from the Victory Group.

The strike of the veins varies from place to place. Most strike northwesterly and most are parallel with the bedding. Vein 25 at the Storm Group strikes north, across the bedding, but vein 56 at the WO_3 Group strikes northeasterly and is described as concordant.

At the WO_3 Group the rocks are "sheared tuffaceous". The Discovery vein at the Dot and Eva contains carbonate, clinozoisite, actinolite and sulphides. The bordering rock contains actinolite and graphite and may be altered calcareous and tuffaceous beds.

Tibbitt Lake (143r)

Tungsten is found in three main zones in an area 0.8 to 1.6 km wide and 9.6 km long extending along the east side of Peninsula Lake, Tibbitt Lake and Cameron Lake. The sediments are tightly folded on northerly trending axes and are invaded by altered gabbroic dykes or sills up to 305 m wide and over a thousand metres long. The sills also strike approximately north. They are cut by aplite dykes and pegmatitic quartz veins. A small granite plug lies about 1.5 km west.

Most of the 150 scheelite-bearing veins are narrow veins less than 15 m long in gabbro sills less than 90 m wide. Some veins consist mainly of clinozoisite, garnet and chlorite, with a little plagioclase, quartz and carbonate, and are gradational into the gabbro. The veins strike northwest in some zones, northeast in others. Of 115 veins sampled, 41 carry more than 0.3 per cent of WO_3 and 12 of these more than 1.0 per cent.

Storm Group and Goodrock Gold Mines (143v)

The Goodrock mine adjoins the Storm Group, which is on the east shore of Gordon Lake, 4 km east of the Camlaren gold mine. Henderson and Jolliffe (1939) described the axial plane, saddle reef and bedded veins at Camlaren, Dome and Sentinel mines in that area. They considered them to have been introduced along zones of structural weakness related to the folding. Similar discontinuous quartz lenses along the ruptured axis of an anticline at Goodrock Gold Mines contain scheelite, and the scheelite-bearing veins at the Storm Group are roughly parallel with the sediments.

Con, Rycon and Negus Gold Mines, Yellowknife Area (144a)

These major gold producers are in basic volcanic rocks that underlie conglomerate and silicic volcanic rocks at the base of the Yellowknife Supergroup. The veins occupy shear zones of several sets related to movement on the West Bay Fault, a major regional feature, according to Henderson and Jolliffe (ibid.). The rocks within the shear zones have been converted to chlorite schist and carbonate.

The veins consist of quartz, mainly dull grey and cherty and ribboned with sericite schist. Locally, lenticular veins in the shear zones consist of rusty-weathering mixtures of quartz and ferruginous carbonate, partly replaced by milky to dark grey quartz. Metallic minerals include pyrite, arsenopyrite, sphalerite and galena but grey minerals, including tetrahedrite, stibnite and jamesonite, are more abundant than any of the metallics except pyrite (ibid.). Gold occurs in all types of gangue but is most common in and near drusy quartz and within the grey metallic minerals. It is scarce in the fine quartz-carbonate mixture and practically absent from the shear zone schist.

Scheelite is present in several of the veins, and a few shoots and lenses contain 1 per cent or more. One shoot 21 m long and 15 cm wide at the Negus contained 1.4 per cent. The scheelite-bearing veins at Negus, mined before 1948, consisted of mottled grey quartz and, here and there, rusty-weathering carbonate. Most of the scheelite is in vein sections that are submarginal as gold ore.

According to Boyle (1961), scheelite was observed only in the epidote-amphibolite rocks of the greenstone, and 5 ppm of tungsten were detected only in this rock. It has no close associations except with carbonate minerals and appears to have been deposited contemporaneously with quartz. It is frequently fractured and seamed with sericite and carbonate. It contains traces of lead, vanadium and boron, but no molybdenum.

Bear Province

Bear Province occupies the northwesternmost part of the Canadian Shield. It is about as old as Churchill Province and, like it, is a uranium-rich metallogenetic province. The only known tungsten occurrence is at Lever Lake (146), where scheelite is associated with chalcopyrite, pyrrhotite and pyrite in quartz veins and magnetite-rich quartz veins in quartz-feldspar porphyry. Drilling done in 1967 by Pine Ridge Exploration Company Ltd. gave disappointing tungsten values (Thorpe, 1969).

CORDILLERAN REGION

Tungsten occurrences are numerous in the Cordillera, and include the three largest known Canadian deposits. Occurrences are found in most parts of the region that have been extensively intruded by granitoid rocks. Except in northernmost Yukon Territory, these intrusions are mainly of late Triassic to early Tertiary age, and mark the culmination of orogenic history in the region. The intrusions in northernmost Yukon are of Devonian and later Paleozoic ages. They appear to be related to a northern Alaska-Arctic orogenic belt, but the area was affected by the main (Mesozoic) Cordilleran orogeny.

Except for the northernmost Yukon intrusions, the practical eastern limit of granitic intrusions and tungsten occurrences is marked by the boundary between "Eastern Cordillera" and "Western Cordillera" on Map 1556A[1]. A more fundamental geological boundary divides the Cordillera into two contrasting terrains with different metallogenic affinities. It is here used to define the boundary between "East" and "West" tungsten zones, as shown on Map 1556A.

The "East Tungsten Zone" is underlain by predominantly Proterozoic and Lower Paleozoic rocks, mainly sedimentary, and forms the western part of the Cordilleran miogeosynclinal belt. The "West Tungsten Zone" embraces a variegated, mainly eugeosynclinal terrain in which the bedded rocks are predominantly Upper Paleozoic and Mesozoic, in large part volcanic. Differences are also apparent in the age, composition, and tectonic setting of granitoid intrusions in different parts of the Cordillera (Gabrielse and Reesor, 1974). In general, granitoid intrusions of the East Tungsten Zone differ in these respects from those of the West Zone, and these differences undoubtedly influenced the development of associated tungsten deposits.

The East Zone, which contains the three largest tungsten deposits and virtually all the beryllium and significant tin occurrences of the region, coincides approximately with a lead-zinc province whereas the West Zone contains nearly all the copper and molybdenum. The wide distribution of tungsten deposits suggests that the deposits formed in diverse ways corresponding to the diversity of metallogenic environments in the region.

In the following discussion the two Cordilleran tungsten zones are described separately. However, the subsequent notes on areal groups and individual occurrences adhere to the general order of listing in the Appendix.

East Tungsten Zone

At its south end, the East Tungsten Zone occupies the East Kootenay district and an adjoining part of the West Kootenay district. The older Proterozoic Purcell Group strata equivalent to the Belt Supergroup in the United States form the core of an anticlinorium that plunges gently northward. These rocks are overlain at the nose and along the flanks of the structure by Late Proterozoic Windermere Supergroup strata and lower Paleozoic formations. The Purcell rocks are predominantly well-sorted clastic sediments, whereas the Windermere rocks include conglomerates and grits, in part feldspathic. The Paleozoic strata include extensive Lower Cambrian and later limestone units.

The Windermere and lower Paleozoic rocks extend northward through the Lardeau area and into the Big Bend area. There they are interrupted by rocks of the Shuswap metamorphic complex but they reappear as equivalent lithologies in the Cariboo district and can be traced northward to about the big bend of Fraser River. From there to the Cassiar district they are interrupted by metamorphic complexes and major faults, and the boundary between the East and West zones as defined by the western contact of these older rocks is uncertain.

In the Cassiar district of northernmost British Columbia the Rocky Mountain Trench loses its identity as the east boundary of the East Tungsten Zone, which thereafter occupies a broad belt on both sides of the Tintina Trench. This distribution may reflect overlap resulting from strike-slip faulting along the Tintina Trench. The area east of the Tintina Trench includes some relatively old Proterozoic rocks that may be equivalent to the Purcell Group in the south. Younger Proterozoic and lower Paleozoic strata overlie them with marked unconformity.

Mainly Proterozoic and lower Paleozoic, the rocks of the East Zone are in part regionally metamorphosed and are locally involved in high grade metamorphic complexes (Shuswap, Wolverine, Horseranch, etc.) but for the most part they are of low to intermediate grade. Their western limit may correspond approximately with that of the Precambrian Shield basement, although this may not apply to parts of the Shuswap Terrane.

Many tungsten deposits throughout the zone are emplaced in Lower Cambrian limestone units. These include two of the three largest deposits, the Emerald, Dodger, and others (46b), and the Canada Tungsten deposit (107g). However, the MacTung (AMAX Northern) deposit (111a) is emplaced in probably Ordovician limestone that overlies Proterozoic and Cambrian rocks. Of perhaps greater importance than the age of the host rocks is the proximity of many deposits to older clastic rocks. At the three major deposits in particular, the host limestone is underlain by thick sequences of predominantly Proterozoic clastic rocks. This suggests that the deposits, although closely associated with granitic rocks and probably formed through their agency, possibly derived their tungsten mineralization from sources deep in the underlying clastic rocks.

Throughout the zone, intrusions are predominantly mid-Cretaceous granitoid rocks ranging from granodiorite to granite. Virtually all of the tungsten deposits, including the three largest Canadian deposits, are associated with these intrusions. However, at least one minor deposit may be related to a small stock of Precambrian granite in the East Kootenay district. This is the only known Precambrian granitic intrusion in the Cordilleran Region.

West Tungsten Zone

The West Tungsten Zone comprises part of West Kootenay district, most of central British Columbia, and parts of northern British Columbia and southwest Yukon, as well as the obviously western areal groups.

The bedded rocks of the zone are mainly Permo-Carboniferous and Mesozoic and include abundant intermediate and mafic volcanic rocks. Intrusions include mafic and ultramafic bodies and large areas of Triassic to Tertiary granitoid rocks. Relatively undeformed volcanic rocks, mainly basaltic, occupy large parts of the Intermontane Belt, and are virtually barren of tungsten deposits.

Nearly all the tungsten deposits are closely associated with granitoid rocks, either of the Coast Plutonic Complex or of crossbelts in southern, central and northern British Columbia that include the Skeena and Stikine arches.

---

[1] Distinction between Eastern and Western Cordillera on this basis is archaic.

Quartz and potassic feldspar content appear to increase generally as age decreases eastward from the Coast Range intrusions to the Omineca Crystalline Belt, where most granitoid rocks are Cretaceous (ibid.). However, many tungsten deposits along the east flank of the Coast Plutonic Complex are associated with intrusions mapped as Cretaceous.

Tungsten deposits occur mainly in the bedded rocks as scheelite skarns and quartz or quartz-carbonate veins, but some vein-scheelite deposits are in granitoid rocks and a few are emplaced in ultramafic rocks. Most wolframite-bearing deposits are in granitic rocks.

The dominant associated metal throughout the zone is copper. Molybdenum is more or less abundant at most tungsten occurrences, but only two major molybdenum deposits contain significant amounts of tungsten. Tungsten is associated with gold in some areas in both West and East zones, and with antimony in a few places.

The West Tungsten Zone, unlike the East, is thought to represent a predominantly island arc environment, developed on oceanic crust, parts of which probably formed at great distances from their present position, and subsequently became attached to the craton during the Mesozoic (Monger et al., 1972).

Groups and Individual Deposits

East Kootenay District

The district east of Kootenay Lake (42-44) is the southern limit of the East Tungsten Zone. It is underlain in large part by argillaceous and arenaceous sedimentary rocks of the Middle Proterozoic Purcell Supergroup, which are the oldest host rocks of tungsten deposits and among the oldest exposed rocks of the Cordillera. Among the small occurrences present, the Leader Group (42c), Sullivan mine (42e) and Val, Molly and Nine Lake (42f) properties are noteworthy because they may represent original concentrations in the Purcell rocks, though perhaps reconcentrated at later times. All except the Leader are in the Aldridge Formation, the oldest rocks in the area.

The Leader Group (42c) is in a fracture near the St. Mary's Fault, one of several major east-northeasterly striking faults, at least some of which have existed since Proterozoic time. On the opposite side of the fault near the Leader (but not apparently related to it) and about 19 km southwest of the Sullivan Mine (42e) lies the Hellroaring Creek stock, a complex of granite cut by pegmatites that contain abundant tourmaline and local concentrations of beryl. This is the only known Precambrian granite in the Cordillera and is of about the same age (1300 Ma by Rb/Sr ratio) as the nearby Sullivan lead-zinc-silver orebody. The Sullivan ore contains a little disseminated scheelite and cassiterite, and the tourmalinized conglomeratic footwall sediments locally contain several hundred parts per million of tungsten and tin. Although it is essentially a stratabound deposit, the source of the base metals may be related to the numerous diorite-micropegmatite sill-like intrusions that are intercalated with the Aldridge sediments and folded with them. I have suggested (Mulligan, 1975) that the Hellroaring Creek stock may be cogenetic with some of them, perhaps emplaced somewhat later. Some anomalous metamorphic rocks between the stock and the Sullivan suggest the presence of similar buried intrusions. Tin and tungsten in the orebody may be related, at least in part, to these metamorphic or intrusive developments. The Sullivan orebody is north of the St. Mary's Fault but adjoins the major subparallel Kimberley Fault.

The Val, Molly, and Nine Lake groups (42f), about 19 km north are in tourmalinized conglomeratic Aldridge rocks like the footwall sediments of the Sullivan, and are likewise intruded by numerous sill-like diorite sheets. Berylliferous tourmaline-rich pegmatites are also common in these rocks. However, these deposits are spatially associated with the White Creek Batholith, which is Cretaceous, and could have been formed or modified at that time.

The Valparaiso (Akokli) deposit (44), the only significant wolframite deposit in the southern Cordillera, has been worked on a small scale. It is also in the belt of lower Purcell rocks but the wolframite-bearing veins are mainly within the Bayonne granite, of Cretaceous or possibly younger age.

West Kootenay District

The West Kootenay district (45-57) contains a part of the East Tungsten Zone in an area west of the southern part of Kootenay Lake and north through Lardeau to the Big Bend area. The district is underlain by Purcell and younger Proterozoic Windermere strata, which are overlain conformably here by lower Paleozoic strata. The Lower Cambrian unit of this group is host to many tungsten occurrences, including the major Emerald and nearby deposits (46a-f, description below). However, several minor occurrences are in upper Proterozoic clastic rocks (52), some in earliest Paleozoic clastics (46d), and some in granitic intrusions (46a).

Windermere and lower Paleozoic rocks extend northward through the Lardeau and Big Bend areas where they merge with equivalent rocks of the East Kootenay district. Notable tungsten occurrences include the Lucky Boy and Copper Chief (51), where minor amounts of scheelite have been recovered from skarns in the Lower Cambrian Badshot Limestone, the Erdahl and Pinchbeck (52), where scheelite occurs with traces of beryllium and tin in quartz veins in Windermere sediments, and the Regal Silver (55, description below), where scheelite was recovered from one zone in a silver-lead-zinc vein deposit that also contains appreciable amounts of stannite.

The western part of the district, underlain by Mesozoic volcanic and sedimentary rocks, forms part of the West Tungsten Zone. Occurrences include a few scheelite skarns and many scheelite-bearing quartz veins in volcanic, sedimentary and intrusive rocks of Mesozoic age. At the Granite Poorman-Venango mines (47d), scheelite occurs in gold-quartz veins in a pseudodiorite-syenite metasomatic complex derived from mafic volcanic rocks. At the St. Elmo (48b), scheelite-bearing quartz veins adjoin a major molybdenum deposit. At the Velvet mine (48c), skarnlike replacement copper-iron sulphide-magnetite deposits in greenstone and ultramafic rocks contain about 0.1 per cent of tungsten as determined by spectrographic analysis of a dump composite. The Velvet, Blue Moon (48b) and perhaps the St. Elmo presumably are related to the Tertiary Coryell syenitic batholith.

Emerald, Feeney, Invincible, Dodger Mines, Salmo Area

These properties (46b) of Canadian Exploration Co., about 13 km south-southeast of Salmo, British Columbia were operated at various times between 1943 and 1973 and were the first major Canadian producers. They also have been the most thoroughly studied and documented, mainly by Stevenson (1943), Little (1950, geology), Whishaw (1954), Ball (1954), Fyles and Hewlett (1959) and Thompson (1973). These typical skarn deposits are especially interesting in their close spatial and stratigraphic association with stratabound lead-zinc deposits (Fig. 11A, in pocket).

The earliest workings in the area were the Old Emerald lead-zinc mines. Specimens of skarn from the area, submitted for molybdenum assay in 1942, were found to contain scheelite. The Emerald and Dodger deposits were explored and developed by Wartime Metals Corp., a Crown company. The property was operated alternately by this company and by Canadian Exploration Ltd. in 1943, 1947-1948, 1951-1958 and finally by Canadian Exploration from 1970 to 1973. In the meantime, that company produced lead and zinc concentrates from the adjoining Jersey mine from 1949 to 1970, when machinery from the mill was used in the rehabilitated tungsten concentrator. Total production of tungsten from the mines was:

	Ore (tonnes)	WO_3 (kilograms)
to 1957	910 194	5 918 909
1958	58 060	313 295
1971	156 500	605 912
1972	179 737	577 512
1973	96 854	640 382

Geology. The geology of the area has been described by Little (1950) and by Fyles and Hewlett (1959), whose detailed map, slightly simplified, is incorporated in Figure 11A (in pocket). According to Pastoor's (1970) small-scale map the boundaries of the Jersey lead-zinc mine completely surround the East Dodger mine area, extending north to the old Dodger mine.

The stratigraphic section according to Fyles and Hewlett is shown in Figure 11A. Archaeocyathids in the Laib limestone establish its Early Cambrian age. The Reno and Quartzite Range formations are considered equivalent to the Gypsy Quartzite of the Metaline area, Washington, in which trilobites have been found.

The area lies between two large granite stocks, one west of Salmo River and one crossing Lost Creek about 3.2 km east. Irregular, more or less concordant lenses of similar granite, including the Emerald, Dodger and Townsite stocks and associated dykes, cut the bedded rocks, and the tungsten deposits are closely associated with them. These and the Lost Creek body resemble the Cretaceous Bayonne granite rather than the Jurassic Nelson granodiorite. Lamprophyre dykes, probably related to a nearby Tertiary monzonite plug, locally cut the ore.

Structure. In the regional setting of the deposits, two structural factors are especially relevant: (i) they are within the zone of maximum curvature of the 'bulge' structure of the Kootenay Arc; and (ii) they are in a strongly fractured zone just east of the trace of the eastward-dipping Waneta Fault, along which the Proterozoic and lower Paleozoic sediments are thrust over a Jurassic volcanic-sedimentary assemblage. This fault here forms the boundary between the East and West tungsten zones.

The fractured zone separated by eastward-dipping thrust faults from Mesozoic rocks to the west and from the 'Black Argillite' belt to the east contains stratiform lead-zinc deposits as well as the tungsten deposits, and is described as the "Mine Belt" (Fyles and Hewlett, 1959). The east boundary fault separates unit 5 from unit 9 in Figure 11A. In the vicinity of the tungsten mines the structure is dominated by an overturned faulted anticline, the Jersey anticline, the axis of which strikes about 15° and plunges northward and southward from about the midsection of the mine area. The axial plane flattens westward and becomes recumbent. The fold has been refolded, and the eastern limb, which is right side up, appears to have ridden over the overturned limb along bedding faults. The eastern upright limb of the anticline contains the Dodger and Jersey orebodies, while the Emerald, Feeney and Invincible are in the overturned limb (see cross-section, Fig. 11A).

Within this framework, a dominant control of mineralization appears to be trough-like structures in the granite surfaces. One of these, especially well developed at the Dodger, plunges at about 5° southward to the East Dodger mine. Another contained the Emerald orebodies on the west flank of the Emerald stock, and similar structures held the Feeney orebodies on the east flank of that stock. The Invincible orebody adjoins the west flank of the Dodger stock, in a trough between it and the Emerald stock.

Skarns and Skarn Minerals. In addition to the main orebodies, skarn with minor scheelite forms numerous bands up to 15 m wide, especially in the Truman and Reeves members. Dolomite of the Reeves limestone is the host rock of the Jersey and old Emerald lead-zinc deposits. They are at a slightly higher horizon than the adjacent tungsten deposits, which are in predominantly calcareous beds. Silicate or sulphide skarn is the host rock of most scheelite mineralization but 'greisen ore' extends as much as 12 m into the granite at the Emerald.

The typical skarn is a green and brown granular rock composed chiefly of pyroxene, garnet and locally amphibole, with various amounts of pyrrhotite, calcite and quartz. Vesuvianite is a common minor constituent at the Dodger. Other silicate minerals reported in varying minor amounts are tremolite-actinolite, epidote, biotite, muscovite and chlorite, and augite has been reported. Small amounts of apatite are common. Tourmaline was reported to be relatively abundant in quartz veins at granite contacts at the Emerald and Feeney. Fluorite in fracture zones at the Emerald, Feeney and Dodger was mentioned by Ball (1954).

Pyrrhotite is the predominant sulphide mineral and is especially abundant in the Invincible ore and in some Emerald ore. Some pyrite has been reported. Chalcopyrite in small amounts is apparently the only base-metal sulphide. Molybdenite and molybdian scheelite are relatively abundant at the Dodger. A little wolframite has been reported.

Emerald Mine. The Emerald deposit is in the overturned west limb of the Jersey anticline, in a southerly plunging trough of Reeves limestone between the easterly dipping upper Laib rocks and the Emerald granite stock (Fig. 11A, Sec. A-B). Skarn is mainly confined to a band up to 1.5 m wide along the contact with the upper Laib argillite. Elsewhere the limestone is locally dolomitized or silicified. The granite transects the trough at the north end and also about midway, where an irregular apophysis extends west and north forming the west flank of the trough for over a hundred metres. The granite is highly altered adjacent to the contact, and this zone of alteration extends up to 12 m into the granite.

Little (1959) distinguished four types of ore in the following order of abundance:

1. Sulphide ore, forming irregular bodies in limestone and dolomite, consists of pyrrhotite, calcite, biotite and scheelite. Locally it contains quartz, pyrite, molybdenite and chalcopyrite. Garnet, pyroxene and tremolite are rare and crystallized early.
2. 'Greisen' ore is in altered granite, and consists of potash feldspars, in some places completely kaolinized, abundant quartz, sericite, pyrite, tourmaline and scheelite. Calcite or ankerite, apatite, pyrrhotite and molybdenite occur locally. Most of the quartz is late. Sericite and kaolin appear to have formed before scheelite, which was followed by tourmaline, carbonates, quartz and pyrite.

3. Skarn ore, mostly at or near contacts of limestone with argillite, consists of garnet, diopside, calcite and quartz, with small amounts of pyrrhotite, pyrite, scheelite and molybdenite. Some calcite cuts garnet and diopside, which formed before scheelite, sulphides and quartz.
4. 'Quartz' ore, which commonly grades into greisen, is silicified limestone intersected by numerous veins of quartz containing abundant ankerite, coarse scheelite, a little molybdenite, and apatite. Some scheelite, pyrite, pyrrhotite and tremolite are disseminated in limestone near veins.

Except in the veins, scheelite grains rarely exceed 1 or 2 mm in diameter. Some of the scheelite is molybdian. Ball (1954) reported fluorite in zones of fracture, and a tabular body labelled 'fluorite' about 9 m long is shown on Little's Figure 15, Sheet 3.

Almost all the Emerald ore was at the base of the trough formed by argillite and granite. At the north end the ore was mainly along the east or granite flank, at the centre it was about evenly distributed, and at the south end almost all was on the west or argillite flank.

Feeney Mine. The Feeney deposit is about 180 m north of the Emerald, on the opposite (east) side of the Emerald stock. Descriptions are sketchy. It appears that the deposit extended north for a tested length of 76 m. According to Little (1959), although the deposit resembled the Emerald, sulphide ore was more abundant and both flanks of the trough were bounded by granite. According to Pastoor (1970), the mine produced 54 431 t of ore grading 0.92 per cent WO_3.

Invincible Mine. The orebody was mined from early 1971 to September 1973, and produced 256 533 t of ore averaging 0.65 per cent WO_3. It adjoins the western margin of the Dodger granitic stock, where it transects flat-lying beds of the Reeves limestone at elevations from 1006 to 1098 m. The following description is from Thompson (1973):

> The invincible orebody is in the overturned limb of the Jersey anticline (Fig. 7) and is bounded above and below by skarn and argillite of the Truman and Emerald Members of the Laib Formation respectively. Most of the tungsten ore (scheelite) occurs in lenticular zones which extend at a high angle from the granitic stock, more or less conformable with layering of the marble. In cross section the ore appears as irregular jagged zones to which the descriptive term 'ore flame' was applied by mine geologists. In longitudinal section the flames are discontinuous and irregular. Ore zones extend up to 80 feet from the stock, and may be more than 10 feet thick, but most ore does not extend beyond 20 feet from the stock and is typically less than 8 feet thick. Continuity of ore along strike seldom exceeds a few tens of feet. Ore grades as high as 7.6 per cent WO_3 (across 1.6 feet) were encountered. However, 0.75 to 1.50 per cent WO_3 are more typical of ore-grade material.
>
> Some of the ore zones comprise aggregates of angular rock fragments enclosed in secondary coarse crystalline quartz; the scheelite is contained within the fragments which consist of diopside and garnet-rich skarn.

Pastoor's (1970) description is as follows:

> The Invincible ore-zone is divided into two zones separated by a 650 foot long area containing granite cross-dykes.
>
> The south zone is approximately 800 feet long and is lying nearly flat in a troughlike structure formed by west-dipping Dodger granite and east-dipping Emerald granite. The Emerald granite underlies a fault surface and dips approximately 35° east. The trough is terminated at both ends by areas of "high granite" and cross-dykes. The north zone is approximately 1100 feet long and has a gentle plunge to the south. The trough structure is formed by west-dipping Dodger granite and the east-dipping contact between Emerald black argillite and limestone. This contact dips about 40° east, and the granite dips about 35° west.
>
> In both zones, tungsten ore occurs where the limestone is in contact with the Dodger granite. The ore is contained in quartz-sulphide replacement of limestone. It is localized in general by fracturing, faulting, and brecciation of the limestone, and in detail by minor fracturing and bedding of the limestone.

In the working places that I visited in August 1971, the ore was mainly massive pyrrhotite speckled with small grains of pyroxene and quartz. Scheelite is abundant as equant subhedral to rounded grains scattered randomly through the pyrrhotite. Some of the skarn is a greenish grey mottled rock with patches and streaks of pyrrhotite and streaks of quartzose material, among which some pyrite and chalcopyrite are visible. A thin section consists chiefly of strongly pleochroic green amphibole, colourless pyroxene, some pyrrhotite and calcite, and a little quartz, muscovite and scheelite. The optical properties of the amphibole suggest hornblende and those of pyroxene suggest hedenbergite. Apparently the amphibole did not replace pyroxene, which is quite fresh and uncorroded. Calcite occurs in crosscutting veins surrounding pyrrhotite. Scheelite in small subhedral grains is mostly in the pyrrhotite areas.

Dodger Mine. The old Dodger mine occupied an embayment in the Dodger stock marking the north end of the southerly plunging 'Dodger Tungsten Trough' (Fig. 11A). The orebody was in limestone, skarn and argillite of the upright limb of the Jersey anticline. Argillite generally forms the floor of the trough, separating limestone, skarn and dolomite from the underlying granite (Ball, 1954, Fig. 10). This section shows most of the ore in a skarn horizon between limestone and dolomite, but penetrating into the argillite at the base of the trough. It also shows lamprophyre dykes generally concordant, with one marking the base of the ore and penetrating through the argillite into the granite.

The orebodies were lenticular and tended to split and splay out. Most of the ore was in garnetiferous skarn containing scheelite associated with pyrrhotite, and local biotite and quartz. Molybdenite and molybdian scheelite were rare. Some scheelite, usually coarse, was reported in 'greisen' underlying the main orebodies.

East Dodger Mine. The orebody was mined from May 1970 to August 1973, producing 204 202 t of ore averaging 0.54 per cent WO_3. It extended, according to Pastoor's (1970) map, from about 6000 north to 8000 north, being surrounded in plan by the Jersey lead-zinc workings. The details of the orebodies, as shown in Figure 11A, Section E-F, is after Thompson (1973, Fig. 5) and is a composite of four sections 7.6 m apart projected onto a plane at 7100 north. Thompson's description is as follows:

> Tungsten mineralization (scheelite) at the East Dodger mine occurs with garnet-bearing skarn adjacent to the granitic Dodger stock, where the stock intrudes the upper limb of the

recumbent Jersey anticline. The relationship of the orebody to the surrounding geology is shown diagrammatically on Figure 4* compiled from several sections belonging to Canex Placer Limited. Mineralization is confined to skarn beds within the Truman and Reeves Members of the Laib Formation which are contained within a re-entrant, or trough, of the Dodger stock formed by a tongue of granite extending upward from the main intrusion. In the area mined the orebody is nearly horizontal at its western contact with the stock but rises rapidly eastward and is overturned at its eastern extremity. Figure 4 also shows the relationship between the East Dodger tungsten orebodies and the lead-zinc orebodies of the Jersey mine. They occur within the lower part of the Reeves Member and are older than the Dodger stock and the tungsten orebodies.

In the mine area, the Truman Member consists of variegated calc-silicate skarn, quartzitic argillite, micaceous quartzite, and marble; the Reeves Member comprises banded grey and white medium to coarse crystalline marble.

The orebody consists of three mineralized zones called the upper lime, middle skarn, and lower lime zones. In each, scheelite occurs in light brown and green garnetiferous diopside skarn. The upper and lower ore zones are bounded by marble whereas the middle zone is in contact with unmineralized skarn, argillite, and marble of the Truman Member. The tungsten ore is roughly conformable with layering but is not stratiform. Individual mineralized areas have irregular outlines, are discontinuous along layers, and may transect layering. Continuity is further disrupted by numerous crosscutting granite and lamprophyre dykes. Scheelite ore normally occurs within or coincident with garnet-bearing zones.

Mining was confined to the more gently dipping parts of the ore zones, in particular the middle skarn which is thickest and has the greatest lateral continuity. Average width of ore mined was 8 to 10 feet but the thickness of the middle skarn zone exceeded 30 feet near its western limit adjacent to the Dodger stock.

The complex interfolding of Reeves limestone is seen also in Fyles and Hewlett's Figure 10, Section D-D, which shows dolomite bands in Reeves limestone, presumably the horizon of the lead-zinc ore, generally above the granite trough.

In working places that I saw in 1971, the typical ore was a green and red mottled rock with relatively little pyrrhotite. The skarn was in gradational contact with overlying argillite. Gash veins of quartz and scheelite cut the skarn, and veins of coarse molybdenite, usually 1 to 2 cm thick, cut across the gradational contact.

A thin section of typical skarn ore consists mainly of garnet, pyroxene, green amphibole, chlorite and vesuvianite, minor calcite and minor quartz (Plate 3). The distribution of the minerals is patchy. Vesuvianite is mostly in elongated grains parallel to fractures. Similar rock locally contains vugs lined with calcite, coarse red garnet and acicular green amphibole. Sections of argillaceous rock show alternating fine bands of quartz-biotite, quartz-muscovite and garnet. Scheelite occurs in very small scattered grains, and sulphides mostly in trains parallel with the layering. Most of the scheelite in specimens collected has a yellowish fluorescence and is evidently molybdian. Intergrown or exsolved powellite was identified by K.M. Dawson (personal communication). Vesuvianite evidently is common at the East Dodger and the Dodger. It was seen in thin sections of all specimens collected, including three obtained in 1963 from 57E, 64F and 63F stopes.

Origin of Tungsten Mineralization. Stevenson (1943) remarked with reference to the Emerald deposit 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 ... Several factors localized the alteration and mineralization. Bedding was the most important ... Some slight difference in original composition or texture seems to have made certain bands more amenable to replacement ... whether or not the original limestone was folded." As further evidence of the

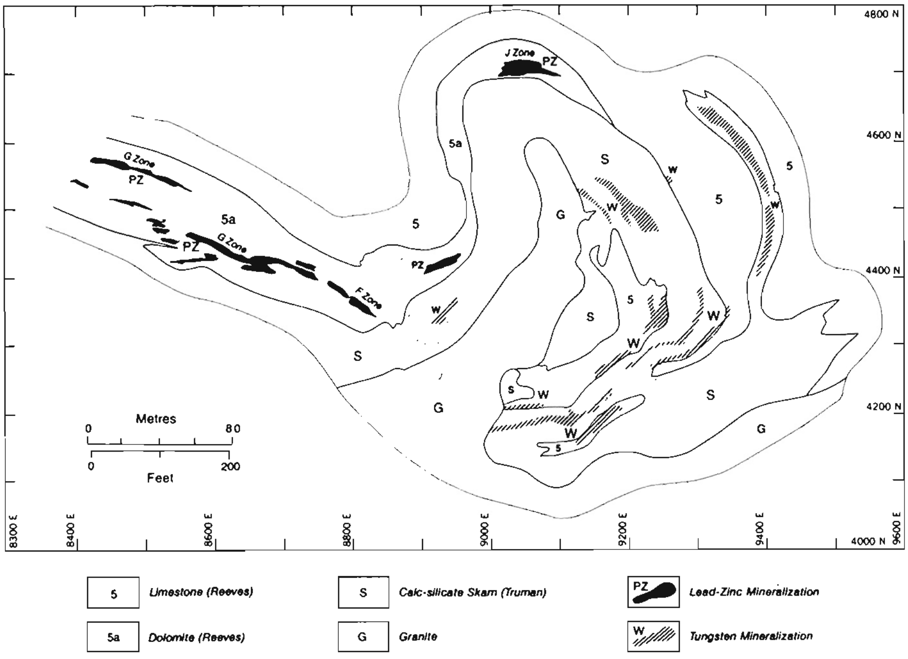


Figure 11B

Composite section looking north of the East Dodger tungsten mine and the Jersey lead-zinc mine (after Thompson, 1973).

---

* Figure 4 mentioned by Thompson is reproduced here as Figure 11B.

stratabound distribution, tungsten occurs at about the same horizon for 3660 m from the Invincible and Dodger mines to the Tungsten King (46a) near the south end of the anticline, and is disseminated through skarn bands in the Reeves and Truman members throughout the mine area. Also noteworthy is the sharp stratigraphic separation between tungsten mineralization and surrounding (in plan) lead-zinc mineralization in the Dodger area. Although both have been deformed, no examples of tungsten in lead-zinc ore, or vice versa, have been reported. Copper is the only significant base metal in the tungsten ore. According to Whishaw (1954), the tungsten ore on the Jersey property contains no zinc. Whishaw also reported less than 10 ppm of zinc in granite from the Jersey mine area whereas argillite stratigraphically above the limestone contained well over 100 ppm. He suggested that as the tungsten ore contained no zinc, the zinc could not have come from the granite but was an original constituent of the argillite.

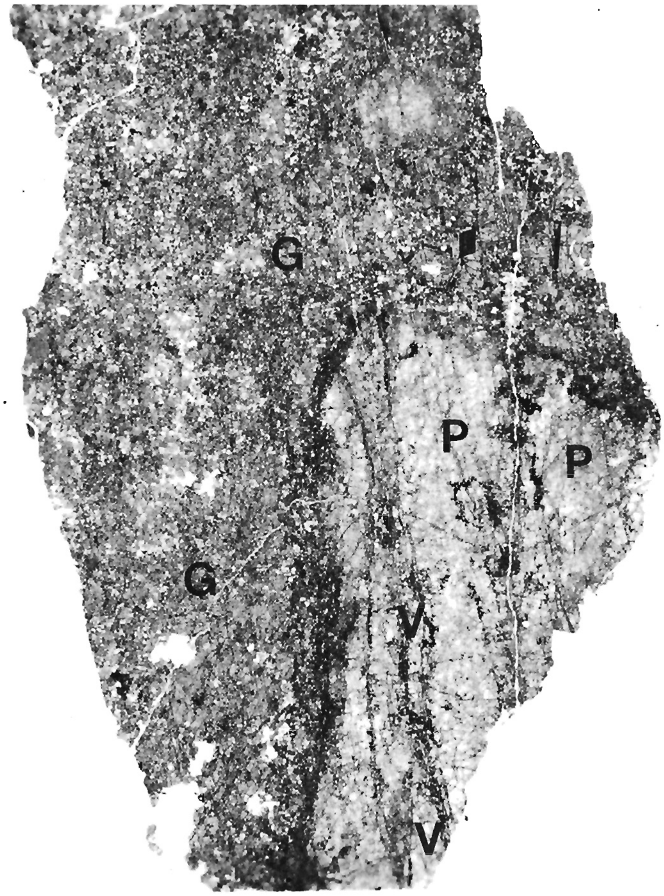


Plate 3. Thin section of skarn ore from East Dodger mine (46b), showing dark, fine-grained rim of amphibole, clinozoisite-epidote and chlorite along contact between corroded garnet (G) and fine pyroxene (P). Tabular vesuvianite grains (V) occur along fractures in pyroxene. (Plain light, X4; GSC 201964-X)

However, no major concentrations of tungsten have been found except in contact with the granite stocks. The abundant evidence of hydrothermal action has been cited. Some light on whether the tungsten was derived from the stocks or was simply remobilized and concentrated by associated hydrothermal action may be found in the chemistry and lithophile element content of the granites and skarns, as shown in Table 6.

The granite samples are composites that can be considered representative of the whole bodies. The Emerald sample is from the Invincible adit, well below the skarn contact of the old mine. The feldspar is mostly fresh and perthitic, though plagioclase is slightly sericitized and biotite slightly chloritized. The samples from the Townsite and Dodger stocks are similar, though a little muscovite is visible in the Dodger granite near the old mine. Lithium, tin and molybdenum are, if anything, a little lower than average in Cordilleran granitoid rocks, and generally lower than in the large Lost Creek body (46a) a few kilometres east. Only the Dodger is slightly anomalous in tungsten, but all the granites are appreciably higher than normal in beryllium. The skarns, however, are not consistently much enriched in beryllium although they are decidedly so in tin. Fluorine (0.02 and 0.03%), and chlorine (0.01 and 0.02%) in the granites are about normal.

Apart from the abnormal beryllium content, which seems to be common to the granites associated with all the large tungsten skarns, there is little to suggest that they are different from other granitic rocks, or that they have undergone any pervasive hydrothermal alteration. The local alteration near the contacts with the mineralized skarns probably was caused by hydrothermal solutions originating outside the granitic stocks, and these solutions probably were the mineralizing agents. They could have been derived from granitic plutons, or from metamorphosed tungsten-bearing clastic rocks, perhaps involving circulating groundwater.

The host limestone overlies a thick sequence of Proterozoic and lower Paleozoic clastic rocks near their western limit and derived partly from the positive Purcell geanticline, in which small tungsten concentrations are fairly common. The underlying Waneta Thrust Fault might have

Table 6. Lithophile element content of granite and skarn, area 46b

		Li	Be	Sn	Mo	W
				(ppm)		
Emerald	granite	21	4.7	1.9	0.2	1
Townsite	granite	18	8.8	1.5	0.2	1
Dodger	granite	16	10.0	1.7	0.2	4
Lost Creek	granite	39	6.6	2.2	0.2	1
Dodger	skarn composite		7.8	160.0		
	vesuvianite		8.0	10.0		
	molybdenite-rich		18.0	120.0		
Invincible	pyrrhotite skarn		23.0	140.0		
	silicate skarn			120.0		
East Dodger	garnet skarn			160.0		

served as a channelway for metal-bearing solutions from hypothetical source beds in these rocks. The granite stocks were probably controlled by imbricate strike faults, which also could have provided channelways for the mineralizing solutions. Overturning of fold axes and overthrusting to the west, steep strike faults and transverse tear faults are characteristic of the Salmo area farther east (Little, 1950, 1965). Perhaps the tungsten-bearing gold-quartz veins of Sheep Creek Camp (46d) are controlled fundamentally by deep-seated imbricate structures.

Regal Silver

The Regal Silver property (55) was operated from 1922 to 1930, about 3660 m of development being done on five levels. It was operated again from 1951 to 1953, when small shipments of silver-lead and scheelite concentrates were made. It was reopened in 1967 by Stannex Minerals, Ltd., and substantial new exploration and development was done in 1968-69.

The property is underlain by carbonaceous black slate and quartzitic grey slate of the lower Paleozoic Lardeau Group (Wheeler, 1963). They dip moderately northeastward. The rocks are virtually unmetamorphosed. The nearest exposed intrusion is quartz monzonite, which cuts granite-gneiss of the Shuswap Complex about 5 km to the southwest. Beryl has been reported in pegmatites in granite-gneiss a few kilometres south of the property (Gunning, 1929). Granitic rocks, locally greisenized, and pegmatite also outcrop within 11 km south. Minor scheelite occurrences (54a,b) are associated with these granites.

The mineralized bodies on the property are quartz-sulphide veins. At least six subparallel veins cross the property within a total distance of about 490 m across their strike. They strike northwesterly and dip 30° to 60° eastward, in general concordance with the country rocks. They range from a few centimetres to 2.5 m in width and up to at least 305 m in length. The veins are commonly banded, with ribbons of unreplaced slate and lenses of slate and sulphides. They generally follow fault surfaces, marked by crush zones and slickensiding. Other faults, distinctly transverse, cut the veins and wall rocks.

The veins consist chiefly of massive milky quartz with lenses of pyrite, varying amounts of argentiferous galena and sphalerite, and minor stannite, chalcopyrite, tetrahedrite and other silver-rich minerals, and scheelite. The principal sulphide mineral, pyrite is locally abundant in the slate wall rocks.

Scheelite amounts are very small throughout the veins (Stevenson, 1943) but the main concentration is in a zone rich in pyrite-chlorite encompassing several levels in the lower workings. There, irregular masses of scheelite several centimetres across are fairly common. A little wolframite and powellite also have been reported. Recorded production amounted to 3328 kg of WO_3 from 1930 to 1954, together with 308 858 g of silver and some lead, zinc and copper.

Stannite occurs mostly in the Snowflake workings, the highest level of the mine. A semblance of vertical zoning is apparent therefore in the relative distribution of scheelite and stannite.

Central Southern British Columbia

Tungsten occurrences in this southern intermontane area (58-65) are not economically or geologically significant. They comprise small, locally scheelite-bearing skarns and quartz veins, some of which have been mined for gold, and for copper and other base metals.

Most of the tungsten is in limestone, greenstone and associated sedimentary rocks of Permo-Carboniferous and Triassic age. These rocks are interspersed among areas of Shuswap gneisses and large and small granitoid plutons of Jurassic to Tertiary age. Occurrences may be associated with Cretaceous rather than older plutons but information is very scarce on many of them.

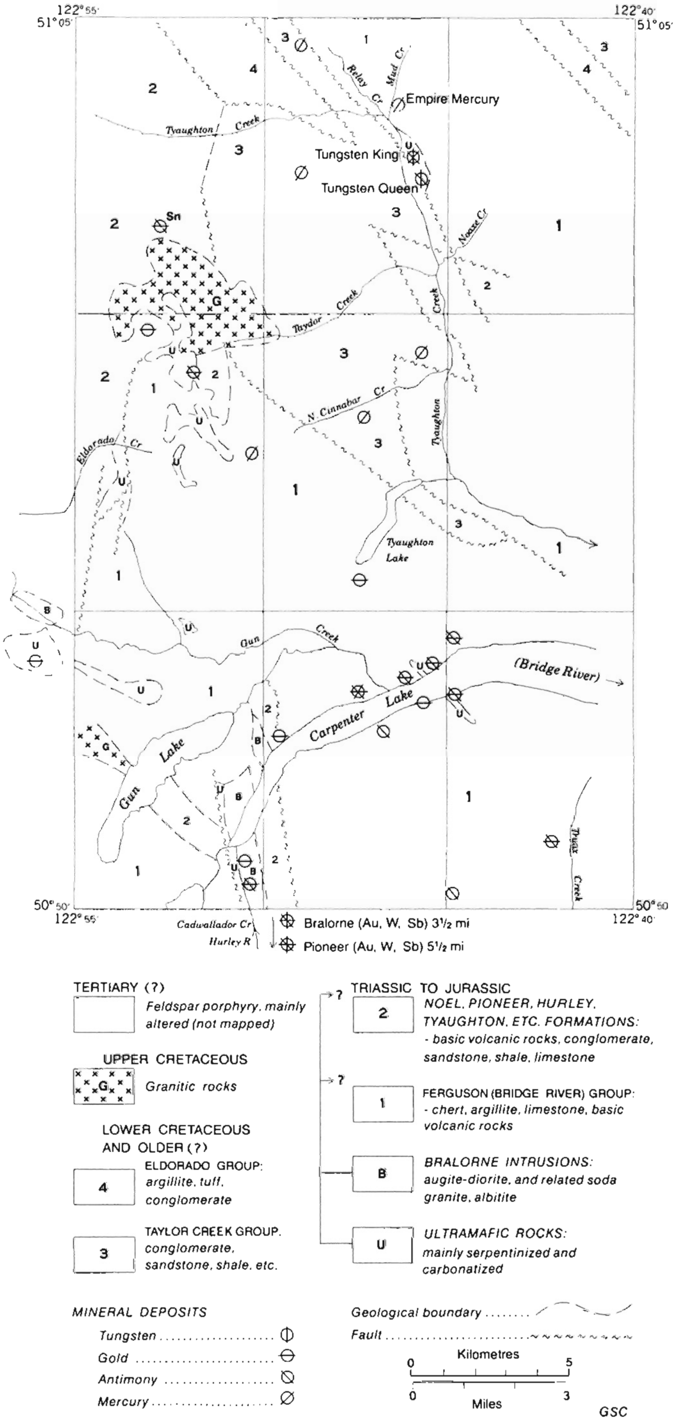


Figure 12. *Geology and tungsten occurrences of Bridge River-Tyaughton Creek area (in part after Pearson, 1975).*

Southwestern British Columbia

The geology of this district (66-73) is dominated by granitoid rocks of the Coast intrusive complex and the Cascade Mountains. These rocks intrude sedimentary and volcanic rocks mainly of Permo-Carboniferous and Mesozoic ages. In the vicinity of the main tungsten occurrences they appear to be mainly Cretaceous, but some stocks cut early Tertiary rocks.

The most significant deposits are in the Bridge River and nearby areas (72a-d, 73a,b, see below), where they are associated with gold, antimony and mercury in partly overlapping zones.

The Mammoth occurrence (66) is in calc-silicate rock in upper Paleozoic greenstone and chert at some distance from Cretaceous diorite stocks. It is one of the many mineral occurrences along or near the Hozameen Fault, a major north-trending element of the Fraser River fault system. The ultramafic rocks along this fault suggest a reason for the unusual and complex mineral association.

The Victory (Westbank) occurrence (68), a vein stockwork in upper Paleozoic or Triassic marble and greenstone, is apparently the only recorded deposit in the Insular Belt. The association with stibnite and gold, as in the Bridge River camp, is also noteworthy.

Bridge River and Tyaughton Creek Areas

The Bridge River (72) and Tyaughton Creek (73) areas together constitute a subprovince that is especially distinctive in the association of tungsten with gold, antimony and mercury in a crude zonal relationship. Modest amounts of scheelite ore have been produced from the Tyaughton Creek properties and from Bralorne, Pioneer (72d) and several other gold properties in the general area. Scheelite is found also in quartz veins east of Gun Creek, according to L.A. Dick (personal communication).

The geology of the area (Fig. 12) has been described by Cairnes (1937, 1943), Roddick and Hutchison (1970) and Pearson (1975). The area, on the east flank of the Coast Range intrusive belt, is underlain by Triassic, Jurassic and Cretaceous sedimentary and volcanic rocks. These are intruded by ultramafic and mafic rocks, and by granitic rocks of Cretaceous and probably Tertiary age. Found at several horizons, conglomerate predominates in the Taylor Creek Group, which covers a considerable area and contains most of the mercury occurrences. Mafic intrusions are host to the gold deposits, which are associated with soda granite. Serpentinite also is found nearby, along the fault zones or 'breaks' that controlled the deposits, and elsewhere in the area, including the locality of the Tungsten Queen and Tungsten King deposits. Fine grained altered feldspar porphyry dykes, probably Tertiary, are especially prominent also in that vicinity.

At the Tungsten Queen property (73a) the workings that I saw in 1975 are in a serpentine-carbonate body between two irregular dykelike bodies of feldspar porphyry. About 3 km south of Mud Creek, the locality is apparently not the showing described by Stevenson (1943). The serpentinite, as exposed for about 305 m along the road, is a dark aphanitic rock locally stained brown or white. A thin section consists mostly of serpentinous chlorite(?), carbonate and quartz, scattered with flakes of green mica. Brown-stained carbonate (ankerite?) forms numerous veinlets. Quartz and quartz-carbonate veins a few centimetres thick cut the body. The feldspar porphyry is a brown-speckled altered rock in which the outlines of original feldspar crystals and biotite can be recognized amongst a fine-grained mass of carbonate and quartz. At one point a vague horizontal banding is visible.

The workings seen are a shaft and, 7.6 m north, an open stope about 1.5 m wide curving in an arc up the rock scarp for about 15 m. The workings are not accessible and no vein material remains at the surface. Below the top of the cut a small adit penetrates about 9 m, exposing several veins 2.5 cm to 7.5 cm thick that dip gently into the hillside. Other similarly oriented veins can be seen above the adit, dipping towards the opencast stope. In the adit scheelite occurs in only a few veins, in hairline stringers along the centres and disseminated in small quartz pods with mariposite. The vein material as seen in a thin section is mostly white carbonate in subparallel bands alternating with thin discontinuous stringers of very fine quartz. The carbonate grains show a slight preferred orientation across the bands but no typical comb structure such as described by Stevenson. Stibnite was not seen in these veins but it was found in bands within solid scheelite in specimens supplied by E. Philips.

According to H.M.A. Rice (unpubl.), who examined the property in 1940, eight veins contained scheelite and stibnite. The quartz and scheelite showed a marked comb structure. Stevenson (1943) described eight scheelite-bearing veins up to 21 m long and 5 cm wide within about 45 m. Neither Rice nor Stevenson saw cinnabar in these veins but Stevenson reported some in greenstone about 137 m to the southeast.

The rocks at the Tungsten King deposit (73b), about 1.5 km north of the Tungsten Queen, are described as similar but scheelite and stibnite occurred in a fracture zone 2 m wide in limestone or dolomite. I did not find the workings. About 27 t of ore containing 5 per cent of WO_3 were shipped to the Bralorne mill in 1942. Mercury also occurs at this property, which was originally called the "Cinnabar King" (Cairnes, 1943).

As these deposits probably are related in some way to the feldspar porphyries, the following analyses of these and other rocks and mineralization are of interest:

	Be	Sn	Li	Rb	Cs	K_2O	F	Cl
	(ppm)					(%)		
Feldspar porphyry								
south	3.5	2.0	20	68	1.0	2.5	0.03	0.01
north	2.9	2.4	164	63	1.8	2.7	0.03	0.04
Ultramafic	<2.0	4.9	36	14	1.8	0.3	0	0.01
Composite scheelite ore		<1.0	201	< 1	0.2	<0.1	0.13	<0.01
Composite mercury ore		<1.0	27	< 1	0.2	<0.1	0.03	<0.01
Composite scheelite veins	<2.0	2.9	33	9	3.8	0.2	0.03	0.04

The high lithium content of the north porphyry body and the scheelite ore composite is remarkable. The lithium and tin content of the ultramafic composite are also unexpectedly high, and the scheelite composite has a notable fluorine content. Although erratic, the values suggest a moderately 'lithophile' environment. A little tin was reported at the Robson arsenopyrite-gold-sulphantimonide property, which is one of those near and believed related to the granite at the head of Taylor Creek (ibid.).

The Bralorne, Pioneer (72d) and other gold mines along the Hurley River – Cadwallader Creek belt also contained stibnite, jamesonite and tetrahedrite as well as various amounts of scheelite. At Bralorne several shoots were mined for their tungsten content. A concentrator was erected and 6779 kg of WO_3 were recovered by 1953. According to some old reports, veins with disseminated scheelite were above average in gold. They also contain mariposite and carbonates. Prominent in fault slices along the belt, the serpentinite is a possible source of the gold mineralization although the veins at Bralorne are mainly in augite diorite and at Pioneer are partly in the closely related soda granite.

A crude zonal relationship between antimony and mercury is apparent because mercury is prevalent in the relatively young conglomeratic Taylor Formation (unit 3, Fig. 12), and antimony, tungsten and gold are scarce or absent from the Taylor and younger formations. This suggests that the latter metals were deposited prior to the Taylor Formation, but no clasts of ultramafic rocks nor Bralorne intrusions have been found in the conglomerate (ibid.). Mercury is practically absent from gold deposits. It is thought to be related to the feldspar porphyries, which cut the younger formations (ibid.). Small segregations of tungsten and antimony in the ultramafic rocks at the Tungsten Queen possibly were mobilized and concentrated by the porphyry intrusions.

Other tungsten in the general area (72a,b,c) is associated mainly with molybdenum and copper, with or without gold. Copper-molybdenum porphyry deposits are known to the west. Mercury deposits are associated with ultramafic rocks along the Yalakom fault zone about 32 km east.

Central British Columbia

This belt includes the Thompson, Cariboo and Omineca districts (74-80). Tungsten occurrences in this belt belong essentially to the East Tungsten Zone although several are in younger rocks and intrusions just outside it. In its northern part the belt is a complex area of major faults and metamorphic complexes that make the two zones difficult to distinguish. Where present and precisely dated, associated granitic rocks are generally Cretaceous, whereas porphyry deposits are associated with older intrusions.

Anticlimax

The Anticlimax occurrence (74) is in a small granitic stock of Cretaceous age (Campbell and Tipper, 1971) among Jurassic, mainly volcanic, rocks. Though principally a molybdenum deposit, it contains appreciable amounts of wolframite, and has the characteristics of a greisen or porphyry deposit. Composite samples of apparently unmineralized granite, and molybdenite-rich and wolframite-rich material are all high in tin (42-120 ppm), lithium (23-77 ppm) and fluorine (0.07-0.65%), as well as tungsten and molybdenum.

Cariboo District

The Cariboo district (75, 76) has been an important supplier of placer and lode gold, and most of the gold occurrences have some associated scheelite. All are as quartz veins, generally with carbonates, and they contain pyrite or pyrrhotite, minor galena and sphalerite, local arsenopyrite, and common antimony and bismuth minerals. Only the Hardscrabble deposit (76e) has produced significant amounts of scheelite.

Much of the district is underlain by Upper Proterozoic sedimentary rocks correlated with the Windermere Group. These are overlain by lower Paleozoic strata, including Lower Cambrian and later major limestone units. They outcrop in anticlinorial belts between synclinoria of younger Paleozoic rocks. Most limestone with associated scheelite mineralization has been considered Early Cambrian but the Hardscrabble and the main gold mines are in a belt now tentatively assigned to the Proterozoic (Campbell et al., 1973).

No granitic intrusions are known in the area that contains the tungsten deposits except at the southern end near Quesnel Lake. Some of these bear muscovite and one contains a fluorite deposit. Rocks there are metamorphosed to biotite-garnet schist. Elsewhere metamorphism generally is low-grade, although in the older rocks, including those of the Lightning Creek anticlinorium, it is somewhat higher than in the younger ones. The rocks in the main area of tungsten occurrences are of the muscovite-chlorite facies, or locally of the biotite-chlorite facies. Metamorphism is thought to have coincided with the folding and foliation of the rocks. This was thought to have taken place mainly in the mid-Paleozoic Caribooan Orogeny (Sutherland Brown, 1963). However, Campbell et al. (1973) presented evidence that it took place mainly during the major Mesozoic orogeny.

The tungsten deposits are quartz and quartz-carbonate veins cutting schist, quartzite and limestone, or bedded replacements in carbonate rocks. The latter are linked to shears or fractures. With few exceptions, the deposits are in a belt less than 1.5 km wide, which extends 69 km from the Hardscrabble property to Quesnel Lake, and also contains most of the gold deposits. The deposits presumably formed during and as a result of the regional metamorphism, but evidently later than the main period of folding. Sutherland Brown (1957) suggested that many of the quartz veins are locally derived segregations, and that the gold mineralization was a later development. Much of the rock in the Hardscrabble dump is black, pyritic, phyllite, probably graphitic, and the 'bedded veins' described below may represent original concentrations of tungsten. It may be significant (see Transportation and Deposition in Part 1) that collophane is abundant locally in the northern part of the Midas Formation, part of the Lower Cambrian or Proterozoic sequence (Campbell et al., 1973).

Hardscrabble

The Hardscrabble property (76e) was developed primarily as a tungsten deposit, though gold was found in some veins. It was operated, mainly between 1935 and 1941, on four levels from a vertical shaft 95 m deep. The workings are inaccessible and the following description is a brief summary of a report quoted by Little (1959).

Micaceous quartzite, sericitic schist and argillite, and interbedded limestone, are strongly sheared and altered. A few drag folds and numerous faults are present. Some faults offset the veins but some may predate mineralization, having provided access for the mineralizing solutions. Most of the scheelite occurred in small quartz stringers of two sets. One set following the bedding is discontinuous, with short thin veins in zones up to 1.2 or 1.5 m wide. Another set of short, narrow veins cuts the bedding. Quartz is accompanied by ankerite and calcite, scheelite, sphalerite and galena. The gold-bearing veins are not known to carry scheelite.

Much of the rock in the dump is black, graphitic-looking and pyritic phyllite. Most of the pyrite, together with a little galena, is in this wallrock schist, and very little is in the quartz. I found practically no scheelite.

Ada and Silver Groups

The minor quartz-vein deposits of the Ada and Silver groups (77c) at the northernmost point of the Fraser River are in paragneisses of the Wolverine metamorphic complex.

About 1.5 km east, these rocks are in fault contact with unmetamorphosed Lower Cambrian and earlier carbonate and shale of the typical Rocky Mountain sequence along the McLeod Lake Fault, which is the outstanding structural feature of the area. The deposits are unusual because they contain graphite. According to Stevenson (1943) graphite was observed only in veins that contain scheelite.

Manson Creek Area

The occurrences of the Manson Creek area (79) are in rocks mapped as Pennsylvanian-Permian Cache Creek Group, off the flanks of the Germansen Batholith. The bedded rocks farther north along the belt contain a section extending from Proterozoic to possible Mississippian (Monger, 1973), and are therefore typical East Tungsten Zone lithologies. The rocks in the area are in fault contact with metamorphic rocks of the Wolverine Complex to the east. The complex probably is derived from Proterozoic and lower Paleozoic rocks typical of the East Tungsten Zone. The Germansen Batholith is a foliated leucocratic biotite granodiorite, bearing muscovite locally and cut by aplite and pegmatite dykes. It is younger than other granitoid bodies of the region. The area, which has been a significant placer gold producer, is cut by major northwesterly trending faults.

At Northern Tungsten (79a) scheelite occurs in placer concentrates and in quartz veins and is disseminated in what appears to be a bed of fine grained quartzite. The contacts are not exposed but the trend appears to parallel nearby dark phyllites. The rock consists of angular quartz grains, subparallel shreds and stringers of biotite, and a few patches of carbonate. It may be a member of the Wolverine Complex, a fault wedge of which was mapped near the locality (Armstrong, 1946).

At the Billy and Glo claims (79b), about 8 km northwest along the Manson Creek fault, scheelite with argentiferous galena and tetrahedrite is found in quartz veins cutting slates and is associated with felsitic dykes. The felsite is common around the Manson Creek area but is seen only locally as crosscutting dykes. It is a light, rusty-weathering, pyrite-impregnated rock. Thin sections show a mosaic of quartz grains and tabular areas of carbonate, sericite and other minerals which appear to be pseudomorphs of feldspar crystals. A composite sample was found to contain 4 ppm of tungsten and 0.09 per cent of fluorine.

The Mill Creek property (79c) is close to molybdenum mapped in the Germansen Batholith (E. Floyd, personal communication). Tourmaline crystals from somewhere in that area contain veinlets of scheelite.

Scheelite (and tin) is more abundant in heavy mineral concentrates from streams draining the north and east flanks of the Germansen Batholith than in the placer workings along the lower part of Germansen River. Samples of granodiorite from south of Germansen Lake are high in fluorine but not in tungsten or tin. The muscovitic granite farther east may be richer in lithophile elements.

The association of tungsten with antimony and gold (in tetrahedrite) and with felsitic dykes is similar to that in the Bridge River area (73a,b). Ultramafic rocks are not mapped in the area, but an asbestos occurrence on Germansen River, an abundance of green (chrome?) mica, and carbonaceous and talcose rocks in and along the Mansen Creek fault zone (B. Thurber, personal communication) suggest that they may be present, as they are along the Pinchi Creek fault to the west.

Central West British Columbia

The central west British Columbia group (81-90) includes the Red Rose mine and numerous other occurrences in the Smithers-Hazelton area, and along the east flank of the Coast intrusions from Whitesail Lake to the Stewart and Portland Canal area. Occurrences are especially concentrated around Terrace. Most are quartz-scheelite veins, and a few are feldspathic and contain a little wolframite. Skarns are rare and small. Host rocks are mainly Upper Triassic to Cretaceous volcanic and sedimentary rocks, and some limestone in the Triassic sequence. Some occurrences are in intrusive rocks, ranging from quartz diorite to granite and from Jurassic to Cretaceous in age as mapped. Probably most of the granite is in plutons east of the main intrusive belt, and at least some of these are Cretaceous.

Deer Horn Mine

Some scheelite occurs in a gold-quartz vein at Deer Horn mine (81) about 305 m east of the main showings. Some is in diorite but most in volcanic rocks. The rocks are contact-metamorphosed and skarn has developed locally but not near the showings. Of the two showings, about 150 m apart, only one contains much scheelite, in numerous small stringers and veins, (see Appendix). The large talus that covers most of the showings averaged about 0.34 per cent WO_3.

Whitewater

At Whitewater (84) a quartz vein up to 0.9 m wide is exposed intermittently for 107 m in talus at the base of a bluff, and carries varying amounts of scheelite. The short adit sampled by Stevenson (1943) was at the richest part of the vein, but he recommended the area for further prospecting.

Glacier Gulch

The Glacier Gulch property (85), on Hudson Bay Mountain near Smithers, is a major porphyry-molybdenum deposit with minor copper and appreciable amounts of tungsten as scheelite and wolframite. A complex series of granitic and rhyolitic intrusions ranging from 60 to 67 Ma cut Jurassic Hazelton Group volcanic rocks. Molybdenum-copper-tungsten mineralization is mainly in fractures and veinlets in a granodiorite sheet that is intruded and brecciated by a rhyolite porphyry plug. The plug is thought to be the source of the main mineralization but is itself mineralized, and is cut by a weakly mineralized quartz monzonite stock. This central mineralized area is surrounded in turn by intermediate zones of barren quartz veining and pyritization, and by outer zones of zinc, lead, copper, silver and arsenic mineralization.

Tungsten, a potential byproduct, occurs mainly as scheelite in the granodiorite sheet, and as minor wolframite in downdip parts. The tungsten zone "straddles the upper 0.2 per cent molybdenum boundary" (Bright and Jonson, 1976).

Hazelton Area

In the Hazelton area (86, 87) the Red Rose mine (86b) was the only major nonskarn tungsten producer in the Canadian Cordillera. The tungsten-bearing deposits are feldspathic ('pegmatitic') quartz veins with various amounts of scheelite and wolframite, copper minerals, and a little gold and silver. Deposits in the area, including to some extent the tungsten deposits, contain a remarkable diversity of minor elements, including cobalt and uranium. The area is towards the west end of the Skeena Arch, a northeasterly trending structural belt that was folded and intruded by granitic plutons in Jurassic to Tertiary times. In some respects this structure forms a link between the area and the East Tungsten Zone.

The areal geology (Fig. 13) has been described by Armstrong (1944) and Sutherland Brown (1960), and the properties by Kindle (1954), Stevenson (1943, 1947) and Sutherland Brown (1960).

The bedded rocks are sedimentary and andesitic volcanic rocks mainly of Cretaceous age, which are known as the Hazelton Group. In the vicinity of the Red Rose mine they include shale, sandstone and hornfelsic rock, which Stevenson described as tuff, and andesitic porphyry bodies that might be sills. These rocks are interbedded with greywacke and minor conglomerate lying mainly to the west. Both members are in fault contact with younger andesitic volcanic rocks on both sides of the Rocher Déboulé stock (86b), a northerly trending elongated body that cuts across the fold trend.

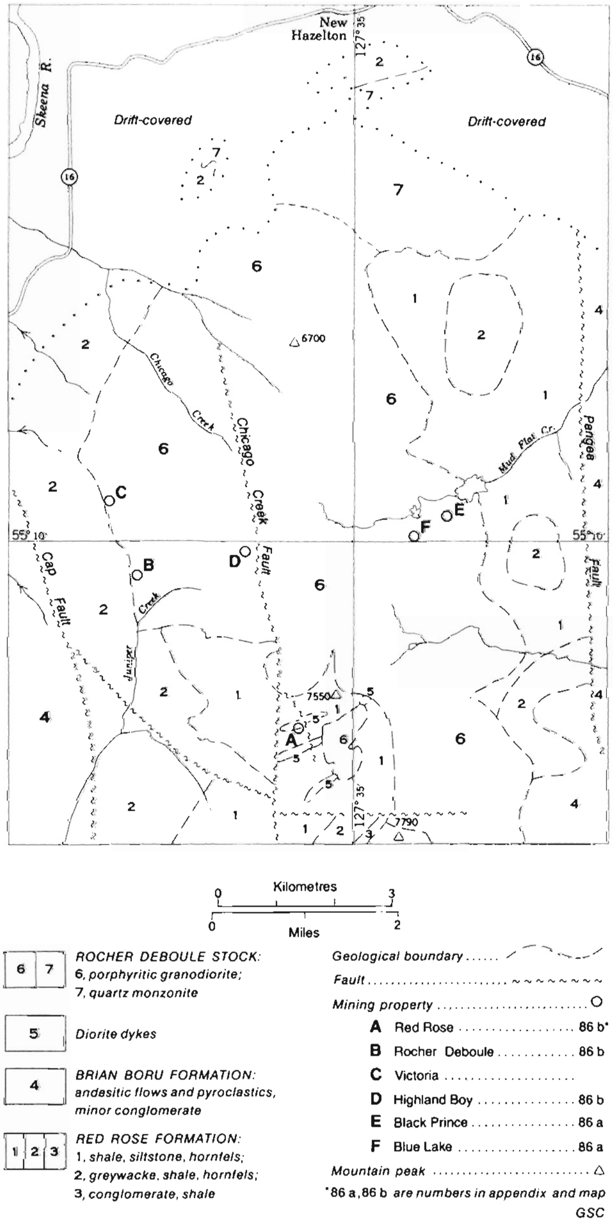


__Figure 13.__ Geological setting of Red Rose and other tungsten and associated deposits, Hazelton, British Columbia.

The stock is composed of porphyritic hornblende granodiorite with abundant inclusions near the roof. Biotite quartz monzonite occupies an area at the north end of the exposed pluton, and dykes at the Red Rose and Rocher Déboulé are probably related. Analyses of composite samples that I took of the granodiorite are as follows:

	Li	Rb	Cs	Sn	Be	Mo	W	K_2O	F	Cl
				(ppm)					(%)	
E of Black Prince to contact	15			<1.5	<5.0	3.0	1			
W of Highland Boy to contact	24			<1.5	<5.0	1.0	28		0.03	0.04
SE of Red Rose	18	95	1.8	1.4	2.5	3.0	1	2.9	0.02	0.06

The lithophile element content is normal or low, except for tungsten west of the Highland Boy (86b), which is probably due to small mineralized quartz stringers. Chlorine content is higher than normal. It is considerably higher than fluorine content in vein material at Red Rose, especially in molybdenum veins.

The stock is in a central block that was uplifted along northerly trending faults. At least part of these are younger than the granodiorite. The Chicago Creek fault passes close to the Red Rose mine and passes far into the stock, passing close to the Highland Boy property. The Rocher Déboulé and Victoria mines are in the stock near its west contact. The Black Prince and Blue Lake properties (86a) are in the eastern part of the stock.

Red Rose Mine (86a). The Red Rose deposit (A in Fig. 13) occurs in hornfelsed sediments, tuff and andesite within 230 m of the Rocher Déboulé stock, between it and another small stock. Three northeasterly trending diorite dykes up to 137 m thick also cut the bedded rocks and the northernmost, the "Mine Diorite", is the main host rock of the deposit. A few felsite and feldspar porphyry dykes cut the diorite and one, the 'vein dyke', locally follows and in part cuts the vein. Similar dykes cut the granodiorite to the north.

The vein occupies a north- to northwest-trending shear zone that is probably tributary to the Chicago Creek fault. It is well defined and mineralized in the diorite, being up to 2.5 m wide for 60 to 120 m along strike and 335 m downdip. It is ill defined and unmineralized in the hornfels and porphyry, where its strike is more northerly. In the diorite, two ore shoots are separated by a low-grade section. According to Stevenson the vein is massive and lacks crustification. It contains lenses of coarse-grained 'pegmatitic' material, some in gradational contact with biotitized wall rock.

The vein material is principally quartz, orthoclase and plagioclase, minor biotite, hornblende, chlorite, ankerite, apatite, scheelite and a little ferberite, chalcopyrite and molybdenite. Orthoclase is considered to be later than pegmatitic quartz crystals but earlier than late fine grained quartz. Hornblende and biotite are considered to be of hydrothermal origin. Scheelite occurs as large crystals in pegmatitic material and small grains in orthoclase and late quartz. Ferberite, which contains only 0.2 per cent of manganese, is in part replaced by scheelite. It is much scarcer than scheelite, according to Stevenson (1947), but formed up to 10 per cent of the vein at the outcrop, according to Kindle (1954). There the vein was coarsely crystalline, with well formed quartz crystals and some vugs and open spaces.

A thin section of ore that I collected (Plate 4) consists mainly of quartz and untwinned feldspar in a mosaic of anhedral grains. Biotite occurs as clumps and most scheelite

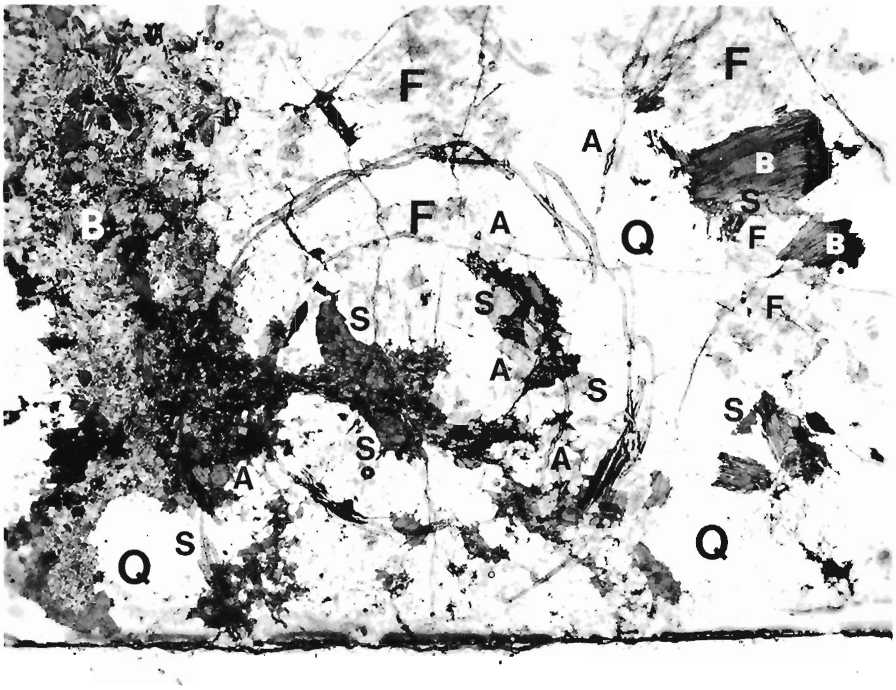


Plate 4

Thin section of vein ore from Red Rose mine (86b). Scheelite (S) and apatite (A) are mainly associated with biotite bands and shreds (mostly dark) in matrix of slightly altered feldspar (F) and clear quartz (Q). (Plain light, X4; GSC 201964-Q)

and apatite are associated with it. Some feldspar appears patchy with vague outlines of included minerals and has numerous parallel wavy fractures that are in part filled by sulphides. The feldspar appears to be potassic. Grains perpendicular to the optic axis have the low negative 2V characteristic of sanidine. A little chlorite and colourles mica border the biotite clusters in places.

According to Stevenson (ibid.), sulphides are rare in the scheelite ore, but are reported in veins up to 15 cm thick elsewhere along the vein shears. I found chalcopyrite to be fairly common in vein material on dumps. Sutherland Brown (1960) reported up to 2 per cent of chalcopyrite in the lower levels. He also reported "green scheelite" containing 0.3 per cent of copper. Stevenson reported appreciable amounts of copper and tin in scheelite. A significant byproduct, copper production of 9655 kg was reported, together with some gold and silver. Molybdenite evidently is rare in the veins, but I found a molybdenum-quartz vein southeast of the lowest adit. It contained much more tin (150 ppm) and other lithophile elements than the scheelite ore composite, and is especially high in chlorine (0.13%). Sulphide veins contain cobaltian arsenopyrite and about 4 per cent of Co (Stevenson, 1947). Uranium is also present. According to Sutherland Brown (1960) most is associated with molybdenite in wall rocks but magnetic rejects from the mill are distinctly radioactive.

Both Stevenson and Sutherland Brown stressed structural control of mineralization. The northerly striking part of the vein is thought to have been closed by compression, whereas the northwesterly striking part, corresponding to the pitch of potential tension fractures, remained mostly open. Stevenson considered the chemistry of the wall rocks also to be an important control. The diorite is 8.2 per cent CaO, whereas the hornfels and tuff are only 1.3 to 2.3 per cent. Stevenson noted that sericitization has been strong for about 15 m from the vein shear, whereas biotite is mostly limited to about 0.3 m, and tourmaline occurs in the biotitized hornfelsic tuff. He reasoned that "the silicification and sericitization of the diorite and the early deposition of scheelite and apatite suggest that the necessary calcium was obtained by reaction of the vein solutions with the dioritic wall rocks." Stevenson (1947) attempted a rock geochemistry approach to the origin of the tungsten mineralization but found less than the 0.2 per cent detection limit in samples of all the rocks. He concluded from the attitude of the vein and granodiorite contact that the source of the tungsten was not in the granodiorite but was in the same magma chamber from which the granodiorite differentiated.

Rocher Déboulé Mine, Highland Boy Property (86b). The Rocher Déboulé mine (B in Fig. 13), about 3 km northwest of the Red Rose mine, is a former producer of gold, silver and copper, and of minor lead and zinc. It also contained fairly abundant cobalt minerals and a little uraninite. Scheelite was fairly abundant in parts of some veins.

The veins follow subparallel fissures in the Rocher Déboulé stock near its west contact, and rarely extend into the sediments. According to Sutherland Brown (1960) they conform to a joint pattern in the intrusion. A few diorite dykes and one of fine grained quartz monzonite are present. As at the Red Rose, the veins contain feldspar, hornblende and apatite, as well as quartz, and were apparently more markedly pegmatitic. They contained some magnetite and molybdenite, as well as cobalt minerals and other sulphides.

Scheelite was found principally in two levels of one vein, over lengths of 180 to 240 m in the western parts close to the granodiorite contact. This zone was also richest in cobalt, and the highest gold values were found where cobalt was most plentiful. According to Kindle (1940), "the presence of scheelite and cobaltite in increasing amounts westerly along No. 2 Vein toward the granodiorite contact with sedimentary rocks indicates zoning. This change of the proportion of different sulphides present is accompanied by a decrease in the amount of hornblende gangue and an increase in the proportion of vein quartz." However, scheelite was found also at the Highland Boy property (86b; D in Fig. 13), 2 km east of the Rocher Déboulé mine, in veins that were thought to be possibly continuous with shear zones at the Rocher Déboulé and were similar in mineralogy. No scheelite was reported at the Victoria mine (C in Fig. 13), which is about 1.5 km north of the Rocher Déboulé. There the veins were considered part of the same system. They also contain feldspar, hornblende and apatite as well as quartz. Cobalt, molybdenum, arsenic and gold were major products. Uranium also apparently was prominent. It may be significant that the veins evidently lacked important copper mineralization as well as scheelite.

From the foregoing data, there seems to be a crude metal zoning along the west contact zone of the Rocher Déboulé stock. Cobalt, and probably uranium, appear to occur in increasing proportion northward, whereas tungsten increases southward and culminates in the Red Rose deposit, beyond the granodiorite contact.

Black Prince, Blue Lake (86a). These neighbouring properties (E and F in Fig. 13) are in the eastern part of the Rocher Déboulé stock. At the Black Prince, quartz veins follow shear zones developed on steeply dipping joints and contain tungsten as wolframite and scheelite. Extending about 305 m horizontally and 210 m vertically, the main zone contains several parallel quartz veins separated by sheared and silicified wall rock, totalling up to 3.7 m in thickness. Several adits have been driven and some open cuts made on benches. Most of the wolframite and scheelite were found near the hanging wall and some locally near the footwall. Analyses reported by Kindle were about 0.38 per cent WO_3 but Sutherland Brown (1960) reported 0.82 and 0.84 per cent of WO_3 in two of three samples. A quartz vein 5 to 25 cm wide, located 244 m east of and parallel to the main vein, contains scheelite with pyrite and chalcopyrite. Kindle (1954) reported that samples from an adit 33 m long contained 1.10 to 2.37 per cent of WO_3 and 0.8 to 1.3 per cent of tin together with some gold and uranium mineralization. Samples that I took from this adit and other accessible workings on the property contained a maximum of 16 ppm of tin.

At the Blue Lake property about 0.8 km west of the Black Prince, similar quartz shear veins in granodiorite contain scheelite and a little ferberite together with pyrite, chalcopyrite, molybdenite and tetrahedrite.

Terrace Area

An area northeast of Terrace (88) contains a great many small quartz vein deposits containing gold and copper, zinc, lead, silver and antimony sulphides, and some molybdenite and scheelite. The Ptarmigan (88a) and White Bluffs (88b) deposits are described as pegmatitic veins in granodiorite, and 25 per cent of orthoclase is reported in the White Bluffs vein. These therefore resemble the Red Rose and Rocher Déboulé deposits in the Hazelton area.

Alice Arm Area

In this area (89) at the Cariboo, Lynx, etc. (B.C. Moly) (89c), a major molybdenum porphyry-type deposit, scheelite occurs in quartz veins up to 0.9 m thick, which cut the molybdenite-bearing veins. The scheelite-bearing veins also contain minor cosalite and other sulphides and some fluorite. They are said to be barren of molybdenum, and the molybdenite veins contain only traces of tungsten.

Stewart Area, Portland Canal

Tungsten occurrences in the area (90) are few and small, but the presence of minor tungsten at the Premier mine (90d), a former major gold and silver producer, is significant. The nearby Riverside mine in Alaska was mined for tungsten. The Premier deposit is in Lower Jurassic volcanic and sedimentary rocks assigned to the Hazelton Group. These are cut by the Jurassic Texas Creek granodiorite, by granitoid dykes of the Premier dyke-swarm, and by the Tertiary Hyder quartz-monzonite batholith. According to Groves (1971), "scheelite has been found in the Premier ores with quartz as veinlets cutting all but the latest phase of quartz-sulphide mineralization." Groves analyzed samples of pyrite, sphalerite and galena from various properties, and reported: "The Premier has a unique Cu-W-Co-Mo group, the Dunswell has a Ni-W-Mo group." His graphs show tungsten highest in galena at the Premier, where it has 100 ppm.

Northern British Columbia and Southern Yukon

This large area (91-102) contains significant tungsten deposits in the Cassiar district (91-100 and 102) and the Atlin district (101). The Cassiar district as here defined includes the Cassiar Mountains in the vicinity of the northern part of the Cassiar Batholith. It is part of the East Tungsten Zone, coinciding essentially with the Omineca Crystalline Belt. From the Cassiar district the eastern boundary of the East Tungsten Zone veers abruptly northeastward to encompass the easternmost granitic plutons east of the Tintina Trench (see general description of East Tungsten Zone). Directly northwestward beyond the north end of the Cassiar Batholith only a few minor tungsten occurrences are known, and no beryllium. Westward from the Cassiar district a chain of granitic plutons extends westward to the Atlin district in the West Tungsten Zone. These plutons include relatively young leucogranites in both areas and have associated wolframite-cassiterite and silver-lead-zinc occurrences. Thus the Atlin district appears to be related metallogenetically to the East Tungsten Zone, although the bedded rocks are younger. (Dawson and Dick, 1978, describe a W,Mo(Zn,Pb,Ag) skarn occurrence, the Mid-Nite, 60°20'N, 130°41-42'W, not listed in the Appendix.)

In addition to wolframite and scheelite deposits, the Cassiar area contains an unusual number and variety of beryllium and tin occurrences, and many small molybdenum and silver-lead-zinc deposits. The Rye (93a), the Wolf and the Ewe (93b) are in a southeastern extension of the Cassiar district.

Blue Light

The Blue Light scheelite skarn deposit (98) is in an enclave of metasedimentary rocks between the west boundary of the Cassiar Batholith and a small outlying stock. Both the stock and the batholith in that area are miarolitic and contain muscovite and disseminated fluorite. The west contact of the batholith is marked by a major fault zone that extends for 145 km (Gabrielse, 1969; Poole et al., 1960) and the granite is sheared and altered for several kilometres from the contact.

Within the metasedimentary enclave the tungsten deposit adjoins an area of berylliferous pegmatites, tin-bearing magnetite-pyrite veins and fluorite replacements in limestone, as well as other small scheelite concentrations.

At the main scheelite showing, in an area about 60 m long exposed by stripping, light-coloured skarn bands up to 1.5 m thick alternate with bands of grey feldspathic augen gneiss (Plate 5A). Both the skarn and the gneiss bands are cut by pegmatite dykes. Only the discrete skarn bands contain scheelite, although transitional bands with large clumps of garnet in biotite-muscovite-quartz-plagioclase rock contain abundant reddish fluorescent apatite (Plate 5B). Scapolite was also identified in this material.

The scheelite skarn is composed mainly of plagioclase, quartz and epidote-group minerals including zoisite, garnet and apatite. Some areas consist largely of muscovite mixed with biotite. Masses of scheelite up to 10 cm long are in the outcrop. In the specimen of Plate 5A, the scheelite is associated with such minerals as garnet and epidote near the boundary of a muscovite-rich area. A thin section (Plate 6)

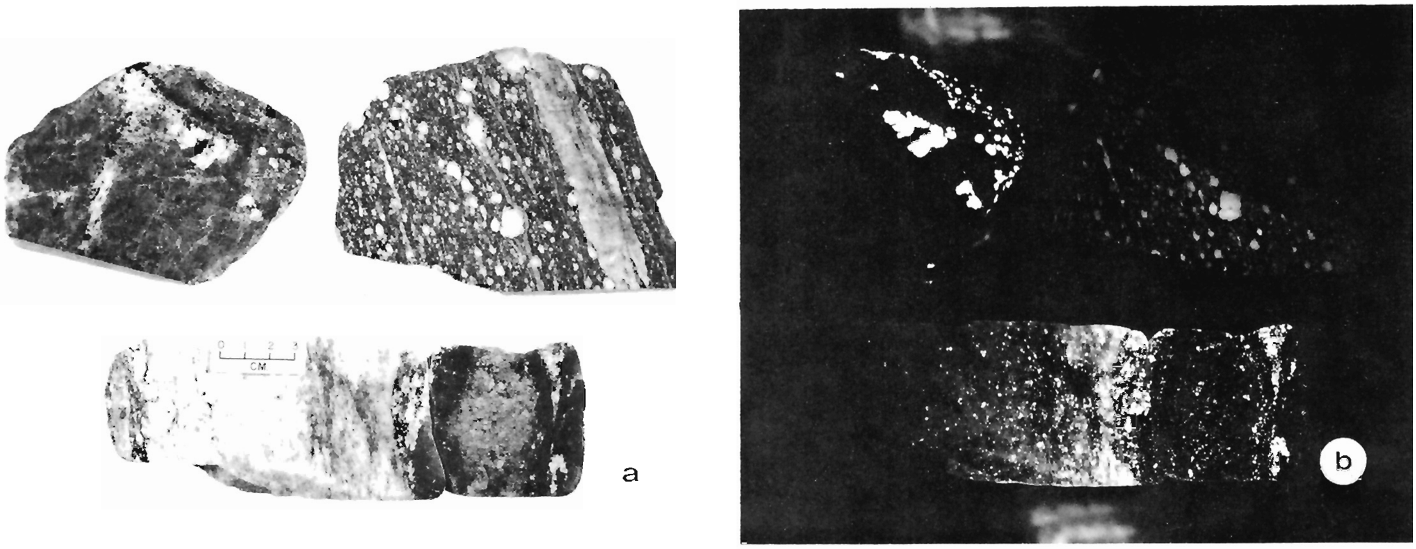


Plate 5. Blue Light skarns and associated rocks (98). On the upper left is scheelite-rich plagioclase-epidote-mica skarn; upper right is interbedded feldspar augen gneiss, and below, transition rock, garnet nodule in dark epidote-mica assemblage. Fluorescent material is mostly apatite. Reflected light (GSC 201964-M). Ultraviolet fluorescence (GSC 201964-O).

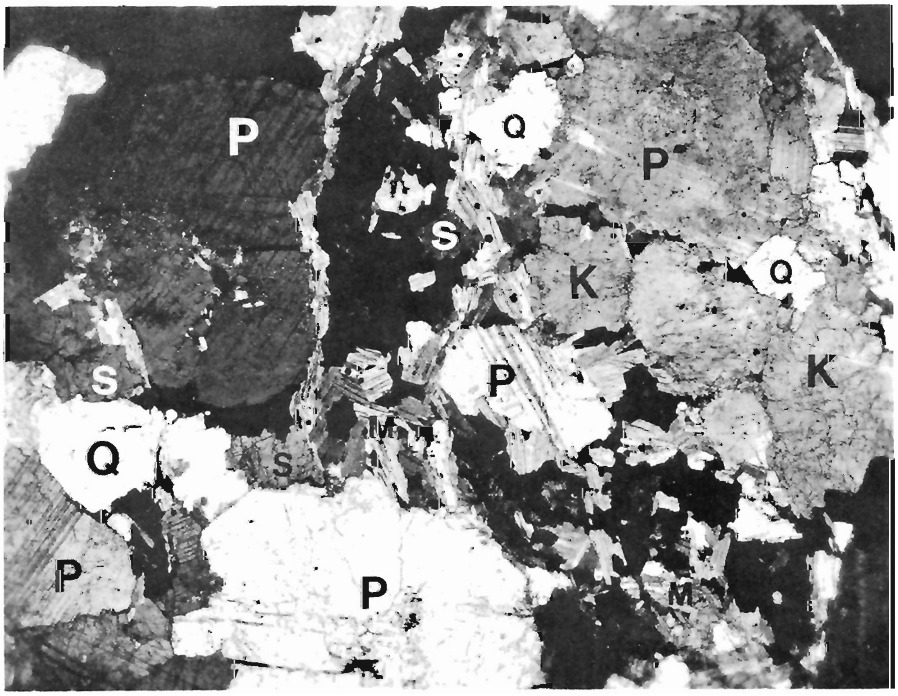


Plate 6

Thin section of Blue Light plagioclase-rich scheelite skarn (98). Plagioclase (P) is partly replaced (?) by potassic feldspar (K); quartz (Q) is minor; scheelite (S) is mostly associated with shreddy, pale mica (M) and epidote; dark areas are partly fluorite. (Crossed nicols, X15; GSC 201964-V)

consists chiefly of plagioclase with much epidote and zoisite, and lesser amounts of apatite, biotite, chlorite, fluorite and yellow sulphides. The plagioclase is mostly in well twinned patches among untwinned feldspar that may be potash feldspar.

The zone containing the skarns is said to extend more than 245 m southward from the stripped area. Assays of 2.8 to 7.9 per cent WO_3 have been reported in bulk samples. A composite sample that I took was found by spectroscopic analysis to contain 0.05 per cent of Be and 0.03 per cent of Sn.

Logjam Creek

At the head of Logjam Creek (100), a small plug of biotite granite is cut by quartz and feldspathic quartz veins containing wolframite, beryl, fluorite, molybdenite and bismuth minerals. These minerals are also disseminated in the granite and occur in quartz veins in the hornfelsic aureole. Beryl is also in small quartz-feldspar veins cutting granite dykes north of the stock. The veins contain a little muscovite as well as fresh perthitic feldspar and apatite. The granite of the stock is generally fresh, only biotite being appreciably altered. Potash feldspar contains abundant inclusions of quartz and plagioclase, but there is no clear evidence of pervasive secondary feldspathization, or of extensive greisenization in the stock.

The stock, about 0.8 km across, is probably a satellite of the nearby Seagull Batholith, a late hypabyssal leucogranite characterized by miarolitic cavities with tourmaline, fluorite and local topaz.

A new occurrence in this area, the "Logtung", is described as a quartz vein stockwork, with scheelite and molybdenite. A zone 2 km long and 1000 m wide is said to contain 194 Mt grading 0.12 per cent WO_3 and 0.051 per cent MoS_2, with some higher grade areas (Northern Miner April 6, 1978, p. 1). The property was optioned from Cordilleran Resources, Ltd. and drilled in 1977 by AMAX. In specimens seen, scheelite forms continuous veinlets and closely spaced parallel groups of veinlets in light grey, white-streaked aphanitic rock that appears to be highly sheared. Vesuvianite occurs in thin radiating groups on fracture surfaces of some specimens. According to K.M. Dawson (personal communication), tungsten skarn adjoins the stockwork.

Atlin District

Tungsten in the Atlan district (101) lies in or near a biotite-granite body mapped as alaskite and quartz monzonite (Aitken, 1959). Of Late Cretaceous or Early Tertiary age, the body extends about 64 km across the northern part of the Atlin map area. It cuts Pennsylvanian and Permian sedimentary and volcanic rocks of the Cache Creek Group, and ultramafic intrusions. It also intrudes hornblendic granodiorite and quartz diorite referred to the Coast intrusions on the west.

Line Lake

At this property (101b), about 56 km east of Atlin, wolframite and scheelite occur with cassiterite, chalcopyrite, sphalerite and galena in quartz veins and are disseminated in limestone bands. Several feldspar porphyry dykes and stocks outcrop on the property, which is about 8 km south of the Surprise Lake alaskitic granite batholith.

Black Diamond Mine, Boulder Creek

Near the western extremity of the Surprise Lake Batholith, tungsten and molybdenum (101c) with minor tin lie in a roughly linear zone across the heads of Boulder and Ruby creeks. This zone includes the Black Diamond tungsten mine and the Adera molybdenum deposits. Wolframite and cassiterite occur in appreciable amounts in the heavy concentrates of gold placer deposits on Boulder and Ruby creeks.

The granitic rocks of upper Boulder and Ruby creeks are highly variable in granularity and texture, and include aplite and quartz and feldspar porphyries as well as coarse porphyritic granite and alaskite. These rocks commonly are altered and laced with quartz veins. Feldspar is altered to sericite or kaolin and biotite to sericite and chlorite. Iron and manganese staining is widespread. Purple fluorite is local.

The Black Diamond mine was explored and worked in a small way by N. Fisher and E. Olsen of Atlin from about 1940 to 1943. A bulk sample of 815 kg of wolframite ore contained 15.2 per cent of WO_3 and 0.18 per cent of tin (B.C. Dept. of Mines, 1944). Bulk concentrates shipped in 1949 from placer operations on upper Boulder Creek averaged 48.5 per cent WO_3 and 9.73 per cent tin. From 1950 to 1952 Transcontinental Resources outlined five mineralized zones. In the main zone of the Black Diamond, an adit was driven for 120 m.

According to available information (Aitken, 1959; Little, 1959), the mineralized zone is 0.6 to 1.2 m wide and contains veins up to 2.5 cm wide in sericitized and kaolinized granite. Wolframite is found with quartz in comb structure extending from the walls. The zone averaged 1.85 per cent WO_3 and had traces of gold, silver and tin across an average width of 1 metre. The workings are inaccessible now. The granite around the portal is greisenized and kaolinized. A composite sample of vein material was found by spectroscopic analysis to contain 0.66 per cent of W, 76 ppm of Sn and 20 ppm of Mo.

The deposit may be related as a peripheral zoning feature to the Adera molybdenum deposit about 1.5 km north.

Adera

In the southern part of the Adera molybdenum deposit on Ruby Creek (101c), wolframite is sporadic in quartz veins (Sutherland Brown, 1970). The numerous molybdenite-bearing quartz veins occur minaly in coarse granite similar to that at the Black Diamond but they may be related to other intrusive phases. The deposit has some of the characteristics of a porphyry deposit but is not typical (White et al., 1976). I took a composite sample of wolframite-bearing veins, which was found by spectroscopic analysis to be 0.2 per cent W and 0.021 per cent Mo. The spiral underflow from development material contained 2.18 per cent of WO_3. This corresponds to an average concentration of 0.0068 per cent WO_3 in the millheads.

White et al. (ibid.) mentioned that there was a wolframite-bearing breccia on the property north of the Black Diamond mine. This suggests a link between the tungsten-bearing veins on the two properties.

Fiddler (Yukon Tungsten)

At the Fiddler property (102), about 9.5 km by secondary road north of the Alaska Highway at Mile 701.6, quartz-greisen veins up to 0.76 m thick cut contorted chloritic mica schist and limy phyllite of early Paleozoic age near the top of a rounded dome. No intrusive rocks are exposed in the immediate area, which is about 2.4 km east of the Cassiar Batholith. An adit was driven in about 1952 from a point about 210 m southeast of the surface showings for about 150 m, and an inclined raise connected it to a pit near the main vein (Green, 1966).

One or more veins up to 0.76 m thick are exposed in trenches on top of the hill. They strike northeasterly and dip moderately southeast. The veins are partly massive but elsewhere contain large quartz crystals interlocking in comb structure. In places they are banded with thin streaks of greenish yellow mica at the hanging wall. Wolframite, in bladed crystals about 10 cm long, is mainly in the upper parts of the veins, and blue-green secondary copper minerals are mostly in the lower parts. A little molybdenite and yellow molybdite are present, and purple fluorite is prominent locally. Thin sections show wolframite crystals broken and veined by sericite, quartz and fluorite.

This vein has been traced for 200 m in a series ot trenches. Crystals of wolframite also are scattered in small veins on the south slope of the hill above the adit. These consist chiefly of quartz and bordering plumose pale greenish mica, scattered green fluorite and cassiterite. The wolframite is reported to contain 12.6 per cent of MnO. A specimen that I selected was found to be 0.2 per cent tin.

A small mill was built near the Alaska Highway but never operated (ibid.) and eventually was destroyed by fire. Some further stripping and trenching were done for Silver Seven Exploration, Ltd. in 1969. A new showing 2 to 4 m wide and possibly 90 m long was reported to contain up to 0.54 per cent of tungsten (Craig and Laporte, 1971). This was described as "Fiddler East". Beryl was reported to occur at

Fiddler West (the old showings?). I found none in the trenches or in thin sections and no sample contained as much as 100 ppm of Be. A composite of samples contained 160 ppm of Li, probably all from the greenish mica.

East Yukon and Western Northwest Territories

This group (103-114) includes the major deposits of the 'main tungsten belt' (Canada Tungsten, AMAX Northern) near the territorial boundary in western Northwest Territories, and an 'inner arc' of minor occurrences farther west in the Yukon east of the Tintina Trench.

Figure 14 shows the distribution of tungsten deposits in relation to the main areas of exposed Proterozoic rocks. Although the carbonate host rocks of Canada Tungsten (107g) and AMAX Northern (111a) differ in age, as do some minor deposits, these major deposits are adjacent to major areas of Proterozoic clastic sediments, and most of the minor ones are in or near Proterozoic belts. Both Proterozoic belts extend northwest into the McQuesten-Mayo district (114). They are separated in part by Cambrian to Mississippian rocks of the Selwyn Basin, which are the hosts of many stratabound zinc-lead and barite deposits (Blusson, 1976). The host rock of Canada Tungsten and several nearby deposits (107a-h) is Lower Cambrian limestone, but several others are in Middle or Upper Cambrian limestone. AMAX Northern is in limestone of probably Ordovician age, and some minor occurrences are in Devonian to Mississippian carbonate rocks.

The deposits of the 'eastern arc', including the Canada Tungsten, AMAX Northern and McQuesten-Mayo, are in areas of numerous small intrusions, which range from quartz monzonite to granite in composition. The bodies at Canada Tungsten in particular may be of somewhat younger Cretaceous age than the major batholiths of the region (Zaw, 1976), of which the one about 16 km southeast

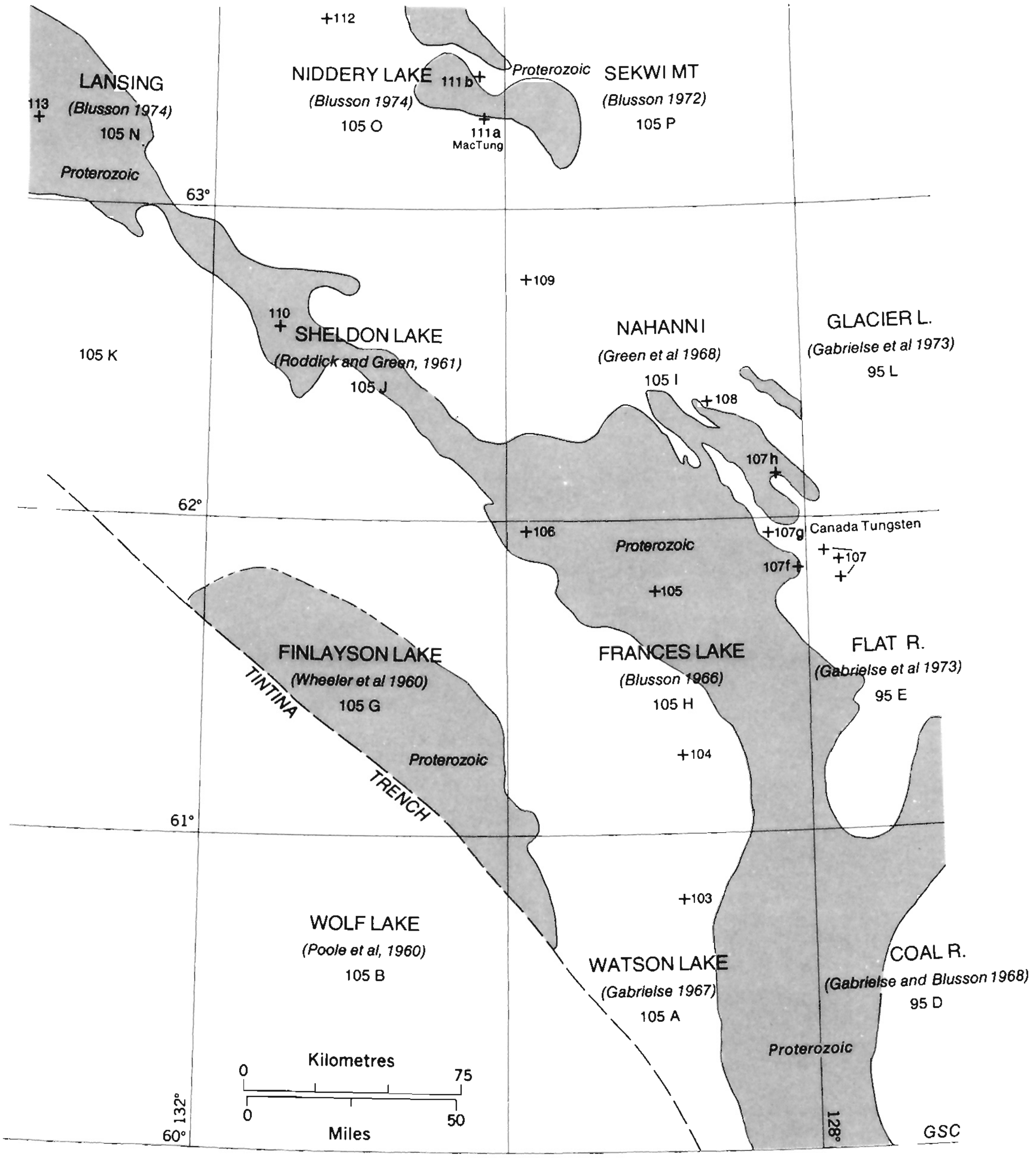


Figure 14. *Proterozoic belts and tungsten occurrences of east Yukon-Northwest Territories, with references to areal geological maps and reports.*

indicated an age of 110 Ma (Gabrielse et al., 1973). This is about the age of the Itzi stock, 45 km south of AMAX Northern (Blusson, 1968), but the O'Grady stock, 80 km southeast of AMAX Northern, indicated an age of 88 Ma. Biotite is the predominant mafic mineral in the granites. Muscovite is rare except in contact greisen zones at Canada Tungsten and AMAX Northern. Textures of the granites, in particular the lack of perthitic intergrowths (in my few thin sections), suggest that they are subsolvus types, crystallized from a water-rich magma at relatively high confining pressures. However, Blusson (ibid.) described the potash feldspar at Canada Tungsten as microperthitic. The most distinctive pluton mineralogically is the Hole-in-the-Wall Batholith. In the vicinity of Pass Creek, about 56 km southeast of Canada Tungsten, it contains much tourmaline in clots of radiating crystals up to 10 cm long with quartz and local cream feldspar. Some of the granite in that area is miarolitic (Gabrielse et al., 1973; Gabrielse, personal communication). Tourmaline is abundant also in quartz veins near the granite contact at AMAX Northern, and it occurs in greisen and margins of pegmatoid quartz veins at Canada Tungsten.

An extensive geochemical survey of the granitic plutons throughout the belt was conducted by Garrett (1971a,b, and unpublished information). Of 102 plutons sampled at 1516 sites, 20 have anomalous maximum tungsten contents ranging from 12 to 480 ppm. Of these only 12 have mean values greater than 2 ppm. Five of the high maxima and two of the mean maxima are in plutons near the MacTung (AMAX Northern) deposit, including 80 ppm maximum and 3.5 ppm

Table 7. Analyses of granitic rocks and skarns, east Yukon-Northwest Territories

	Li	Rb	Cs	Sn	Be	Mo	W	F	Cl
				(ppm)				(%)	
Canada Tungsten									
Granite									
adit	54	152	9.9	19.0	5.8	2.0	4.0	0.08	0.03
north, core	62	177	10.0	3.3	6.0	1.0	2.0		
	69	181	12.0	6.4	6.0	1.0	1.0		
	45	182	8.0	11.0	9.0	1.0	1.0	0.05	0.01
	75	153	8.4	3.3	4.6	1.0	2.0		
	67	175	12.0	8.6	4.1	0.5	2.0		
south	76	199	10.0	9.7	8.0	1.0	12.0	0.06	0.00
Aplite, Pit	15	109	2.8	10.0	5.0	0.5	2.0		
	29	195	5.1	9.2	7.0	0.5	4.0		
				4.5	7.3				
Quartz veins, Pit	12	24	1.2	9.2	3.0	15.0	0.6%		
	15	24	1.4	3.3	2.0	3.0	0.4%		
Skarn, high-grade									
E Zone	160	257	4.5	38.0	3.0		11%	0.26	0.01
Pit	24	44	3.8	65.0	42.0	3.0	0.3%		
				37.0	32.0		0.2%		
AMAX Northern (MacTung)									
Granite									
North Face	48	16	8.9	4.6	20.0	15.0	20.0		
North Saddle	80	314	20.0	7.9	7.0	1.0	4.0	0.03	0.01
SE corner	83	252	11.0	5.0	5.0	3.0	8.0		
Greisen									
SE corner	146	253	31.0	110.0	7.0	1.0	8.0		
North Face	78	21	13.0	37.0	51.0	8.0	0.5%		
Quartz veins									
North Face	22	24	2.8			92.0	60.0		
North Saddle	42	74	2.4	7.5	23.0	120.0	0.16%	(tourmaliniferous)	
(Mo) North Saddle	36	294	11.0	7.6	4.0	50.0	0.02%		
Skarn									
B Zone	12		0.6	110.0	50.0	5.0	0.2%		
sulphide	30	45	4.0	61.0	45.0	20.0	0.7%		
McQuesten-Mayo									
Granite									
Dublin Gulch	37			1.0	< 5.0	0.5	4.0	0.06	0.02
Highet Creek	56			4.0	5.0	0.2	16.0		
Roop Lake	39			5.0	< 5.0	0.5	1.0	0.09	0.03

mean in the associated pluton. This is one of "two distinct areas of higher mean tungsten content" in the belt (Garrett, 1971b). The other area is the McQuesten-Mayo district, where several of the plutons locally contain scheelite in veinlets. One other pluton with outstandingly high maximum and mean tungsten content (275 and 28.6 ppm, respectively) is the one associated with the Lened deposit (108) 51 km northwest of Canada Tungsten. The few samples from Canada Tungsten north and south plutons were found to contain only 1 to 2 ppm of W. These values may be less representative than my sampling results (Table 7). The average for all plutons in the belt is 2.9 ppm W.

Analyses for tungsten and other lithophile elements of skarns, quartz veins and granite that I sampled are shown in Table 7. These meagre data suggest that the skarns and granite at AMAX Northern are, on balance, somewhat more enriched in lithophile elements, especially molybdenum, than corresponding rocks of Canada Tungsten. Tungsten seems to be appreciably higher in granite at AMAX Northern but the samples were taken somewhat closer to skarned or veined rock. The granites of McQuesten-Mayo district apparently are higher in fluorine than the others but otherwise are relatively impoverished. The high tungsten content of Highet Creek granite is suspect because at the source scheelite-bearing veins abound. The granites of both Canada Tungsten and MacTung (AMAX Northern) areas are moderately enriched in lithium, caesium and tin. Both granites and skarns are distinctly enriched in beryllium.

The earliest deformation recorded in the region, the 'Racklan Orogeny', caused tilting and block-faulting of the oldest exposed Proterozoic rocks of the northern Cordillera, and a conspicuous unconformity beneath the Rapitan Group (Gabrielse et al., 1973). They were further mildly deformed in later Precambrian time. An important episode of deformation in probably post-Middle Cambrian time is marked by tight folding and strong cleavage in Proterozoic to Lower Cambrian rocks along Hyland River (ibid.). This may apply to the belt of 'Proterozoic' rocks west of Canada Tungsten. 'Metamorphic' Zn-Pb skarns in the Hyland River area probably formed during a pre-Devonian metamorphic event (K.M. Dawson, personal communication).

The main period of deformation and granitic intrusion in this part of the Cordillera was in mid-to-Late Cretaceous time. All the tungsten deposits are closely related spatially, and apparently genetically, to granite bodies. However, prior orogenic episodes and ancient structures may have been instrumental in bringing about unusual concentrations of tungsten where the deposits are now. The arch structure that extends through the area east of Tintina Trench is a major Cordilleran feature. The strike of fold axes changes from generally north-northeast at the south end to nearly west in McQuesten-Mayo district. The curvature of the fold belt in Sekwi Mountain area east of AMAX Northern is especially sharp. The entire area northeast of the Tintina Trench may have been displaced as much as 350 or 450 km southeastward of the area southwest of the trench (Roddick, 1967; Tempelman-Kluit, 1977).

This is also the part of the Cordillera closest to the exposed Precambrian Shield, specifically to the Slave structural province, in which tungsten and usually rare lithophile metal-bearing pegmatites are abundant.

The main deposits are scheelite skarns and most of the minor ones are also skarn types. Scheelite-quartz veins are subordinate at Canada Tungsten and AMAX Northern but are important in the McQuesten-Mayo district, where some also contain wolframite. Copper is the main base metal of most tungsten deposits, although they are in a zinc-lead province and most of them, including Canada Tungsten and MacTung (AMAX Northern), contain some zinc. Zinc also exceeds copper in some scheelite skarns west of Hyland River ('inner arc', see above), and some skarn zinc-lead deposits there contain a little scheelite (Dawson and Dick, 1978). However, some bedded copper deposits (Redstone, etc.) are, perhaps significantly, present in older Proterozoic rocks, where the outcrop in the Mackenzie Mountains about 115 km northeast of Canada Tungsten (Gabrielse et al., 1973).

Occurrences summarily described by Dawson and Dick (1978) are presented here; some ore was produced from the Max deposit in 1977.

	Metals	Coordinates	NTS Number	Number in Appendix and Map 1556A
MacTung	W, Cu (Zn, Mo)	63°17' 130°09'	105 O	111a
Clea (Omo)	W, Cu (Zn)	62°46' 129°52'		109
Lened (Nip)	W, Cu (Mo)	62°22' 128°38'		108
Cantung	W, Cu (Zn)	61°57' 128°15'	105 I	107g
Nar	Zn, Pb, Cu, Ag (W)	62°01' 129°53'		
Marchilla (Ptarmigan Creek)	Zn, Pb (W, Cu)	61°57' 129°52'		106
Woah	W (Mo, Zn)	61°51' 129°11'		105?
Tai	W (Zn, Cu, Mo)	61°49' 129°00'		
Tanya	W (Cu, Zn, Pb, Ag)	61°48' 128°54'		
Zeus (Ldg)	Zn, Pb (W, Cu)	61°52' 128°58'		
Ckap	Zn, Pb (W, Cu)	61°52' 128°53'		
Ron	Zn, Pb (Cu, Ag)	61°27' 128°30'	105 H	
Firtree	Zn, Pb (W, Ag)	61°25' 128°27'		
Blackjack	Zn, Pb (W, Ag)	61°22' 128°23'		
Max (BM)	W + Zn, Pb, Ag, Cu	61°16' 128°41'		104?
Glenna-Miko	Zn, Pb (W, Cu)	61°16' 128°35' (61°15' 128°30')		
Bailey	W, Cu	60°46' 128°51'	105 A	

Canada Tungsten Mine

The Canada Tungsten mine (107g), a skarn-scheelite deposit, is in the District of Mackenzie, Northwest Territories, just east of the Yukon boundary. Since the start of operations in 1962 it has been the only Canadian producer of tungsten, except from 1970 to 1973, when it was still the main one. Between 1962 and 1973, 1 221 245 t of ore averaging 1.64 per cent WO_3 were mined from an open pit at the site of the original discovery. In 1971, drilling revealed the presence of the E zone orebody about 610 m north-northwest of the Pit orebody. It was developed and explored by underground methods between 1972 and 1973 and the concentrator changed over to underground ore in 1974. About 453 592 t of this ore had been processed by mid-1977 (Cummings and Bruce, 1977; Cummings, personal communication).

Ore reserves in the E zone (geological) were estimated as 4 746 945 t at 1.54 per cent WO_3 as of January 1, 1977. Remaining reserves in the Pit orebody are 226 796 t of 'skarn ore' at 1.35 per cent WO_3 and 557 919 t of 'chert ore' at

0.80 per cent WO_3. These are not practical to mine by open pit methods, and recovery is not contemplated at this time (Cummings, personal communication).

At the mill, after flotation of chalcopyrite yielding a 20 per cent copper concentrate and flotation of remaining sulphides (mostly pyrrhotite) the coarse fraction is tabled to yield a concentrate containing 55 to 60 per cent of the scheelite in the mill heads. After purification it grades over 75 per cent WO_3. The balance is treated by scheelite flotation, which yields a product containing about 25 per cent of WO_3. Leaching subsequently upgrades this to 65 per cent of WO_3 (Cummings and Bruce, 1977).

General Geology. The geology of the mine area has been described by Blusson (1968) and, as amended by the mine geologists, is shown in Figure 15A. The orebodies are in the Lower Cambrian carbonate units that overlie a thick sequence of noncalcareous, fine clastic sedimentary rocks: slate, phyllite, siltstone and quartzite. These were designated "Lower Cambrian and ?Earlier" by Blusson, but are considered to be mainly Proterozoic by the mine geologists. The host carbonate strata comprise a lower unit of dolomitic siltstone and impure limestone 35 to 45 m thick, and an upper unit of relatively pure (7 per cent by weight HCl-insoluble in typical banded rock) fine-grained limestone and marble up to about 60 m thick. In the lower unit limestone characteristically forms pods and lenses in the siltstone ("Swiss Cheese Limestone"). The silty matrix appears very fine grained and cherty and has a pale greenish cast. Skarn mined from the unit, termed 'chert ore', averaged less than 0.5 per cent WO_3. The Lower Cambrian age of this unit is established by the presence of archaeocyathids near the mine area.

The main scheelite skarn zone is in the base of the upper unit, a blue-grey finely laminated recrystallized limestone or marble, which is termed the 'Ore Limestone' (Plate 7). This is overlain in the mine area by the 'Upper Argillite', 45 to 60 m of shale with some quartzite and lenses of limestone like the Ore Limestone and local development of skarn and minor scheelite. The Upper Argillite in the mine area is overlain by light buff massive dolomite which, with interbedded quartzite, siltstone and limestone, totals about 460 m and marks the top of the Lower Cambrian sequence. Both archaeocyathids and olenellids were found in the unit near the mine. Middle and ?Upper Cambrian carbonate ('Wavy Banded Limestone'), believed to overlie the dolomitic unit unconformably, outcrops around the lower northern limit of the mine area.

These rocks, away from contacts with intrusions, are essentially unmetamorphosed, except for development of sericite in the phyllite of the lowermost unit.

Granitic rocks outcrop in two bodies, one within 1464 m northwest, and the other 850 m east of the open pit. The northern body forms a circular stock about 1220 m in diameter from the 1128 m contour to beyond the top of the ridge. The eastern body extends about 5 km southeastward to the vicinity of the Baker property. Granite immediately underlies part of the underground workings of the E Zone, but lies about 305 m below the open pit (Pit orebody).

Both bodies are equigranular medium-grained biotite granite or quartz monzonite, containing about equal proportions of potassic feldspar and plagioclase. K-feldspar is mostly microperthitic microcline, and plagioclase is zoned from An_{35} to An_{18} (ibid.). Muscovite occurs with chlorite as an alteration product of biotite, and also as probably primary grains. Accessories include apatite, zircon, sphene and rare black tourmaline and pink garnet. Clearly intrusive, the plutons have fine grained margins, sharp contacts and virtually no inclusions. Contact metamorphic effects are minor except where skarn has developed at contacts with calcareous rocks. Locally in pelitic rocks, spotted slates give way near the contact to hornfels in which biotite, andalusite, graphite and rare cordierite have developed (ibid.). According to Zaw (1976) the age of the granite by potassium-argon dating on biotite is about 92 Ma, somewhat less than that of the nearby Pyramid Mountain (110 Ma) and the Itsi stock (Blusson, 1968). Zaw (1976) quoted results of age determinations: biotite from granite 91.6 ± 6.6 Ma, biotite from skarn 92.3 ± 4.9 Ma, amphibole from skarn 94.9 ± 1.4 Ma, and muscovite from greisen 89.9 ± 1.4 Ma.

Numerous apophyses, mostly fine leucogranite or aplite, extend from the plutons into the bedded rocks, some of them cutting scheelite-bearing skarn. Some of the many quartz veins that cut the skarns and the roof zone of the granite in the E Zone are 'pegmatoid', and K-spar is commonly as abundant as quartz. The veins are numerous only in the vicinity of the skarn and many are rich in scheelite and molybdenite. Some that cut granite in the E Zone have greisenized borders with muscovite and tourmaline.

Some data on the lithophile element, fluorine and chlorine content of intrusions, veins and skarns already have been given.

Structure. The deposit comprises two main skarn zones in similar stratigraphic but different structural situations (Fig. 15B). The upper Pit orebody is in the lower, upright limb of a major overturned syncline, which extends northwesterly through the mine area (Blusson, 1968). The lower E Zone, an underground orebody, is in the lower

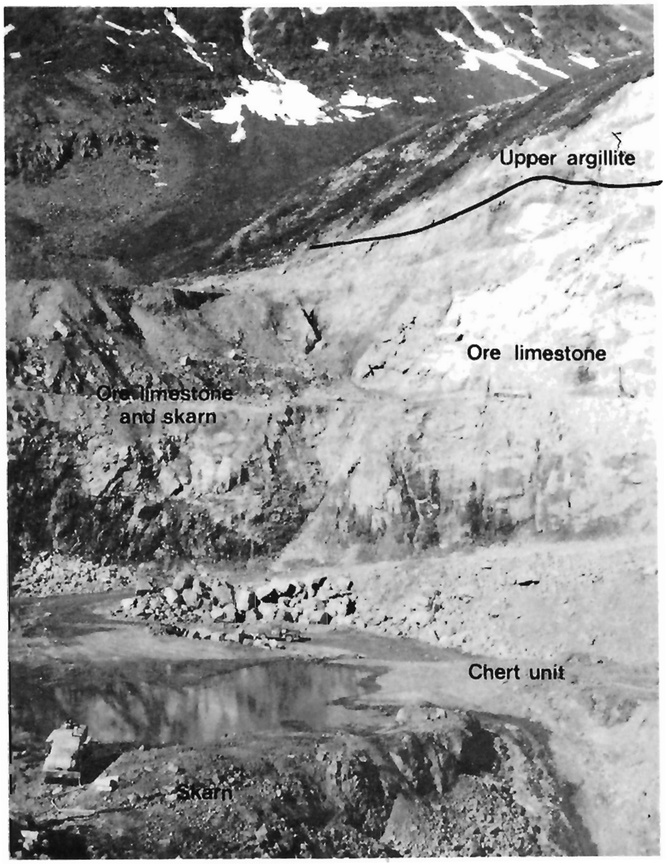


Plate 7. Partial view of Canada Tungsten open-pit mine in 1972, showing the succession of lithological units. Skarn (dark) extends irregularly upward into the Ore Limestone unit. The floor of the pit is partly skarn, partly chert unit. (GSC 113134)

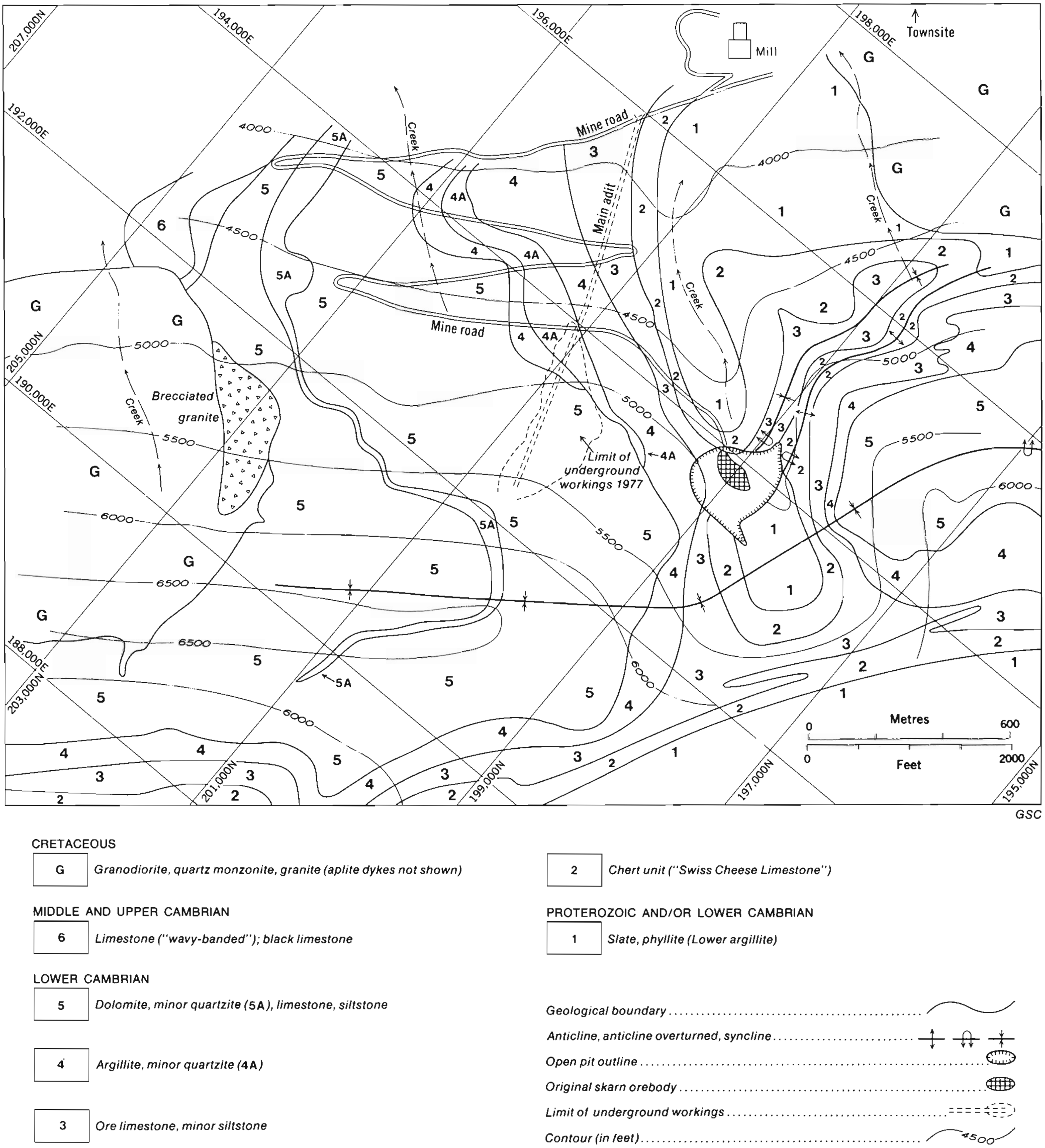


Figure 15A. *Canada Tungsten mine (107g) geology plan and workings.*

overturned limb of a recumbent anticlinal fold, developed on the same lower limb of the main syncline that contains the Pit orebody. The E Zone is consequently about 550 m north of and 305 m below the Pit orebody.

The stratigraphic units are somewhat thinned tectonically on the lower limbs of the folds, compared with the axial parts. This is most apparent in the Ore Limestone of the E Zone, where it is truncated by the granite contact (Fig. 15B).

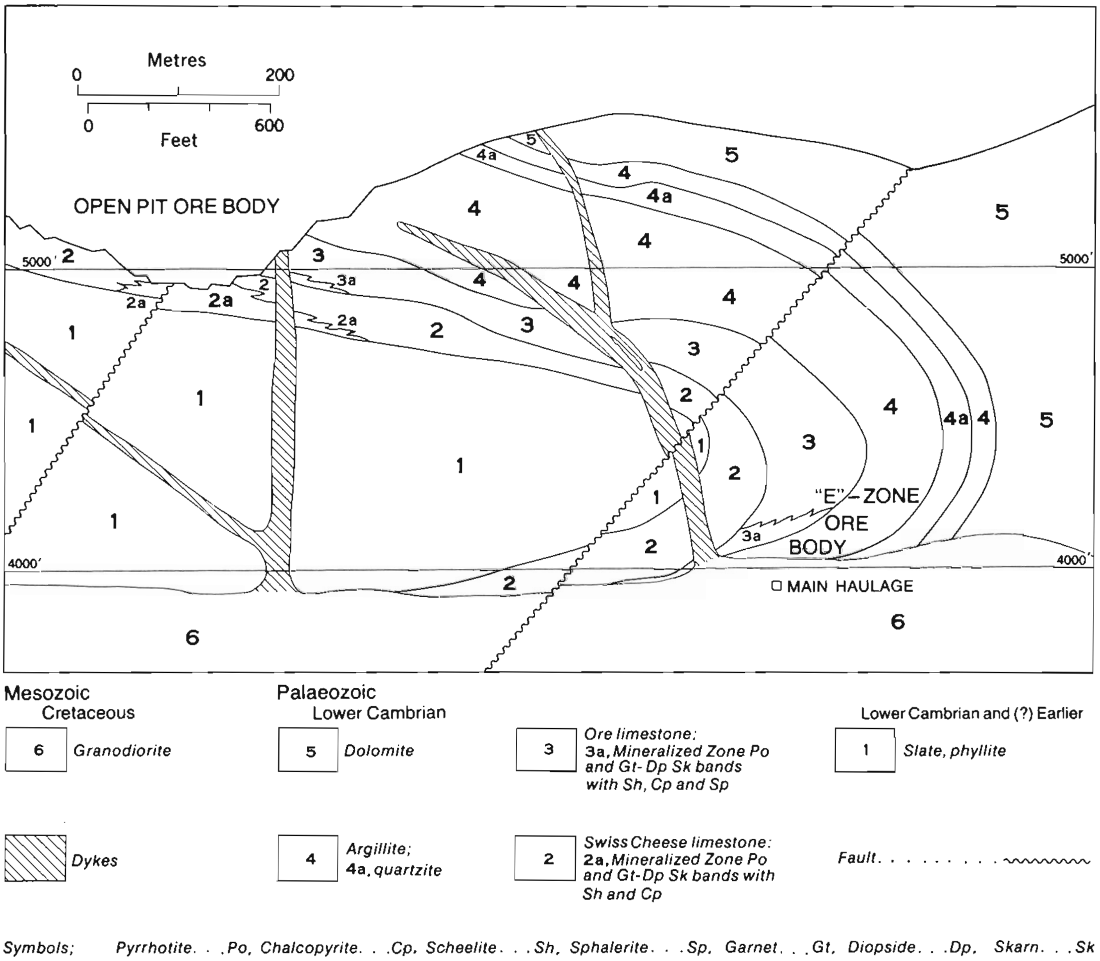
In addition to a pervasive axial planar slaty cleavage, a later impersistent fracture cleavage has developed almost perpendicular to the fold axes. Closely parallel to the second cleavage is a prominent joint set (ibid.). This would therefore appear to be the main control for the quartz veins mentioned above, which are mostly perpendicular to the axes of regional folds (ibid.).

Faults developed in at least two periods: during regional folding early in the structural history, and during or after granitic intrusion (ibid.). Several moderately to steeply dipping faults of minor displacement cut the bedded rocks and skarns in the mine area. The one beneath the Pit orebody was formed prior to mineralization, though some subsequent movement has occurred, and it is thought to be an important control for mineralization. According to Brown's early data (1961), it is a zone up to 7.6 m wide and 610 m long, which trends 50° east and dips about 70° southeast. The best mineralization occurs in the west limb of an anticlinal flexure within 120 m of the fault plane.

The Scheelite Orebodies. At the Pit orebody (Plate 7), according to early descriptions (Skinner, 1961), the 'main orebody' was about 200 m long, 90 m wide and 20 m thick. This did not include skarn ore in the 'chert unit'. Current plans show the outline of the open pit as about 305 m long from east to west by about 230 m north to south. The ore zone pinches out south of a fault zone but dips northward in the north wall of the pit. According to Cummings and Bruce (1977), drilling indicates that it pinches out without any structural cause.

The E Zone orebody has the form of a crude east-west lens more than 820 m long, with an average thickness of 12 m and slope width of 150 m. The average dip is about 20° southerly and the ore zone terminates as the Ore Limestone thins out or is truncated by the underlying intrusive. Updip (northward) the sulphide and skarn bands steepen and separate as the Ore Limestone swells out around the nose of the anticline, and the ore limits updip have not been determined (ibid.). The orebody appears to be plunging gently both eastward and westward from the central part. It is cut by three major faults striking northeastward with steep dips and vertical displacements of up to 6 m. Minor faults and drag folds are common (Cummings and Bruce, 1977, and personal communication).

Skarn Mineralogy and Characteristics. The skarn of the E Zone differs in bulk mineralogy and probably in bulk chemistry from the silicate skarn of the Pit orebody, which



GSC

Figure 15B. *Cross-section through the orebodies of Canada Tungsten mine (after Cummings and Bruce, 1977).*

consists essentially of diopside-hedenbergite pyroxene with various but considerable amounts of garnet, and in which pyrrhotite is only locally abundant. In the E Zone pyrrhotite is abundant, garnet is prominent only in places, and amphibole and biotite have often taken the place of pyroxene. The differences may be partly because the E Zone orebody is confined mainly to the Ore Limestone, and little chert ore has developed. This is important economically, as the chert ore is much more difficult to mill. However, the differences, undoubtedly developed mainly because the E Zone was closer to the underlying granite, and underwent more intense metasomatism (see below).

The principal minerals of the skarn in the Pit orebody are dark green diopside-hedenbergite, reddish brown grossularite-andradite, quartz and calcite. The pyroxene occurs as bladed crystals usually 1 cm or more long, and as fine-grained aggregates. Garnet forms single crystals 0.5 cm across, and aggregates and lenses several centimetres across. These minerals generally make up more than 50 per cent of the skarn. Plagioclase feldspar, commonly corroded and replaced by interstitial microcline and calcite, is a minor but distinctive component of skarn, and often is closely associated with scheelite (Blusson, 1968). Other minor silicates are actinolite, epidote and sphene. Grains of scheelite up to several millimetres across are scattered in silicate skarn; the grains generally are finer in skarn that is rich in sulphide. Sulphides are almost entirely pyrrhotite, containing 0.25 to 0.5 per cent of copper as chalcopyrite and cubanite, and a little sphalerite. They occur as interstitial replacements of the skarn and tiny veinlets cutting skarn minerals and scheelite. No pyrite has been reported in the skarn. The skarn assemblages are in both the chert unit and the Ore Limestone and they project irregularly up from the contact into the Ore Limestone horizon (Plate 7). Other minerals reported by Brown (1961) are axinite, tourmaline, antigorite and biotite in the skarn, and wollastonite with garnet and some scheelite around the periphery of the orebody and in the top 1.5 m of the skarn zone. According to Brown, an initial garnet-wollastonite assemblage was replaced by epidote-quartz-scheelite and brown mica in the main stage, followed by pyrrhotite and other sulphides, the remaining silica being deposited in joints and shrinkage cracks (see "Veins", below).

The E Zone has less pyroxene-garnet skarn. Mostly in the upper part, it is in irregular lenses up to 3 m thick in two areas (Zaw, 1976). It contains fine scheelite and large amounts of sulphides, mostly pyrrhotite but some chalcopyrite and local sphalerite. According to Zaw (ibid.) the garnet is zoned and anisotropic, is predominantly grossularite with some manganese, and is locally altered to epidote. The pyroxene is diopside-hedenbergite – 15 to 48 per cent diopside, 41.5 to 70 per cent hedenbergite and 7 to 24 per cent johannsenite. Amphibole is abundant in fractures in the lower part of the zone, and in bands with pyrrhotite and scheelite in recrystallized limestone (Plate 8). It forms random needles and bladed columnar to fibrous aggregates of light to dark green, faintly pleochroic crystals. According to Zaw (ibid.) it is tremolite-actinolite but, like the garnet and pyroxene, it has a considerable manganese content. Biotite skarn (Plate 9) occurs mainly in the lower part of the zone close to the granite contact and is richer than the other skarns in tungsten and sulphides. It is rich in magnesium and contains more iron than phlogopite but less than the biotite of the granite (ibid.). Some biotite is altered to chlorite. Fine sericitic mica, probably secondary, is abundant in some high-grade ore (Plate 10). This section also shows abundant apatite, especially near scheelite grains. Scheelite is present in all three skarn types but is most abundant and coarse in biotite skarn. It is also purer in the hydrous skarns, containing 0.5 per cent of $CaMoO_4$ compared with 1.1 per cent in the pyroxene-garnet skarn (ibid.). No molybdenite has been seen in the E Zone. Scheelite is closely associated with pyrrhotite, the main sulphide, which according to Zaw is all hexagonal. Up to 2 per cent of copper as chalcopyrite occurs locally with pyrrhotite and is recovered by flotation. Zinc as sphalerite amounts to 5 per cent in a few places, one of which is at the contact between Ore Limestone and the (inverted) 'Lower Argillite'. Other minerals reported by Zaw are idocrase and local tourmaline. Tourmaline is conspicuous in a greisenlike muscovitic assemblage bulging up into argillite at a contact with granite.

Veins. Scheelite-bearing quartz veins cut the skarns in the Pit and E Zone orebodies. In the E Zone they also cut the roof zone of the granite (ibid.). Veins are up to 3 m thick and extend for as much as 30 m but in the skarn zones they are generally narrower and lenticular. In the E Zone veins cut all units and the roof zone of the granite, where they follow joints and fractures. None of these has been traced into the skarns (ibid.). Veins in granite contain fine biotite, especially along their margins, together with minor microcline, plagioclase, chlorite, actinolite and calcite. Near some veins granite is greisenized and contains muscovite, quartz and pyrite. Tourmaline occurs locally in nests. Tourmaline-bearing greisen bulges into argillite at a granite contact at about 193,800 E in 1056-116 North Ramp. A thin section consists mainly of quartz and altered feldspar, including some plagioclase, and minor coarse muscovite and tourmaline.

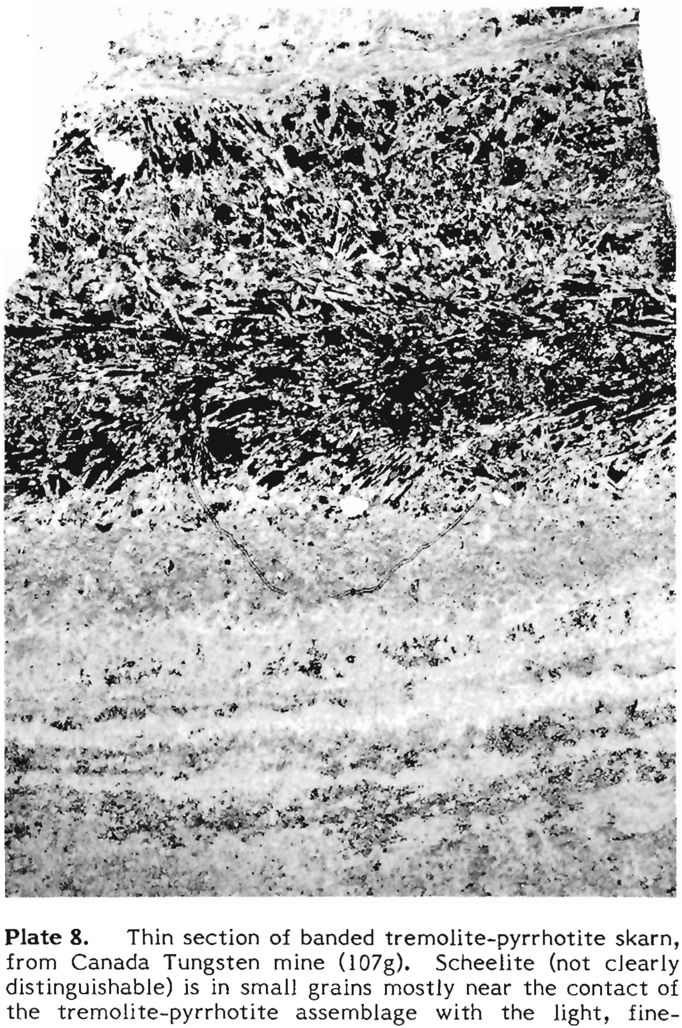


Plate 8. Thin section of banded tremolite-pyrrhotite skarn, from Canada Tungsten mine (107g). Scheelite (not clearly distinguishable) is in small grains mostly near the contact of the tremolite-pyrrhotite assemblage with the light, fine-grained pyroxene?-quartz-calcite assemblage. (Plain light, X4; GSC 201964-Z)

Tourmaline and muscovite are said to be abundant in the margins of some "leucocratic quartz-feldspar pegmatoid dykes" with euhedral quartz and microcline-microperthite phenocrysts (ibid.).

In the Pit area at least, most veins strike northeast and dip steeply, and are perpendicular to axes of regional folds (Blusson, 1968). There also, they contain microcline "commonly equal to quartz in abundance", together with minor low-iron biotite partly altered to chlorite. "A few specks of native bismuth were seen in one specimen. Locally the quartz is cut by chalcopyrite veinlets lined with fine biotite containing specks of scheelite, quartz and sulphides. This outer biotite-scheelite zone marginally fills interstices and appears to replace quartz" (ibid.). Some veins contain a little pyrite as well as pyrrhotite. Some quartz veins are bordered by light greisenized-looking rock containing greenish and colourless mica and scattered fine pyrrhotite and chalcopyrite. In thin section this is seen to consist of large granular areas of patchy feldspar with common optical orientation but which are full of inclusions and irregular areas of quartz and 'old feldspar', some of which show ghosts of relict plagioclase twinning. The 'new feldspar' is untwinned with indices less than balsam and is evidently secondary K-spar. A little quartz, calcite, sulphide and mica occur interstitially. According to Blusson (ibid.), "The veins are found only in the vicinity of skarns, especially below mineralized areas within it. Some veins terminate in laterally-extending replacement masses of skarn, scheelite, and sulphides in ore limestone and thicker marble of the Swiss Cheese (lower) limestone." Brown (1961) also emphasized the significance of quartz veins and "silicification", especially near the fault. Composite samples of veins that I took contained 0.4 to 0.64 per cent of tungsten by spectroscopic analysis (Table 7).

Skarn Zoning. Zaw (1976) emphasized the zonal distribution of skarn types in the E Zone, which he interpreted as a metasomatic sequence from the 'anhydrous' upper pyroxene-garnet

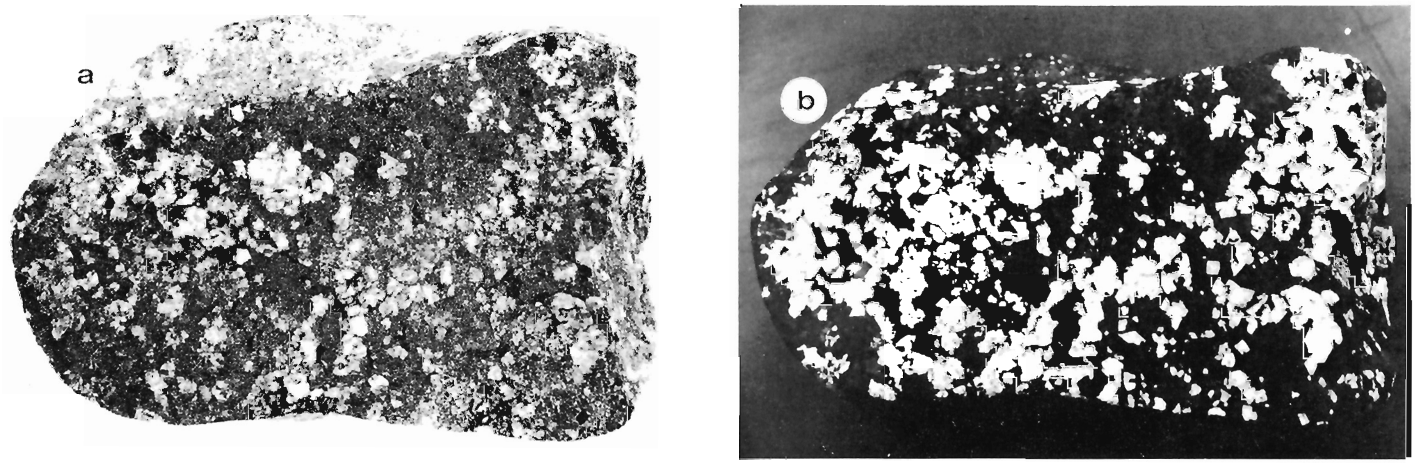


Plate 9. Slab of Canada Tungsten high-grade ore (107g). Reflected light (GSC 201964-A). Ultraviolet fluorescence (GSC 201964-B). Pyrrhotite (lightest reflection) forms a network around the scheelite and dark grains, mainly biotite. (Both X3/4)

Plate 10

Thin section of Canada Tungsten high-grade ore from slab i Plate 9. Scheelite (dark grey) is associated with abundant apatite (white grains and rods) in fine mica-quartz skarn. Black (opaque) material is pyrrhotite. (Plain light, X15; GSC 201964-R) skarn through amphibole-rich skarn to biotite skarn in the lower part, closest to the granite contact. The inverse sequence is found laterally outward in fractures and biotite skarn "cuts amphibolite skarn in the upper part". It appeared to me that amphibolitic skarn was closely related to biotite skarn, and I saw bands of amphibole in biotite skarn in one area. This may be exceptional and may be the result of differences in original composition.

From bulk chemistry (ibid.), it appears that the sequence represents a progressive depletion in Ca from pyroxene-garnet to biotite skarn. Al, K and P are at a maximum in biotite skarn. Mg is at a maximum and Fe at a minimum in amphibole skarn. Fluorine (as measured by electron probe) is much higher in skarn mica (0.82-2.98%) than in skarn amphibole (0.25-0.9%), and is higher than in mica from the granite (0.3-0.42%).

The lateral zoning mentioned above applies to some extent in the Pit orebody. Amphibole skarn is mentioned but not as part of a zonal sequence. However, high-grade ore rich in biotite in the "siliceous sections" of numerous quartz veins and masses is attributed to an "advanced replacement" stage following "initial metasomatism" that produced garnetiferous skarn (Brown, 1961). I saw biotite-rich skarn in the Pit orebody only in the vicinity of quartz veins. Green amphibole is also conspicuous in and bordering quartz veins, mainly in hornfels of the chert unit. Here again it appears to me that mineralogical differences may result partly from differences in original composition.

There is some suggestion that skarnification is controlled mainly by fracture. At one point in the E Zone, intersecting fractures in Ore Limestone are filled by scheelite-bearing pyroxene-garnet skarn. However, there is no obvious relationship in the E Zone between major faults and skarn formation.

Other Analytical Data Bearing on Conditions of Formation of Skarns, Veins and Greisen. Zaw (1976) found the FeS of sphalerite coexisting with pyrrhotite and pyrite in a quartz vein to average 18.8 mole per cent, compared with 20.3 per cent in sphalerite coexisting with pyrrhotite alone. Using the temperature of formation of vein quartz deduced from fluid-inclusion studies, he inferred that confining pressure during mineralization was 100 000 ± 25 000 kPa.

From studies of fluid inclusions in quartz and scheelite, Zaw (ibid.) found that:

1. pressure-corrected homogenation temperature ranged from 521° to 456°C in pyroxene skarn, to 464° to 358°C in biotite skarn, and 420° to 350°C in greisen veins in granite;
2. the fluids of inclusions are dilute brines with no more than 10 per cent of NaCl equivalent; and
3. CO_2 pressure was less than 7380 kPa (critical pressure CO_2), and (assuming 100 000 kPa confining pressure) was not more than 5000 ± 1000 kPa.

From the fluorine content of skarn mica, Zaw calculated that $\log f_{H_2O}/fHf$ was about 4.0. This indicates that the skarn is only moderately enriched in fluorine, which is compatible with the fact that fluorite has not been reported at Canada Tungsten. The granite, however, is significantly higher in fluorine (0.05-0.08%) than average, according to my data.

Origin of the Orebodies. Zaw's work suggests that metasomatic activity was greater in the E Zone orebody than in the Pit orebody and in tungsten skarns generally. This probably is to be expected, as the E Zone orebody lies immediately above the roof of a large granite body, whereas the Pit orebody is in the trough between the north and south plutons. Contrary to some previous speculation, there is no evidence for a 'cupola' structure beneath either the E Zone or the Pit orebodies. The granite surface is nearly flat beneath the E Zone and extending southwestward to the Pit area, so that it lies about 305 m beneath the latter, according to current data. West of the E Zone, it is nearly flat for some distance, then steepens abruptly to the outcrop.

Some light on the relationship of orebodies to granite may be found in the content of other lithophile elements in granite, skarn and other rocks (Table 7). Granite sampled along the main adit (E Zone) was the highest in tin (19 ppm) and fluorine (0.08%) of all the granite that I sampled. However, composites of this granite from drill cores are not significantly higher in tin (3.1-11 ppm) or in Be (4.1-9 ppm) than the surface composite of the south pluton (9.7 ppm Sn, 8 ppm Be). The south pluton also had the highest Li (76 ppm) of all, and the only significantly high W (12 ppm compared with 1-4 ppm in the north pluton by colorimetric analysis). The data suggest that both plutons are about equally enriched in these lithophile elements and in fluorine (0.06 and 0.05%). Chlorine (0.01%) is uniformly low. These values are considerably higher than normal for biotite granite (e.g., granites at the Emerald and nearby mines (46b)), though not uncommon in muscovitic granites, and generally lower than found in typical greisen deposits. Incidentally, Blusson (1968) reported that pyrrhotite is notably more abundant in the Canada Tungsten stocks than in the much larger body southeast of Pyramid Mountain (which has small scheelite skarns associated with it). These facts suggest that the granitic plutons played a major role in the development of the orebodies, but they fall short of proving that the granite was their actual source. The Hole-in-the-Wall Batholith east of Flat River, which contains quartz-tourmaline clots and miarolitic phases about 56 km southeast of Canada Tungsten (Gabrielse et al., 1973 and Gabrielse, personal communication), is a more plausible source.

The fact that some unmineralized dykes cut the skarns, and that the aplites are generally poorer in lithophile elements than the granite indicates that mineralization was not the last phase of igneous activity. The skarns and veins are only feebly enriched in Sn and Be, less so than at AMAX Northern (see below) and much less than at the Emerald area (46b).

Blusson (1968) remarked that quartz veins are abundant only in the vicinity of the orebody, and Brown (1961) emphasized the significance of the "zones of silicification" and the accompanying development of tungsten-rich biotite skarn in the Pit body and apparent control by the fault zone. The large dykes undoubtedly followed major fractures, which might previously have been channelways for mineralizing fluids.

Blusson noted that the Ore Limestone unit is confined to the area of the Canada Tungsten, Baker and other nearby scheelite occurrences. Small scheelite skarns occur elsewhere in other units. Thus it appears that the stratigraphic position, per se, is not a decisive factor. Of perhaps more importance is the proximity to large areas of older pelitic and clastic rocks, as suggested in the previous section. These might have been strongly metamorphosed or granitized at depth, and remobilized tungsten conducted to the site together with presently exposed granite along some old rift or other structure. A high geothermal gradient is suggested by the hot springs near the deposit and elsewhere in the general area.

No geochemical concentration of tungsten in the Lower Argillite unit is revealed by McDougall's data (1977). However, the analytical method used for tungsten was not considered sufficiently discriminatory to establish trends for concentration in unmineralized rocks. Her data do establish a weak correlation between tungsten and copper in the Lower Argillite, as well as a strong one in "granodiorite" and "all data" (including some mineralized rocks). This might suggest that the source of tungsten is in some way related to copper-bearing older Proterozoic rocks that outcrop about 115 km northeast (Gabrielse et al., 1973).

MacTung (AMAX Northern), Macmillan Pass

The MacTung property (111a) straddles the Yukon – Northwest Territories boundary at a point about 8 km northwest of Macmillan Pass between 1830 and 2135 m elevation (Fig. 16A). It was staked in 1962 and explored by surface work in 1963 and 1964. In 1968, 1416 m of drilling was done, and another 9450 m in 1971 and 1972. In 1973 an adit about 440 m long and three crosscuts were driven to provide bulk samples and drilling stations. About 27 Mt of ore averaging 0.9 per cent WO_3 had been outlined by 1973 (Northern Miner, Feb. 8, 1973).

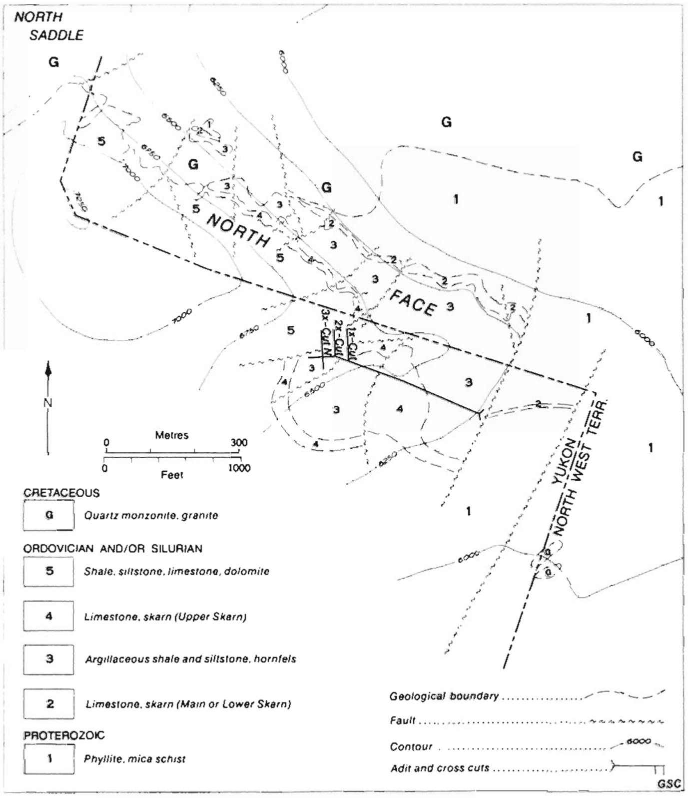


Figure 16A. *Geological plan, MacTung tungsten deposit, Yukon – Northwest Territories.*

Geology. The deposit consists of scheelite-bearing skarn developed in two main limestone horizons in a sedimentary sequence near the south contact of a granitic intrusion. The main outcrop area is in the steep northeasterly facing slope of a ridge above a small cirque lake (the North Face, Fig. 16A and Plate 11). The crest of the ridge slopes downward from west to east along the general line of the Yukon – Northwest Territories boundary and on the North Face the bedding is approximately parallel with the contours. The sequence strikes roughly east and dips southward, so that only the upper of the skarn horizons outcrops in places on the gentle south slope of the ridge where most of the drilling was done and the adit driven.

The skarn-bearing sequence, of Ordovician and Silurian age (Blusson, 1974), unconformably overlies phyllite or schist of probably Proterozoic age. The phyllite unit (unit 1 in Fig. 16) has a banded structure with alternating biotite and muscovite-rich layers parallel to the schistosity. Locally it contains andalusite, cordierite and chloritized and tourmalinized areas. Pyrite is widely disseminated in some layers, and small quartz veinlets locally contain sphalerite and galena. A greisenlike rock rich in muscovite is developed at contacts with the granitic intrusion and this rock is strongly enriched in tin (Table 7). The phyllite unit underlies the base of the North Face and extends southward in fault contact with the other units in the eastern part of the property.

The limestone of the main skarn band (unit 2) extends intermittently for about 610 m along the lower part of the North Face, cut and offset by numerous northerly striking faults. The unit is partly in contact with phyllite of unit 1 but partly with and interrupted by the granitic intrusion. It generally is recrystallized to white marble and part of it is converted to several varieties of skarn. These are predominantly fine-grained greenish rocks composed mainly of diopside-hedenbergite, with locally abundant red-brown garnet and various amounts of pyrrhotite. Tremolitic amphibole and biotite-rich skarns occur in patches, evidently derived from pyroxenitic skarn, and clinozoisite-epidote minerals have locally replaced much of the original garnet (Plate 13). Vesuvianite is fairly common in places near the east boundary fault. These retrograde skarns are enriched in scheelite, which is generally coarser than that disseminated in the primary skarn. Retrograde-metamorphosed areas may be gradational with pyroxene skarn, or confined to veinlets in which scheelite is more abundant and coarser than in the parimary skarn (Plate 14). The main mineralized zone on the North Face averages 13.7 m in thickness for about 550 m along strike (Findlay, 1969).

The main hornfels unit (unit 3), which lies between the Lower and Upper Skarn zones, is derived basically from a shale-siltstone succession about 60 m thick. It varies in colour from light to dark brown or black depending on the relative contents of muscovite, biotite and graphite.

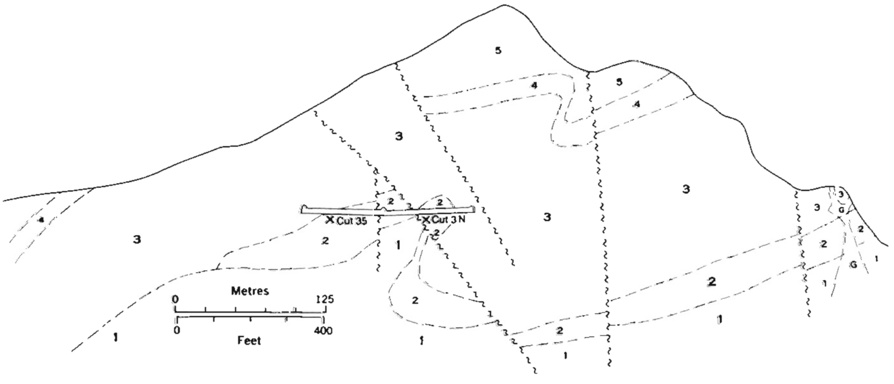


Figure 16B

South-north cross-section of MacTung (AMAX Northern) tungsten deposit through crosscuts 3 south and 3 north (after Dick, 1977, Figure 4, simplified).

Graphitic argillite or slate is abundant and contains appreciable amounts of pyrite, partly in thin conformable beds. Thin fragmented lenses of microcrystalline apatite or collophane are common, locally associated with pyrite (Dick, 1977). Numerous thin quartz and quartz-carbonate veins cut the rocks of the unit. Locally they contain pyrite or pyrrhotite, apatite, scheelite and molybdenite, together with pyroxene, tremolitic amphibole or biotite and muscovite (Plate 15). Where the veins cut black pelitic hornfels they are bordered by bleached zones from which graphite has been removed (Plate 12). Destruction of graphite is also apparent in zones on the scale of the orebody, as the black graphitic rock is farthest from the skarn units and is never in contact with them (ibid., Fig. 5).

The Upper Skarn zone (unit 4), about 30 m thick, comprises interbedded shale and white limestone with calc-hornfels and pyroxene, garnet and wollastonite skarn at several horizons. Calc-hornfels consists mainly of fine pyroxene or rarely of amphibole, and quartz, but locally contains clinozoisite or plagioclase. Scheelite and pyrrhotite occur in veins, fractures and disseminations.

Unit 5 comprises argillite, siltstone and hornfels, with interbedded limestone, marble, calc-silicate rock and minor skarn, and forms the top of the exposed section.

The granitic intrusion cuts obliquely across the bedded succession in the North Face. It penetrates the succession in large tongues, dykes and sills and is in contact with each of the other units at some point. Felsite dykes and sills also cut the hornfels and skarn. The granite is about 35 per cent potassium feldspar, 24 per cent plagioclase, 33 per cent quartz, 5 per cent biotite, and 3 per cent muscovite and accessory apatite, tourmaline, garnet and other minerals (Dick, 1977). Granite samples from the North Face, the North Saddle and the southeast corner of the property contain 20, 4 and 8 ppm of tungsten, respectively, and are

Plate 11

North Face of MacTung (AMAX Northern, loc. 111a). A strongly banded part of the Upper Skarn Zone (unit 4) is in the foreground. Contact with granite (right) is at North Saddle (snowpatch) beyond and Keele Peak is faintly visible in the right background. (GSC 201751-B)

Plate 12

Leaching of graphitic hornfels along quartz veins at MacTung (AMAX Northern, loc. 111a). (GSC 201751-A) also variably enriched in Mo, Be, Sn and other lithophile metals (Table 8). Garrett (1971a,b) found samples from 53 sites in the pluton to range from 1.0 ppm (detection limit) to 80 ppm of tungsten, averaging 3.5 ppm. Another granitic stock outcrops about 3.2 km south of the deposit. According to Garrett (1971b) the group of plutons in the general vicinity of the MacTung deposit constitute one of two distinct areas of higher than normal tungsten content in granites in the whole east Yukon – Northwest Territories belt.

In contact with phyllite of unit 1 in places along the North Face, a muscovite-rich greisen rock is developed. A composite sample of this was found to contain 0.5 per cent of W and anomalous Sn, Be and Mo. Similar greisen at contacts with the small granite outcrops in the southeast corner of the property is less enriched in W, Mo and Be but is high in Sn and Li (Table 8).

The granite is cut by numerous quartz veins. Near the contact with bedded rocks at the North Saddle, the veins contain abundant black tourmaline, some scheelite and a little molybdenite (analyses in Table 8). A thin section shows a well defined growth zoning in the larger tourmaline crystals. Molybdenite-bearing veins were seen at one place in the upper unit near the summit of the ridge. According to K.M. Dawson (personal communication), quartz-scheelite veinlets are widespread in the intrusion.

Structure. The general southward dip of units 2 to 4 is interrupted by several major drag folds, and also by some easterly trending major faults (Fig. 16B). Numerous northerly trending faults also cut and offset the units. The main (Lower) skarn unit thins and apparently pinches out to the south.

Mineralogy. Pyroxene is the most abundant silicate mineral of skarns and calc-hornfels. According to Dick (1977) the composition of pyroxene in the skarns is closer to hedenbergite than to diopside, and contains a few per cent of the johannsenite (Mn) molecule. The pyroxene of the calc-hornfels is closer to diopside and contains little johannsenite. Some of the skarn pyroxene is compositionally zoned. Generally fine grained, pyroxene reaches 5 mm across in some skarns.

Garnet is less abundant than pyroxene but predominates in some patches. It is red-brown and mostly anhedral. It is closer to grossularite than to andradite, and closer to almandine than to andradite (ibid., Fig. 11). Much of the garnet, especially in the Lower Skarn zone is strongly corroded and altered to clinozoisite-epidote minerals, coexisting with pyroxene (Plate 13).

Amphibole is not common but occurs as alteration rims of pyroxene in retrograde skarn of the lower unit, and in veins cutting hornfels. Its composition is intermediate between tremolite and ferroactinolite (Dick, 1977).

Biotite is an essential constituent of brown hornfels of unit 3. It also occurs locally in rather coarse grained assemblages in retrograde skarn of the Lower Skarn unit, notably near quartz veins, and also in quartz-scheelite-pyrrhotite veinlets in pyroxene skarn (Plates 14, 15). Clinozoisite-epidote is found mainly as an alteration product of garnet in skarn, coexisting with pyroxene.

Plagioclase is reported to occur with clinozoisite, ferrotremolite and pyrrhotite in retrograde skarn of the lower unit, in alteration envelopes of quartz-calcite-silicate veins and locally in calc-hornfels (ibid.). Some fine potassium feldspar occurs with quartz and biotite in alteration envelopes of quartz-calcite veins.

Wollastonite has been found only in the Upper Skarn unit, with garnet, pyroxene, quartz and calcite. Vesuvianite is quite common in the Lower Skarn zone near the east boundary fault. Much of the associated garnet is fresh and euhedral. Vesuvianite apparently is scarce elsewhere, as it was reported in only one locality in the Upper Skarn unit, associated with garnet and wollastonite (ibid.). Other silicate minerals include muscovite, chlorite and potassium feldspar, small amounts of which are generally associated with biotite in veins and their alteration envelopes.

Collophane, a microcrystalline form of calcium phosphate, is present as fragments generally 50 to 100 mm across in skarns as well as in the hornfels unit. As in the latter, it forms thin beds in the Upper Skarn, and it is thought to be an original sedimentary constituent (ibid.). Apatite is also abundant in retrograde skarn and quartz and quartz-calcite veins. It is commonly coarse grained and euhedral

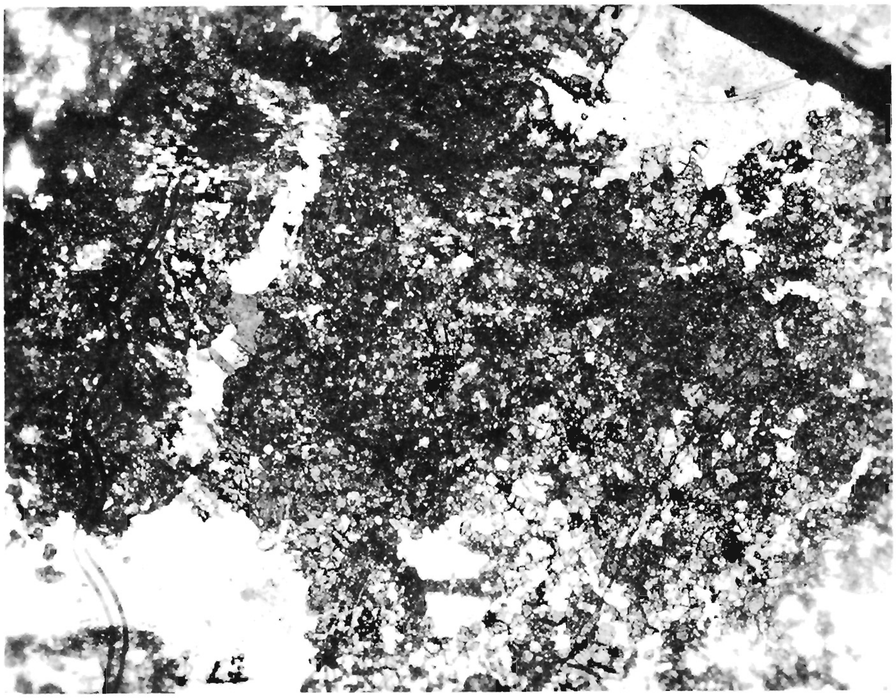


Plate 13

Thin section of MacTung (AMAX Northern, loc. 111a) skarn. Corroded garnet (dark areas) is largely altered to clinozoisite, which is mixed with original pyroxene. Light areas are quartz and calcite. (Crossed nicols, X15; GSC 201964-S)

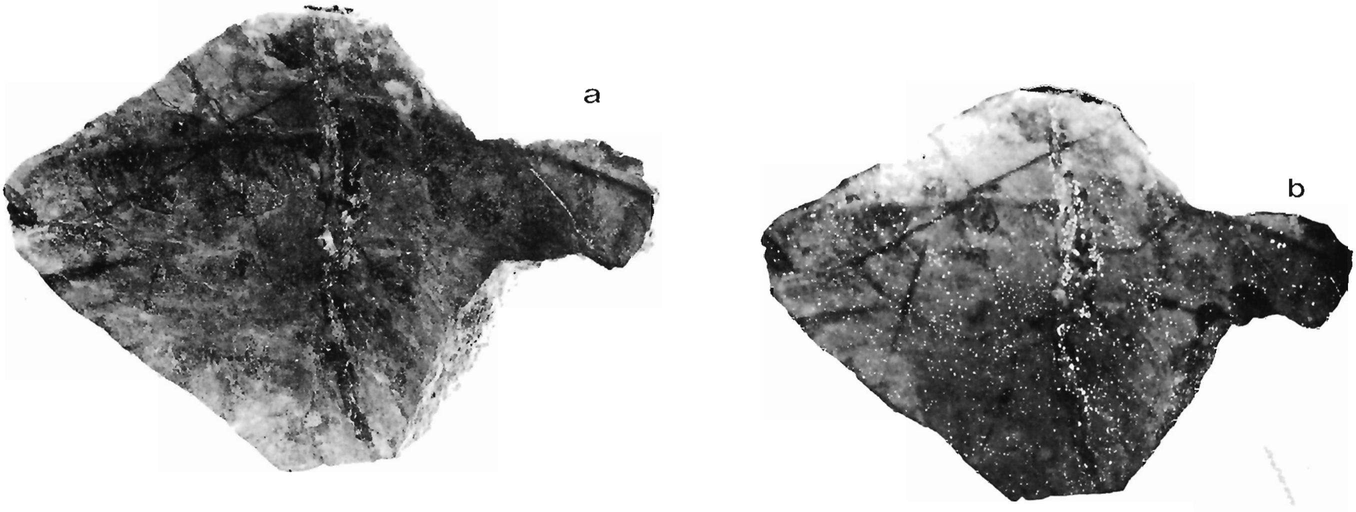


Plate 14. MacTung (AMAX Northern, loc. 111a) skarn ore. A scheelite-rich quartz-pyrrhotite-biotite veinlet cuts fine pyroxene-pyrrhotite skarn. Plain light (GSC 201964-G). Ultraviolet fluorescence (GSC 201964-K). (Box X3/8)

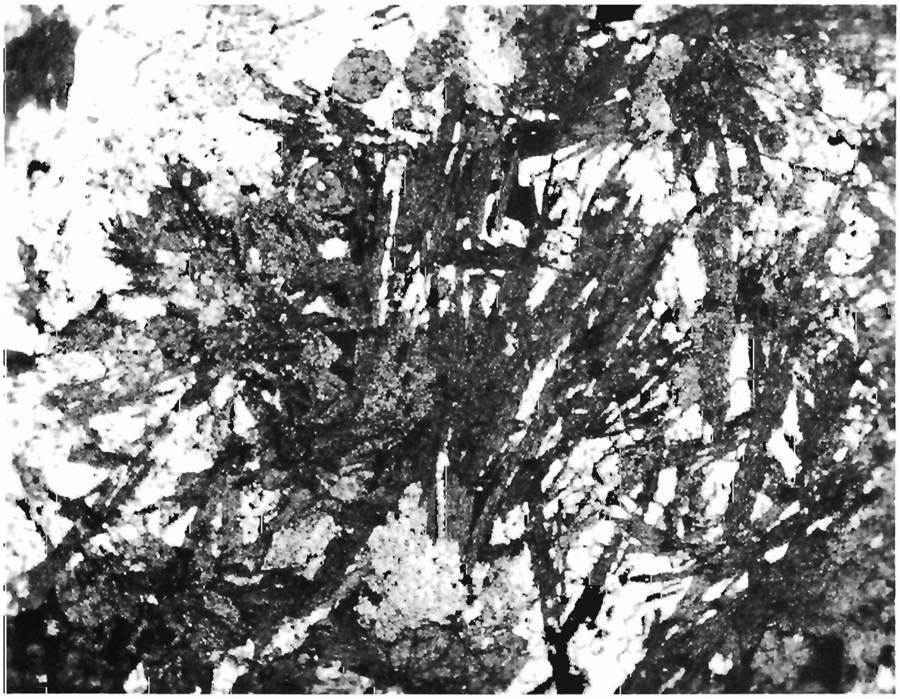


Plate 15

Thin section of MacTung (AMAX Northern, loc. 111a) ore, showing abundant scheelite (medium grey) along contact of biotite skarn (plumose) with quartz vein. (Plain light, X15; GSC 201964-U)

and is thought to have formed by recrystallization of collophane (ibid.). Scheelite is notably concentrated in the vicinity of collophane fragments and apatite crystals.

Sphene is another distinctive minor constituent of skarns and calc-hornfels. It does not occur in graphitic hornfels, whereas rutile does, and the sphene may be a reaction product of rutile.

Pyrrhotite is widely but irregularly distributed in patches and veinlets mainly in the Lower Skarn (Plate 14), and disseminated in the Upper Skarn unit. It is more abundant in pyroxenite than in garnetiferous skarn, and most abundant in retrograde amphibole skarn associated with scheelite. Retrograde skarn of the lower zone contains a little pyrite, and also chalcopyrite in economic concentration (ibid.). Sphalerite is relatively scarce.

Formation of Skarns and Mineralization. The outstanding features of the MacTung deposit are the abundance of pyritiferous graphitic rocks in the hornfels unit, the formation of graphite-free zones adjacent to skarns and veins, and the presence of collophane in conformable lenses in the hornfels and as fragments in the skarn units.

According to Dick's (ibid.) interpretation, the graphite-free zones represent the first stage of metasomatism resulting from the displacement of CO_2 by hydrous fluids. The parallel oxidation of pyrite provided the iron and sulphur to form pyrrhotite in the skarns. Apatite in the skarns was derived from sedimentary collophane already present in the limestone horizons or mobilized from the hornfels unit. Scheelite is especially concentrated in the vicinity of collophane fragments and apatite crystals. Formation of the skarns involved an exchange in which Fe, Mg, Si, Al and Mn, to form pyroxene, garnet and other primary skarn minerals, migrated from the hornfels into the limestone units and calcium migrated from the limestone to form calcsilicate hornfels. The course of the skarn reactions was promoted by the escape of CO_2 through fractures that developed in the overlying rocks and its replacement by hydrous fluids from the crystallizing granite or some other source.

The dependence of the various skarn reactions on variations in relative H_2O-CO_2 concentration together with temperature is illustrated in Figure 2. This shows that CO_2 must be efficiently removed and replaced by fluid very rich in water. Even the primary skarn minerals formed in equilibrium with a water-rich fluid phase.

Tungsten to form scheelite was introduced by the invading hydrous fluids, whatever their source. The anomalously high content of tungsten and some other lithophile elements in the associated intrusion suggests that it or its parent magma may well have been the source. However, other sources are not ruled out. Derivation from the rocks of the hornfels unit is considered unlikely because the average tungsten content of analyzed samples is low, although the copper and zinc content of the graphitic hornfels is high (ibid.). In my view, derivation of tungsten from sources deep in the underlying Proterozoic rocks remains a viable alternative possibility, chiefly because of the lithostratigraphic setting of the deposit. This is analogous to that of the other major skarn deposits in Canada and some elsewhere, at Sangdong for example. The intrusion or its parent magma undoubtedly provided the energy required to form the deposit. It seems most probable that it is also genetically related to the deposit, possibly having assimilated or been formed from the same source beds as the mineralization.

McQuesten-Mayo District

The McQuesten-Mayo district (114), just northeast of the Tintina Trench, forms the northwest end of the main tungsten belt of the East Tungsten Zone (Fig. 17). Scheelite and some wolframite are abundant in some gold placer concentrates and other streams. Scheelite occurs in quartz veins in a few places but the few skarns contain very little.

The bedded rocks are relatively gently deformed argillite, quartzite, and related schists and limestone of generally low metamorphic grade. They were formerly considered to be Proterozoic (Bostock, 1947; Kindle, 1962) but are now known to include Paleozoic and some Mesozoic rocks (Green, 1971). The distinctive Keno Hill Quartzite, the main host rock of the important silver-lead-zinc deposit, is now considered by Blusson (1978) to be of mid- to late Paleozoic age. The younger rocks are partly in fault contact with the Proterozoic rocks and the structure is complex.

Intrusive rocks include numerous and widespread sill-like bodies of diorite and greenstone, especially in the lower units. The thin bodies are generally sheared and altered to greenstone. Granitic rocks form a few large and many smaller rounded or irregular bodies suggestive of 'cupolas', and numerous dykes. These are believed to be Cretaceous. Quartz porphyry and granite porphyry dykes, which resemble Tertiary lavas in the valley of Minto Creek (Bostock, 1947) are found mainly in a belt from Mt. Haldane through Keno Hill. A group of syenite intrusions occurs in the northern part of the McQuesten area.

Bostock's maps (1947, 1964) show the upper limits of late glacial advance. Some of the larger creek valleys in the McQuesten area are floored by brown and rust gravels believed partly of Pliocene age. The gold placers associated with old gravels probably contain the most abundant tungsten concentrations.

Tungsten concentrations, both lode and placer, are commonly related spatially to the granitic intrusions. Some streams, especially Haggart Creek and its tributary, Dublin Gulch, contain moderate amounts of cassiterite, as well as scheelite and wolframite. These drain areas in which a lode tin deposit is known, as well as scheelite veins. The main placer occurrences are shown in Figure 17. The only ones where any significant recovery has been recorded are Dublin Gulch and Haggart Creek (114e), although some tungsten probably was present in cassiterite-rich concentrate recovered at Clear Creek (114j) for a short time. Much information on placer tungsten occurrences and potential is given in Little (1959). He reported recoveries in Dublin Gulch of 225 kg of scheelite from Bawn Boy Gulch, and 1090 and 910 kg from below Eagle Pup in 1942 and 1943. According to Green and Godwin (1963), approximately 2.7 t of tungsten concentrate, mainly scheelite and ferberite, were shipped from Dublin Gulch in 1962. I am not aware of other shipments before or since. A trial shipment of 384 kg of concentrate from Haggart Creek in 1942 was found to contain 14.24 per cent of WO_3, together with 30.8 per cent of tin and 353 g/t of gold.

Gleeson (1967) conducted a geochemical survey of stream sediments in the district. Figure 17 shows the approximate boundaries of areas between Mt. Haldane and South McQuesten River in which tungsten contents are greater than 3 ppm.

The McQuesten-Mayo district is one of two distinct areas in the main tungsten belt in which the granitic plutons have higher than average mean tungsten contents (Garrett, 1971a,b). Six plutons have mean contents greater than 2 ppm and eight have maxima ranging from 20 to 480 ppm, including the Potato Hills – Lynx Creek stock (114e) and Scheelite Dome (114f), both of which contain scheelite-bearing veinlets. Another is Two Buttes (114a), which has the highest maximum and mean tungsten contents (480 and 29.5 ppm) of all the plutons. Scheelite was found in joint-planes in the granite (Garrett, personal communication).

I also found anomalous tungsten in a sample from the Scheelite Dome pluton (Highet Creek, Table 8) and slightly more than normal in a sample of the Dublin Gulch pluton. Both of these were slightly higher than normal in fluorine.

The district is different from the rest of the main tungsten belt in that most of the lode occurrences are of the vein type, associated with placer gold deposits. Wolframite has been reported in several tungsten-enriched placer occurrences but none has been found in veins.

A reasonable hypothesis is that the gold of the placers was derived originally from the numerous sill-like greenstone ("diorite, gabbro, serpentine") bodies in much of the Mayo area (Bostock, 1947; Green, 1971; Kindle, 1962). Its concentration near and within certain granitoid intrusions may result from alteration and assimilation of greenstone by the younger granitic bodies. Some tungsten may even have been derived from the greenstones (see "Scheelite Creek and Castnor Creek", below). However, very few of these greenstone bodies are mapped in the gold- and scheelite-rich northern part of McQuesten area (Bostock, 1964).

Lode tungsten deposits comprise scheelite-bearing quartz veins near and within granitic intrusions, and small skarn concentrations near their contacts with limy rocks. They occur in only three limited areas.

Roop. South of Roop Creek (114c), limestone and limy beds are interbedded with schists and quartzite at the southeast end of a large granitic stock. The rocks near the contact include coarsely crystalline skarn consisting of silicates and garnet interbanded with quartz-rich material.

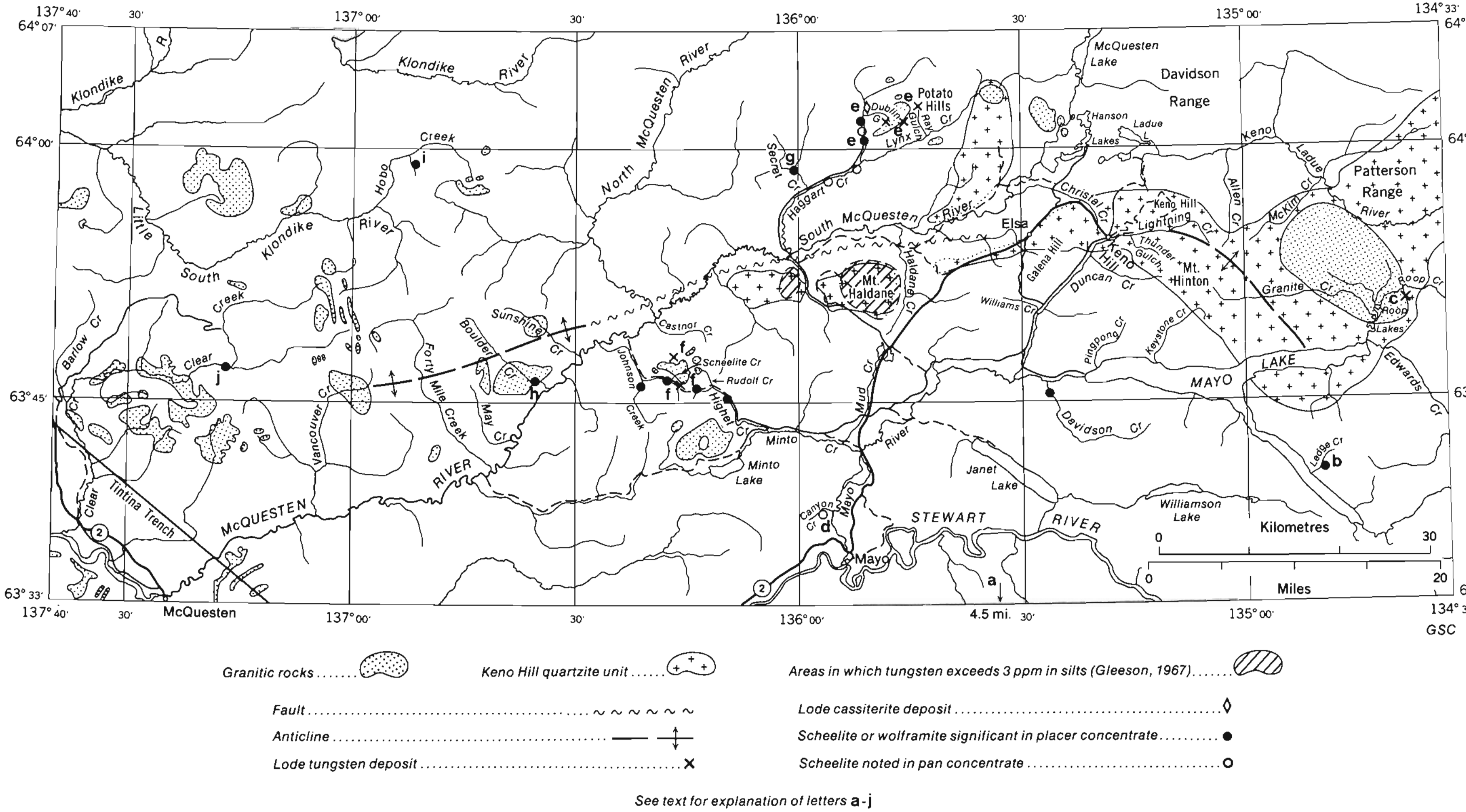


Figure 17. *Tungsten deposits and geology, McQuesten-Mayo district (114).*

Coarsely crystalline titanite and radiating brown tourmaline are present in patches with bands rich in garnet. The bedded rocks and the granite are cut by numerous pegmatites of quartz and feldspar and abundant black tourmaline. The tourmaline occurs in long crystals in the interior of the pegmatites and as radiating masses of smaller crystals along the sides. Scheelite is thinly disseminated or in small patches in the skarn. In one place a few small crystals were seen in pegmatite.

Dublin Gulch, Ray Gulch and Potato Hills (114e). At the head of Dublin Gulch, scheelite was found in quartz veins and pegmatite dykes that cut schist and granodiorite in the contact area of the stock. The veins are in three sets of fractures approximately at right angles to one another, and range from 2.5 to 20 cm in thickness. None has been traced for any great distance. Scheelite is found both in the veins and in the wall rock. Quartz is usually the only gangue mineral but some places have calcite and white mica forming a transition into pegmatite dykes, which occur in several places along the contact. In one place a pegmatite dyke 0.3 m wide cuts granodiorite and contains white mica, quartz, feldspar and hornblende, with minor amounts of tourmaline, siderite, graphite, scheelite and possibly wolframite. A sample from the dyke assayed 6.35 per cent WO_3. Cassiterite-bearing quartz-tourmaline veins occur on the north side of Dublin Gulch, and gold-bearing arsenic-rich veins are common along the north contact of the granitic pluton south of Dublin Gulch.

Around the head of Ray Gulch, on the east side of the same stock, scheelite is disseminated in skarn zones in limy beds totalling about 23 m in schist and quartzite. They are cut by granitic dykes. Samples assayed 0.27 to 0.50 per cent WO_3.

In the Potato Hills area, a short distance east of the foregoing localities, scheelite is disseminated in a quartz stockwork within a granitic intrusion (Cathro, 1969). Drilling in about 1970 revealed tungsten, silver, tin and very minor gold values in the stockwork, and also gold in arsenopyrite, silver in galena-jamesonite veins, and silver and cassiterite on the fringe (K.M. Dawson, personal communication).

Scheelite Creek and Castnor Creek Area (114f). These streams, together with Sabbath and Rudolph creeks and other small tributaries of Johnson and Highet creeks, drain an area that contains a small granitic stock and small satellites. Scheelite is more or less abundant in all these creeks.

The stock and its satellites intrude schist, quartzite and limestone. The stock is cut profusely by veinlets, some pegmatitic dykelets and rusty fractures, and scheelite is scattered thinly through them. Some small deposits around the stock contain gold, antimony and copper as well as tungsten.

A scheelite-bearing skarn zone lies within an embayment on the north side of the stock. The skarn is a finely speckled, dark greenish grey rock strikingly like some of the dioritic greenstones of the district. It consists mainly of dark green pyroxene, calcite and quartz. Pyrrhotite and scheelite are the main ore minerals, and a little pyrite, chalcopyrite and molybdenite are found in places. The scheelite is disseminated or in small high-grade patches.

Central and Southwest Yukon

Most of the tungsten occurrences of this area southwest of Tintina Trench (115-123) are either in a northwest extension of the Omineca Crystalline Belt (the East Tungsten Zone) or in a belt along the northeast fringe of the Coast Plutonic Complex. The occurrences, all minor, include scheelite skarns and quartz veins, and also some wolframite suggestive of the quartz-greisen type.

The East Zone (115-118) is an extension of the zone northwest from the Cassiar district. Stream sediment concentrates from creeks in the Quiet Lake area (NTS 105 F) also contain anomalous amounts of tungsten. This part of the zone, however, is much weaker as a tungsten belt than either the Cassiar district or the 'main belt' northeast of the Tintina Trench.

Canadian Creek

Of the occurrences in the West Zone, only Canadian Creek (123) is of special interest. The source of the abundant wolframite in the placer-gold concentrates there is unknown; tungsten has not been reported in the nearby Casino porphyry-copper-molybdenum deposit at the head of the creek. An upper wolframite-rich zone may have been removed by erosion. Pieces of quartz-tourmaline vein material are common in the stream, but wolframite was not recognized in them nor was tungsten detected by spectroscopic analysis. However, significant amounts of tungsten were found by colorimetric analysis of some nearby granitic rocks. Altered granite on the fringes of the Casino deposit was found to contain 28 ppm of tungsten, compared with 1 ppm in surrounding fresh Klotassin granite. Nisling-type alaskitic granite about 32 km south was found to contain 12 and 16 ppm of tungsten in two composite samples, and an associated 'volcanic' facies contains 12 ppm. This granite may be equivalent to the Casino Complex, which intrudes the Klotassin granite in the form of breccia pipes, plugs and dykes at the Casino deposit (Godwin, 1976).

Wolframite is seen also in samples reported to be from Miller Creek in the Sixty Mile gold placer area. This locality, which is not listed in the Appendix or shown on the map, is west of Dawson at lat. 64°00', long. 140°44'. Samples of placer concentrates collected in the Sixty Mile placer area were found by spectroscopic analysis to contain 0.2 to 0.3 per cent of tungsten.

Northern Yukon

The tungsten occurrences of northernmost Yukon (124-127) are related to granitic intrusions some of which are known to be of Paleozoic age, although the bulk of deformation in the area is believed to be Laramide (Bamber et al., 1963). The earlier orogeny would appear to have been part of the Ellesmerian Orogeny that affected northern Alaska and the Arctic Islands in Paleozoic time. The tungsten is documented mainly by scheelite, and locally by wolframite, in heavy mineral concentrates from streams and altered bedrock (Gleeson, 1963). However, I have seen scheelite-rich skarn samples reported to be from the Mount Fitton area (R. Bell, personal communication). It may be relevant that cassiterite has been found in heavy mineral concentrates from Devonian(?) and Mississippian conglomerate in Brooks Range in northeastern Alaska (Reed, 1968).

BIBLIOGRAPHY

Admakin, L.A.
1974: Metal content of genetic types of coal in some fields of Transbaikalia; Doklady Akademiya Nauk SSSR, v. 217, p. 919-922. (Trans.: American Geological Institute, 1974, p. 195-197.)

Ahlfeld, F.
1936: The Bolivian tin belt; Economic Geology, v. 31, p. 48-72.

1967: Metallogenic epochs and provinces of Bolivia; Mineralium Deposita, v. 2, p. 291-311.

Aho, A.E.

1949: Mineralogy of some heavy sands of the McQuesten River area, Yukon; unpubl. thesis, University of British Columbia.

Ahrens, L.H.

1964: The significance of the chemical bond for controlling the geochemical distribution of the elements, Part I; in Physics and Chemistry of the Earth, Pergamon Press, v. 5, p. 1-54.

1966: The chemical bond and the geochemical distribution of the elements; Chemistry in Britain, v. 2, p. 14-19.

Aitken, J.D.

1959: Atlin map-area, British Columbia; Geological Survey of Canada, Memoir 307.

Allen, C.C. and Folinsbee, R.E.

1944: Scheelite veins related to porphyry intrusions, Hollinger Mine; Economic Geology, v. 39, p. 340-348.

Armstrong, J.E.

1944: Preliminary map, Hazelton, British Columbia; Geological Survey of Canada, Paper 44-24.

1946: Manson Creek, Cassiar District, British Columbia; Geological Survey of Canada, Map 876A.

1949: Fort St. James map-area, Cassiar and Coast districts, British Columbia; Geological Survey of Canada, Memoir 252.

Armstrong, J.E., Hoadley, J.W., Muller, J.E., and Tipper, H.W.

1969: Geology, McLeod Lake, British Columbia; Geological Survey of Canada, Map 1204A.

Bahyrycz, G.S.

1957: Geology of the Grey River area, Newfoundland, with special reference to metamorphism; M.Sc. thesis, McGill University.

Ball, C.W.

1954: The Emerald, Feeney, and Dodger orebodies, Salmo, British Columbia, Canada; Economic Geology, v. 49, p. 625-638.

Ball, C.W., Whishaw, Q.C., and Mylrea, F.H.

1953: The lead-zinc and tungsten properties of Canadian Exploration Ltd., Salmo, B.C.; Canadian Institute of Mining and Metallurgy, Transactions, v. LVI, p. 241-246.

Bamber, E.W., Hughes, O.L., Mountjoy, E.W., Norford, B.S., Norris, A.W., Norris, D.K., Price, R.A., Procter, R.M., and Taylor, G.C.

1963: Geology, northern Yukon Territory and northwestern District of Mackenzie; Geological Survey of Canada, Map 10-1963.

Barabanov, W.F.

1970: Geochemistry of tungsten; Vestnik Leningrad University, 1970, No. 6, p. 64-81. (Trans. International Geology Review, No. 3, p. 332-334, 1971.)

Barsukov, V.L.

1957: On the geochemistry of tin; Geochemistry, No. 1, p. 41-45.

1975: Composition and metal content of the upper mantle and its magmatic products; Geologiya Rudnykh Mestorozhdeniy, 1975, p. 17-19. (Trans. International Geology Review, No. 19, p. 254-264.)

Barsukov, V.L. and Dmitreyev, L.V.

1975: Role of mantle sources in formation and distribution of certain mineral deposits; Geologiya Rudnykh Mestorozhdeniy, 1975, p. 17-19. (Trans. International Geology Review, No. 19, p. 254-263.)

Baskina, V.A.

1974: Ore-bearing magmatic associations: typical features of their distribution in the Sikhote-Atlin Region; in Metallization Associated with Acid Magmatism (Symposium), Volume 1, M. Stemprok, ed., Ustredni Ustav Geologicky, Prague, p. 323-325.

Bell, K.C., Blenkinsop, J., and Moore, J.M.

1975: Evidence for a Proterozoic greenstone belt from Snow Lake, Manitoba; Nature, v. 258, p. 698-701.

Bentzen, E.H. III and Wiener, L.S.

1973: Scheelite discovered in certain soapstone deposits in the Blue Ridge of Madison County, North Carolina; Economic Geology, v. 68, p. 703-707.

Berzina, A.P. and Sotnikov, V.I.

1977: Endogene processes in copper-molybdenum deposits of central Asia; Economic Geology, v. 72, p. 25-36.

Black, P.T.

1961: Tin, tungsten, molybdenum mineralization, Mount Pleasant area, New Brunswick; Canadian Mining Journal, v. 61, p. 94-96.

Blecha, M.

1974: Batchawana area, a possible Precambrian porphyry copper district; Canadian Institute of Mining and Metallurgy, Bulletin 748, p. 71-76.

Blusson, S.L.

1966: Geology, Frances Lake, Yukon Territory and District of Mackenzie; Geological Survey of Canada, Map 6-1966.

1968: Geology and tungsten deposits near the headwaters of Flat River, Yukon Territory and southwestern District of Mackenzie, Canada; Geological Survey of Canada, Paper 67-22.

1971: Sekwi Mountain map-area, Yukon Territory and District of Mackenzie; Geological Survey of Canada, Paper 71-22.

1974: Five geological maps of northern Selwyn Basin (Operation Stewart), Yukon Territory and District of Mackenzie, N.W.T.; Geological Survey of Canada, Open File Report 205.

1976: Selwyn Basin – Yukon and District of Mackenzie; in Report of Activities, Part A, Geological Survey of Canada, Paper 76-1A, p. 131, 132.

1978: Regional geological setting of lead-zinc deposits in Selwyn Basin, Yukon; in Current Research, Part A, Geological Survey of Canada, Paper 78-1A, p. 77-80.

Bostock, H.S.

1947: Mayo, Yukon Territory; Geological Survey of Canada, Map 890A.

1964: Geology, McQuesten, Yukon Territory; Geological Survey of Canada, Map 1143A.

Boyle, R.W.

1961: Geology, geochemistry, and origin of the gold deposits of the Yellowknife District; Geological Survey of Canada, Memoir 310.

Boyle, R.W., Shafiqullah, M., Durham, C.C., Tupper, W.M., Friedrich, G., Ziauddin, M., Carter, M., and Bygrave, K.
1968: Minor and trace element distribution in the heavy minerals of the rivers and streams of the Bathurst – Jacquet River district, New Brunswick; Geological Survey of Canada, Paper 67-45 (Maps 12-1967, 13-1967).

Brett, P.R.
1960: Southeast La Motte and southwest Lacorne Townships; Quebec Department of Mines, Preliminary Report 428.

1961: A magmatic-pegmatite-hydrothermal sequence at Lacorne, Quebec; Economic Geology, v. 56, p. 784-789.

Bright, E.G.
1972a: The Timmins area; 24th International Geological Congress Guidebook, Field Excursion A39-39bC39, p. 59-96.

1972b: Timmins District; Ontario Division of Mines, Annual Report of Research, Geology Section, Miscellaneous Paper 50.

Bright, M.J. and Jonson, D.C.
1976: Glacier Gulch (Yorke-Hardy); in Porphyry Deposits of the Canadian Cordillera; Canadian Institute of Mining and Metallurgy, Special Volume 15, p. 455-461.

British Columbia Department of Mines
1944: Annual Report of the Minister of Mines of the Province of British Columbia for the year ended 31st December 1943.

Brown, G.J.
1961: Geology of the Flat River tungsten deposit, Canada Tungsten Mining Corp. Ltd.; Canadian Institute of Mining and Metallurgy, Transactions, v. LXIV, p. 311-314.

Burnham, C.W.
1967: Hydrothermal fluids at the magmatic stage; in Geochemistry of Hydrothermal Ore Deposits, H.L. Barnes, ed., Holt, Rinehart and Winston, New York.

Burt, D.M.
1971a: Some phase equilibria in the system Ca-Fe-Si-C-O; Carnegie Institute Yearbook 70 (70-71), p. 178-184.

1971b: The facies of some Ca-Fe-Si skarns of Japan; Carnegie Institute Yearbook 70 (70-71), p. 185-188.

1972: The influence of fluorine in the facies of Ca-Fe-Si skarns; Carnegie Institute Yearbook 71, p. 443-450.

Burton, C.K.
1972: Outline of the geological evolution of Malaya; Journal of Geology, v. 80, p. 293-309.

Cachau-Herreillot, F. and Prouhet, J.P.
1971: The utilization of the metalloids (As, P, F) as pathfinders for skarn tungsten deposits in the Pyrenees (France); in Geochemical Exploration; Canadian Institute of Mining and Metallurgy, Sepcial Volume 11, p. 116-120.

Cairnes, C.E.
1937: Geology and mineral deposits of Bridge River mining camp, British Columbia; Geological Survey of Canada, Memoir 213.

Cairnes, C.E. (cont.)
1943: Geology and mineral deposits of Tyaughton Lake map-area, British Columbia; Geological Survey of Canada, Paper 43-15.

Campbell, R.B.
1961: Geology, Quesnel Lake (west half), British Columbia; Geological Survey of Canada, Map 3-1961.

1963: Geology, Quesnel Lake (east half); Geological Survey of Canada, Map 1-1963.

1967: Geology of Glenlyon map-area, Yukon Territory; Geological Survey of Canada, Memoir 352.

Campbell, R.B., Mountjoy, E.W., and Young, F.G.
1973: Geology of McBride map-area, British Columbia; Geological Survey of Canada, Paper 72-35.

Campbell, R.B. and Tipper, H.W.
1971: Geology of Bonaparte Lake map-area, British Columbia; Geological Survey of Canada, Memoir 363.

Card, K.D.
1968: Economic geology of the Espanola-Whitefish Falls area; Ontario Department of Mines, Open File Report 5017.

1976: Geology of the Espanola-Whitefish Falls area, District of Sudbury, Ontario; Ontario Division of Mines, Geoscience Report 131.

Carter, N.C.
1964: Alice (British Columbia Molybdenum Ltd.); in Lode Metals in British Columbia, British Columbia Department of Mines, Annual Report.

Cathro, R.J.
1969: Tungsten in Yukon; Western Miner, v. 42, No. 4, p. 23-40.

Chang, Luke L.Y.
1967: $Li\ Zr(WO_3)_3$, a wolframite-like compound; Mineralogical Magazine, v. 36, p. 436, 437.

Cobbing, E.J.
1974: The tectonic framework of Peru as a setting for batholithic emplacement; Pacific Geology, v. 8, p. 63-65.

Cockfield, W.E.
1948: Geology and mineral deposits of Nicola map-area, British Columbia; Geological Survey of Canada, Memoir 249.

Cooke, H.C.
1957: Coaticook-Malvina area; Quebec Department of Mines, Geological Report 69.

Cotelo Neiva, J.M.
1972: Tin-tungsten deposits and granites from northern Portugal; Transactions, 24th International Geological Congress, Section 4, p. 282-288.

Craig, D.B. and Laporte, P.
1971: W (Sn, Be) Fiddler; in North of 60, Department of Indian Affairs and Northern Resources, Mineral Industry Report, 1969-1970.

Cummings, W.W. and Bruce, D.E.
1977: Canada Tungsten: the change to underground mining and description of mine-mill procedures; Canadian Institute of Mining and Metallurgy Bulletin, v. 70, p. 94-101.

Dagger, G.W.
1972: Genesis of the Mount Pleasant tungsten-molybdenum-bismuth deposit, New Brunswick, Canada; Canadian Institute of Mining and Metallurgy, Transactions, v. 81, p. B73-B102.

Davies, J.F.
1954: Geology of the West Hawk Lake – Falcon Lake area, Lac du Bonnet Mining Div., Manitoba; Manitoba Department of Mines and Natural Resources, Publication 53-4.

Davis, A.W.
1948: Red Rose Mine; in Structural Geology of Canadian Ore Deposits; Canadian Institute of Mining and Metallurgy, Symposium Volume, p. 129-131.

Davis, S.G.
1961: The distribution and occurrence of tungsten minerals in South China and Hong Kong; Proceedings, Symposium on Land Use and Mineral Deposits, Hong Kong, Southern China and Southeast Asia, Golden Jubilee Congress, Hong Kong University Press.

Dawson, K.M. and Dick, L.A.
1978: Regional metallogeny of the northern Cordillera tungsten and base metal-bearing skarns in southeastern Yukon and southwestern Mackenzie; in Current Research, Part A, Geological Survey of Canada, Paper 78-1A, p. 287-292.

Dick, L.A.
1973: Conditions during metamorphism of a contact metamorphic scheelite deposit near MacMillan Pass, Northwest Territories; B.Sc. thesis, University of British Columbia.

1977: Metamorphism and metasomatism at the MacMillan Pass tungsten deposit, Yukon and District of Mackenzie, Canada; M.Sc. thesis, Queens University.

Douglas, G.V. and Campbell, C.O.
1941: New Ross area; Nova Scotia Department of Mines, Annual Report of Mines, 1941.

Douglas, R.J.W. (editor)
1970: Geology and Economic Minerals of Canada; Geological Survey of Canada, Economic Geology Report 1, 5th ed.

Douglas, R.J.W. and Norris, A.W.
1974: Geology of Great Slave, District of Mackenzie; Geological Survey of Canada, Map 1370A.

Duffell, S. and Souther, J.G.
1964: Geology of Terrace map-area, British Columbia; Geological Survey of Canada, Memoir 329.

Duong, P.K.
1969: Skarns et minéralisations associées, Pt. 2; Chroniques des Mines et de la Récherche Minière, 37 Ann. No. 388, p. 339-342.

Eskenazy, Gr.
1977: On the binding form of tungsten in coals; Chemical Geology, v. 19, p. 153-159.

Eskola, P.
1952: Around Pitkaaranta; Academia Scientiarum Fennicae, Annales, Series A III, no. 27, 89 p.

Faribault, E.R.
1908: Lunenburg County, Nova Scotia; Geological Survey of Canada, Summary Report 1907, p. 78-83.

Faribault, E.R. (cont.)
1924: Map sheet 87, Chester Basin Sheet, Lunenburg County, Nova Scotia; Geological Survey of Canada, Map 1981.

1931: Map sheet 86, New Ross Sheet, Lunenburg, Hants and Kings Counties, Nova Scotia; Geological Survey of Canada, Map 2259.

Ferguson, S.A.
1968: Geology and ore deposits of Tisdale Township, Ontario; Ontario Division of Mines, Geological Report 58.

Ferreira, J.A. de M. and Albuquerque, J. do P.T.
1969: Sinopse da geologia da Folha Serido; SUDENE, Ser. Geologia Regionale, No. 18.

Findlay, D.C.
1969: The mineral industry of Yukon Territory and southwestern District of Mackenzie; Geological Survey of Canada, Paper 68-68.

Fogwill, W.D.
1965: Mines and mineral occurrence map of the Island of Newfoundland; Newfoundland Department of Mines, Agriculture, and Resources, Information Circular 11.

Fortier, Y.O.
1947: Preliminary map, Ross Lake, Northwest Territories (map and descriptive notes); Geological Survey of Canada, Paper 47-16.

Foster, R.P.
1977: Solubility of scheelite in hydrothermal solutions; Chemical Geology, v. 20, p. 27-43.

Freeze, A.C.
1966: On the origin of the Sullivan orebody, Kimberley, British Columbia; Canadian Institute of Mining and Metallurgy, Special Volume 8, p. 263-294.

Frommurze, H.F., Gevers, T.W., and Rossouw, P.J.
1942: Geology and mineral deposits of the Karibib area, South West Africa; Union South Africa, Geological Survey, Explanation Sheet 79.

Fyles, J.T. and Hewlett, C.G.
1959: Stratigraphy and structure of the Salmo lead-zinc area; British Columbia Department of Mines, Bulletin 41.

Gabrielse, H.
1963: McDame map-area, Cassiar District, British Columbia; Geological Survey of Canada, Memoir 319.

1967: Geology, Watson Lake, Yukon Territory; Geological Survey of Canada, Map 19-1966.

1969: Geology of Jennings River map-area (104 O); Geological Survey of Canada, Paper 68-55.

Gabrielse, H. and Reesor, J.E.
1974: Nature and setting of granitic plutons in the central and eastern parts of the Canadian Cordillera; Pacific Geology, v. 8, p. 109-138.

Gabrielse, H., Blusson, S.L., and Roddick, J.A.
1973: Geology of the Flat River, Glacier Lake and Wrigley Lake map-areas, District of Mackenzie and Yukon Territory; Geological Survey of Canada, Memoir 366.

Garrett, R.G.
1971a: Molybdenum and tungsten in some acid plutonic rocks of southeast Yukon Territory; Geological Survey of Canada, Open File 51.

Garrett, R.G. (cont.)
1971b: Molybdenum, tungsten and uranium in acid plutonic rocks as a guide to regional exploration, southeast Yukon; Canadian Mining Journal, v. 92, p. 37-40.

Gleeson, C.F.
1963: Reconnaissance heavy-mineral study in northern Yukon Territory; Geological Survey of Canada, Paper 63-32.

1967: Tungsten and tin content of spring and stream sediments, Keno Hill area, Yukon Territory; Geological Survey of Canada, Map 52-1965.

Godwin, C.I.
1976: Casino; in Porphyry Deposits of the Canadian Cordillera; Canadian Institute of Mining and Metallurgy, Special Volume 15, p. 344-354.

Gray, I.M.
1958: The Grey River tungsten deposit; thesis, Royal School of Mines.

Gray, R.F.
1968: Bishop tungsten district, California; in Ore Deposits of the United States 1933-1967, American Institute of Mining and Metallurgical Engineers, Graton-Sales Volume, John D. Ridge, ed.

Green, L.H.
1965: The mineral industry of Yukon Territory and southwestern District of Mackenzie, 1964; Geological Survey of Canada, Paper 65-19.

1966: The mineral industry of Yukon Territory and southwestern District of Mackenzie, 1965; Geological Survey of Canada, Paper 66-31.

1971: Geology of Mayo Lake, Scougale Creek and McQuesten Lake map-area, Yukon Territory; Geological Survey of Canada, Memoir 357.

Green, L.H. and Godwin, C.I.
1963: Mineral industry of Yukon Territory and southwestern District of Mackenzie; Geological Survey of Canada, Paper 63-38.

Green, L.H., Roddick, J.A., and Blusson, S.L.
1968: Geology, Nahanni, District of Mackenzie and Yukon Territory; Geological Survey of Canada, Map 8-1967.

Grenier, P.E.
1967: Annotated bibliography on metallic mineralization in the region of Noranda, Matagami, Val d'Or, and Chibougamau; Quebec Department of Natural Resurces, Special Paper 2.

Grip, E.
1951: Tungsten and molybdenum in sulphide ores in northern Sweden; Geologiska Foereningen i Stockholm, Forhandlingar H 3, p. 455-472.

Groves, E.W.
1971: Geology and mineral deposits of the Stewart area, British Columbia; British Columbia Department of Mines and Petroleum Resources, Bulletin 58.

Gunning, H.C.
1929: Geology and mineral deposits of Big Bend map-area, British Columbia; Geological Survey of Canada, Summary Report 1928A, p. 136-193.

Hall, W.E., Friedman, I., and Nash, J.T.
1974: Fluid inclusions and light stable isotopes study of the Climax molybdenite deposits, Colorado; Economic Geology, v. 69, p. 884-901.

Hamaguchi, H., Nakai, T., and Ideno, E.
1962: Determination of tungsten in rocks and meteorites by neutron activation analysis; Chemical Abstracts, v. 56, 6658b.

Hanson, G.
1929: Bear River and Stewart map-areas, Cassiar District, British Columbia; Geological Survey of Canada, Memoir 159.

Harmon, K.A., Crocket, J.H., and Shaw, D.M.
1975: Tungsten in iron formation; Mineralogical Association of Canada, Program Abstracts --- papers presented at Waterloo session.

Harris, D.C.
1972: Mineralogical investigation of some base metal ore deposits and occurrences in the Red Lake Mining Division, Ontario; Canada Mines Branch, Technical Bulletin 146.

Haughton, S.H., Frommurze, H.F., and Gevers, T.W.
1939: Geology and mineral deposits of the Omaruru area, South West Africa; Geological Survey of Pretoria, Explanation Sheet 71.

Hawley, J.E.
1939: Association of gold, tungsten, and tin at Outpost Island, Great Slave Lake, Northwest Territories; University of Toronto Studies, Geology Series 42.

Helsen, J.N.
1975: Tungsten and some other trace elements in basalts and andesites; Program Abstracts, Geological Association of Canada – Geological Society of America, Symposium, Waterloo.

Henderson, J.F. and Jolliffe, A.W.
1939: Relation of gold deposits to structure, Yellowknife and Gordon Lakes areas, Northwest Territories; Canadian Institute of Mining and Metallurgy, Transactions, v. XLII, p. 314-336.

Höll, R. and Maucher, A.
1972: Synsedimentary-diagenetic ore fabrics in the strata- and time-bound scheelite deposits of Kleinartal and Felbertal in the eastern Alps; Mineralium Deposita, v. 7, p. 217-226.

1976: The stratabound deposits in the eastern Alps; in Handbook of Strata-Bound and stratiform Ore Deposits, K.H. Wolf ed., Elsevier, Amsterdam.

Holland, S.S.
1954: Yanks Peak – Roundtop Mountain area, Cariboo District, British Columbia; British Columbia Department of Mines, Bulletin 34.

Horn, M.K. and Adams, J.A.S.
1966: Computer-derived geochemical balances and element abundance; Geochimica et Cosmochimica Acta, v. 30, p. 279-297.

Hosking, K.F.G.
1963: Geology, mineralogy, and paragenesis of the Mount Pleasant tin deposits; Canadian Mining Journal, v. 84, p. 95-102.

1973: The search for tungsten deposits; Geological Society of Malaysia, Bulletin 5.

Hsu, L.C.
1976: The stability relations of the wolframite series; American Mineralogist, v. 61, p. 944-955.

Hübner, H.
1972: Molybdenum and tungsten occurrences in Sweden; Sveriges Geologiska Undersoekning Serie Ca. Nr. 46.

Il'in, N.P. and Ivanova, G.F.
1972: X-ray microanalysis of muscovite from zones with tungsten mineralization; Geokhimiya, No. 3, p. 288-296. (Trans. Geochemistry 1972, p. 186-193.)

Ivanova, G.F.
1963: Content of tin, tungsten, and molybdenum in granites enclosing tin-tungsten deposits; Geochemistry, No. 5, p. 492-500.

1974: Geochemical and physicochemical conditions of tungsten migration and deposits; in Metallization Associated with Acid Magmatism (Symposium), Volume 1, M. Štemprok, ed., Ústred Ústav. Geol., Praha, p. 267-269.

Ivanova, G.F. and Khodakovskiy, I.L.
1968: Transport of tungsten in hydrothermal solutions; Geokhimiya No. 8, p. 930-940. (Trans. Geochemistry International, No. 8, p. 779-780 (abstract).)

Jeffery, P.G.
1959: The geochemistry of tungsten with special reference to the rocks of the Uganda Protectorate; Geochimica et Cosmochimica Acta, v. 16, p. 278-286.

Johnston, W.A. and Uglow, W.L.
1926: Placer and vein gold deposits of Barkerville, Cariboo District, British Columbia; Geological Survey of Canada, Memoir 149.

Johnston, W.D., Jr. and de Vasconcellos, F.M.
1945: Scheelite in northeastern Brazil; Economic Geology, v. 40, p. 34-50.

Jolliffe, A.W.
1944: Rare element minerals in pegmatites, Yellowknife, Beaulieu area, Northwest Territories; Geological Survey of Canada, Paper 44-12.

1946: Prosperous Lake, District of Mackenzie, Northwest Territories; Geological Survey of Canada, Map 868A.

Kerr, F.A.
1948: Lower Stikine and western Iskut River areas, British Columbia; Geological Survey of Canada, Memoir 246.

Kerr, P.F.
1946: Tungsten mineralization in the United States; Geological Society of America, Memoir 15.

Khitarov, N.I., Arutyunyan, L.A., and Malinin, S.D.
1967: On the possibility of migration of molybdenum in the vapour phase of molybdate solutions at elevated temperatures; Geokhimiya No. 2, p. 155-160. (Trans. Geochemistry International 1967, p. 98 (abstract).)

Kindle, E.D.
1937: Mineral Resources of Terrace area, Coast District, British Columbia; Geological Survey of Canada, Memoir 205.

1954: Mineral Resources, Hazelton and Smithers areas, Cassiar and Coast districts, British Columbia; Geological Survey of Canada, Memoir 223. (revised edition)

1962: Geology, Keno Hill, Yukon Territory; Geological Survey of Canada, Map 1105A.

1964: Copper and iron resources, Whitehorse Copper Belt, Yukon Territory; Geological Survey of Canada, Paper 63-41.

Klepper, M.R.
1947: The Sangdong tungsten deposit, Southern Korea; Economic Geology, v. 42, p. 465-477.

Kozlov, V.D., Sheremet, Ye.M., and Yanovskiy, V.M.
1974: Geochemical characterization of the Mesozoic plumasite leucocratic granites of the Transbaykalia tin-tungsten belt; Geokhimiya No. 10, p. 1451-1463. (Trans. Geochemistry International 1974, p. 997-1008.)

Krauskopf, K.B.
1964: The possible role of volatile metal compounds in ore genesis; Economic Geology, v. 59, p. 22-45.

Landis, G.P. and Rye, R.O.
1974: Geologic, fluid inclusion, and stable isotope studies of the Pasto Buena tungsten deposit, northern Peru; Economic Geology, v. 69, p. 1025-1059.

Leech, G.B.
1957: St. Mary Lake, Kootenay District, British Columbia; Geological Survey of Canada, Map 15-1957.

Levashev, G.B., Golubeva, E.D., and Govorov, I.N.
1974: Distribution of tungsten in mafic, intermediate, and silicic volcanics of the continental part of the circum-Pacific, as illustrated by the Sikhote Alin; Doklady Akademiya Nauk SSSR, 1974, v. 214, p. 434-437. (Trans. Geochemistry International 1974, p. 199-202.)

Li, K.C. and Wang, C.Y.
1943: Tungsten; American Chemical Society, Monograph No. 94, Reinhold, New York.

Little, H.W.
1950: Salmo map-area, British Columbia (report and map); Geological Survey of Canada, Paper 50-19.

1959: Tungsten deposits of Canada; Geological Survey of Canada, Economic Geology Report 17.

1965: Geology, Salmo, British Columbia; Geological Survey of Canada, Map 1145A.

Lord, C.S.
1951: Mineral industry of District of Mackenzie, Northwest Territories; Geological Survey of Canada, Memoir 261.

Malcolm, W.
1976: Gold fields of Nova Scotia; Geological Survey of Canada, Memoir 385 (reprint of Memoir 156).

Marleau, R.A.
1964: Descriptions of mining properties examined in 1961 and 1962; Quebec Department of Natural Resources, Preliminary Report 529, p. 35.

1968: Région de Woburn – Megantic-est – Armstrong; Ministère des richesses naturelles du Québec; Rapport géologique 131.

Martin, R.F.
1970: Petrogenetic and tectonic implications of two contrasting Devonian batholithic associatins in New Brunswick, Canada; American Journal of Science, v. 268, p. 308-321.

Mathews, W.H.
1953: Geology of the Sheep Creek Camp, British Columbia; British Columbia Department of Mines, Bulletin 31.

Maucher, A.
1972: Time- and strata-bound ore deposits and the evolution of the earth; Proceedings of 24th International Geological Congress, Section 4, p. 83-87.

McDougall, G.F.E.
1977: Trace element bedrock geochemistry around the Canada Tungsten skarn type scheelite deposit at Tungsten, Northwest Territories; Ph.D. thesis, Queen's University.

McMillan, R.H.
1972: Petrology, geochemistry, and wallrock alteration at Opemiska – a vein copper deposit crosscutting a layered Archean ultramafic-mafic sill; Ph.D. thesis, University of Western Ontario, 1972.

Messervey, J.P.
1931: Tungsten in Nova Scotia; Nova Scotia Department of Public Works and Mines, Pamphlet No. 29, p. 28, 29 (also in Departmental Annual Report, 1930).

Miller, C.K.
1974: Scheelite mineralization in the Moose River gold district, Halifax County, Nova Scotia; B.Sc. thesis, Dalhousie University.

Miller, C.K., Graves, M.C., and Zentilli, M.
1976: Scheelite mineralization of southeastern Nova Scotia; in Report of Activities, Part A, Geological Survey of Canada, Paper 76-1A, p. 331, 332.

Monger, J.W.H.
1973: Upper Paleozoic rocks of the western Canadian Cordillera; in Report of Activities, Part A, Geological Survey of Canada, Paper 73-1A, p. 27-29.

Monger, J.W.H. and Hutchison, W.W.
1971: Metamorphic map of the Canadian Cordillera; Geological Survey of Canada, Paper 70-33.

Monger, J.W.H., Souther, J.G., and Gabrielse, H.
1972: Evolution of the Canadian Cordillera: a plate-tectonic model; American Journal of Science, v. 272, p. 577-602.

Muller, J.E.
1967: Kluane Lake map-area, Yukon Territory; Geological Survey of Canada, Memoir 340.

Mulligan, R.
1952: Bonnington map-area, British Columbia; Geological Survey of Canada, Paper 52-13.

1965: Geology of Canadian lithium deposits; Geological Survey of Canada, Economic Geology Report 21.

1969: Metallogeny of the region adjacent to the northern part of the Cassiar Batholith, Yukon Territory and British Columbia; Geological Survey of Canada, Paper 68-70.

1975: Geology of Canadian tin occurrences; Geological Survey of Canada, Economic Geology Report 28.

1980: Lithophile element content of some Canadian granitoid rocks; Geological Survey of Canada, Open File 666.

Naumov, G.B. and Khodakovskiy, I.L.
1972: Thermodynamic analysis of mineral formation factors for hydrothermal deposits; Geokhimiya No. 12, p. 1561-1568. (Trans. Geochemistry International, 9, p. 1051-1055.)

Nekrasov, I.Ya.
1973: Tin content of antimony and mercury deposits of northeast USSR; Sovetskaya Geologiya No. 6, 1973, p. 18-29. (Trans. International Geology Review, v. 16, p. 704-713.)

Oelsner, O.
1966: Atlas of the most important ore mineral paragenesis under the microscope; Pergamon Press, New York (translation).

Okulitch, A.V.
1975: Evolution of the Shuswap metamorphic complex in south-central British Columbia: a preliminary report; Geological Society of America – Geological Association of Canada, Program Abstract, Annual Meeting, Waterloo.

Parrish, I.S.
1977: Mineral catalogue for the Mount Pleasant deposit of Brunswick Tin Mines; Canadian Mineralogist, v. 15, p. 121-126.

Parrish, L.S. and Tully, J.V.
1971: Molybdenum, tungsten, and bismuth mineralization at Brunswick Tin Mines, Ltd.; paper presented at Canadian Institute of Mining and Metallurgy Annual Meeting.

1977: Porphyry tungsten zones at Mount Pleasant, New Brunswick; paper presented at Canadian Institute of Mining and Metallurgy Annual Meeting.

Pastoor, D.W.
1970: Geology of the Invincible tungsten ore zone of Canadian Explorations, Ltd., Salmo, British Columbia; State of Washington Department of Natural Resources, Bulletin 61, p. 103-106.

Patrick, T.O.H.
1956: Comfort Cove, Newfoundland (map with marginal notes); Geological Survey of Canada, Paper 55-31.

Pearson, D.E.
1975: Bridge River map-area (92 J/15); in British Columbia Department of Mines and Petroleum Resources, Geological Fieldwork 1974, p. 35-39.

Pentland, A.G.
1943: Occurrence of tin at the Sullivan Mine; Canadian Institute of Mining and Metallurgy, v. XLVI, p. 17-22.

Petruk, W.
1964: Mineralogy of the Mount Pleasant tin deposit, New Brunswick; Canada Mines Branch, Technical Bulletin 56.

1973: The tungsten-bismuth-molybdenum deposit of Brunswick Tin Mines, Ltd.; its mode of occurrence, mineralogy, and amenability to mineral beneficiation; Canadian Institute of Mining and Metallurgy, Bulletin 66, p. 113-130.

Pitcher, W.S.
1974: The Mesozoic and Cenozoic batholiths of Peru; Pacific Geology, v. 8, p. 51-62.

Poole, W.H.
1960: Hayesville and McNamee map-areas, New Brunswick; Geological Survey of Canada, Paper 60-15.

1963: Geology, Hayesville, New Brunswick; Geological Survey of Canada, Map 6-1963.

Poole, W.H., Roddick, J.A., and Green, L.H.
1960: Geology, Wolf Lake, Yukon Territory; Geological Survey of Canada, Map 10-1960.

Potter, R.R.
1969: The geology of the Burnt Hill area and ore controls of the Burnt Hill tungsten deposit; unpublished Ph.D. thesis, Carleton University, 124 p.

Rankama, K. and Sahama, T.G.
1950: Geochemistry; University of Chicago Press, 911 p.

Reed, B.L.
1968: Geology of the Lake Peters area, northeastern Brooks Range, Alaska; United States Geological Survey, Bulletin 1236.

Reedman, A.J.
1973: Partly remobilized tungsten deposit at Nyamalilo Mine; Institute of Geological Science, Overseas Geological and Mineral Resources, No. 41, p. 101-106.

Reesor, J.E.
1957: Lardeau (east half), Kootenay District, British Columbia; Geological Survey of Canada, Map 12-1957.

1958: Dewar Creek map-area, with special emphasis on the White Creek Batholith, British Columbia; Geological Survey of Canada, Memoir 292 (Map 1053A).

Rice, H.M.A.
1937: Cranbrook map-area, British Columbia; Geological Survey of Canada, Memoir 207.

1941: Nelson map-area, east half, British Columbia; Geological Survey of Canada, Memoir 228.

1949: Smithers – Fort St. James, British Columbia; Geological Survey of Canada, Map 971A.

Riddell, J.E.
1962: Tin in southern New Brunswick, with special reference to the Mount Pleasant deposit; Canadian Mining Journal, v. 83, p. 69-75.

Riley, G.C.
1959: Geology, Burgeo-Ramea, Newfoundland; Geological Survey of Canada, Map 22-1959.

Roddick, J.A.
1967: Tintina Trench; Journal of Geology, v. 75, p. 23-33.

Roddick, J.A. and Green, L.H.
1961: Geology, Sheldon Lake, Yukon; Geological Survey of Canada, Map 12-1961.

Roddick, J.A. and Hutchison, W.W.
1970: Pemberton (east half) map-area, British Columbia; Geological Survey of Canada, Paper 73-17.

Routhier, P. and Brouder, P.
1973: Some major concepts of metallogeny; Mineralium Deposita, v. 8, p. 237-258.

Rub, M.G., Taksubayeva, G.P., and Chernov, B.S.
1969: Composition and origin of a tungsten-bearing magmatic complex in an area of Soviet Maritime Province; Sovetkaya Geologiya, 1969, No. 4, p. 3-21. (Trans. International Geology Review, v. 12, p. 313-326.)

Ruitenberg, A.A.
1963: Tin mineralization and associated rock alteration at Mount Pleasant, Charlotte County, New Brunswick; M.Sc. thesis, University of New Brunswick.

Ruitenberg, A.A. (cont.)
1967: Stratigraphy, structure, and metallization, Piskahegon – Rolling Dam area, New Brunswick; Leidse Geologische Mededelingen, Leiden University, Holland, p. 79-120.

1968: Geology, St. Steven – Pleasant Mountain area; Geological Survey of Canada, Map 20-1966.

1969a: Tungsten-molybdenum mineralization, Square Lake area; New Brunswick Department of Natural Resources, Mineral Resources Branch, Report of Investigation No. 9.

1969b: Mineral deposits in granitic intrusions and related metamorphic aureoles in parts of the Welsford, Loch Alva, Musquash, and Pennfield areas; New Brunswick Department of Natural Resources, Report of Investigation No. 9.

Sandell, E.B.
1946: Abundance of tungsten in igneous rocks; American Journal of Science, v. 244, p. 643-648.

Satterly, J.
1941: Geology of the Dryden-Wabigoon area; Ontario Department of Mines, Annual Report, v. 50, pt. 2.

Scherba, G.N.
1968: Greisens; in Genesis of Endogene Ore Deposits, Nedra Press, Moscow, Chapter 6. (Trans. International Geology Review, v. 12, p. 114-150.)

Shatkov, G.A.
1975: Fluorine and chlorine in basalts as possible indicators of metallogenetic zonation; Sovetskaya Geoligiya, 1975, No. 6, p. 121-127. (Trans. International Geology Review, v. 18, p. 1182-1188.)

Shcherbina, V.V., Ivanova, G.F., and Studennikova, Z.V.
1971: The geochemistry of molybdenum and tungsten; Nauka Publishing House, Moscow. (Trans. Geological Survey of Canada, Trans. No. 533.)

Shepherd, T.J., Beckinsdale, R.D., Rundle, C.C., and Durham, J.
1977: Genesis of Carrock Fell tungsten deposits, Cumbria: fluid inclusion and isotope study; Institute of Mining and Metallurgy, Transactions, v. 85, Sec. B, p. 63-73.

Shimazaki, H.
1974: Characteristics of tungsten mineralization in Japanese skarn deposits; in Metallization Associated with Acid Magmatism; Symposium 1974, Vol. 1, p. 312-318, Ustredni Ustav Geologicky, Prague.

1977: Grossular-spessartine-almandine garnets from some Japanese scheelite skarns; Canadian Mineralogist, v. 15, p. 74-80.

Shklanka, R.
1969: Copper, nickel, lead, and zinc deposits of Ontario; Ontario Department of Mines, Mineral Resources Circular 12.

Simon, F.O. and Rollinson, C.L.
1975: Determination of tungsten in geological materials by neutron activation analysis; United States Geological Survey, Journal of Research, v. 3, p. 475-478.

Skaarup, P.
1974: Strata-bound scheelite mineralizations in skarns and gneisses from the Bindal area, northern Norway; Mineralium Deposita, v. 9, p. 299-308.

Skinner, R.
1961: Mineral industry of Yukon Territory and southwestern District of Mackenzie, 1960; Geological Survey of Canada, Paper 61-23.

Smith, F.G.
1947: Transport and deposition of the non-sulphide vein materials, 2. Cassiterite; Economic Geology, v. 42, No. 3, p. 251-264.

Solomon, M., Groves, D.I., and Klominsly, J.
1972: Metallogenesis in the Tasman orogenic zone of Australia; Proceedings, 24th International Geological Congress, Section 4, p. 137-145.

Štemprok, M.
1974: Geological significance of immiscibility in fused silicate systems containing tungsten and molybdenum; Akademiya Nauk, SSSR, Izvestiya, Seriya Geologicheskaya No. 4, p. 60-71. (Trans. International Geology Review, v. 17, p. 1306-1316.

Štemprok, M. and Urbanova, Vera
1976: Liquid coexistence of albite melts with sodium molybdate or tungstate: a geological application; Ústredni Ústav Geologicky, Vestnik, Prague, v. 51, p. 139-152.

Stevenson, J.S.
1943: Tungsten deposits of British Columbia; British Columbia Department of Mines, Bulletin 10.

1947: Geology of the Red Rose tungsten mine, Hazelton, British Columbia; Economic Geology, v. 42, p. 433-464.

Sutherland Brown, A.
1957: Geology of the Antler Creek area, Cariboo district, British Columbia; British Columbia Department of Mines, Bulletin 38.

1960: Geology of the Rocher Déboulé Range, British Columbia; British Columbia Department of Mines, Bulletin 43.

1963: Geology of the Cariboo River area, British Columbia; British Columbia Department of Mines, Bulletin 47.

1970: Adera property (Atlin district); in Geology, Exploration and Mining in British Columbia; British Columbia Department of Mines and Petroleum Resources, 1970, p. 29-35.

Swanson, C.O. and Gunning, H.C.
1944: Geology of the Sullivan Mine; Western Minera, v. 17, p. 74-94.

Tait, S.
1964: Breccias of Mount Pleasant; M.Sc. thesis, McGill University.

Takenouchi, S. and Imai, H.
1971: Fluid inclusion study of some tungsten-quartz veins of Japan; Society of Mining Geology, Japan, Special Issue 3, p. 348-350.

Taylor, F.C. and Schiller, E.A.
1966: Metamorphism of the Meguma group of Nova Scotia; Canadian Journal of Earth Sciences, v. 3, p. 959-974.

Taylor, S.R.
1964: Abundance of chemical elements in the continental crust; Geochimica et Cosmochimica Acta, v. 28, p. 1280, 1281.

Tempelman-Kluit, D.J.
1977: Stratigraphic and structural relations between Selwyn Basin, Pelly-Cassiar Platform, and Yukon Crystalline Terrane in Pelly Mountains, Yukon; in Report of Activities, Part A, Geological Survey of Canada, Paper 77-1A, p. 223-227.

Thompson, R.I.
1973: Invincible, East Dodger; in Geology, Exploration and Mining in British Columbia; British Columbia Department of Mines and Petroleum Resources, p. 54-57.

Thorpe, R.
1969: Metallogeny and exploration in Northwest Territories; in Guidelines to Prospecting, Canadian Mining Journal, v. 90, p. 78-80.

Tipper, H.W.
1961: Geology, Prince George, British Columbia; Geological Survey of Canada, Map 49-1960.

Tremblay, L.P.
1950: Fiedmont map-area, Abitibi County, Quebec; Geological Survey of Canada, Memoir 253.

Tupper, W.M.
1959: McDougall Lake map-area, Charlotte County, New Brunswick; New Brunswick Mines Branch, Paper 59-2.

Turekian, K.K.
1972: Chemistry of the Earth; Holt, Rinehart and Winston, New York, Physical Science and Technology Series.

Turekian, K.K. and Wedepohl, K.M.
1961: Distribution of the elements in some major units of the earth's crust; Geological Society of America Bulletin, v. 72, p. 175-192.

Tweto, O.
1960: Scheelite in the Precambrian gneisses of Colorado; Economic Geology, v. 55, p. 1406.

1968: Mineral deposits in Colorado and south-central Wyoming; in Ore Deposits of the United States 1933-1967; American Institute of Mining and Metallurgical Engineers, Graton-Sales Volume.

U.S. Geological Survey
1976: Geological Survey Research 1976; U.S. Geological Survey Professional Paper 1000, 414 p.

Van de Poll, H.W.
1967: Carboniferous volcanic and sedimentary rocks of the Mount Pleasant area, New Brunswick; New Brunswick Department of Natural Resources, Report of Investigation 3.

Varlamoff, N.
1972: Central and West African rare-metal granitic pegmatites, related aplites, quartz veins, and mineral deposits; Mineralium Deposita, v. 7, p. 202-216.

Victor, Iris
1957: Burnt Hill wolframite deposit, New Brunswick, Canada; Economic Geology, v. 52, p. 149-168.

Vinogradov, A.P.
1962: Average contents of chemical elements in the principal types of igneous rocks of the earth's crust. (Trans. Geochemistry, 1962, No. 7, p. 641-664.)

Walker, R.R. and Mannard, G.W.
1974: Geology of the Kidd Creek mine – a progress report; Canadian Institute of Mining and Metallurgy, v. 69, p. 41-57.

Wallace, H.
1973: No. 10 Opikeigen Lake area, District of Kenora, Patricia Portion; in Summary of Field Work 1973, Ontario Division of Mines, Miscellaneous Paper 56, p. 80-84.

Wallace, S.R., Muncaster, N.K., Jonson, D.C.,
Mackenzie, W.B., Bookstrom, A.A., and Surface, V.E.
1968: Multiple intrusion and mineralization at Climax, Colorado; in Ore Deposits of the United States 1933-1967; American Institute of Mining and Metallurgical Engineers, Graton-Sales Volume, p. 606-640.

Warren, H.V. and Thompson, R.M.
1944: Minor elements in gold; Economic Geology, v. 39, p. 457-471.

Watson, K. de P. and Mathews, W.H.
1944: The Tuya-Teslin area; British Columbia Department of Mines, Bulletin 19, p. 41-43.

Wedepohl, K.H. (exec. editor)
1969: Handbook of Geochemistry, Volume 2, Part 4; Springer-Verlag, New York.

Wheeler, J.O.
1963: Rogers Pass map-area, British Columbia and Alberta; Geological Survey of Canada, Paper 62-32.

1965: Big Bend map-area, British Columbia; Geological Survey of Canada, Paper 64-32.

Wheeler, J.O., Green, L.H., and Roddick, J.A.
1960: Geology, Finlayson Lake, Yukon Territory; Geological Survey of Canada, Map 8-1960.

Whishaw, Q.G.
1954: The Jersey lead-zinc deposit, Salmo, British Columbia; Economic Geology, v. 49, p. 521-529.

White, D.F.
1955: Thermal springs and epithermal ore deposits; Economic Geology, 50th Anniversary Volume, p. 99-154.

White, W.H., Stewart, D.R., and Ganster, M.W.
1976: Adanac (Ruby Creek); in Porphyry Deposits of the Canadian Cordillera; Canadian Institute of Mining and Metallurgy, Special Volume 15, p. 476-483.

Williams, H.
1964: The Appalachians in northeastern Newfoundland – A two-sided symmetrical system; American Journal of Science, v. 262, p. 1137-1158.

Wright, W.J.
1940a: Burnt Hill tungsten deposit; New Brunswick Department of Lands and Mines, Paper 40-2.

1940b: Tungsten and molybdenite deposits at Square Lake, Queens County, New Brunswick; New Brunswick Department of Lands and Mines, Paper 40-3.

1940c: Molybdenum, tungsten, and tin in New Brunswick; New Brunswick Department of Lands and Mines, Paper 40-5.

Young, F.G., Campbell, R.B., and Poulton, T.P.
1973: The Windermere Supergroup in the southeast Canadian Cordillera; Proceedings of the Belt Symposium, Idaho Bureau of Mines, v. 1, p. 181-203.

Young, G.A.
1918: Burnthill Brook map-area, New Brunswick; Geological Survey of Canada, Summary Report 1917, Pt. F.

Zaw, Khin
1976: The Canada Tungsten E-Zone orebody, Tungsten, Northwest Territories; M.Sc. thesis, Queen's University.

Zharikov, V.A.
1970: Skarns, Part 2; International Geology Review, v. 12, p. 619-647 (translation).

Zhelyaskova-Panajotova, M., Petrussenko, S.V., and Iliev, Z.
1972: Tungsten and bismuth-bearing skarns from the region of the Seven Rila Lakes in Bulgaria; Proceedings, 24th International Geological Congress, Section 4, p. 519-522.

APPENDIX

CANADIAN TUNGSTEN OCCURRENCES AND GEOLOGICAL CHARACTERISTICS

APPENDIX

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
APPALACHIAN REGION – Newfoundland, Nova Scotia, New Brunswick, Southeastern Quebec						
1,2	49°24'30" 54°29'55" 2 E/8	Charles Cove Prospect, Gander Bay, Nfld.	qz vein	sh	3 main conc. in vein 0.5-4.5 m by 1025 m	
3	47°35.5' 57°06.3' 11 P/11	Grey River, La Poile District, (south coast) Nfld.	qz vein, greisen	wo, sh	prob. .45 Mt 1.1% WO_3 main sec. above adit	py, cp, fl, sb; Mo, Bi
4	47°35.7' 57°05.9' 11 P/11	Grey River, La Poile District, (south coast) Nfld.	qz vein			
5	47°50' 56°45' 11 P/15	NE of Grey River, Nfld.				
6	44°47'55" 63°37' 11 D/13	Waverley Gold District, Halifax Co., N.S.	qz vein	sh	Scat. lenses in vein 20 cm by 100 m	
7	44°45'35" 63°39'55" 11 D/13	Lower Sackville, Halifax Co., N.S.	qz vein	sh, ts	L, vein 20 cm trenched 12 m	minor asp.
8	44°53' 63°25'30" 11 D/14	Goffs, Nova Scotia Emsdale, Halifax Co., N.S.	qz vein	sh	L, 6 veins 15-45 cm by 6-24 m	asp.
8a	44°55' 63°28' 11 D/14	Oldham Gold District, Halifax Co., N.S.	qz vein	sh	L, 0.2% WO_3 in stamp-mill tailings	Au
9	44°58.5' 62°57' 11 D/15	Moose River "Scheelite Mine", Halifax Co., N.S.	(micac.) qz vein (ankerite)	sh	> 12 088 kg WO_3 recov. recorded (partial)	asp. (Au E of Moose R. mine)
9a	45°03' 62°58' 11 E/2	Caribou Gold District, Halifax Co., N.S.	qz vein	sh	0.22% in sample mill tailings	Au, Cariboo mine
10	44°52' 62°58.5' 11 D/15	Lake Charlotte, Halifax Co., N.S.	qz vein dissem.	sh	4.6% WO_3 1 lens 10-15 cm by 1.5 m	asp., py.; Pb, Au
11	45°01' 63°03' 11 E/03	Middle Musquodoboit, Murchyville, Halifax Co., N.S.	qz vein	sh	L	
12	45°20'58" 61°04'25" 11 F/06	Fox Island Main, Chedabucto Bay, Guysborough Co., N.S.	qz vein dissem.	sh	to 2.19% WO_3 across 0.3 m	
13	46°15' 61°03' 11 K/6	Emerald, near Northeast Margaree (Murphy Brook), Inverness Co., N.S.	qz vein	wo, hu	0.45 t boulder 66% WO_3 on lenticular vein	minor cp.
14	44°23'40" 65°04'30" 21 A/6	Harmony Mills, Queens Co., N.S.	qz vein	sh	seam to 5 cm wide in vein 10-15 cm by 9 m	
14a	44°22' 64°55' 21 A/7	Ballou Mine, Ponhook L., Queens Co., N.S.	qz vein	sh	locally in 1 vein	py, asp; Au (Malaga Gold Dist.)
15	44°24' 64°43'40" 21 A/7	Bakers Settlement, 19 km W Bridgewater, Lunenburg Co., N.S.	qz vein	sh	pockets of thin veinlets along walls of narrow veins	asp.

BCAR – Annual Report, British Columbia Ministry of Mines and Petroleum Resources.
GEMBC – Geology, Exploration and Mining in British Columbia.
Nfld AR – Annual Report of the Department of Mines, Agriculture and Resources, Province of Newfoundland.
ODM – Ontario Department of Mines.

L	low	ap	apatite
Pr	present	asp	arsenopyrite
R	reported	ba	barite
Tr	trace	by	beryl
ab	albite	cp	chalcopyrite
ak	actinolite	ep	epidote
am	amphibolite	fb	ferberite

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
	quartzite, slate (Ord.?), granodiorite	granodiorite (Dev.?)	Little, 1959, p. 201 Patrick, 1956	Expl. by Nalco and Norlex, 1965-70; other sh-bearing veins in area
mineralized vein avg. 1.2 m by 640 m	Ord. schist, gneiss	granite (Dev.)	Nfld. AR 1967, 1968; Riley, 1959; Bahyrycz, 1957; Gray, 1958	Adit near sea level 1615 m long and raises 244 m below surface; Buchans, A.S. and R.
faulted extension(?) of main vein	granite			
			Fogwill, 1965	Several occurrences (unconfirmed) on Fogwill map
conformable	slate, arkose		Little, 1959, p. 197	225 kg 37.5% WO_3 shipped 1917
	quartzite (Goldenville)		Little, 1959, p. 196	
	quartzite, slate (Goldenville)		Little, 1959, p. 198	2.72 t conc. 72% WO_3 recov. by 1940
			Little, 1959, p. 197	Dunbrack mine
numerous thin veins, part conformable, folded (saddle-reef)	quartzite, slate (Goldenville)		Messervey, 1931; Miller, 1974; Miller et al., 1976; Little, 1959, p. 198	Some sh lenses also at Moose R. and adjoining Tanguay Au mines
	quartzite, slate (Goldenville)		Little, 1959, p. 198	
3 veins E of lake; 5 veins W of lake	quartzite, slate (Goldenville)	granite (Dev.)	Little, 1959, p. 200	0.27% WO_3 two bulk mill tests over mining widths
corrugated and lenticular veins	slate, quartzite		Little, 1959, p. 197	
small veinlets & dissem. in quartzite, zone 1.5-2.5 m	quartzite, slate, schist (Meguma)		Northern Miner, Mar. 2, 1972, p. 15	Drilled 1953, 1955, and 1971
	gneissic granite (Precamb.?)		Little, 1959, p. 201	No rept. on workings in vein
veins in slate beds between layers of quartzite, open folds	quartzite, slate (Goldenville)		Little, 1959, p. 194	
	siliceous slate (Halifax F.)		Little, 1959, p. 195	

fel	feldspar	ks	cassiterite	Cu	copper	Sn	tin	py	pyrite	st	stolzite
fl	fluorite	mag	magnetite	In	indium	Te	tellurium	qz	quartz	su	specularite
gn	galena	Ag	silver	Li	lithium	W	tungsten	ru	rutile	tet	tetrahedrite
gt	garnet	Au	gold	Mo	molybdenum	Zn	zinc	sb	stibnite	tl	tourmaline
hem	hematite	Be	beryllium	Ni	nickel	mu	muscovite	sh	scheelite	to	topaz
hu	hueberite	Bi	bismuth	Pb	lead	po	pyrrhotite	se	sericite	ts	tungstite
id	idocrase	Cr	chromium	Sb	antimony	pt	powellite	sp	sphalerite	wo	wolframite
										wol	wollastonite

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
15a	44°43' 64°33' 21 A/10 44°48' 64°24' 21 A/16	New Ross (4.8 km W of), Mill Road (6.4 km N of), Lunenburg Co., N.S.	pegmatite qz vein greisen	wo, sh	L	fl, ks, asp; Li, Sn, Cu, etc.
16	44°19'45" 64°20'30" 21 A/8	Indian Path mine, 9.6 km S of Lunenburg, Lunenburg Co., N.S.	qz vein	sh	0.34% WO_3 in 22.7 t bulk sample 1940	asp, minor Au, Pb product from 1 vein
16a	44°13' 64°53' 21 A/2	Fifteen Mile Brook, 24 km NW of Liverpool, Queens Co., N.S.	qz vein	sh		
17	45°27' 66°22'30" 21 G/8	Square Lake, 3.2 km W Welsford, Queens Co., N.B.	qz greisen vein	wo	0.68% WO_3 in wo greisen sample, numerous veins to 3 m x 30 m greisen border to 3.7 m	py, asp, fl, to; Mo, Bi, Sn
17a	45°26' 66°49' 21 G/7	Mount Pleasant (Brunswick Tin Mines), St. George, Charlotte Co., N.B.	qz greisen vein	wo	est. 38.65 Mt 0.2% W, .08 Mo, .08 Bi + fl, Sn	asp, py, fl, to; Cu, Zn, Mo, Bi, Pb, Sn, In
18	46°34'25" 66°49'10" 21 J/10	Burnt Hill Tungsten Mine, 56 km NW Fredericton, York Co., N.B.	qz greisen vein	wo	0.45% WO_3 in 181.4 t milled 1916; 1% test sample 1969	py, asp, to, fl, by; Mo, Cu, Zn, Pb, Bi, Sn
18a	47°41' 65°54' 21 P/12	Bathurst area (Nicholas Denys), 21 km WNW Bathurst, N.B.	skarn	sh	small amounts	Mo
18b	49°00' 65°30' 22 A/13	Gaspé Copper, near Murdochville, Que.	skarn?	sh	"fairly abundant in parts of orebody"	po; Cu, Mo
19	45°02' 71°54' 21 E/4	Sawchuck, 13 km SW Coaticook, Stanstead, Barnston IX, X, 70-20, 8-20, Que.		sh	L?	
19a	45°42' 70°58' 21 E/10	Maheu Property, NW Megantic Lake Frontenac, Whitton V, 6-10, 11-14, 15-25, Que.	qz veins	sh	L?	Mo, Bi+Pb, Zn, Ag
20	45°43.5' 70°37.5' 21 E/10	Risborough Tp., Frontenac, Risborough, X 2, Que.		sh	L?	
20a	45°46' 70°31.7' 21 E/15	Mine Hill, 35 km NE Megantic, Frontenac, Marlow VI, VII, 1, 2, Risborough XV, 1,2, Que.	qz veins	sh, ts		py; Pb, Ag, Au, Bi, Sb
PRECAMBRIAN SHIELD						
GRENVILLE PROVINCE – Ontario						
21a	44°44' 77°12' 31 C/11	Addington Mines, Ont. Lennox and Addington Co., Kaladar, VI 24, 25	qz veins	sh	Pr	py, cp, asp, po+Au, tl
21b	44°46' 77°08' 31 C/14	Star Gold Mine, Ont. Frontenac, Barrie, X 24-26, IX 25	qz veins	sh	Pr	py, cp+Au, tl

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
contact anticlinal wedge quartzite and slate	granite (L. or post-Dev., muscovite-biotite)		Faribault, 1908, 1924, 1931 Messervey, 1931; Douglas and Campbell, 1941; Mulligan, 1975; Little, 1959, p. 194	
veins to 0.6 m in zone 1798 m, anticlinal axis fissure vein intersects bedded vein	slate (Halifax F.)		Messervey, 1931; Little, 1959, p. 195	Shafts and underground devel. several thousand tonnes low-grade milled 1942
			Little, 1959, p. 194	sh-bearing float nearby
	granite (L. or post-Dev.)		Wright, 1940b; Ruitenberg, 1969a,b; Mulligan, 1975; Little, 1959, p. 191	Also at granite contact, nearby Nerepis area
2 zones related to intrusive vents (?)	rhyolite, breccia, tuff (Carb.)	late or post-Dev. hypabyssal granite, near St. George Bath.	Ruitenberg, 1963, 1967, 1968; Parrish and Tully, 1971; 1977; Petruk, 1964, 1973; Mulligan, 1975, p. 117-123; Northern Miner Aug. 31, 1974, p. 11	Expl. & devel. cont. 1975 (Sullico)
30 veins, parallel joint system in sediments and granite	argillite, slate, quartzite	muscovite-biotite granite (late phase? of Dev. Bath.)	Wright, 1940a; Potter, 1969; Poole, 1960, 1963; Mulligan, 1975; Little, 1959, p. 191	Wo also near Todd Mt. fire-tower, NW Boiestown (Wright, 1940c, p. 5), also in granite, Burnt Hill area
contact aureole		granite stock (Nicholas-Denys)	Boyle et al., 1968	Also anomalous in some stream sediments
gentle folds	siltstone, chert, limestone (L. Dev.)	porphyry stocks, dykes	Little, 1959, p. 190	
	quartzite, limestone porphyry dykes	granite	Cooke, 1957	Trenches
	slate, quartzite	granite alaskite, qz-fel porphyry	Marleau, 1964	
	porphyry dykes		Marleau, 1968	
	L. Dev. argillite, schist		Little, 1959, p. 189	First sh ident. in Canada 1890; small mill shipment 1958
			Little, 1959, p. 178	
			Little, 1959, p. 178	

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
SUPERIOR PROVINCE – Quebec						
22	47°18' 79°04' 31 M/6	Lot 29, Range IV, Gaboury Tp., Témiscamingue	qz veins	sh	samples to 0.3% WO_3 in 137 m zone	py
22a	47°22' 79°14' 31 M/6	Spencer Jutras, Témiscamingue, Laverlochère X, 20		sh	4.25% WO_3 in zone 18 cm by 1.2 m	
23	48°12' 79°21' 32 D/3	Dasserat Lake, Abitibi, Dasserat		sh	L	
23a	48°46' 79°24' 32 D/14	Manly Quebec Gold Mines, Abitibi, La Reine, IV 29	qz veins	sh	L	py, cp + Au
24a	48°39' 78°10' 32 D/9	Nortrac-Colonial, Abitibi, Dalquier V 19, VI, III 10-13	qz veins	sh	L, 457 m by 1.2-2.75 m	Au, Ag
24b	48°39.5' 78°01' 32 D/9	East Dalquier Gold Mines, Abitibi, Dalquier VI 51, 52	qz vein	sh	L	Au, Cu
25a	48°15' 79°10' 32 D/3,6	Halliwell Gold Mines, Témiscamingue, Beauchastel VIII, 34		sh	L?	Au, Cu in py., cp + Zn, Mo
25b	48°13' 78°54' 32 D/2	McWatters Gold Mines, Témiscamingue, Rouyn Block 196	qz veins	sh	L	py, po, asp + Au, Cu, Zn, Mo, tl
25b	48°13' 78°52' 32 D/2	New Rouyn (O'Neill-Thompson mine), Témiscamingue-Joannès, Block 13	qz veins	sh	L	py, po, asp + Pb, Au, tl
25c	48°14' 78°28.5' 32 D/1	O'Brien Gold Mine, Abitibi, Cadillac Block 15	qz veins	sh	L	asp, py, po, cp + Pb, Au, tl
25c	48°14' 78°20' 32 D/1	Consolidated Central Cadillac, Abitibi, Cadillac Block 61	qz veins	sh	L?	asp, py, tl; Au
25c	48°14' 78°17-21' 32 D/1	Pandora Gold Mines, Abitibi, Cadillac	qz veins	sh	L	asp, py, tl; Au
25d	48°07.5' 78°07.5' 32 D/1	Canadian Malartic Gold Mines, Val d'Or area Abitibi, Malartic	qz-albite-pegmatite vein+ replacements	sh	L?	py + Cu, Zn, Pb, Mo, Au, fl, ru, ab
25d	48°07.5' 78°05' 32 D/1	East Malartic Gold Mines, Val d'Or area, Abitibi, Malartic	pegmatite-qz veins+ replacements	sh	L	py, mag, su + Pb, Cu, Zn, Au, tl, ru, Mo, by
25e	48°09' 77°52' 32 C/4	Siscoe Gold Mines, Val d'Or area, Abitibi, Dubuisson	qz veins	sh	locally fairly abundant	py, cp, tl; Au
25e	48°08' 77°51' 32 C/4	Sullivan Consolidated Mines, Val d'Or area, Abitibi, Dubuisson	qz veins	sh	L?	py + Cu, Zn, Pb, Au, Ag, Te, tl, ab
25f	48°06' 77°46' 32 C/4	Shawkey Gold Mining Company, Siscoe Extension, etc., mines Abitibi, Bourlamaque, Val d'Or area	qz veins	sh	L	Au

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
	"Archean" volcanics	fel porphyry	Little, 1959, p. 188	
	pegmatite in hornblendite		Little, 1959, p. 189	
	granite	alaskite dykes	Grenier, 1967; Little, 1959, p. 179	Small amount recov. 1942
	granite		Grenier, 1967; Little, 1959, p. 179	Shaft VI-13
	granite		Grenier, 1967	
	andesite	qz diorite (contact)	Little, 1959, p. 187	Conical body sulphides source(?) of small shipment of ore 1943
veins folded, shattered	conglom., volcanics	rhyolite, porphyry	Little, 1959, p. 187	Small shipment sh 1942
	conglom., greywacke, diorite		Little, 1959, p. 188	"Small amount in NE zone"
			Grenier, 1967; Little, 1959, p. 182	
	greenstone, iron form.		Grenier, 1967; Little 1959, p. 182	Small production 1942
plunging syncline, fault			Little, 1959, p. 182	
fault, fracture	greywacke, locally silicified	qz syenite-porphyry, porphyry-pegmatite	Little, 1959, p. 183	sh shipped 1942
shear	volcanics, diorite, syenite, porphyry	diorite, syenite, porphyry	Little, 1959, p. 183	
shear	greenstone, granodiorite		Little, 1959, p. 184	
fractures-shears	granodiorite, Bourlamaque Bath.		Little, 1959, p. 184	Small shipment sh
			Little, 1959, p. 184	

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
25f	48°05.5' 77°45.5' 32 C/4	Lamaque Gold Mines, Abitibi, Bourlamaque, Val d'Or area	qz veins	sh	L?	py + Au, Te, tl
25f	48°06.5' 77°45' 32 C/4	Sigma Mines (Quebec) Ltd., Abitibi, Bourlamaque, Val d'Or area	qz veins	sh	L?	py, Au, tl
25g	48°18' 77°59' 32 C/5	Lacorne mine (Molybdenite Corp.) Abitibi, La Corne, Val d'Or area	pegmatite-qz veins	sh	L	py + Cu, Bi, Mo, mu, te, fl, by, ap
25h	48°05.5' 77°26' 32 C/3	Bevcourt (Beaucourt) Gold Mines, Abitibi, Louvicourt, VII 44-51, Val d'Or area	qz veins	sh	Pr	py + Bi, Te, Cu, Zn, Au
25i	48°10' 77°31' 32 C/4	Perron Gold Mines, Abitibi, Pascalis, Val d'Or area	qz veins	sh	"local pockets"	py, tl; Au
26	49°48' 74°52' 32 G/15	Opemiska Copper Mines, Territoire-du-Nouveau-Québec, Lévy	qz veins+ replacements	sh	"minor"?	cp, py, mag + Mo, Au, Ag + Sn
SOUTHERN PROVINCE – Ontario						
27a	46°14' 81°39' 41 I/14	Foster Township, Sudbury District, Ontario III 8, 9	skarn, qz veins	sh, pt	medium, erratic, 0.13-0.39% W in samples	py, po, asp; Cu, Zn, Mo
27b	46°26.5' 81°05.5' 41 I/6	Fielding Property, 3.2 km SW Copper Cliff, Sudbury District, Waters V, VI 2	dissem.	sh	L	
SUPERIOR PROVINCE – Ontario						
28a	47°40' 81°00' 41 P/11	Tyranite Mines and Duggan, Timiskaming, Tyrrell Tp.	qz vein?	sh	R	py, po, cp, Zn, Pb, Au, Ag + su, Mo
28b	47°57' 80°41' 41 P/15	Matachewan Consolidated Mines, Young Davidson Mines, Timiskaming, Powell Tp.	qz veins	sh	L	Au
29a	48°08' 79°35' 32 D/4	Kerr-Addison Gold Mines, Larder Lake area, McGarry Tp.	qz veins	sh		py, asp + Cu, Zn, Pb, Au
29a	48°09' 79°34' 32 D/4	Chesterville-Larder Lake Gold Mining, McGarry Tp.	replacement	sh	L	py, asp + Cu, Zn, Pb, Au
29b	48°07' 79°42' 32 D/4	Omega Gold Mines, Larder Lake area, McVittie Tp.	replacement	sh	L	sulphides, Au
29c	48°08' 79°49' 32 D/4	Upper Canada Mines, Larder Lake area, Gauthier Tp.	replacement	sh	Pr	py + Cu, Pb, Mo, Au
29c	48°04' 79°57' 32 D/4	Bulldog mine, Boston Tp., 19 km SE Kirkland L.		sh	L?	
29d	48°10' 79°55' 32 D/4	Bidgood-Kirkland Gold Mines, near Kirkland Lake-Lebel Tp.	qz vein	sh	Pr	py, Au, ba

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
thrust faults	granodiorite, diorite, porphyry		Little, 1959, p. 185	Small shipment sh 1943
shears, fractures	volcanics, breccia		Little, 1959, p. 185	Small production sh 1943
most minerals in E-trending set	biotite schist	Lacorne Bath. (Li, Be, pegmatite area)	Tremblay, 1950; Brett, 1960, 1961; Little, 1959, p. 181	Former important Mo, Bi producer
shear, fracture	granodiorite, volcanic, porphyry		Grenier, 1967; Little, 1959, p. 185	
most ore in NW set	granodiorite		Little, 1959, p. 186	Small shipments sh 1942-43
differentiated mafic sill, folds	gabbro	granodioritic Opemiska L. pluton	Grenier, 1967; McMillan, 1972	8% W and 0.12% Sn in bulk composite
	carbonate (Espanola) & clastic (Mississagi)		Card, 1968, 1976; Shklanka, 1969	
	gabbro sill in greywacke		Little, 1959, p. 169	Pit; sh also in dump, Victoria Mine
			Little, 1959, p. 177	
	syenite, porphyry		Little, 1959, p. 176	
fault zone	carbonatized tuff, etc.		Little, 1959, p. 175	Some sh cobbed from veins in tuff, little or no Au
fracture zone	basalt		Little, 1959, p. 176	Best showing 0.2% WO_3 over 1.5 m
	dacite flows silicified		Little, 1959, p. 175	Best showing 0.1% WO_3 over 6 m^2
shear zones	volcanics, syenite		Little, 1959, p. 174	
			Little, 1959, p. 174	
	volcanics, porphyry, syenite		Little, 1959, p. 174	

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
29d	48°09' 79°55' 32 D/4	Morris Kirkland Gold Mines, near Kirkland Lake-Lebel Tp.	qz vein	sh	Pr	py, gn, cp; Au
29d	48°12' 80°14' 32 D/4	Republic Tungsten Mines, etc., Sesekinika, Maisonville Tp.		sh	Pr	
30a	48°26' 81°07' 42 A/6	Aunor Gold Mines, Timmins area-Deloro Tp.	qz vein	sh	L?	py, cp, tl; Au
30b	48°27' 81°14' 42 A/6	Preston East Dome Mines, Timmins area-Tisdale Tp.	qz vein stockworks	sh	L?	po, py + Zn, Pb, tl; Au
30c	48°27' 81°14' 42 A/6	McIntyre-Porcupine Mines, Timmins area-Tisdale Tp.	qz vein	sh	L?	sulphides, tellurides, Au, tl
30c	48°28' 81°19' 42 A/6	Hollinger Consolidated Gold Mines, Timmins area-Tisdale Tp.	qz vein	sh	mill heads averaged 0.5% WO_3	asp, po + Cu, Zn, Pb, Te, Au, tl + Mo, Bi
30c	48°26' 81°18' 42 A/6	Delnite Mines, Timmins area-Deloro Tp.	qz vein	sh	L?	py, asp, tl; Au
30d	48°26' 81°23' 42 A/6	DeSantis Porcupine Mines, Timmins area-Ogden Tp.	qz vein	sh	L?	Ag, Au
30e	48°42' 81°22.5' 42 A/11	Kidd Creek mine (Texasgulf), 24 km N Timmins, Kidd Tp.	strata-bound massive sulphide	wo	Pr	py, Zn, Cu, Pb, Ag + Sn, produced
30f		near Kam Kotia mine, Timmins area	qz vein	sh	Pr	
31a	47°05' 84°30' 41 N/2	Tribag (Briar Court Mines), Batchawana area, Tp. 27, 28	breccia pipe ("porphyry copper")	sh?	Pr	py, cp; Ag, Mo
31b	47°58' 85°06' 41 N/14	Fenlon, Algoma Dist. Tp. 32, R. 23 nr. Michipicoten	qz vein	sh	samples to 3.6% WO_3 locally	Mo, pt
31c	48°49' 84°27' 42 C/15	Cline Lake Mine, 9.6 km Lochalsh, Algoma Dist.	qz veins	sh	Pr	py, po, asp + Zn, Cu, Mo, tl, Au
32a	49°41' 86°56' 42 E/10	MacLeod Cockshutt mine, Thunder Bay, near Geraldton	qz veins	sh	Pr	py; Au
32a	49°41' 86°53' 42 E/10	Hard Rock Gold Mines, Thunder Bay, near Geraldton	qz veins	sh	Pr	py, po, asp + Cu, Au, tl
32b	49°42' 86°57' 42 E/10	Little Long Lac Gold Mines, Thunder Bay, near Geraldton	qz vein	sh	L?	sulphides; Au
32c	49°42' 87°03' 42 E/11	Magnet Consolidated Gold Mines, Thunder Bay, Errington Tp.	qz vein	sh	0.25% WO_3 locally over 1 m	asp, py, po + Cu, Zn, Pb, Au
32c	49°42' 87°04' 42 E/11	Bankfield Consolidated Mines, Thunder Bay, Errington Tp.	qz vein	sh	Pr	py, po, asp + Zn, Cu, Au

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
	volcanics, porphyry contact		Little, 1959, p. 174	
			Little, 1959, p. 173	
ladder-vein	andesite, tuff	diorite, qz-fel. porphyry	Little, 1959, p. 170	549 kg WO_3 recov.
	volcanics, porphyry		Little, 1959, p. 173	669 kg WO_3 recov. 1941-52
	volcanics	Pearl L. qz porphyry	Little, 1959, p. 173	257 kg WO_3 recov. 1941-52
anticlinal axis faults	volcanics, qz porphyry		Allen and Folinsbee, 1944; Little, 1959, p. 171	161 261 kg WO_3 recov. 1940-1953 in custom mill
	greenstone carbonatized	qz porphyry	Little, 1959, p. 170	Small production sh from shipment 1945
			Little, 1959, p. 170	87.5 kg WO_3 recov. 1942
complex folds, faults	acid volcanics, minor sediments, chert	hypabyssal qz-fel. porphyry intrusion?	Bright, 1972a,b; Mulligan, 1975; Walker and Mannard, 1974	Major base metal, Ag producer, also Sn
			Bright, E.G., pers. comm., 1972	
	granite		Northern Miner, July 28, 1966, p. 1; Blecha, 1974	
shear	granite		Little, 1959, p. 169	
faults	volcanics, iron form., granodiorite, porphyry		Little, 1959, p. 168	
	greywackes, iron form.		Little, 1959, p. 168	
plunging syncline	greywacke, volcanics		Little, 1959, p. 168	
dragfold	sediments, conglom., iron form.		Little, 1959, p. 166	Conc. containing about 8618 kg WO_3 from 1226.5 t sorted ore in pilot mill, 1943
	sediments, conglom., iron form., diorite, etc.		Little, 1959, p. 166	
	slate, iron form., lava, greywacke, porphyry		Little, 1959, p. 165	

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
32c	49°42' 87°05' 42 E/11	Tombill Gold Mines, Thunder Bay, Lindsley Tp.	qz vein and replacement	sh	Pr	py, po, asp + Zn, Cu, Au
32c	49°42' 87°06'? 42 E/11	Jellicoe Mines, Thunder Bay, Lindsley Tp.			Pr	
32d	49°38' 88°01' 52 H/9	Leitch Gold Mines near Beardmore, Thunder Bay-Eva and Summers Tps.	qz veins	sh	L?	py, sp, tet, se; Au
32d	49°37' 88°03' 52 H/9	Sand River Gold Mining, Thunder Bay-Eva Tp. near Beardmore	qz vein	sh	L	py, tet; Au
32e	48°35' 89°17' 52 A/11	Lakehead Gold Mines, Thunder Bay-Gorham Tp., Conces. 2, 7, 8	qz vein	sh	L	
33a	51°34' 87°44' 42 M/12	Dorne Mines, Fort Hope area		sh	L	
33b	51°37' 88°07.5' 52 P/9	Rich Lake Patricia, 6.4 km NW Fort Hope	qz vein	sh	to 1.5% W rept., considerable expl.	asp, po, py; low Au Li pegmatites near
33b	51°35' 88°03' 52 P/9	Dome Mines, Fort Hope area	qz vein	sh	0.936% WO_3 in bulk samples from 4 trenches	py, po + Cu, Au
33c	51°29' 90°09' 52 O/8	Central Patricia Gold Mines, Connell Tp.	qz vein carbonate	sh	Pr	po, asp, py, tl; Cu, Au
33d	51°30' 90°03' 52 O/9	Pickle Crow Gold Mines, Connell Tp.	qz vein carbonate	sh	L?	py, po, asp, tl + Cu, Pb, Zn, Au
34a	49°47' 92°20' 52 F/16	Sandybeach Lake, near Dryden, Kenora M.D. MacFie Tp.	qz vein	sh	L?	minor sulphides, Au
34b	49°48.5' 92°42' 52 F/15	Kenora M.D. Zealand Tp. near Dryden	qz vein	sh	L?	Be and Li occurrences
34c	49°24' 92°51' 52 F/7	Gold Rock Mines near Dryden, Kenora M.D. – Manitou lakes area	qz vein	sh	Pr	py + Cu, Au
34d	52 F/7	Dryden Red Lake property, Kenora M.D. – Manitou lakes area	qz vein	sh	Pr	py
34e	49°17' 92°57' 52 F/7	Gaffney Claims, Kenora M.D. – Manitou lakes area	qz vein	sh	Pr	py, cp, tl; Au
34f	48°42' 92°24' 52 C/9	Corrigan Property, NE of Rainy L. Fort Frances M.D., Farrington Tp.	qz vein	sh	?	
34g	49°36' 94°14' 52 E/9	Wendigo Gold Mines, Kenora M.D. – Manross Tp.	qz vein carbonate, ankerite	sh	Pr	sulphides, Au
34h	50°01' 93°28' 52 K/3	Redvers Lake, N of Quibell, Kenora M.D. – Redvers Tp.	qz veins	sh	L	Mo, py, cp

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
shear zones	greywacke, porphyry		Little, 1959, p. 165	
			Little, 1959, p. 165	
shear zones	greywacke, iron form., conglom., greenstone		Little, 1959, p. 164	About 1225 kg WO_3 recov. in conc. 1943
	greywacke		Little, 1959, p. 164	A little sh conc. shipped
shear zones				
	lavas, tuffs			Surface trenching
conformable veins 0.3-0.6 m by 90 m	greenstone, tuff		Wallace, 1973; Little, 1959, p. 162	Also in Li pegmatites N of Lilypad L.
shear zone	volcanics		Little, 1959, p. 163	Trenching and drilling 1942
2 vein systems	volcanics; iron form., chert, sheared qz porphyry		Little, 1959, p. 162	
strong fracture	volcanics, iron form.		Little, 1959, p. 162	Small amount W conc. from picked ore
	greenstone, qz porphyry		Little, 1959, p. 159	Trenched for 305 m
		tl, pegmatite, granite	Satterly, 1941; Mulligan, 1965 (Li, Be)	Sample supplied by L. Pigeon of Wabigoon cont. 93 ppm Be, 250 ppm Sn, 620 ppm W
	qz diorite		Little, 1959, p. 158	Shaft and crosscut
	andesite		Little, 1959, p. 158	N of Lower Manitou L.
	andesite, chlorite schist, qz porphyry		Little, 1959, p. 158	Manitou Is., Lower Manitou L. incl. former Beehive mine
			Little, 1959, p. 158	
	basalt, diorite, qz porphyry		Little, 1959, p. 158	End of Andrew Bay, Lake of of the Woods
	granitic gneiss			Sample "normal gneiss" cont. 26 ppm W, 80 ppm Mo; vein material 384 ppm W

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
35a	51°28' 92°21' 52 N/8	New Jason Mines, Casummit L., Red Lake M.D. (Argosy Mine)	qz veins carbonate	sh	Pr	sulphides, ab; Au
35b	51°04' 92°35' 52 N/1	Uchi Gold Mines, W of Uchi L. Red Lake M.D. – Earngey Tp.	qz veins carbonate	sh	Pr	sulphides; Au
35c	51°07' 92°40' 52 N/2	South Bay mine, Confederation L. Red Lake M.D. – Dent Tp.	strata-bound massive sulphide	wo, sh	Pr	py, sp, cp, ks; Ag
36a	51°05' 93°47' 52 N/4	Marboy (McMarmac) Mines, Red Lake M.D. – Dome Tp.	qz carbonate replacement	sh	L	asp; Au
36b	51°01' 93°49' 52 N/4	Howey Gold Mines, Red Lake M.D. – Heyson Tp.	qz vein	sh	Pr	py + Zn, Pb, Cu, Te, Au, Ag
36b	51°01' 93°50' 52 N/4	Hasaga Gold Mines, Red Lake M.D. – Heyson Tp.	qz vein	sh	Pr	py + Zn, Pb, Cu, Te, Au, Ag
36c	57°05' 93°50' 52 N/4	Gold Eagle and McKenzie, Red Lake M.D. – Dome Tp.	qz vein	sh	L	Au
36d	50°58' 93°55' 52 K/13	Madsen Red Lake Gold Mines, Red Lake M.D. – Baird & Heyson tps.	qz vein	sh	Pr	sulphides, Au, Ag
36e	51°02' 93°56' 52 N/4	Scheelaur (Campbell Dome) mine, Red Lake M.D. – Baird Tp.	qz vein	sh	Pr	Au
36f	51°05' 94°14' 52 M/1	Cole, Pipestone Bay, Red Lake M.D. – Ball Tp.	qz vein	sh	L	Au
37	50°41',43' 95°08.5' 52 L/11	North of Odd Lake near Manitoba, Kenora M.D.				
SUPERIOR PROVINCE – Manitoba						
38	51° 95.5° 52 M/3-4 52 L/13-14	Wallace Lake (Rice Lake-Beresford Lake area)	qz vein carbonate	sh	"among minerals found in area"	sulphides, tl; Mo, Au
39	49° 95° 52 E/11	Falcon Lake-West Hawk Lake Range 16E, 17E, Tp. 6	qz vein skarn	sh		
39a	49°42-44' 95°17-19' 52 E/11	M.J.T., P.M.W., Lake, Felrite groups, 0.8 to 2.4 km NW Barren Lake	qz vein skarn	sh	to 0.33% WO_3 in short lenses	py, po, cp, gt, ep, am
39b	49°47' 95°12-14' 52 E/14	Black, Letain, etc., claims, Star Lake, West Hawk Lake	qz vein	sh	to 0.56% WO_3 in lenticular pods	py, po, cp, gt, ep, am
CHURCHILL PROVINCE – Manitoba and Saskatchewan						
40a	54°48' 99°43' 63 J/13	Apex mine, Herb Lake (village), Wekuśko Lake, Tp. 67, R 15W, Manitoba	qz vein	sh	Pr	py + Au

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
	greenstone, greywacke, slate, iron form., diorite		Little, 1959, p. 161	Granite SW of Casummit L. cont. Mo, py, etc.
shear zones	greenstone, metagabbro, rhyolite, cherty tuff		Little, 1959, p. 161	
complex folds, faults	rhyolite, volcanics	hypabyssal qz-fel. porphyry, granite	Harris, 1972; Mulligan, 1975	To 92 ppm W in qz-fel. porphyry composite samples taken by Mulligan
carbonate zones	greenstone, slate, iron form., qz porphyry dykes		Little, 1959, p. 161	sh in table conc. in mill
	qz porphyry dyke in volcanic breccia	diorite, qz porphyry, granite	Little, 1959, p. 160	
	qz porphyry dyke in volcanic breccia	diorite, qz porphyry, granite	Little, 1959, p. 159	
	diorite, granodiorite sediments		Little, 1959, p. 160	Some sh shipped from McKenzie Red L., 1945
lenses in sheared tuff	volcanics	granite, granodiorite, diorite, gabbro, qz-fel. porphyry	Little, 1959, p. 159	
			Northern Miner, Nov. 8, 1951, p. 7; Little, 1959, p. 159	Scheelaur Mines Ltd., Inc. 1951
			Northern Miner, Nov. 8, 1951, p. 7; Little, 1959, p. 161	sh in surface and underground workings
			ODM Map 2175	2 occurrences W, Au on map
	volcanics, chert, iron form.		Little, 1959, p. 155	Belt cont. former Au producers, incl. San Antonio, Central Manitoba
				Cobbed ore shipped 1918
shear zones and minor folds	basic metavolcanics	granodiorite porphyry and Falcon L. stock	Little, 1959, p. 155	
shear zones and minor folds		granodiorite porphyry and Falcon L. stock	Little, 1959, p. 157	
	schistose granite	qz-fel. porphyry ("Quartz eye granite")		Li-Be pegmatites 6.4 km NE

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
40a	54°47.5' 99°45.5' 63 J/13	Rex mine (Laguna mine) Herb Lake (village), Wekusko Lake, Tp. 67, R 15W, Manitoba	qz vein	sh	Pr	py + Au
40b	55° 99°50 ± 5' 63 J/13	Herblet, Tiger, Heeker, Tungold, west shore north arm Herblet L., Tp. 69, R 16W, Manitoba	qz vein	sh	Pr	Au
40c	54°48' 100°05' 63 K/16	WOW No. 1 claim, Edwards Lake, Snow Lake area, Tp. 67, R 17W, Manitoba	qz vein	sh	Pr	
40d	54°53' 100°07' 63 K/16	Northern Tungsten, Squall Cr. 0.8 km N of west end Snow Lake, Tp. 68, R 18W, Manitoba	qz vein	sh	4536 t 1% WO_3 est.	rare asp, py, po
40e	54°44' 101°11.5' 63 K/11	Gurney Gold Mines, 19 km NE Cranberry Portage, Manitoba	qz vein	sh	Pr	py, po, Au
40f	54°35' 101°22' 63 K/11	Gold Hill, Cranberry Portage, Manitoba	qz vein	sh	L	Au, Ag
40g	54°44' 101°49' 63 K/12	Mosher, etc., Flin Flon area, E shore Schist Lake, Manitoba	qz vein	sh	L, fairly abundant in narrow stringers locally	
40h	54°41-43' 101°51-56' 63 K/12	Phantom Lake, Douglas Lake, Mosher L. etc., Thompson's, Man-Sask. properties	qz vein	sh	L, 2-3% WO_3 in limited areas, Mosher Landmark Ward	
40i	54°40.5' 102°03.5' 63 L/9	Moody Bay, Mosher Lake, Amisk Lake areas, Saskatchewan	qz vein	sh	L	
41	59°34' 108°24' 74 N/9	Radiore Uranium Mines, Uranium City, Saskatchewan		sh	L (probably local)	pitchblende, gn, py

CORDILLERAN REGION – British Columbia

East Kootenay District, Upper Columbia Valley

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
42a	49°44' 115°29' 82 G/11-12	Cedar Creek, Wild Horse River, NE of Fort Steele, Kootenay District	dissem.	sh		
42b	49°27' 115°53' 82 G/5 49°22' 116°10' 82 F/8	Moyie River, Lumberton; Caribou Creek, N Moyie River	qz vein? qz-carbonate	sh sh	1.17% WO_3 across 4.3 m	Pb, Zn, Ag
42c	49°32' 116°08' 82 F/9	Leader Group (Wellington) Angus Creek, S. St. Mary L., E. Kootenay District	qz vein	sh, st		py, hem + Pb, Cu, Zn
42d	49°37' 116°17' 82 F/9	Dominion Group, 4.8 km W of St. Mary Lake, East Kootenay	qz vein	sh		gt; Pb, Cu, Ag
42e	49°42.5' 116°00' 82 F/9 82 F/12	Sullivan mine, Kimberley, East Kootenay	strata-bound massive sulphide	sh	Tr	po, py, Zn, Pb + Ag, Cu, Sn, tl in footwall sediment, etc.
42f	49°57.5' 116°15' 82 F/16	Val (Sko + Chuck?) groups, Skookumchuck Creek, East East Kootenay	qz veins	wo, sh		tl, ks

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
	greywacke, arkose, conglom.	qz-fel. porphyry ("Quartz Eye granite")		Li-Be pegmatites 13 km NE
	feldspathized basic lava, "Quartz eye granite"	pegmatite	Little, 1959, p. 154	
			Little, 1959, p. 154	
conformable? veins (parallel foliation)	hornblende gneiss in qz-biotite-plagioclase-gt gneiss		Little, 1959, p. 152	954 kg cobbed ore avg. 32.68% WO_3 shipped
	volcanics, sediments	granite stocks	Little, 1959, p. 152	Operated until 1939
	greenstone, granite		Little, 1959, p. 151	Operated until 1942
	greenstone	qz porphyry	Little, 1959, p. 150	
	greenstone, etc.		Little, 1959, p. 149	
	greenstone		Little, 1959, p. 149	
fault zone	gneiss altered to fine-grained chloritic		Little, 1959, p. 147	Native Sn rare component of pitchblende ore at nearby Nesbitt-Labine mine
dissem.	in tremolitic dolomite, Kitchener F.		GEM BC 1970, p. 473	
stockwork veinlets	argillite, quartzite (Creston F.)		GEM BC 1969, p. 347; Little, 1959, p. 119	Old shaft sampled
fault	Purcell sediments	pegmatite granite with tl; by (Precamb.)	Rice, 1941; Leech, 1957; Little, 1959, p. 120	Shaft, adit
fault	diorite, quartzite (Purcell)		Leech, 1957	Several adits
conformable	Purcell clastic sediments, conglom. in footwall		Pentland, 1943; Swanson and Gunning, 1944; Freeze, 1966	2% WO_3 in Sn conc.; to 0.05% W in tourmalinized footwall rocks (spectro. anal.)
	quartzite, argillite conglom. diorite sills	granite (White Creek Bath.), Be pegmatite	BCAR 1966, p. 240; P. Taylor (pers. comm.); Reesor, 1958	sh also in gt-ep skarn on Burnt Cr., 6.4 km E and 1.6 km N

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
42f	49°57' 116°18' 82 F/16	Molly Group, Skookumchuck Creek East Kootenay	skarn	sh		Mo
42f	49°59' 116°13' 82 F/16	Nine Lake Group, Skookumchuck Creek (Greenland Cr.), East Kootenay	qz vein	sh?		Pb, Zn, Cu sulphide
43a	50°37' 116°28' 82 K/9	Annette, Slide, Forster Creek, Lardeau area, East Kootenay				Mo, W
43b	50°40' 116°36' 82 K/10	Bee, Taurus Mt., Lardeau area, East Kootenay	skarn	sh		
44	49°25' 116°43.5' 82 F/7	Valparaiso (Akokli Tungsten), E of Kootenay Lake	qz vein	wo	501.67 t milled 1955, 5080 kg conc. (incl. pyrite?)	py, asp; Pb, Zn, Cu, Au, Ag
West Kootenay District, Lardeau, Big Bend Columbia River						
45a	49°09' 116°57.5' 82 F/2	Bayonne mine, W of Creston, West Kootenay District	qz vein	sh	Pr	py; Pb, Zn, Cu, Au, Ag (tet, hessite, petzite, incl.)
46a	49°05' 117°12' 82 F/3	Molly, Lost Creek, Salmo area, ea, West Kootenay	skarn	sh	0.5 to 1.5 or 2% WO_3 in lenses up to 1.2 m wide	Mo (minor)
46a	49°07' 117°11' 82 F/3	Jumbo Group, Salmo area, West Kootenay District	skarn	sh	to 0.5% across 1.5 m	Mo (minor)
46a	49°05' 117°14' 82 F/3	Tungsten King, Salmo area, West Kootenay District	skarn	sh	to 2% WO_3 in bands to 15 cm	Mo (MoS_2, molybdian sh) minor po, etc.
46b	49°06'30" 117°13'35" 82 F/3	Emerald mine (Canex) Iron Mt., Salmo area, West Kootenay District	skarn	sh, minor wo	major producer 1943, 1947-49, 1951-53	po, py, tl, ap, vesuvianite; MoS_2
46b	49°06'40" 117°13'30" 82 F/3	Feeney mine (Canex), Salmo area, West Kootenay District	skarn	sh	major producer 1952-53?	po, etc.
46b	49°06'50" 117°13'25" 82 F/3	Invincible mine (Canex), Salmo area, West Kootenay District	skarn	sh	major producer 1971-73	po abund.
46b	49°06'30" 117°13' 82 F/3	Dodger mines (Canex), Salmo area, West Kootenay District	skarn	sh	major producer (East Dodger, 1971-73)	po, etc., minor, MoS_2 abund.
46c	49°08' 117°10' 82 F/3	Victory (Little Keen, Sapples) Bennett Cr. (trib. Sheep Cr.),	skarn	sh	to 2% WO_3 in streaks to 20 cm by 3-3.7 m	MoS_2 abund., pt
46d	49°08.5' 117°08' 82 F/3	Kootenay Belle and Queen mines, Sheep Creek, West Kootenay	qz veins	sh, wo, ts	bunches, kidneys to 13.6 kg; local, minor	minor sulphides; Pb, Zn, Cu, Au, Ag
46d	49°11' 117°08' 82 F/3	Reno mine, N of Sheep Creek, West Kootenay	qz vein	sh, wo, ts	some recovered from mill tables	Pb, Zn, Cu, Au, Ag
46e	49°14' 117°09' 82 F/3	Balsam mine (Jack Pot Mine), S of Porcupine Creek, West Kootenay	skarn	sh	1.5% WO_3, 1 small area	minor po, cp, py

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
		granite	BCAR 1969, p. 344	
	diorite, micaceous quartzite siltstone		GEM BC 1973, p. 82	
			GEM BC 1970, p. 469	
	limestone	granite stocks	GEM BC 1973, p. 93	Diamond drilling, 10 holes on Bee 10
vein system over 305 m, to 7.6 m wide	granite		Rice, 1941; BCAR 1953, 1954, 1955; Little, 1959, p. 119	sh also at Gold Basin 49°25.5', 116°39.5'(?) (Au, Ag prod. 1933)
	granodiorite	granite (Bayonne Bath.) (Cret.)	Stevenson, 1943; Rice, 1941, p. 62; Little, 1959, p. 119	Rice believed host granodiorite older, ore zone mostly oxidized
lenses near contact	limestone (L. Camb., Laib Group)	granite stock	Little, 1959, p. 102	sh deposit 305 m E and 122 m above Mo mine (181 t Mo ore shipped)
lenses near contact	limestone (L. Camb., Laib Group)	granite stock	Little, 1959, p. 103	
	limestone (L. Camb., Laib Group)		Little, 1959, p. 104	
fold trough, faults part conformable	limestone (L. Camb., Laib Group)	granite stocks (Emerald)	Little, 1959, p. 105; Stevenson, 1943; Ball et al., 1953; Ball, 1954; Fyles and Hewlett, 1959	2 399 034 kg WO_3 produced to 1955 incl. Feeney and part Dodger?
fold trough, faults part conformable	limestone (L. Camb., Laib Group)	granite stock (Emerald)	Little, 1959, p. 110; Stevenson, 1943; Fyles and Hewlett, 1959	
fold trough, faults part conformable	limestone (L. Camb., Laib Group)	granite stock (Emerald, Dodger)	Pastoor, 1970; GEM BC, 1973, p. 54-57; Thompson, 1973	256 533 t ore avg. 0.65% WO_3, 1971-73
fold trough, faults part conformable	limestone (L. Camb., Laib Group)	granite stock (Dodger)	Pastoor, 1970; GEM BC, 1973, p. 54-57; Thompson, 1973; Little, 1959, p. 112	204 202 t avg. 0.54% WO_3, 1970-73
	limestone (L. Camb., Laib Group)	granite stock	Little, 1959, p. 112	Reserves 181 437 t avg. 0.4% WO_3 rept.
fault system	quartzite, argillic alteration zone	granite stock (Queen mine) qz porphyry dykes	Mathews, 1953; Little, 1959, p. 114	
fault system	quartzite, argillite	qz porphyry dykes	Stevenson, 1943; Little, 1959, p. 115	
	limestone (L. Camb., Laib Group)	granite	Stevenson, 1943; Little, 1959, p. 115	

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
46f	49°04' 117°23' 82 F/3	Bunker Hill, Limpid Cr. N of Pend-d'Oreille River, West Kootenay	skarn	sh	0.33% WO_3 across 10.7 m, 1 trench	minor py
47a	49°17' 117°16' 82 F/6	Arrow Tungsten (Stewart), Nelson-Bonnington, West Kootenay	skarn	sh	to 1% WO_3 across 1-1.5 m, several trenches	
47a	49°19' 117°19.5' 82 F/6	Porto Rico Mine, Nelson-Bonnington, West Kootenay	qz vein?	ts	found on concentrating tables	sulphides; Au
47b	49°22' 117°17' 82 F/6	Mammoth Group, N of Barrett Cr., Nelson-Bonnington, West Kootenay	qz vein	sh	sparse dissem.	py, asp, Cu, Zn?, Mo
47c	49°22' 117°14' 82 F/6E	Euphrates, N of Ymir, West Kootenay	qz vein	sh	L?	sulphide; Pb, Zn, Ag, Au
47d	49°28' 117°23' 82 F/6W	Granite Poorman and Venango mines, Nelson-Bonnington, West Kootenay	qz vein	sh	L	minor py; Cu, Pb, Au
47d	49°28' 117°24' 82 F/6W	Royal Canadian and Nevada mines, Nelson-Bonnington, West Kootenay	qz vein	sh	Pr	minor py; Cu, Au
48a	49°04' 117°47' 82 F/4	Commander, SE Rossland, West Kootenay		sh	Pr	
48b	49°05.5' 117°49' 82 F/4	St. Elmo, Red Mt., Rossland, West Kootenay	qz vein	sh	scattered thin sheets, patches	po, py; Cu, Pb, Zn, Mo, Au
48b	49°07' 117°50' 82 F/4	Blue Moon (Blue Eyes), Topping Creek, N Rossland, West Kootenay	qz vein, dissem.	sh	fairly abund. in small veinlets and wall rock, locally 0.33% WO_3 across 0.3 m sample	py; Mo
48c	49°01' 117°55' 82 F/4	Velvet mine, 19 km SW Rossland, West Kootenay	qz-calcite vein, replacement	sh	Pr	py; Cu, Mo, Ag, Au
48c	49°00.5' 117°58'? 82 F/4	Santa Rosa, W of Big Sheep Creek, W of Rossland, West Kootenay	qz vein?	sh?	Pr	
48d	49°16.7' 117°55' 82 F/5W	PS, Moonglow, Highway 3, W Kinnaird, West Kootenay	skarn	sh		
48e	49°26' 117°58' 82 F/5W	Groundhog Group, E Deer Park, Lower Arrow Lake, West Kootenay	skarn	sh	L? zone to 18 m wide	po, cp
49a	49°41' 117°15.5' 82 F/11	Alpine Mine, Sitkum Creek, NE of Nelson, West Kootenay	qz vein	sh	Pr	py; Pb, Zn, Au
49b	49°46' 117°21' 82 F/14	Meteor Group, S of Springer Cr., Slocan, West Kootenay	qz vein	sh	masses to 227 kg in lenses to 3.7 m long	py; Cu, Zn, Ag, Au
49c	49°47.5' 117°03' 82 F/14	Scranton, Woodbury Creek, N of Ainsworth Hot Springs, West Kootenay	qz vein	sh	Pr	py, gn, sp; Ag minerals
50	50°02' 116°57'? 82 K/2W	Ivy, Schroeder Cr., N of Kaslo, Lardeau area	qz vein?	sh	4.2% WO_3 in 2 veins 30 cm and 60 cm wide	Pb, Zn, Ag

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
	argillaceous quartzite, schist, skarn (L. Camb.)	granite	Little, 1959, p. 100	
	quartzite, skarn (Jur.)	pegmatite, granite	Little, 1959, p. 115	Examined by Little before underground expl., 1951
	volcanic, sill or dyke (Jur.)	lamprophyre dyke	Little, 1959, p. 117	Also rept. at nearby Spotted Horse Claim
	volcanic, metasediments, altered granite dykes (Jur.)	granite, diorite	Little, 1959, p. 117	
	volcanics (Jur.)		Little, 1959, p. 118	Attempt to recover as byproduct 1941
	metadiorite	syenite?	Little, 1959, p. 118	
	metadiorite	syenite?	Little, 1959, p. 118	
			Little, 1959, p. 98; (BCAR Index, 1955)	W also at Renata prop., Trail Cr. M.B.
lenticular veins in shear zone	volcanics, argillaceous quartzite		Little, 1959, p. 99	Close to Red Mountain Mines, major Mo producer
shears, joints	granodiorite	?granite (Coryell) (Tert.)	Little, 1959, p. 99	Underground expl. 1942-43
	serpentine	Coryell syenite (Tert.)	Little, 1959, p. 98	Production Au, Ag, Cu to 1946, 0.1% W in dump composite
			Little, 1959, p. 98	Prospected 1943
		diorite dykes	GEMBC 1970, p. 436	
	sediments, gt, limestone		Stevenson, 1943, p. 152; Little, 1959, p. 97	
	granite		Little, 1959, p. 119	
	sheared granite		Little, 1959, p. 96	First discovery and production of W in B.C.
sheared zone	granite		Little, 1959, p. 96	
			Western Miner, Feb. 1952, p. 47; BCAR 1901, p. 1027	

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
51	50°38.5' 117°36.5' 82 K/12E	Lucky Boy, Copper Chief, 5 km W Trout Lake, Lardeau	qz vein	sh	significant conc. in 3 underground workings	py; Pb, Zn, Cu, Ag
52	50°34' 117°00' 82 K/11E	Erdahl-Pinchbeck Group, Cockle Creek (Duncan River), Lardeau	qz vein	sh	scattered grains; 1.9% WO_3 in 1 sample	py, po, gn, tl; minor Sn, Be
53	50°45' 117°10' 82 K/14E	Farside, Duncan River near Stevens Creek, Lardeau	qz vein	sh		py, po, ap; Zn, Bi, Mo
54a	50°54' 117°33.5' 82 K/13E	United Victory, at 915 m between Boyd and Kellie creeks, Lardeau	skarn	sh		
54b	50°58-59' 117°36-38' 82 K/13	McDougal Creek, Incomappleux River, Lardeau	stream sediment	sh	Pr	ks
55	51°12' 117°54' 82 N/4	Regal Silver (Columbia, Stannex) Clabon Creek near Albert Canyon	qz vein	sh, wo	significant in zone lower levels	py; Pb, Zn, Ag, Cu, Sn
56	51°42' 118°27' 82 M/9	Ole Bull and Orphan Boy, McCulloch Creek, Goldstream River, North Revelstoke	qz vein	sh	L	Au
57	51°23' 118°25' 82 M/8W	Robina, 4.8 km N Mars Creek, 43 km N Revelstoke		?		"Mo, Ag, Cu, Ni, W"
Central Southern British Columbia						
58	49°12'40" 118°25'40" 82 E/1	Wyoming, Granby River near Miller Creek, 22.5 km N Grand Forks		sh?		
59a	49°32' 119°03' 82 E/11	Knob Hill, 11 km NE Beaverdell	skarn	sh	sparse, dissem.	
59b	49°33' 119°06' 82 E/11	Kettle River, 8 km NE Carmi	skarn	sh	sparse, dissem.	
59b	49°34' 119°07' 82 E/11	Elite, 8.4 km NNE Carmi	skarn	sh	dissem.	
60a	49°09' 119°56' 82 E/4W	PA 1-18, 10.4 km SW Keremeos	skarn	sh		
60b	49°13' 119°40' 82 E/4E	Salmo Prince, E Keremeos				
60c	49°24' 119°56' 82 E/4W	Billy Goat (Penticton Tungsten), Mt. Riordan, 22.5 km NNW Keremeos	skarn	sh		po, py, cp
60d	49°21' 119°45' 82 E/4	Ben Williams prospect, Yellow Lake Rd., 16 km NNE Keremeos	skarn	sh		
61	50°07'? 119°32'? 82 L/12	White Elephant, 3.2 km W Okanagan L.; 27 km S of head	qz vein?	sh		po, py, cp, tetradymite; Au

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
	"siliceous limestone"		Little, 1959, p. 93	22.7 t sh ore sorted from dump by Sept. 1942, assayed 1.41% WO_3, 0.63% P
	schist, quartzite, limestone (Windermere)		Little, 1959, p. 96; BCAR 1943, p. 107; Reesor, 1957	
	schist, quartzite		GEMBC 1970, p. 463	
	limy schist, limestone	granite sill underlies, near large granite bath.	Little, 1959, p. 93	
			Stevenson, 1943, p. 131	Reported by B.C. Mines Engineer, 1942
parallel veins to 305 m by 2.4 m	carbonaceous slate (Lardeau Group)	none, nearest exposed, granite 4.8 km	Stevenson, 1943; Mulligan, 1975; BCAR, 1950-53, 1967-70; Wheeler, 1963, 1964; Little, 1959, p. 92	Recovered 1953-54
	quartzite, mica schist (Windermere)		Little, 1959, p. 91	
			GEMBC 1970, p. 464	
			Little, 1959, p. 98	Prospecting and trenching, 1943
	diopside-gt-calc-silicate	granite dykes	Little, 1959, p. 91	
	garnetiferous crystalline limestone		Little, 1959, p. 91	
	gt-diopside-calc-silicate		Little, 1959, p. 90	
	limestone, volcanics, chert		GEMBC 1973, p. 45	
			Western Can. Mining News, 15 Sept., 1952, 15 Oct., 1952	
	limestone (Wolfe Cr. F., Hedley F.)	granite, gabbro	Little, 1959, p. 89	
	garnetite in limestone		Little, 1959, p. 89	
	granite		Little, 1959, p. 89	

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
62a	49°24' 120°05' 92 H/8	Jupiter, 4.8 km N Hedley	skarn	sh	scarce	po, py, asp; Cu, Mo, Mo-sh, Pb
62a	49°22' 120°01' 92 H/8	Nighthawk, 1.6 km SE Nickel Plate mine, Hedley	skarn	sh	assay nil	
62a	49°22' 120°01' 92 H/8	Good Hope, SE slope Nickel Plate Mt., Hedley	skarn	sh?	assay nil	sulphides; Au, Te
62b	49°23' 120°08' 92 H/8	Stirling Cr., 6.4 km W of Hedley	vein		L	
63	49°20' 120°53' 92 H/7	Granite Group, Granite Mt., 29 km SW Princeton	qz vein	sh	L	minor py; Pb, Zn, Au, Ag
64	50°20' 120°23' 91 I/8	Don (Scottie) Group, E of Stump Lake, 39 km NE of Merritt	qz vein	sh	L, 0.25% WO_3 in sample near bottom of shaft	
64	50°21' 120°23' 92 I/8	Consolidated Nicola Goldfields, Mineral Hill, Stump Lake, 39 km NE Merritt	qz-calcite vein	sh	L, 0.52% WO_3 across 1 m, local	py, po, asp; Pb, Ag, Zn, Cu, Au
65	50°18' 120°41' 92 I/7	Last Chance, Swakum Mt., 21 km N Nicola	skarn	sh	scattered streaks good grade 0.15-0.22% WO_3 across 7.6 m	po, py, cp
Southwestern British Columbia						
66	49°14' 121°06' 92 H/3	Mammoth, Sumallo River near Skagit River, 30.5 km SE of Hope	skarn	sh	Pr	Ni-po + Zn, Cu, Pb, Sb, Ni, etc.
67	49°24' 121°27' 92 H/6	Fort Hope, 3.2 km N of Hope	qz vein	sh	Pr	minor Au
68	48°36'? 123°58' 92 B/12	Victory (Westbank), San Juan River, 35 km W Shawnigan Lake, Vancouver Island	qz vein, carbonate	sh	L, max. 0.30% WO_3 across 1 m	minor py, local sb + Au
69	49°55'? 123°25'? 92 G/14	Ashloo Gold Mines, Ashlu Creek, NW of Squamish	qz vein	sh	Pr	Au, Ag, Cu
70	50°04' 123°09' 92 J/3	Van, Sunny Cave, Callaghan, Tarn, 6.4 km NW Brandywine Falls	qz vein	sh		Pb, Zn, Cu, Sb sulphides, Ag, Au
71	50°30' 122°49' 92 J/7-10	Gin, 20 km N Pemberton				po + Cu, Zn
72a	50°45.3' 122°11.3' 92 J/16	Lubra, Nosebag Mt. 8 km NW Seton Portage, Anderson Lake	skarn	sh		sulphides, pt, MoS_2
72b	50°43' 122°38' 92 J/10	Chalco, Piebiter Creek near Cadwallader Creek, 13 km SE Bralorne	skarn	sh	to 1.2% WO_3 across 2.7 m locally, 4 showings	po, cp + Ag, Mo, Cu to 6%
72c	50°48'40 122°32'06" 50°50'25" 122°31'22" 92 J/15	Bristol, Tommy Creek, 19 km ENE Bralorne	qz vein	sh	to 6.5% WO_3 across 38 cm 0.6% across 76 cm	py, asp; Au

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
	limestone (Tri. Hedley Group)	diorite	Little, 1959, p. 88	
		granodiorite	Little, 1959, p. 88	
			Little, 1959, p. 89	
			Western Miner, Oct. 52, p. 114	
	granodiorite and contact		GEMBC 1969, p. 282; Little, 1959, p. 79	Adit 45 m, mill test 1969
			Cockfield, 1948, p. 58; Little, 1959, p. 87	
			Cockfield, 1948; Little, 1959, p. 86	Mined for Ag, Au, Cu, Pb, Zn, 1916-44
near contact	limestone bands, greenstone		Little, 1959, p. 80	Small shipments copper ore 1917
in 1 m vein along contact	15 m belt calc-silicate in chert, greenstone	qz diorite, diorite (Cret.)	Little, 1959, p. 79	A little sh rept. at Canaan Copper (49° 10', 121°02')
	andesite			
stockwork, small veins	limestone, marble in greenstone		BCAR 1952; p. 215; Little, 1959, p. 78	
	granodiorite		Little, 1959, p. 78	Several thousand tonnes milled for Au, Ag, Cu to 1939
	altered sediments, volcanics	diorite, granodiorite	GEMBC 1969, p. 191, 1970, p. 230	Ag, Pb, Cu, Au produced 1970 (old Astria & Cambria property)
po-pyroxenite lens in volcanics at contact	U. Triassic metavolcanics	granite/granodiorite	GEMBC 1970, p. 226	
	Perm. crystalline limestone		GEMBC 1970, p. 225	
close to contacts, granodiorite tongues	Perm. limestone, sediments greenstone, granodiorite	granodiorite (Bendor Pluton)	Little, 1959, p. 75	Several adits
shear zone, veinlets calcite + quartzite	cherty quartzite + argillite	granodiorite (Bendor Pluton)	Little, 1959, p. 75	

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
72d	50°46' 122°45' 92 J/15	Pioneer Gold Mines, Cadwallader Creek, Bridge River area	qz-carbonate vein	sh	locally abundant	py, asp; Zn, Cu, Sb, Au
72d	50°47' 122°48' 92 J/15	Bralorne Mine, Cadwallader Creek, Bridge River area	qz-carbonate vein	sh	local high-grade shoots, some mined for W, mill	py, asp; Cu, Sb, Au
73a	51°02'05" 122°45' 92 O/2	Tungsten Queen, Tyaughton Creek, Bridge River area	dolomite, qz vein	sh	nearly pure sh 2.5 to 7.5 cm, by 1 m vein	sb, cinnabar near
73b	51°02'45" 122°46'03" 92 O/2	Tungsten King, Tyaughton Creek, Bridge River area	dolomite vein?	sh	27 t 5% WO_3 ore milled Bralorne	cinnabar (major), sb
Central British Columbia District – Thompson, Cariboo, Omineca						
74x	51°36' 120°18' 92 P/9	Anticlimax Not shown on map	qz greisen	wo		Mo (major)
74	51°50' 119°42' 82 M/13	Boulder, Maxwell Cr., 4 km N Silence Lake, 30.5 km NNE Birch Island, Thompson District	skarn	sh		
75	52°44' 120°52' 93 A/10	Cariboo Scheelite; Limestone Point, North Arm Quesnel Lake, Cariboo District	qz vein	sh	scattered grains	
76a	52°53' 121°20' 93 A/14	Cariboo Hudson; head Cunningham Creek, Cariboo District	qz vein	sh	abund. in lenses 0.5 m by 4.6 m 14.1% WO_3 across 107 cm, 1 sample	py; Au, Ag, Pb, Zn veins
76a	52°54' 121°20' 93 A/14	Rand (Cariboo Thompson); Copper Creek (Upper Cunningham Creek), Cariboo District	qz carbonate vein	sh	to 18% WO_3 across 36 cm in patches, 227 kg WO_3 produced 1937	minor tet, etc., fl
76b	52°52' 121°27' 93 A/14	Gold Coin (Taylor Tungsten); 6.4 km N of Keithley Creek, Cariboo	qz vein	sh, ts, st	exposed 2.5 to 10 cm by 5.5 m, 26.2% WO_3 10 cm by 1.2 m	minor py, gn, sp in bedded lenses
76b	52°53' 121°26' 93 A/14	Paxton, 8.8 km N of Keithley Creek, Cariboo	qz vein	sh	scattered clusters locally, 1 vein	po, py; Zn, Pb, Cu in some lenses
76c	52°58' 121°24' 93 A/14	Gisco, Park, Pittman, Antler Creek, 25.7 km N of Keithley Creek, Cariboo	qz vein, & replacement	sh		py, gn, sp
76d	53°05' 121°33' 93 H/4	Cariboo Gold Quartz mine; 1.6-3.2 km SSE of Wells, Cariboo	replacement, & vein calcite	sh	Pr	py + po, Pb, Zn, Sb, Bi
76d	53°06' 121°34' 93 H/4	Island Mountain Mine (Aurum); 0.8 km W of Wells, Cariboo	qz vein carbonate & replacement	sh	Pr "sporadic"	py, asp; Pb, Zn, Bi, Au, Ag (cosalite)
76e	53°08' 121°38' 93 H/4	Hardscrabble (Columbia Tungsten); 6.4 km NW of Wells, Cariboo	qz-carbonate vein	sh, ts, wo	to 1.9% WO_3 over 61 cm, 12 564 kg WO_3 prod. 1937-41	py; Zn, Pb, Au local
77a	53°55' 122°31' 93 G/15	Burn Group, 1.6 km E of Tabor Lake, 16 km E of Prince George, Cariboo	qz? vein skarn	sh		py, po, MoS_2, pt
77b	54°05' 122°22' 93 J/1	32 km West end Eaglet L.; NE of Prince George, Cariboo			Tr	Pb, Zn, Cu, Mo

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
esp. flat veins + qz cutting main vein	sedimentary & volcanic, granite	granodiorite (Bendor Pluton)	Little, 1959, p. 74	Former major Au producer
vein fractures intersect at 45°	augite diorite, sedimentary & volcanic	granodiorite (Bendor Pluton)	Little, 1959, p. 73	sh with high-grade Au, also at BRX Consol., E of Bralorne (former major Au producer)
numerous veinlets parallel contact	serpentine (carbonatized) greenstone chert	fel-qz porphyry	Stevenson, 1943; BCAR 1952, p. 114; Little, 1959, p. 72	743 kg cobbed ore (55% WO_3) shipped 1940, some subsequent
2 m fracture zone	limestone		Stevenson, 1943; BCAR 1942, p. 79, 1952, p. 114; Little, 1959, p. 73	27 t 5% WO_3 shipped 1942, 6.35 t yield 0.9 t conc. 1952
dissem. qz veins	granite	qz-fel porphyry	GEMBC 1974, p. 276	
roof pendants	marble, qz-biotite schist, quartzite	qz monzonite, granodiorite, pegmatite & acid intrusive	GEMBC 1973, p. 118	
narrow reticulating veinlets	limestone (L. Camb.)		Little, 1959, p. 71; Western Miner, Jan. '66	Also rept. with fl near Junction Point, Quesnel L.
shear zone, Copper Cr. fault	quartzite, qz-sericite schist	basic intrusive	GEMBC 1973, p. 294; Holland, 1954, p. 57; Little, 1959, p. 70	Most sh & Au in smaller of 2 type veins; 161 303 g Au produced to 1939
shear zone, Copper Cr. fault	L. Camb. limestone, graphite (Snowshoe F.)		Holland, 1954; Sutherland Brown, 1957; Little, 1959, p. 68	Most sh in footwall limestone adjacent vein wall
sh vein cuts bedded lenses	quartzite, sericite schist		Stevenson, 1943; Little, 1959, p. 71	
	fissile quartzite, minor graphitic argillites		Little, 1959, p. 70	
small sh replacements in limestone, also veins (?)	phyllite, limestone, (Snowshoe F., Camb.?)		GEMBC 1973, p. 295; Sutherland Brown, 1957; BCAR 1946, p. 94	
replacements in limestone mainly conformable	quartzite, limestone Snowshoe F., Midas F. (Camb.)		Sutherland Brown, 1957; Little, 1959, p. 67	38 261.4 t avg. 17 g Au mined to 1953
dragfolds, faults; most veins in quartzite, replacement in limestone	quartzite, limestone, phyllite (Camb.)		Sutherland Brown, 1957; Little, 1959, p. 67	10 382 kg Au and 1490 kg Ag produced to 1954
transverse and bedded veins, fault zone	limestone (lenses) micaceous quartzite, phyllite, argillite		Little, 1959, p. 62; Stevenson, 1943, p. 82; Johnston and Uglow, 1926	Au not in sh-bearing veins
	limestone (Tri., Jur.)	granodiorite (Jur.?)	Tipper, 1961	
	serpentinized volcanics		Armstrong et al., 1969	

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
77c	54°16' 122°22' 93 J/8	Ada Group; north point Fraser River 45 km NE of Prince George, Cariboo	qz vein	sh	to 4% WO_3 across 0.6 m	py + Pb, Ag, graphite
77c	54°16' 122°20' 93 J/8	Silver Group; 1.6 km up Averil Creek from Fraser R., 45 km NE of Prince George, Cariboo	qz vein	sh	Pr in outcrop only	py + Pb, Zn, graphite
78	55°04' 124°49' 93 N/2	Chuchi; head Jean Marie Creek, Chuchi Lake, Fort St. James-Manson Cr., Omineca	qz vein?	sh	.075% WO_3 in grab sample	cp, pt, MoS_2
79a	55°36' 124°22' 93 N/9	Northern Tungsten; Boulder Creek, Manson Creek area, Omineca	qz vein, dissem. black sands	sh		Cu, minor Mo, qz veins, Pb-Zn-Ag veins near; Au
79b	55°40' 124°28' 93 N/9	Billy and Glo claims, Lost Creek, 2.4 km SE Manson Creek Post Office, Omineca	qz vein	sh		Pb, Zn, Ag
79c	55°37' 124°34' 93 N/10	Mill Creek; SW of Manson Creek Post Office, Omineca	qz vein	sh		near Mo occurrences
80	54°35' 126°14' 93 L/9	Silver Cup, Friday Creek, 11 km NNE (?) of Topley	qz vein	sh		
Central West British Columbia – Coast Range, Terrace, Smithers, Hazelton, Alice Arm, Portland Canal						
81	53°22' 127°16' 93 E/6	Deer Horn mine, W end Whitesail L.	qz vein	sh	0.84% WO_3 across 18 m 1.55% WO_3 across, 21 m large sh-bearing talus	Au in separate deposits
82	53°35' 127°39' 93 E/12	Sandifer L., 33.5 km NW of W end Whitesail L.	skarn	sh?		cp; Bi
83	53°10' 128°42' 103 H	"Butedale area", Princess Royal Island				
84	54°30.5' 127°41.5' 93 L/12	Whitewater; near head Telkwa River, 45 km SW Smithers	qz vein	sh	to 20% WO_3 in adit, shoot 1.2 m x 1.2 m exposure, elsewhere low	Zn, Pb, Ag, Au
85	54°49' 127°18' 93 L/14W	Glacier Gulch (Climax), Hudson Bay Mt., Smithers	qz vein	sh, pt, minor wo	"recoverable as by-product"	py, asp; Mo, Cu, Bi, K-fel., mu
86a	55°10' 127°33' 93 M/4	Black Prince, Mudflat Creek, 9.2 km SSE New Hazelton	qz vein dissem.	sh, wo	to 1-2% WO_3 across 15 cm	py, cp; Mo, Sn, U, vein, tl
86a	55°10' 127°34' 93 M/4	Blue Lake, 9.2 km SSE New Hazelton	qz vein dissem.	sh	0.25-2% sh across 15-35 cm	cp, Mo, tet
86b	55°08' 127°36' 93 M/4	Red Rose mine, E of Juniper Creek, 11.6 km S of New Hazelton	qz vein "pegmatitic"	sh, minor wo	1 002 847 kg WO_3 produced 1941-42 and 1951-54	py, mag, cp, tl, ap; local orthoclase
86b	55°09' 127°39' 93 M/4	Rocher Déboulé mine, Juniper Creek, 10.4 km SSW New Hazelton	qz vein part pegmatitic	sh	to 3% sh in shoots to 15 m by 0.6 m	Cu, Au, Ag + Pb, Zn, Co, U, Mo; fel, ap, tl, etc.

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
2 veins conformable	siliceous? qz muscovite schist (Wolverine)	granitic gneiss	Stevenson, 1943, p. 74; Little, 1959, p. 61	Graphite only in sh-bearing veins, workings incl. adit, 210 m
conformable shear zone, near major fault	qz sericite, biotite schist		Little, 1959, p. 61	Adit, 62 m
fracture zone 12 ft. wide at contact	andesite	granite stock	Rice, 1949; Little, 1959, p. 60	
dissem. conformable? in quartzite	argillite, quartzite, limestone	granite (Germansen Bath.)	GEMBC 1972, p. 450, 1973, p. 367; Armstrong, 1946	
zone of narrow veins	argillite	felsite dykes (Germansen Bath.)	GEMBC 1970, p. 182	
		granite (Germansen Bath.)	E. Floyd, Manson Cr., pers. comm.	
			Little, 1959, p. 60	Reported "in underground workings"
stockwork stringer embayment in granite	sediments & volcanics (+ skarn) Hazelton Group	granite, qz diorite, diorite (Coast Intrus.)	Little, 1959, p. 57	
			GEMBC 1969, p. 76	
			Little, 1959, p. 42	"Reported from area"
2 lenses 20 to 35 cm thick branch main vein	granite		Stevenson, 1943, p. 72; Little, 1959, p. 58	
dome, faults	granodiorite volcanics + sediments (Hazelton)	porphyry qz monzonite (Tert.) stock & dykes, rhyolite	BCAR 1966, p. 86; Bright and Jonson, 1976	Adit 1830 m 1965; intra-mineral dykes
shear zone	granodiorite (Rocher Déboulé stock)		Kindle, 1954; Little, 1959, p. 54	Several adits on different veins
	granodiorite (Rocher Déboulé stock)		Little, 1959, p. 56	Several veins
shear zone	diorite, sediments	granodiorite (Rocher Déboulé stock) fel, porphyry dykes	Kindle, 1954; Stevenson, 1947; BCAR 1954, p. A86; Sutherland Brown, 1960; Little, 1959, p. 51	sh abundant only in diorite, some Au, Ag, Cu produced
subparallel veins from contact sediments	granodiorite (Rocher Déboulé stock)	qz monzonite, diorite, etc., dykes	Little, 1959, p. 46; Kindle, 1954; Stevenson, 1943; Sutherland Brown, 1960	Cu, Au, Ag + Zn, Pb produced 1915-1952, no record W production; sh also at Highland Boy, 2 km

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
86b	55°09' 127°38' 93 M/4	Highland Boy property, 2 km E Rocher Déboulé		sh	P	
87	55°18' 126°59.8' 93 M/7	Higgins, NW of Netalzul Mt., 45 km E of Hazelton	qz vein	sh	Pr	sulphides, Zn, Pb, Cu, Sb
88a	54°29' 128°26' 103 I/8	Ptarmigan, Mt. Thornhill, 9.6 km SE of Terrace (Annie Laurie)	pegmatitic qz vein	sh	irregular streaks & small nodules	py + Cu, Pb, Au, fel, ba
88b	54°33' 128°25' 103 I/9	Black Bull; SW Kleanza Mt., ca. 11 km ENE Terrace	qz vein	sh	R	Traces; Au, Ag
88b	54°32.5' 128°26' 103 I/9	White Bluffs depos., W. Kleanza Mt., 10.4 km ENE Terrace	pegmatitic qz vein	sh	Pr	py + Au orthoclase (25%)
88c	54°37.5' 128°27' 103 I/9	Lucky Luke; 2.4 km SW of Usk, 16 km NE of Terrace	qz vein	sh	Pr	py; Cu, Au, Ag
88c	54°38.5' 128°26' 103 I/9	Cordillera; 1.6 km SW Usk, 16 km NE of Terrace	qz vein	sh	Pr	Cu, Au, Ag
88d	54°38' 128°23' 103 I/9	Emma and IXL, base Bornite Mt., 2.5 km SE of Usk, 16 km NE Terrace	qz vein	sh	R (local)	Cu, Au, Ag
88e	54°39'? 128°08' 103 I/9	Zona May; head of Legate Creek, 33.5 km NE Terrace	qz vein	sh	R (local)	Pb, Zn, Cu, Sb
88f	54°43' 128°21' 103 I/9	Grotto; Hardscrabble Creek, 1.6 km NW Pitman, 27 km NE Terrace	qz vein	sh	Pr	py, su, cp
88g	54°46' 128°23' 103 I/16	Gold Dome, Carpenter Creek, 30 km NNE Terrace	qz vein	sh	"some high grade in streaks and patches"	Au, Ag, Cu, Pb, Zn in nearby veins
88h	54°49' 128°40' 103 I/15	Bear and Cub; Maroon Mt., 8 km E Kitsumkalum L., Terrace area	qz vein	sh	R	py, po; Pb, Zn, Cu, Au, Ag
89a	55°29.5' 129°29.5' 103 P/6	Esperanza mine, 1.6 km N of Alice Arm, Observatory Inlet	qz vein	sh	to 0.3% WO_3 across 35 cm in total area 46.5 m^2	asp, py, po; Cu, Pb, Zn, Sb, Ag, Au
89b	55°34' 129°26' 103 P/11	"Red Bluff Mt.", Washout Creek slope, 9.6 km NNE Alice Arm?		sh	R	
89c	55°25.5' 129°25' 103 P/6	Cariboo, Lynx, etc. (B.C. Moly), Lime Creek, 8 km SE Alice Arm	qz vein	sh	Pr	py, po; Pb, Zn, Cu, Bi, F, gypsum
90a	55°54.5' 129°57.5' 103 P/13	Rainier (Silverado), Portland Creek, 5 km SE Stewart, Portland Canal	qz vein	sh	to 0.22% WO_3 across 14 cm	py; Cu, Pb, Zn, Sb, Ag
90a	55°57' 129°58' 103 P/13	Molly B; 0.8 km E Stewart, Portland Canal	skarn	sh	0.15-1.5% WO_3 across 1-1.5 m	Mo, 0.2% py, po, Sn trace
90b	55°59'55" 129°57'40" 103 P/13	Louise and Dot; W side Bear River Valley, 7 km N Stewart, Portland Canal	skarn	sh	0.27% WO_3 max.	

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
	granodiorite		Little, 1959, p. 48	
	granodiorite		Little, 1959, p. 43	
vein & conformable with andesite?	andesite (Hazelton Group)	granodiorite	Little, 1959, p. 43	
	granodiorite		Little, 1959, p. 43	
	volcanics (Hazelton Group)		Little, 1959, p. 43	
	volcanics (Hazelton Group)		Little, 1959, p. 43	
	volcanics (Hazelton Group)		Little, 1959, p. 43	
vein follows contact	volcanic breccia (Hazelton Group)	granodiorite, qz porphyry dyke	Little, 1959, p. 45	In granodiorite W of Legate Cr.
	volcanics (Hazelton Group)		Little, 1959, p. 45	sh also rept. at Ridge, S of Hardscrabble Cr.
	granodiorite		Duffell and Souther, 1964, p. 90	
veins partly conformable	conglomerate, greywacke, argillite (Bowser Group)		Duffell and Souther, 1964; Stevenson, 1943; Little, 1959, p. 42	
vein fracture anticlinal form, partly conformable	argillite, quartzite	nearest granite 5 km W	Stevenson, 1943; Hanson, 1935; Little, 1959, p. 42	2143 kg Ag, 3.3 kg Au, 613 kg Cu, and 482 kg Pb produced 1911-27
			Little, 1959, p. 42	
in veins to 1 m cutting Mo mineralization veins	qz monzonite porphyry	various phases - intramineral dykes; K-feld. metasomatism	BCAR 1964, p. 30	sh in other nearby large Mo deposits?
subparallel qz veins in schist	breccia, volcanics (Hazelton Group)	granodiorite ca. 1.6 km	Little, 1959, p. 42; Hanson, 1935; Groves, 1971	685 kg Ag, 15 728 kg Pb, and 1069 kg Cu produced 1922-32
	diopside-gt-ep bed in silicic metasediments	granodiorite 550 m	Stevenson, 1943; Little, 1959, p. 41	
	metasediments	granite 45 m	Little, 1959, p. 41	

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	•Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
90c	56°01.5' 129°53.5' 104 A/4	Little Pat; SE Bitter Creek Bridge, 14.5 km N Stewart, Portland Canal	qz vein	sh	0.12% WO_3 max.	py, cp; Mo
90d	56°03.5' 130°01' 104 B/1	Premier mine; Salmon River Valley, 13 km N Stewart, Portland Canal	qz vein	sh	Pr (major producer Au, Ag 1924-68)	py; Zn, Pb, Cu, Sb, Au, Ag
Northern British Columbia and Cassiar Mountains, South Yukon						
91	57°34' 131°41' 104 G/12	Devils Elbow; Devils Elbow Mt., 46.5 km SW Telegraph Creek	skarn	sh	Pr	mag, po; Cu, Pb, Zn
92	57°38' 125°57' 94 F/12	Fox Pass, Finlay River	skarn?	sh	Pr	po, py; Cu, Mo
93a	58°33.8' 128°12.9' 104 I/9	Rye; W of Cassier River, S Turnagain River, Cry Lake area	skarn	sh	Pr	
93b	58°37-40' 128°13-14' 104 I/9	Wolf; S of Turnagain River, 6.4 km Cassiar River, Cry Lake area	skarn, qz vein	sh	Pr	
93b	58°40'? 128°06-14' 104 I/9	Ewe; N Turnagain River, W Cassiar River, Cry Lake area	skarn	sh	Pr	
94	58°27.2' 130°26.4' 104 J/8	Mack; SE side Snow Peak, 24 km W of S end Dease Lake	qz vein	sh	Pr	Mo, Cu
95	59°14.5'? 17.5' 129°24.4' 104 P/6	Dome; near McDame Creek, 22 km E Cassiar, McDame area	skarn	sh	Pr	Mo
96	59°19.3' 129°52.2' 104 P/5	Contact; 3.2 km NNW Cassiar. McDame area	qz vein	sh	Pr	py; Bi, Mo, trace Sn
97	59°18' 130°31' 104 O/9	Ash Mountain; 1.6 km N of Ash Mt., 40 km W Cassiar, Jennings River area	skarn qz vein	sh	to 2.2% in qz veinlets cutting skarn	Sn (in andradite, epidote, ferroactinolite)
98	59°39' 130°28' 104 O/9	Blue Light deposit; 54.5 km NW Cassiar, Jennings River area	skarn	sh	high grade, limited area	trace Mo; Be pegmatite, Sn skarn
99	59°39' 131°07' 104 O/11	13 km N of W end Klinkit Lake, Jennings River area	skarn	sh	Pr	po
100	59°59.5' 131°36' 104 O/13	Logjam Creek, 9.6 km N Alaska Highway, mile 750, Jennings River area	qz vein dissem.	wo	to 1-10% W (spectrographic analysis of samples by writer)	Be, Bi, F, Mo
101a	59°41.5' 132°59' 104 N/10	Mt. Weir, 42 km ENE Atlin		wo	Pr	
101b	59°32' 132°48' 104 N/10	Line Lake (3.2 km E of lake), S Rapid Roy Creek, about 55 km E Atlin	qz vein	wo, sh	Pr	Mo, Cu; Pb, Zn, Ag, Sn
101c	59°43' 133°24' 104 N/11	Adera, etc. (Adnac) head Ruby Creek, .24 km NE Atlin	qz vein & dissem.	wo	L	Mo, local minor py, fb (major Mo deposit)

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
	qz diorite		Little, 1959, p. 40	
late qz veins cutting, early sulphide mineralization	volcanics, conglomerate & tuff (Hazelton Group)	Texas Cr. granodiorite Premier dyke swarm	Groves, 1971	sh produced briefly from nearby Riverside mine, Alaska
at contact & within? granodiorite conformable lenses	limestone and granodiorite?	granodiorite	Kerr, 1948, p. 72; Little, 1959, p. 40; Stevenson, 1943	sh associated with gn
	gt gneiss & limestone	granodiorite dykes	Little, 1959, p. 61	
	chloritic silicified skarn zone in metasediments	qz monzonite granodiorite	GEMBC 1971, p. 47	
	limestone, quartzite, qz veins		GEMBC 1969, p. 48	
	limestone		GEMBC 1969, p. 45	
	qz monzonite stock		GEMBC 1969, p. 44, 1970, p. 37	
		porphyry	GEMBC 1970, p. 35; GEMBC 1969, p. 42	Lat. 59° 17.5' is close to Della where 0.035 W rept. in sample by writer
	granite porphyry	Cassiar Bath.	GEMBC 1969, p. 40; Gabrielse, 1963, p. 120	Cu, Zn, Pb, Ag, Sb, Mo, Bi & minor Sn in nearby skarn
	limestone, greywacke, argillite	granite stocks	Watson and Mathews, 1944; Mulligan, 1975; Gabrielse, 1969	
cut by pegmatite dykes	fel augen gneiss interlayered	granite (Cassiar Bath.)	Mulligan, 1969; BCAR 1968, p. 33; Gabrielse, 1969	
	limestone, hornfels, quartzite	granite (Nome L. Bath.)	Gabrielse, 1969	
veins & dissem. in granite and contact	granite stock, argillite, quartzite & dykes	Be pegmatite		Also sh-bearing skarn and porphyry-like Mo-W bodies nearby (LogTung)
	postorogenic "alaskite" granite		Aitken, 1959	
	pyritiferous chert, sediments, limestone	porphyry dykes stock?	GEMBC 1973, p. 514	
numerous veins in intrusive complex	granite alaskite, porphyry		GEMBC 1969, p. 29-35; Sutherland Brown, 1970	numerous occurrences Boulder Cr., Ruby Cr. area; 2.7 t black sands from Boulder Cr. avg. 48.5% WO$_3$, 10.0% Sn shipped 1949

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
101c	59°42' 133°24' 104 N/11	Black Diamond mine, head Boulder Creek, 21 km NE Atlin	qz greisen vein; placer, Boulder Cr.	wo	to 1.85% WO_3 across 1 m by 134 m, 1 zone	asp, local minor Ag, Sn, Au, trace U, fb in kaolinized granite
102	60°08.2' 130°26' 105 B/1	Fiddler (Yukon Tungsten) 90 km W Watson Lake, Cassiar Mts., Yukon	qz greisen vein	wo + ts, sh?	good grade locally in several veins but no economic reserves	minor py, po, cp, etc., MoS_2, fl, ks
East Yukon and Northwest Territories, northeast of Tintina Trench						
103	60°47' 128°51' 105 A/15	Oscar Lake (6.4 km NW of lake) 80 km N Watson Lake, Yukon		sh	R	
104	61°14' 128°52' 105 H/2	Max Property? 29 km E of S end Frances Lake, Yukon		sh	R	
105	61°48' 129°05' 105 H/14	"Broten River" (Guy, Mat), 9.6 km NE Tustles Lake, Frances Lake area, Yukon	skarn	sh		
106	61°57' 129°52.5' 105 H/13	Ptarmigan Creek, 53 km NNW of N end Frances Lake, Yukon	skarn	sh		Cu, Pb-Zn
107a	61°33' 127°28' 95 E/11	B.C. Group, 6.4 km NW Lucky Lake, Flat River area, N.W.T., Yukon	skarn	sh	L	Pb, Zn, Cu
107b	61°36' 127°36' 95 E/12	"Flat River", 6.4 km SW of river, Flat River area, N.W.T.	skarn	sh	L	po
107c	61°48.9' 127°48.6' 95 E/13	M.B., 5 km NE of Flat River, 29 km SE Cantung mine, N.W.T.	skarn	sh	0.3-0.4% WO_3 across 3 m, 1 local	minor py, po, tl, id
107d	61°51' 127°54' 95 E/13	Whistler North and South, 3.2 km NE Flat River, N.W.T.	skarn	sh	0.3-0.4% WO_3 in thin veneer	cp and sh film in joints in granite
107d	61°50'45" 127°56' 95 E/13	Simons, House of Lords; 1.6 km NE Flat River, N.W.T.	skarn	sh	0.2-0.4% WO_3 about 1.2 m	minor po, cp
107d	61°53'30" 127°57' 95 E/13	Glacier, 5.6 km NE Flat River, N.W.T.	skarn	sh	less than 0.1% WO_3	
107e	61°53' 127°59' 95 E/13	Pyramid Mt., 3.2 km NE Flat River, N.W.T.	skarn	sh	less than 0.3% WO_3 in thin veneer	minor py, po
107f	61°50' 128°02' 105 H/16	Bus, 3.2 km SW Flat River, Frances Lake (Yukon) area, N.W.T.	skarn	sh	L	po, minor cp
107g	61°57.7' 128°15' 105 H/16	Cantung (Canada Tungsten) mine, SW Flat River, Frances Lake (Yukon) area, N.W.T.	skarn, minor qz vein	sh	main Canadian producer since 1962, reserves 1974: 3.63 Mt of 1.6% WO_3, 0.2% Cu	po, cp; Zn, Bi, trace Mo, Sn
107g	61°57' 128°15' 105 H/16	Baker prospect, 5 km SE Cantung, SW Flat River, Frances Lake (Yukon) area, N.W.T.	skarn	sh	similar to Cantung, to 3 m wide	sp, po, cp, fl, id
107h	62°06' 128°13' 105 I/1	Moon, 16 km N Cantung, N.W.T.	skarn	sh		

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
6 shear zones cont. qz veins	granite, alaskite, porphyry		BCAR 1949, p. 238, 1950, p. 72, 196; Aitken, 1959; Little, 1959, p. 38	see above
veins banded, vuggy, mu borders & interbands	mica-chlorite schist interbeds in crystalline limestone	E contact, Cassiar Bath. 3.2 km	Poole, 1960; Green, 1966; Craig and Laporte, 1971; Little, 1959, p. 37	Adit; mill near Mile 701.6 Alaska Highway, no product recorded
contact granite	Dev. – Miss.	granite	Gabrielse, 1967	
near contact granite	limy beds in metasediment (mica-schist, gneiss, quartzite) (Proteroz.)	granodiorite (Logan stock)	Cathro, 1969	Several other W and Mo-W occurrences in area
	(Proteroz.)			
	Camb.	porphyry dykes, qz diorite stock	Cathro, 1969	
	L. Camb., limestone, argillite	granite stock opposite Pass Cr.		
on SW limb, anticline	Camb.-Ord. silty limestone	granite (Pyramid Mt. stock)	Cathro, 1969; GSC Map 1313A; Blusson, 1968; Gabrielse, et al., 1973	
	L. Camb. limestone	granite (Pyramid Mt. stock)		
	L. Camb. limestone	granite (Pyramid Mt. stock)	Gabrielse et al., 1973	On GSC Map 1313A
	L. Camb. limestone	granite (Pyramid Mt. stock)		Two other occurrences marked on E contact, Pyramid Mt. Pluton on GSC Map 1313A
	L. Camb. carbonate	granite (Pyramid Mt. stock)		
			Cathro, 1969	
	L. Camb. limestone	qz monzonite plug, aplite dykes	Blusson, 1968	Numerous nearby occurrences SE and NW along belt, see GSC Map 2-1966
	L. Camb. limestone	granite	Blusson, 1968	
	L. Camb.? limestone	granite		

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
108	62°22.5' 128°37' 105 I/9	Lened, 9.6 km SW of South Nahanni River, 51 km NW Cantung, N.W.T.	skarn	sh	0.75 to 2.5% WO_3 across 6.7 m (footwall); 2.2 to 7.6% - 2.4 m (hanging wall)	po + cp
109	62°47' 129°52' 105 I/13	Hi-Min (Clea) 14.5 km SW Mt. Wilson, 128 km NW Cantung, Nahanni area, Yukon	skarn	sh	L?	po + cp
110	62°37' 131°32' 105 J/12	Dragon Lake, 6.5 km NW Mile 205, Canol Rd., Sheldon Lake area, Yukon	skarn	sh	L?	po + cp
111a	63°17'15" 130°08'45" 105 O/8	MacTung (AMAX Northern) 8 km NW Macmillan Pass, Mile 283, Canol Rd., Yukon, N.W.T.	skarn, minor qz vein, greisen	sh	1973 reserves est 27 Mt 0.9% WO_3	po + cp, local Mo, tl
111b	63°25.5' 130°14' 105 O/8	Keele Peak (5 km SE of peak) 22.5 km NNW Macmillan Pass, Mile 283, Canol Rd., Yukon			R	
112	63°36' 131°18' 105 O/11	Emerald Lake (6.5 km NW of lake), Hess Mts., Niddery Lake area, Yukon	qz & carbonate vein & dissem.	sh	minor amounts	po, cp, py, asp, Mo
113	63°14' 133°16' 105 N/8	Mt. Armstrong, 137.5 km ESE Mayo, Lansing area, Yukon	placer	sh?	rept. recovery Russel Cr. placer	
114a	63°29' 135°23' 105 M/6	Two Buttes Mt., 29 km ESE Mayo, Yukon	anomalous wo in granite	sh		
114b	63°41' 134°55' 105 M/10	Ledge Creek, SE arm Mayo Lake, Yukon	placer	sh	major in sluice conc.	Au, ks
114c	63°51' 134°38' 105 N/15	Roop, S of Roop Creek, 3.2 km NE Roop Lakes, Mayo area, Yukon	skarn, pegmatite	sh		tl, titanite
114d	63°40' 135°56' 105 M/12	Canyon Creek, 9.5 km N Mayo, Yukon	placer	sh		Au, cinnabar
114e	64°02' 135°50' 106 D/4	Dublin Gulch, Ray Gulch and Potato Hills; Haggart Cr., 50 km N Mayo, Nash Creek area, Yukon	qz vein, pegmatite placer	sh, wo, fb	sh abundant locally in numerous small veins and skarns; sh & wo major in sluice conc.	Au, ks
114f	63°48' 136°15' 115 P/16	Scheelite Creek and Castnor Creek etc., 27 km NW Mayo, McQuesten area, Yukon	qz vein, pegmatite skarn placer	sh	locally high in veins and skarn; major in sluice conc.	local po, py + Cu, Mo, Sb; Au, Sn (placer)
114g	63°49' 136°01' 115 P/16	Secret Creek, 43 km N Mayo, McQuesten area, Yukon	placer	sh	in sluice conc.	Au, Sn
114h	63°46' 136°33' 115 P/15	Boulder Creek, 43 km NW Mayo, McQuesten area, Yukon	placer	sh	major in sluice conc.	Au, Sn
114i	63°59.5' 136°52' 115 P/15	Arizona Creek, 64 km NW Mayo, McQuesten area, Yukon	placer	sh	minor in sluice conc.	Au, Sn
114j	63°47' 137°17' 115 P/14	Clear Creek, access via Barlow, NW McQuesten Cross, McQuesten area, Yukon	placer	sh	major in sluice conc.	Au, Sn

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
zones on each side altered, granite dyke	L. Camb.	granite	Cathro, 1969; Green et al., 1968	
	Dev.-Miss. limestone and argillite	qz monzonite stock	Cathro, 1969	
	Camb. or older metasediments	granite stock	Cathro, 1969	
essentially conformable	Camb.? limestone (main zone); Ord. limestone, chert shale (upper)	granite	Cathro, 1969; Dick, 1973, 1977	Bulk sample from adit 1973
	syenite stock		Cathro, 1969	
		granite stock	Cathro, 1969	>1% W in heavy mineral conc. in 2 streams draining Mt. Armstrong (writer)
		granite stock	Garrett, 1971a,b, pers. comm.	sh in joint planes in granite
	limestone, quartzite, schist (Yukon Group)	granite stock, pegmatite	Little, 1959, p. 30	sh in soil between Roop and Edwards creeks
			Little, 1959	
	granodiorite, metasediments, limestone (Yukon Group) Tert. gravel	granodiorite stock	Cathro, 1969, p. 32; Bostock, 1947, 1964	
	granodiorite, metasediments, limestone (Yukon Group)	granodiorite stocks	Kindle, 1962; Green, 1971	Placers incl. Johnson, Sabbath, Rudolph, Highet creeks
			Aho, 1949; Gleeson, 1967	Also Goodman and Rodin creeks farther SW in 115 P/16
			Cathro, 1969; Aho, 1949; Gleeson, 1967	Various other streams and stream sediments contain anomalous amounts W
	Tert.? gravel			
	Tert.? gravel			

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
Central and Southwest Yukon, S.W. of Tintina Trench						
115	61°29.5' 132°48' 105 F/7	Canol Metal Mines; upper Sheep Creek, E Canol (Mile 93), Quiet Lake area	skarn dissem.	sh	est. 15 422 t 1.05% WO_3 in "tungsten zone"	Mo
116a	61°45' 133°17' 105 F/11,14	Ham Group, W Canol (Mile 106), Quiet Lake area				
116b	61°53' 133°21' 105 F/14	Fox (Cab Group?); upper Fox Creek, W Canol (Mile 117), Quiet Lake area	skarn	sh	0.5-1.0% WO_3 2 bands 4.5 m by 793 m (No. 2 zone)	po; Cu minor
117	62°12' 134°09' 105 L/1	Little Salmon Lake (11 km E of lake) Glenlyon area	skarn	sh	minor wo	mag-po-py + Pb, Zn, Cu, fl, Sn
118	62°35' 134°48' 105 L/10	Harvey Creek, SW Pelly River, Glenlyon area	skarn	sh	mineralized bed 2 m max.	
119	60°44' 135°10' 105 D/11	Pueblo and Scheelite, 6.5 km WNW Whitehorse	qz & pegmatite qz vein	sh	to 3.0% WO_3 across 10 m (Pueblo) 0.4 across 1.2 m (S)	Cu, Mo
120	61°12' 136°57' 115 H/2	Giltana Lake, 1.6-3.2 km E of S end Aishihik Lake	qz vein	sh		sulphides
121	61°29.5' 138°10.5' 115 G/8	Alaskite Creek, trib. Talbot Creek E Kluane Lake	qz vein	wo		Mo, Cu, fl
122	61°49' 139°30' 115 G/13	Kluane River to Donjek River, Kluane Lake area	skarn	sh	small quantity	
123	62°45' 138°51' 115 J/10-15	Canadian Creek, 16 km SSW Yukon River at Britannia Creek, Snag area	placer	wo	est 305 822 m^3 holding 1814.37 t crude WO conc., black sands 15-17% WO_3	Au; qz-tl vein material; Mo and Pb, Ag (Casino)
Northern Yukon						
124	67°28-29' 140°35-45' 116 N/7	Old Crow, 3 local., 40 km WSW of village near Porcupine River	placer lode?	sh	to 1% sh in nonmagnetic fraction pan conc. of approx. gravity 3.3 +	
125	68°28-29' 138°00' 117 A/5	Mt. Fitton, 64 km SW Shoalwater Bay, Arctic coast	placer lode	sh, wo	to 10% sh in conc. (see above)	py, asp; Mo, Au
126	68°53' 139°00' 117 B/13,14	Mt. Sedgwick, 48 km SW Phillips Bay, Arctic coast	placer	sh	to 2% sh in conc. (see above)	
127a	69°14' 139°31' 117 D/5	Firth River, 25.5 km SW Arctic coast near Herschel Island	placer	sh	Tr sh in conc. (see above)	Cr
127b	69°03' 140°54' 117 C/2	Aspen Creek, trib. Joe Creek-Firth River, British Mts., Alaska-Yukon border	placer	sh	Tr sh in conc. (see above)	Cr
127c	69°18' 140°15' 117 C/8	Malcolm River, 40 km SW Arctic coast, Yukon	placer	sh	Tr sh in conc. (see above)	Cr

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
at gently dipping intrusive contact and within	Camb.? limestone and mica schist	granite	Cathro, 1969	1 grain wo? seen (writer)
			Atlas Exploration Ltd., 1968, Ann. Report, p. 10	
skarn bands separated by 3 m granite sill	limestone, metasediments	granite		
contact zone	limy tuff?	qz-fel porphyry	Cathro, 1969; Campbell, 1967	
alternating layers skarn & hornfels	Camb. limestone, argillite	qz monzonite dyke	Cathro, 1969; Campbell, 1967	
		granodiorite	Cathro, 1969; Kindle, 1964	Also in skarns of Whitehorse copper belt at Copper King, Grafter, Cowley Cr., etc.
lenses at granite-limestone contacts	limestone, mica schist, quartzite		Cathro, 1969	
	alaskite granite (Ruby)		Cathro, 1969; Muller, 1967	
contact	limestone	granite	Little, 1959; Cathro, 1969	
			Little, 1959, p. 16; Cathro, 1969; Godwin, 1976 (Casino)	225-270 kg recovery rept.; test shipment, 1941 assayed 14.8% WO_3; W also rept. SW of Casino Creek
		Dev.? granite	Gleeson, 1963	3 W localities in & N of pluton
	metamorphic rocks	Dev.? granite		1 locality S, 2 N of granite. A. Hoidahl reported local occurrence
		post-Miss.? granite	Norris et al., 1963	3 localities on Trail R. near Mt. Sedgwick
			Gleeson, 1963; Cathro, 1969	1 locality
				1 locality
				1 locality

APPENDIX (cont.)

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
CHURCHILL? and SLAVE PROVINCES – Northwest Territories						
142	61°44' 113°27' 85 H/11	Fox Group (Philmore-Yellowknife, etc.) Outpost Islands, Great Slave Lake	qz greisen	wo (fb), sh	zones to 457 m by 3 m; mined ore 0.6-0.75% WO_3	py, cp, mag, hem; Cu, Mo, Sn, Au
143a	62°10' 112°13' 85 I/1	Moose Group, Hearne Channel, Great Slave Lake	qz vein	sh	?	area of Li-Be-Ta pegmatites
143b	62°20' 112°05' 85 I/8	Doubling Lake, W of outlet; Yellowknife-Beaulieu River area	qz vein	sh	Pr	
143c	62°16' 112°30' 85 I/8	Andre and W groups (Mystery L.) Yellowknife-Beaulieu R. area	qz vein	sh	L?	(Au)
143d	62°24.5' 112°21' 85 I/8	COD Group (S. François L.), Yellowknife-Beaulieu R. area	qz vein	sh	1% WO_3 3 m by 0.6 m, 0.38% WO_3 10 m by 1.3 m	gt, ep, fel, ak
143e	62°27.5' 112°34' 85 I/7	Ruth (6.4 km W. François L.), Yellowknife-Beaulieu R. area	qz vein	sh	0.1% WO_3 90 m by 19 cm	asp, py; Au
143f	62°33' 112°28' 85 I/9	Desperation Lake, Yellowknife-Beaulieu R. area	qz vein	sh	Pr? (reported)	
143g	62°20.5' 112°45' 85 I/7	TA Group (E. Campbell L.), Yellowknife-Beaulieu R. area	qz vein strata-bound?	sh	to 4% WO_3 locally 1 vein	minor py; Au
143h	62°25' 112°54' 85 I/7	Norma (Consolidated Beaulieu Mines, N of Campbell L.), Yellowknife-Beaulieu R. area	qz vein strata-bound?	sh	0.1 to 0.2% WO_3 in vein 244 m by 21 cm	py, asp, po + Cu, Pb, Zn, Au
143i	62°27' 112°50' 85 I/7	July Group, Cleft Lake, Yellowknife-Beaulieu R. area	qz vein	sh	L	Au
143j	62°29-30' 112°40-50' 85 I/7	AC Group (Arctic Circle) (3 loc.) Cleft Lake, Yellowknife-Beaulieu R. area	qz vein strata-bound?	sh	to 1.1% WO_3, 10 m by 40 cm, about 4.5 t mined	
143k	62°28.5' 112°56.5' 85 I/7	Dot and Eva groups, Gilmour Lake, Yellowknife-Beaulieu R. area	qz vein-carbonate, strata-bound?	sh	to 2% WO_3, 15 m by 0.3 m	asp, py, ak; Au clinozoisite, graphite
143l	62°28.5' 112°57.5' 85 I/7	Lucky Group, 0.8 km W Gilmour Lake, Yellowknife-Beaulieu R. area	qz vein	sh	to 1.4% WO_3, 9 m by 15 cm	
143m	62°29.5' 112°57' 85 I/7	Dick Group, NW Gilmour Lake, Yellowknife-Beaulieu R. area	qz vein strata-bound	sh	0.3% WO_3, 33 m by 0.5 m 0.5% WO_3, 8 m by 15 cm	
143n	62°29.5' 112°57.5' 85 I/7	WO_3 Group, NW Gilmour Lake, Yellowknife-Beaulieu R. area	qz vein strata-bound?	sh	0.3% WO_3, 72 m by 0.3 m	
143o	62°30' 112°57' 85 I/7	Storm Group, East Consolation Lake, Yellowknife-Beaulieu R. area	qz vein	sh	2.5% WO_3, 4.6 m by 0.8 m	
143p	62°33' 112°55.5' 85 I/10	Victory Group, 6.4 km North of Gilmour Lake, Yellowknife-Beaulieu R. area	qz vein	sh	1% WO_3, 2.8 m by 1.3 m 1.1% WO_3, 10.4 m by 0.4 m	Li pegmatites near

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
conformable sheared, silicified zones	qz-mica, schist + gneiss, quartzite conglom.		Little, 1959, p. 143	12 565 kg WO_3 in conc., 1941-42; mine, mill; Au, Cu, W produced
			Little, 1959, p. 142	Original claims staked to cover sh showings (rept.)
			Little, 1959, p. 142	Tibbitt Lake Gold Mines drilled 1952
aplite + porphyry	aplite + porphyry dykes cutting schist, greywacke			
	argillite greywacke		Little, 1959, p. 141	C.M.&S. Co. 1941
	slate, greywacke	qz porphyry	Little, 1959, p. 140	C.M.&S. Co. mine, mill 1940-59? (Au); some sh ore hand picked
			Little, 1959, p. 142	
conformable veins	nodular greywacke, schist		Little, 1959, p. 138	Cominco drill shaft 1940-41, small production Au
conformable vein follows slate band	schistose greywacke, slate		Little, 1959, p. 138	Mine, mill, small production Au 1947
			Little, 1959, p. 138	
conformable veins	sediments		Little, 1959, p. 133	
conformable vein	qz-mica schist, slate, alternated, calcareous? near vein		Little, 1959, p. 135	About 27.2 t, 2.18% WO_3 mined, 91 kg sample shipped 1941
	sedimentary		Little, 1959, p. 135	
conformable veins	sedimentary		Little, 1959, p. 134	
conformable vein	"sheared tuffaceous"		Little, 1959, p. 135	
vein cuts bedding	sediments		Little, 1959, p. 134	10 t ore mined 1942, conc. 35% WO_3 shipped 870 kg
1 V-shaped vein	sediments		Little, 1959, p. 135	About 18 t mined, 2 veins

No.	Latitude Longitude NTS area	Identification, Location	Type	Tungsten Mineral	Concentration, Size	Assoc. Metals/Minerals
143q	62°37-39' 112°57 ' 7' 85 I/10-11	Ruth Group, Victory Lake to Trout Lake, Yellowknife-Beaulieu R. area	qz vein	sh	L	dissem. asp, py, po + Pb, Zn, Cu
143r	62°30-35' 113°20-23' 85 I/11	Tibbitt Lake-Peninsula Lake, Yellowknife-Beaulieu R. area	qz vein carbonate-replacements?	sh	41 veins more than 0.3% WO_3 12 veins more than 1% WO_3	clinozoisite, gt, chlorite, plagioclase
143s	62°36' 113°25' 85 I/11	Thompson-Lundmark mine, Yellowknife-Beaulieu R. area	qz vein strata-bound?	sh	L?	py + Pb, Zn, Cu, Au
143t	62°32' 113°44' 85 I/12	MT Group, S.E. Prelude Lake, Yellowknife-Beaulieu R. area	qz vein	sh	0.45% WO_3, 2.5 m by 0.6 m	
143u	62°46-47' 113°14-15' 85 I/14	Dome Lake (inlet and 1.6 km N), Gordon Lake, Yellowknife District	qz vein? carbonate	sh	Pr	? gossan, fel
143v	63°01' 113°08.5' 85 P/3	Storm Group and Goodrock Gold Mines, E Gordon Lake, Yellowknife District	qz vein carbonate	sh	to 0.5% WO_3, 21 m by 1.8 m 0.38% WO_3, 18.6 m by 2 m	py, pr + Cu, Pb, Au
144a	62°26' 114°21-22' 85 J/8	Con and Rycon gold mines, Yellowknife area	qz vein	sh	to 1% locally, avg. 0.1; 0.3% WO_3, shoot 14.6 m by 12 cm	minor asp, py + Zn, Cu, Sb, etc., sulphides, Au, Ag
144a	62°26' 114°21' 85 J/8	Negus gold mine, Yellowknife area	qz vein carbonate	sh	to 3.5% WO_3 locally, 1 shoot 21 m by 0.3 m	minor py, asp + Zn, Cu, Sb, etc., sulphides, Au, Ag
144b	62°31' 114°12' 85 J/9	Ptarmigan mine, Yellowknife area	qz vein	sh	Pr	tl, Li pegmatites; Au, Ag
144c	62°33' 114°13' 85 J/9	Ted Group, W of Prosperous Lake, Yellowknife area	qz vein	sh	Pr	gt in veins near Li pegmatites
144d	62°35.5' 114°22' 85 J/9	NE Ryan Lake (near Crestaurum) Yellowknife area	qz vein?	sh?	?	Mo, Au
145a	64°01' 111°10' 76 D/3	Homer Yellowknife Mines, S of Matthews Lake, Courageous Lake area	qz vein	sh	Pr	py, asp; Au
145a	64°02' 111°11' 76 D/3	Bulldog Yellowknife Gold Mines, S of Matthews Lake, Courageous Lake area	qz vein	sh	Pr	asp, tl; Au
145b	64°04' 111°13' 76 D/3	Salmita Consol. Mines, E side Matthews Lake, Courageous Lake area	qz vein-replacement (strata-bound?)	sh	Pr	minor py, asp + Pb, Zn, etc., tl, mica, fel; Au
BEAR PROVINCE – Northwest Territories						
146	65°23.5' 117°08' 86 F/6	Lever Lake, NE of Hottah Lake	qz vein	sh	L?	cp, pr, py, mag

Structure	Host Rocks	Associated Intrusions	Selected References	Remarks
along contact zone of gossans	lava + sediments		Little, 1959, p. 132	
fracture + shear zones, 150 veins to 15 m long	gabbro sills, sediments		Little, 1959, p. 126	est. ore 1126.7 t, 2968 kg WO_3
part conformable, 6 veins	qz-biotite, schist + phyllite			
	qz-mica schist, greywacke		Little, 1959, p. 125	
lenses, patches follow anticline	argillite		Little, 1959, p. 131	
conformable veins, most scheelite near hanging wall	greywacke, argillite, slate		Henderson and Jolliffe, 1939; Little, 1959, p. 130	4 km NE of Camlaren Au mine (bedded and saddle-reef deposit)
lenses, shoots in some veins, 4 systems shears	andesite + basaltic greenstone		Little, 1959, p. 121	lenses and shoots rich in sh carry low Au and vice versa
lenticular patches to 1.8 m by 21 cm, some veins	greenstone		Little, 1959, p. 124	Most sh in vein sections submarginal as Au ore
	metasediments	Prosperous L. granite	Little, 1959, p. 125	
qz lenses	nodular qz-mica-andalusite, schist hornfels		Little, 1959, p. 125	
	greenstone, granite (contact)		Jolliffe, 1946	Mo common along granite contact, 0.06% W in Likely L. Mo occurrence (62°39' 114°18')
lenticular in shear zone	volcanics, sediments		Little, 1959, p. 147	
lenses in sheared ropy & fragmental lavas	sheared lava, part altered to gt schist		Little, 1959, p. 147	
conformable with slate, near contact	slate, gt tuff?		Little, 1959, p. 145	
	qz-fel porphyry		Thorpe, 1969	Drilled by Pine Ridge Exploration Co., 1967

Energy, Mines and
Resources Canada

Énergie, Mines et
Ressources Canada