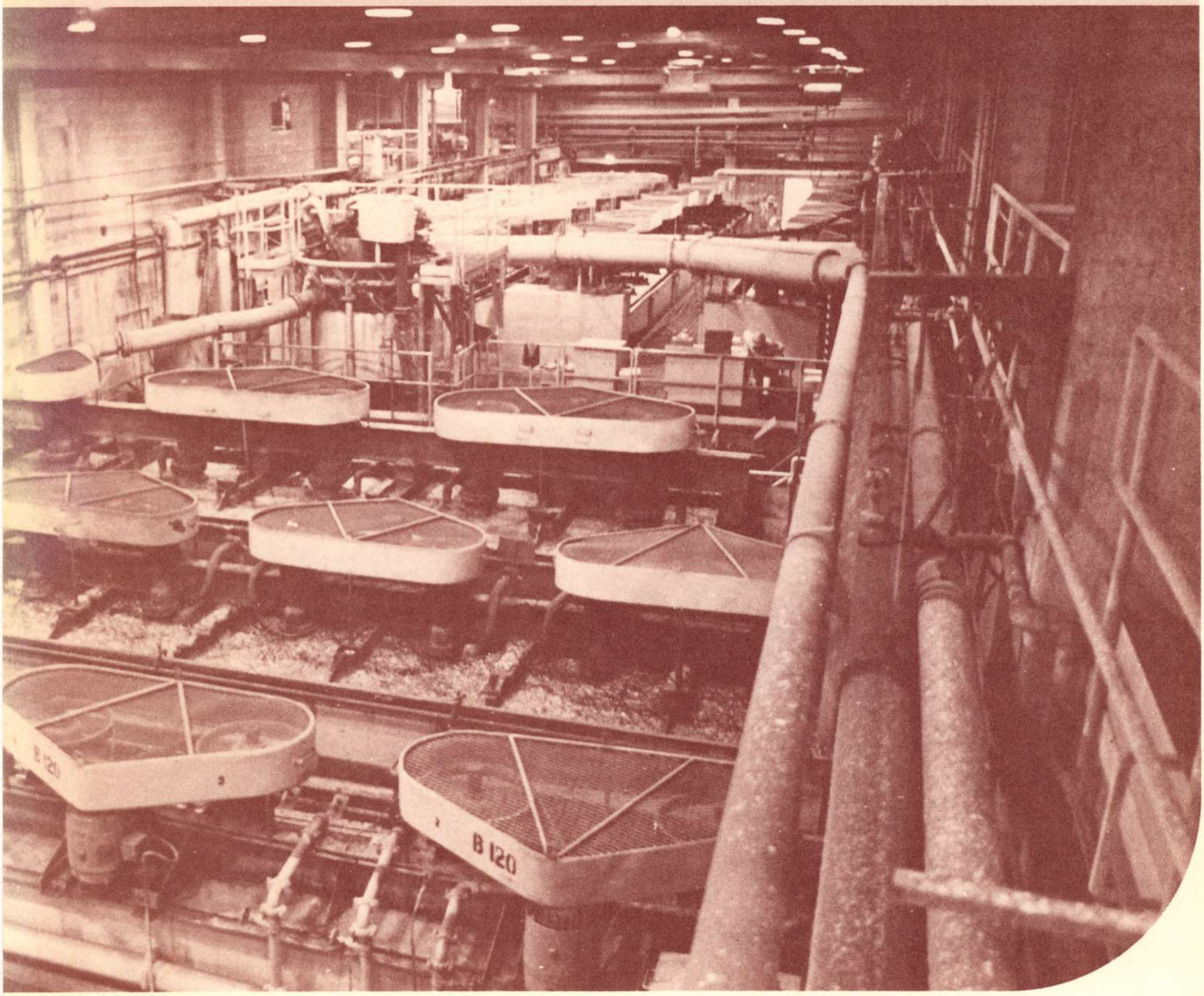
Molybdenum

The British Columbia Perspective



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MINERAL ECONOMICS DIVISION

MOLYBDENUM
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F O R E W O R D

This study is a mineral commodity investigation of molybdenum, the production of which has become increasingly important to British Columbia. The authors wish to acknowledge their debt to various sources of information, as footnoted in each sector, and in particular to Mr. J.A. Ganshorn, Placer Development Ltd., Mr. R.C. Steininger, Climax Molybdenum Company, and Dr. N. Carter, Geological Division, Ministry of Energy, Mines and Petroleum Resources.

The views expressed and conclusions drawn are those of the authors, and do not reflect the opinions of these sources.

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INTRODUCTION

Molybdenum is a silver-grey metal, used principally as an alloy to impart hardness, strength, corrosion and temperature resistance to iron and steel. The metal is produced by recovering and concentrating molybdenite (molybdenum disulphide, MoS_2) from ore, the molybdenum concentrate containing between 85% to 95% MoS_2, or 51% to 55% molybdenum by weight.

Molybdenum disulphide has few direct end-use applications, with the result that the concentrate is usually roasted to drive off sulphur and produce molybdic oxide (MoO_3). The oxide in turn is used to produce ferromolybdenum, which results from the reduction of MoO_3 by ferrosilicon in the presence of iron, flux (CaO), aluminum and magnesium.

Molybdenum is second only to copper in value of production among the metals produced in British Columbia. The province is a major world producer of the metal, and supply shortages caused by an industrial dispute in 1979 aggravated an international shortage of the metal which had been developing over the last four to six years. This was reflected in dramatic price increases in 1978 and 1979 from the historically stable pattern, and also in fundamental changes in the market for the metal.

This report examines the background to the molybdenum market situation and profiles supply and demand on a domestic and world scale. An attempt is made to predict market conditions and price changes in the near future, and an examination is made of opportunities for further processing of molybdenum in British Columbia.

I. STRUCTURE OF DEMAND

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I.1 Historical Profile

Although world production of molybdenum increased by about 4,500 tonnes of contained Mo in 1978, it was exceeded by demand for the sixth consecutive year. Non-communist world consumption in 1978 was approximately 88,000 tonnes of contained Mo, up 6.5 percent from 1977. The growth in consumption to such levels is a relatively recent phenomenon, however. While molybdenum was first discovered over 200 years ago, it was not until this century that its first industrial uses were developed, and not until the 1930's that demand reached significant levels by today's standards. Consumption of the metal has traditionally been spurred by war; tungsten shortages during the First World War caused the first substantial use of molybdenum as an alloying element in the production of military hardware. While demand slumped in the 1920's and the world's molybdenum industries collapsed as a result, demand began to grow again by the mid-1930's and was again stimulated by war in 1939.

World consumption of molybdenum during the Second World War, approximately 170,000 tonnes of the metal, was significantly more than that during the First World War (about 2,300 tonnes). World War II may have been the most important event in the history of the metal, given that military consumption of molybdenum alone during the campaign was greater than cumulative use up to that time. By 1939 molybdenum was becoming a widely accepted alloying metal, with its end-use applications constantly expanding. After World War II, reconstruction under the Marshall Plan kept demand for molybdenum from slumping as it had in the 1920's; as a result world consumption in the period 1946-50 actually grew by 34 percent to 14,500 tonnes in 1950. By the early 1950's the Korean War had provided a new demand stimulus, with yearly world consumption for military requirements alone growing close to 14,500 tonnes by the war's third year.[1]

Another factor in the metal's demand growth was the ambitious research and development program of the world's largest producer, Climax (now part of AMAX). When the company first opened the Climax mine in Colorado in 1917, research effort was directed primarily at perfecting the metal as an alloy in armament and tool steels, but eventually other applications in the chemical, petroleum and fertilizer industries were developed.

In the past two decades molybdenum has become practically indispensable as a steel additive for the nuclear and aeronautical industries. Mineral exploration and development, particularly in the petroleum sector, has been another growth area with alloys used in drill-pipe sampling apparatus and oil and natural gas transmission pipelines.

World consumption of non-communist molybdenum production has increased at a rate of 4.2 percent per year since 1966, and at about 6 percent since 1972.[2]

1.2 End Use Characteristics

1.2.1 General:

Corrosion resistance, high melting point, hardenability, and ductile strength are properties of molybdenum that are developed when the metal is used in an alloy. It may be used as either the sole alloying material or in conjunction with others such as chromium, nickel and tungsten. The metal is also used in pure or near-pure form in wear-resistant products such as carbide cutting edges and electronic semi-conductor devices. Molybdenum has several important chemical applications as a catalyst, chemical reagent, or as an additive in paint pigments, in addition, the unique molecular properties of MoS_2 make it an excellent lubricant additive. These uses are described in more detail below[3]. (See also Figure I-1).

1.2.2 High Strength Low Alloy (HSLA) Steels:

HSLA steels account for about 42-44 percent of molybdenum consumption despite a molybdenum content by weight of 0.5 percent or less. Such steels are used in the manufacture of transportation equipment, industrial machinery and in such structural applications as long-span bridges and oil and gas pipelines. Molybdenum is used to impart toughness, and to reduce weight in favour of strength.

1.2.3 Stainless Steels:

Stainless steel applications account for about 20 percent of consumption. Molybdenum is added at rates of from 1 to 7 percent to improve corrosion resistance to chemicals and the environment. Recently developed ferritic stainless steels, containing from 1 to 4 percent molybdenum in combination with chromium, are already in commercial use in hot water storage and distribution systems, solar heat exchangers, power generating and desalinization equipment and automotive trim to protect from salts and moisture. The nuclear industry is a growing user of such stainless steels in pressure vessels and heat transfer systems.

1.2.4 Tool Steels:

Tool steels, containing from 4 to 9.5 percent molybdenum, have captured a good deal of the market in drills, taps, punches, dies, shear blades and other tool uses. Tungsten, vanadium, titanium, cobalt and molybdenum are basically substitutes in such applications, but molybdenum has been able to capture much of this end-use area as a result of its past market stability and performance, and its qualities of heat-resistance and durability. For example 2.5 percent molybdenum has replaced a tungsten content of 9 percent in hot work tool steels. This use accounts for about 9 percent of consumption.

1.2.5 Super Alloys and Pure Metals:

Superalloys (with 4-5 percent of end-use consumption) and pure molybdenum metal (with 5-6 percent) have similar uses - mainly in heat and corrosion-resistant and protective surfaces. Molybdenum-based coatings are used in high-temperature engines and turbines thereby allowing the performance and efficiency of such engines to increase. Superalloys may contain a third molybdenum by weight or more, in combination with nickel or cobalt as a base.

1.2.6 Chemicals, Pigments and Lubricants:

This area of expanding consumption accounts for about 9 percent of consumption. Molybdenum is used as a catalyst in the desulphurization of petroleum products at refineries. The metal is also used in poly-hetero acids for the production of such commodities as synthetic rubber and plastics. Molybdenum as a molybdate is an efficient pigment constituent, imparting whiteness and corrosion resistance without toxicity. Molybdenum disulphide, due to its platelike molecular structure makes a good lubricant alone or as a lubricant additive since its stable state over great temperature ranges increases the lubricant's versatility.

1.2.7 Sector Use of Molybdenum:

Table I-1 gives a breakdown of sector consumption of molybdenum in the United States. The machinery sector, using molybdenum both in HSLA and tool steel applications, has consumed an increasing portion of the metal in the

TABLE I-1

UNITED STATES MOLYBDENUM DEMAND PATTERN BY SECTOR

1964 - 1977

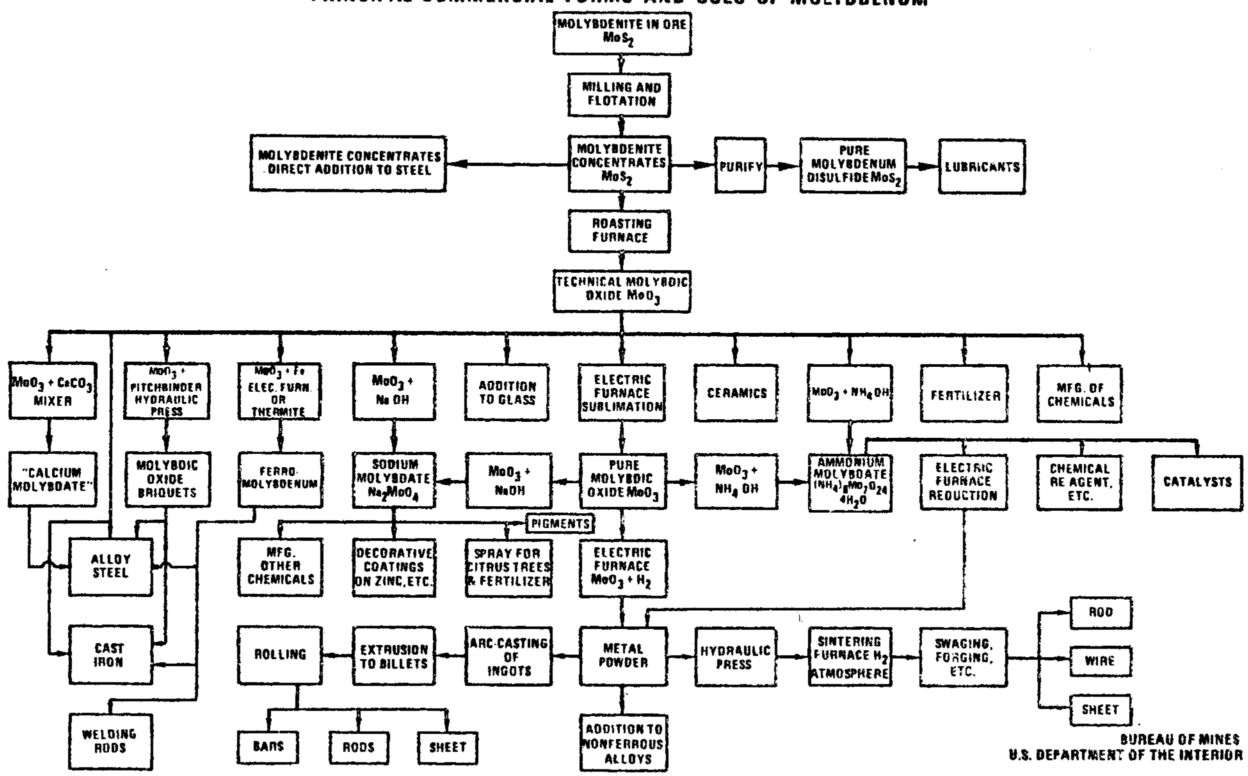
SECTOR	PERCENTAGES*				
	1964	1968	1972	1976	1977
Transportation	30.0	29.9	20.3	21.9	21.1
Machinery	23.5	23.9	34.4	35.1	34.2
Oil and Gas Industries	18.6	17.8	14.6	14.8	14.9
Chemicals	7.9	8.1	12.2	9.9	11.6
Electrical	2.4	2.5	8.6	8.8	8.5
Other	17.5	17.8	9.9	9.5	9.6

* May not add to 100% due to rounding

Source: U.S. Bureau of Mines, Molybdenum Commodity Profiles, 1975 and 1979.

Figure I-1

PRINCIPAL COMMERCIAL FORMS AND USES OF MOLYBDENUM



period shown. The electrical sector, using high-alloy steels and superalloys, has shown a pattern of growth similar to that of the chemical sector. Areas with a declining proportion were Transportation, Oil and Gas Industries and "Other".

1.3 International Demand and Trade

World consumption of molybdenum produced in non-communist countries is displayed in Table I-2. Table I-3 shows the world trade situation, as reflected by the exports of the three largest producing countries which account for about 95 percent of total world production of the metal.[4] A more complete breakdown of Canadian exports appears in Table I-4.

1.3.1 The United States was the world's largest consumer until quite recently, when it was passed by W. Europe. The country imports some concentrates, mostly from Canada, but these are mainly for further processing purposes and not to satisfy domestic demand requirements. The United States is the world's largest exporter, with W. Europe its largest customer and Japan a distinct second.

1.3.2 W. Europe is now the world's largest consumer of molybdenum, and with almost no production, the world's largest net importer. About two-thirds of W. European imports from the United States go to the Netherlands, where AMAX operates processing facilities. The Netherlands has a 6 million mtpy (metric ton per year) steel production capacity, but most molybdenum products are exported, mainly to other parts of W. Europe, and increasingly to Eastern Bloc countries.

TABLE I-2

WORLD CONSUMPTION OF MOLYBDENUM PRODUCED
IN NON-COMMUNIST COUNTRIES, 1966/70/73-78

(1000 Metric tons contained Mo)

	1966	1970	1973	1974	1975	1976	1977	1978e
U.S.A.	27.2	23.6	31.8	34.0	24.9	25.9	27.2	29.5
W. Europe	19.9	30.4*	29.5	35.4	29.9	31.8	31.8	32.7
Eastern Bloc	0.9	*	5.4	6.4	6.8	6.8	7.7	9.1
Japan	4.9	9.1	10.4	12.2	9.5	11.3	10.9	11.3
Others	-	3.2	5.0	5.9	5.0	4.5	5.0	5.4
	53.5	66.2	82.1	93.9	76.2	80.3	82.6	88.0

e - estimate

* - Eastern Bloc included in W. Europe

Source - Goth, J.W., AMAX, E & MJ March 1979, March 1976
except 1966 - Placer Development.

TABLE I - 3

International Molybdenum Trade 1976/77
(metric tons contained Mo)

Exporters	USA*		CANADA		CHILE**
Importers	1976	1977	1976	1977	1977
Austria	39	272	-	-	862
Benelux	3 112	3 210	4 028	5 797	920
France	179	264	423	356	-
W. Germany	3 646	2 539	519	1 156	1 040
U.K.	496	406	2 275	2 268	2 023
Italy	19	280	-	-	453
Netherlands	12 678	14 777	962	402	2 676
Sweden	1 245	1 035	53	-	497
Others	246	-	46	-	48
W. Europe	21 660	22 783	8 306	9 979	8 519
E. Europe	30	1 083	-	-	39
Argentine	75	81	20	-	136
Brazil	105	137	-	-	1 270
Canada	169	238	-	-	208
Mexico	399	288	-	-	-
U.S.	-	-	1 104	1 223	208
Venezuela	271	-	-	-	-
Americas	1 091	744	1 124	1 223	1 822
Japan	5 322	4 729	4 866	3 920	689
India	209	234	134	-	-
Phillipines	1	2	40	40	-
S. Africa	34	85	6	-	140
Others	20	118	75	147	39
World Totals	28 300	29 778	14 551	15 309	11 209

* Exports of ore, concentrates and molybdic oxide

** Chilean data not available for 1976

Sources: U.S. Bureau of Mines, Dept. of Energy, Mines and Resources Canada, Chilean Copper Commission, Chilean Banco del Estado.

1.3.3 Belgium-Luxembourg (Benelux), with 23 million mtpy steel industry, is a major European importer, importing from 5,000 to 10,000 tonnes of the metal per year and exporting much of this in the form of molybdenum products to western and communist Europe. Canada is a major supply source for Benelux, with Noranda operating processing facilities in Belgium (Sadacem).

1.3.4 West Germany is the largest end-use consumer of molybdenum in W.Europe. The country is the major destination for exports from the Netherlands and Benelux, as well as being the fourth largest consumer of U.S. molybdenum exports. W. German steel production is the fourth greatest in the world, but molybdenum consumption by the country is less intense than in the United States; while steel output in the U.S. is 2.5 to 3 times greater than the West German, American molybdenum consumption is from 3.5 to 4 times higher. West German exports of molybdenum are related to lubricant/chemical refinery usage.

1.3.5 Great Britain imports about 7,000 tonnes of molybdenum in ores and concentrates, chiefly for use in its own steel industry. Sources of supply are mainly Canada, Chile and the Netherlands. Less than a third of the country's imports are processed and transferred to other European and world consumers.

1.3.6 France has a steel output capacity of 27 million mtpy, consuming molybdenum in its chemical and lubricant industries as well. Total consumption of molybdenum in the country is about 4,000-5,000 mtpy, with main sources of supply being other W.European countries.

1.3.7 Italy has about 10 percent less steel production capacity than France, but is a less intensive molybdenum consumer at about 2,500-3,000 mtpy

1.3.8 Sweden is W.Europe's second largest end-use consumer of molybdenum after West Germany at about 6,000 mtpy. The country's 6 million mtpy steel industry is small by world standards but it produces much stainless, high alloy, highspeed and superalloy steels and thus the unit consumption of molybdenum is large. Sources of supply are mainly other W.European countries, but the United States provides a significant share of the country's molybdenum imports.

1.3.9 Minor W. European consumers of molybdenum include: Austria which processes most of its imports into molybdenum products for further export; Spain, with a sizeable steel industry but low unit consumption molybdenum use, and Yugoslavia, which has some molybdenun resources but is still a net importer.

1.3.10 The Soviet Union and Soviet Bloc countries are large net importers of molybdenum. The major source for these countries has traditionally been W.Europe, where molybdenum from the Americas is processed and re-exported. W.European exports to the Soviet Bloc have increased substantially in recent years but no recent statistics are available. U.S.

exports to the Soviet Union increased to almost 1,200 tonnes in 1978 from 1,035 tonnes in 1977, the first year of direct Soviet-bound exports. Canada started exporting to the Soviet Union in 1978 at 357 tonnes and may have increased this figure slightly in 1979.

1.3.11 Japan is the non-communist world's second largest crude steel producer behind the United States and is second only to that country in molybdenum consumption at about 11,000 mtpy. Japanese molybdenum production is minimal (less than 200 mtpy) and thus the country must import all its requirements. Imports of molybdenum contained in concentrates and molybdic oxide reached a peak of 10,673 tonnes in 1976 and were 9,740 tonnes in 1978 (see Appendix Table A-2). 39% of these imports in 1978 came from Canada, 52 percent from the U.S.A., 8.5% from Chile and minor amounts from W. Germany and The Netherlands. Imports are mainly in the form of oxide, with further conversion to ferro-molybdenum taking place within the country. The United States provided 53% of the 295 tonnes of molybdenum imported as ferro-molybdenum in 1978.

1.3.12 Latin America

The largest importers of molybdenum in this region are Brazil, with consumption of about 1,200 mtpy, and Venezuela at 300 mtpy. Mexico consuming about 250 mtpy, and Argentina with similar imports, are net importers today, but have molybdenum resources that may be developed in future to satisfy domestic demands. Chile and Peru are large net

TABLE I - 4

CANADA MOLYBDENUM TRADE, 1977-1978

	1977		1978	
	Kg	$	Kg	$
Exports				
Molybdenum in ores and concentrates and scrap[2]				
Japan	3 920 400	41 739 000	4 262 600	53 443 000
Belgium and Luxembourg	5 797 400	40 844 000	4 214 800	30 496 000
United States	1 222 900	9 781 000	3 364 800	20 065 000
United Kingdom	2 267 500	16 049 000	1 654 200	12 036 000
Germany, West	1 156 300	8 866 000	728 500	9 480 000
U.S.S.R.	-	-	357 300	4 463 000
France	356 300	3 111 000	300 500	3 482 000
Australia	147 100	1 645 000	91 400	1 525 000
Other Countries	442 500	3 559 000	166 900	2 063 000
Total	15 310 400	125 594 000	15 141 000	137 053 000
Imports				
Molybdic oxide (containing less than 1 per cent impurities)	192 142	1 221 000		
Molybdenum in ores and concentrates[3] (Mo content)	237 668	1 702 635		
Ferromolybdenum[3] (Gross weight)	74 330	498 485		
Consumption (Mo content)				
Ferrous and nonferrous alloys	875 686	...		
Electrical and electronics	2 719	...		
Other uses[4]	49 442	...		
Total	927 847	...		

Source: Statistics Canada, except where noted.

[1]Producers' shipments (Mo content) of molybdenum concentrates, molybdic oxide and ferromolybdenum. [2]Includes molybdenite, molybdic oxide in ores and concentrates. [3]United States exports of molybdenum to Canada, reported by the U.S. Bureau of Commerce, Exports of Domestic and Foreign Merchandise (Report 410), value in U.S. currency. These imports are not available separately in official Canadian trade statistics. [4]Chiefly pigment uses.

[P] Preliminary; ... Not Available

- molybdic oxide and ferromolybdenum both contain about 60% Mo.

Source: Energy, Mines and Resources.

exporters. Both countries consume less than 1 percent of domestic molybdenum production. The United States and Chile supply most of the Latin American molybdenum imports.

1.3.13 Australasia and Africa

Australia has had no mine production since 1974 and has had to rely on imports from the U.S. and the Commonwealth since then. S. Korea and Taiwan import small amounts of the metal, mainly from the U.S.; South Korea is also a small net exporter. India and S.Africa consume about 200-250 mtpy each with most imports coming from Canada and the U.S. A number of other countries in the region consume minor amounts of molybdenum. Generally, demand is diffuse and local production of the metal minimal.

1.3.14 Canada

Canadian molybdenum consumption as estimated by Energy Mines and Resources (Ottawa) is profiled below:

TABLE 1-5

CANADA - Consumption of Molybdenum*
(Metric tons contained Mo)

1960	1965	1970	1975	1976	1977	1978[e]
473	772	1037	1437	1260	928	1700

Source: Energy, Mines and Resources, Minerals Yearbook
* As estimated by consumers
[e] Estimate

Consumption ranges between 5 and 10 percent of domestic production, thus the country is a large net exporter. Prior to 1965 Canada was a net importer, and even now the country relies on imports to satisfy a modest portion of her molybdenum requirements. Import data (Table I-4) is poor and incomplete but according to United States export figures (U.S. Bureau of Commerce), Canadian imports of contained molybdenum from that country alone in 1976 were 246.5 tonnes or 19.6 percent of domestic consumption and in 1978, 282.3 tonnes or 30.5 percent of domestic consumption in that year. These figures may, however, reflect exports of molybdenum from concentrate which has been roasted in the U.S. on a toll basis.

Canada, with a crude steel production capacity of about 14 million mtpy was the world's eleventh largest producer of crude steel in 1977. The country consumes about 2.5 times less molybdenum per pound of crude steel than the United States. Nevertheless metallurgical applications account for over 90 percent of molybdenum consumed in the country. The remainder of consumption is used mainly in pigments and chemicals.

1.4 Factors Affecting Demand for Molybdenum

1.4.1 Tariff Structure

Table 1-6 shows the tariff structure of Canada and the world's major importing areas. During the 1979 General Agreement on Tariffs and Trade negotiations in Tokyo, new duties were developed that reduce the tariff burden on molybdenum products, or changed the tariff structure to a straight ad valoreum basis. These new duties will be phased in over an eight-year period beginning January 1, 1980, and thus the yearly change is minor in

TABLE I - 6

TARIFF PROFILE:

GATT Import Duties

ITEM	EEC		USA		JAPAN		CANADA	
	I	II	I	II	I	II	I	II
Moly ores and conc.	Free	Free	12¢/lb	9¢/lb	-	Free	Free	Free
A. Quota	-	-	-	-	Free	-	-	-
B. Other	-	-	-	-	7.5%	Free	-	-
Molybdic oxide	8%	5.3%	10¢/lb+3%	6¢/lb+1.9%	-	-	15%	12.5%
Ferromolybdenum	7%	4.9%	10¢/lb+3%	4.5%	7.5%[1]	4.9%	5%	4%
Molybdates	11.2%	?	10¢/lb+3%	4.3%	7.5%[1]	4.9%	15%	9.2%
Molycarbides	9.6%	8%	10¢/lb+3%	4.3%	5%[2]	3.7%	5%	4%
Moly Metal:								
A. Unwrought powder	6%	n.c.	10¢/lb+3%	6.3¢/lb+1.9%	5%[2]	3.7%	Free	Free
Waste and Scrap	5%	n.c.	Free[2]	6%	5%[2]	3.7%	Free	Free
B. Wrought	8%	n.c.	12.5%	6.6%	7.5%[2]	4.9%	Free	Free
C. Other	10%	n.c.	12.5%	6.6%	7.5%[2]	4.9%	Free	Free

Source: Tariff Schedules, countries shown

1- Temporarily reduced by 20%.
2- Temporarily suspended from 10.5%.
n.c. - no change
I- Old rates.
II- New rates to be applied over 8 years (Multilateral Trade Negotiations, 1979)

most cases.

Generally, tariffs on less processed materials are quite minor, with Canadian exports of concentrate to the E.E.C. and concentrate and oxide to Japan entering free of duties since mid-1976. These type of exports account for most of the current Canadian shipments (see Section 5).

1.4.2 Derived Demand

Perhaps the most important aspect of the demand for molybdenum is that, like all alloying metals, its demand is a function of that for the product in which it is an additive. Since 70 percent of molybdenum consumption is in the production of various grades of steel, the demand for steels in which molybdenum is used is the major derived-demand factor. World crude steel output is shown in Table I-6A. There is a high correlation between a country's molybdenum and steel production, as expected, with certain exceptions. These exceptions result from the production of differing grades and types of steel in different countries. Sweden, for example, is W.Europe's second largest end-use consumer of the metal, but its seventh largest crude steel producer. This results from Sweden's large speciality steel output*.

Derived demand is evident in the way molybdenum demand cycles follow the roughly four-year industry cycles. Molybdenum shows a wider variance from the cyclical trend

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* In 1976, the country consumed 0.75 kg of molybdenum per ton of steel produced, U.S.A. 0.2 kg/ton, and Canada 0.1 kg/ton[5].

TABLE I - 6A

World Crude Steel Production (1972 – 1977) by Countries

(in 1,000 M/T)

Countries \ Calendar	1972	1973	1974	1975	1976	1977	77/76
U.S.S.R.	125,589	131,481	136,206	141,325	144,805	147,800	+ 2.1%
U.S.A.	120,876	136,805	132,197	105,818	116,122	113,170	- 2.5
E C (9 countries)	(139,144)	(150,073)	(155,587)	(125,235)	(134,156)	(126,140)	- 6.0
Japan	96,900	119,322	117,131	102,313	107,399	102,405	- 4.6
West Germany	43,705	49,521	53,232	40,415	42,415	38,981	- 8.1
United Kingdom	25,422	26,649	22,379	19,780	22,396	20,474	- 8.6
France	24,054	25,270	27,020	21,530	23,221	22,103	- 4.8
China	23,000	25,000	25,000	26,000	21,000	24,000	+14.3
Italy	19,813	20,995	23,798	21,837	23,446	23,336	- 0.5
Poland	13,424	14,057	14,556	15,007	15,640	18,000	+15.1
Belgium	14,532	15,522	16,225	11,584	12,145	11,257	- 7.3
Czechoslovakia	12,727	13,158	13,640	14,324	14,693	15,180	+ 3.3
Canada	11,860	13,386	13,624	13,025	13,290	13,631	+ 2.6
Spain	9,554	10,809	11,646	11,242	11,086	11,290	+ 1.8
Australia	6,827	7,699	7,785	7,869	7,794	7,335	- 5.9
Rumania	7,401	8,161	8,840	9,549	10,970	11,600	+ 5.7
India	6,768	6,915	7,068	7,989	9,313	9,921	+ 6.5
Brazil	6,518	7,149	7,507	8,308	9,194	11,141	+21.2
East Germany	6,070	6,640	6,165	6,480	6,740	6,950	+ 3.1
Sweden	5,257	5,664	5,989	5,611	5,140	3,950	-23.2
Luxembourg	5,457	5,924	6,448	4,624	4,566	4,329	- 5.2
Netherlands	5,585	5,623	5,840	4,826	5,185	4,927	- 5.0
South Africa	5,340	5,633	5,833	6,580	7,159	7,303	+ 2.0
Mexico	4,431	4,760	5,138	5,250	5,297	5,545	+ 4.7
Austria	4,070	4,238	4,699	4,069	4,478	4,110	- 8.2
Hungary	3,273	3,332	3,466	3,671	3,652	3,700	+ 1.3
North Korea	2,650	2,800	3,200	2,900	3,000	3,300	+10.0
Yugoslavia	2,588	2,676	2,836	2,916	2,750	3,210	+16.2
Argentina	2,151	2,205	2,354	2,200	2,422	2,676	+10.5
Bulgaria	2,121	2,246	2,188	2,265	2,460	2,600	+ 5.7
South Korea	608	1,240	2,274	2,534	3,511	4,245	+20.9
Finland	1,456	1,615	1,656	1,618	1,644	2,150	+30.8
Turkey	1,448	1,169	1,464	1,464	1,405	1,847	+31.5
Venezuela	1,128	1,063	1,058	1,100	927	881	- 5.0
Others	7,897	11,273	11,638	10,977	11,235	10,653	- 5.2
TOTAL	631,500	700,000	710,100	647,000	676,500	674,000	- 0.4

Source: MITI ; Tex Coking Coal Manual, p.15.

Note: Figures for "Total" represent production by 65 nations in the world.; Figures for 1977 are based on preliminary reports,; Figures for "Others" represent production by countries producing less than 1.00 million tons.

than does steel, likely due to the consumption of molybdenum in steels used in capital expansion projects (pipelines, mineral exploration, nuclear energy) rather than in more consumer-oriented steels (appliances, construction starts, etc.). Steel cycles are most often closely tied to the latter, rather than the former, type of consumption[5].

Technological advance is an exogenous or "unexplained" variable that disrupts the orderly relationship between demand for a metal and demand for its end-use products. The discovery of new applications and products and changes in alloying and refining techniques will affect the demand for an additive metal like molybdenum in a fashion unrelated to the demand for existing products. The effect of technological change on molybdenum demand can be seen in the difference between the growth rate for steel consumption (3-4 percent per year) and that for molybdenum (6-7 percent). As new steel applications for molybdenum have been found, its use in steel products has increased proportionally; an offsetting factor, however, is the fact that the use of molybdenum reduces the amount of steel needed by increasing the strength to weight ratio.

1.4.3 Price Elasticity of Demand: Cost Contribution and Substitution

The price elasticity of demand is a measure of the magnitude of demand changes that result from a unit price change. Generally, metals tend to share the common characteristic of unelastic demand in the short run*. This means that for

* The "short run" is defined by the amount of time required to make plant changes or additions - it is usually from 1 to 3 years.

a given percentage increase in price the demand for a commodity decreases by less than that percentage in the short-run. This is common amongst most metals because: (i) demand for metals is derived from that of their end-products. In most cases, metals contribute only a fraction of the final cost of the consumer good produced (like an automobile or an appliance). Thus metal prices can climb substantially without having a significant effect on the cost of a consumer good and hence its demand; (ii) substitution is often not possible in the short-run due to the time required for equipment and process changes that may be required to enable it to occur.[6]

In the case of molybdenum, the metal's contribution to the cost of the final or consumer good varies widely depending upon the end-use involved*. The metal's greatest end-use, in HSLA steels, involves a lower cost of molybdenum per pound of steel produced than any other steel application, but this may not imply that short-run demand is inelastic, since HSLA steels usually are the final good and not just a constituent of a larger product. In superalloy applications, cost per pound is high but the contribution to the total cost of a good may be low, since small quantities are often used to cover a relatively minor surface of the final

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* Actual cost-per-weight data on molybdenum in different steels was not available.

product. Despite these inconsistencies, the fact that molybdenum is an additive metal suggests it would fit the scenario in (i) above quite well.

Molybdenum has enjoyed substantial gains since the 1950's through its substitution for other alloying agents. Substitution results from a combined engineering/economic decision based on the price-performance of alternative metals in achieving a given goal. Molybdenum has "won out" over other alloying agents because its price-performance ratio is better than other metals and because it has simply out-performed its competitive metals in certain applications. The possibility of substitution in steel and alloy applications is analysed below by end-use:

1.4.3.1 Stainless Steels and Superalloys

Molybdenum's corrosion and temperature resistant qualities are difficult to replace because the metal simply outperforms its substitutes in these areas.[7] In stainless steels, chromium and nickel, the other alloy constituents, contribute to corrosion resistance (the key quality in stainless steels), but under certain conditions such as high temperature, molybdenum is crucial. This means that substitution in these highly resistant steels is unlikely. Another factor inhibiting substitution in the short-run is that these steels are produced and sold by their chemical content, not by physical specifications. Producers with supply contracts will therefore tolerate short-term price increases because increased costs must be tolerated to fulfill these contracts. Also, in certain cases, these increased costs can be passed along to consumers in the form of molybdenum-content surcharges by weight of steel sold.

1.4.3.2 Tool Steels

Strength and hardenability were among the qualities of molybdenum that enabled it to substitute for tungsten in tool steels. It out-performed tungsten by virtue of its relative stability of price and supply in comparison to the unstable tungsten market. The first sustained use of molybdenum occurred when, in World War I, tungsten was in short supply.

Substitution between these steels is thus a possibility in the long-run if the current molybdenum market instability continues.

1.4.3.3 High-Strength Low-Alloy (HSLA) Steels

Substitution for molybdenum is most likely in this area. Substitutes in this application include vanadium and columbian (niobium); columbian being the main additive metal used in HSLA steels prior to popular use of molybdenum.

Since these steels are sold on their physical specifications (e.g. tensile strength), there is a great incentive for producers to substitute as price-performance changes, in order to keep costs down. In the short-run different steel rolling techniques can be used to reduce molybdenum content and, as in the case of large diameter X-70 pipeline steel, these techniques have completely eliminated the molybdenum content. In the long-run, alloying techniques can be changed.

(Table I-7 gives a description of common steel addition agents and their contribution to the qualities of the product.

1.5 Summary

Short-run demand for molybdenum was deemed to be price-inelastic due to the minor cost contribution the metal has historically made to most of its iron and steel products and in other areas of growing demand. It is reported, however, that the price spiral in 1979 did affect demand and that substitution did take place. Such substitution is limited by the time required to make the process changes that substitution necessitates, and by the presence of production contracts for specialty steels which specify a given molybdenum content for the steel produced.

In the longer run, substitution is more likely, especially in tool and HSLA steel applications. But even in the long-run the possibility of substitution is reduced by the traditional price/supply reliability and physical performance of molybdenum.

TABLE I-7

COMMON ADDITIVE AGENTS IN STEELMAKING

ELEMENT	HOW USED	MAIN EFFECTS ON STEEL
Aluminum	Metal	Deoxidizes; hardens.
Chromium	Ferroalloy, oxide	Improves corrosion resistance. Strengthens.
Cobalt	Metal	Improves resistance to high temperatures, hardens.
Columbium	Ferroalloy, metal	Deoxidizes; desulphurizes.
Molybdenum	Ferroalloy, oxide	Hardens improves corrosion resistance.
Nickel	Ferroalloy, metal, oxide	Toughens improves corrosion and heat resistance.
Silicon	Ferroalloy	Deoxidizes; hardens.
Tantalum	Ferroalloy	Improves corrosion resistance; controls grain size.
Titanium	Ferroalloy	Improves high temperature characteristics; deoxidizes.
Tungsten	Ferroalloy, metal, oxide	Hardens; improves high temperature characteristics.
Vanadium	Ferroalloy, oxide	Control grain size; toughens.

Source: Department of Energy, Mines and Resources, Ottawa.

Section I Footnotes

1 Sutulov, A., Molybdenum and Rhenium, 1976, p.55.

2 Placer Development data

3 Based on AMAX and Placer Development data. See Appendix Table A-1.

4 Based on 1973 figures in, Sutulov, A., Molybdenum and Rhenium, 1976 p.175. Canada, Chile and the U.S.A. accounted for 95.3% of non-communist world trade in that year.

5 Butterfield, J.A., and Ganshorn, J.A., "Molybdenum Supply and Demand Forecast", C.I.M., Annual Volume, 1977.

6 Tilton, J., The Future of Non-Fuel Minerals, 1977, Chapter 5.

7 Greene, Norbert D., Corrosion Engineering, McGraw-Hill.

2. INTERNATIONAL SOURCES OF SUPPLY

2. INTERNATIONAL SOURCES OF SUPPLY

2.1 World Production

2.1.1 Historical Profile

World Molybdenum production is profiled in Table II-1 and Figure II-1. The United States has dominated world production since the 1920's when the Climax mine in Colorado began operating on a sustained basis and the Questa, New Mexico mine was developed. Major world sources of molybdenum prior to World War I had been Norway, where the world's first molybdenum production occurred at the Knaben mine in the late 1800's, and Australia.

Over the last decade the trend has been toward steady erosion of the United States' leading share of world production (see Table II-3). A factor in this trend may have been American stockpiling of the metal that began in the 1950's. By 1959 stockpiles reached 38 000 metric tonnes - more than total world production for that year. In 1963 release of stockpiled materials began and until 1977 this source offset the pressure on sources of supply in the United States. U.S. demand for the metal peaked in 1973 and 1974 when release of stockpiled materials totalled about 16 000 metric tonnes. Since 1977, when the stockpile was totally

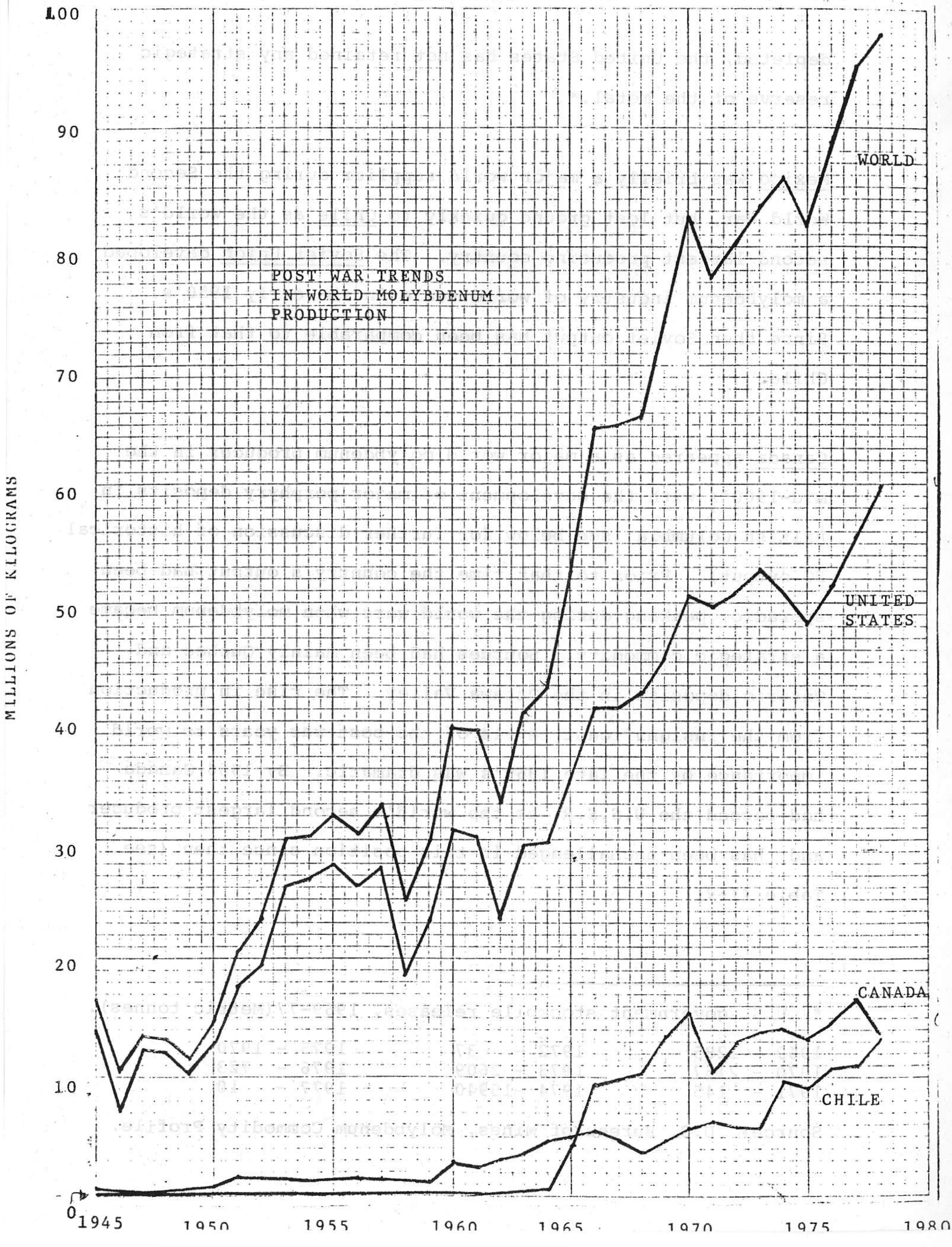
TABLE II-1

WORLD MOLYBDENUM PRODUCTION 1901-78
(1 000 kg of Mo content)

	CANADA [1]	U.S.A.	CHILE	U.S.S.R.*	OTHERS	TOTAL
1901-1910	-	22	-	-	656	678
1911-1920	247	874	-	-	1 577	2 698
1921-1930	26	7 402	-	-	980	8 408
1931-1940	12	79 795	297	265	9 387	89 756
1941-1950	1 504	159 442	6 419	3 540	12 308	183 213
1951-1960	2 793	243 947	15 341	23 950	8 223	286 031
1961-1970	64 013	367 564	43 353	62 892	21 854	559 676
1971-1978	109 013	418 693	72 068	71 571	21 572	692 917
1961	386	30 153	2 558	5 000	1 049	39 145
1962	409	23 215	3 014	5 000	1 417	33 055
1963	453	29 445	3 587	5 500	1 844	40 829
1964	550	29 719	4 713	6 000	1 967	42 949
1965	4 230	35 049	4 746	6 200	2 131	52 356
1966	9 330	41 011	5 451	6 500	2 412	64 704
1967	9 684	40 814	4 877	6 700	2 844	64 919
1968	10 189	42 331	3 865	6 700	2 689	65 774
1969	13 432	45 213	4 842	7 565	2 452	73 504
1970	15 350	50 614	5 706	7 727	3 050	82 441
1971	10 280	49 710	6 321	7 983	3 197	77 491
1972	12 924	50 865	5 917	8 210	3 163	81 079
1973	13 785	52 552	5 885	8 482	2 798	83 502
1974	13 942	50 807	9 759	8 800	2 608	85 916
1975	13 027	48 072	9 091	9 060	2 535	81 784
1976	14 619	51 361	10 899	9 350	2 387	88 616
1977	16 568	55 523	11 000	9 707	2 388	95 186
1978	13 868**	59 803	13 196	9 979*	2 425	99 271

1 Shipments
* Estimate
** Preliminary
1901-1970 Sutulov, A., World Molybdenum Encyclopedia

1971-1978 a) U.S. Bureau of Mines, Commodity Profile 1979
b) Energy Mines and Resources, molybdenum preprints .


POST WAR TRENDS
IN WORLD MOLYBDENUM
PRODUCTION
WORLD
UNITED STATES
CANADA
CHILE
MILLIONS OF KILOGRAMS
100
90
80
70
60
50
40
30
20
10
0
1945
1950
1955
1960
1965
1970
1975
1980

depleted, the United States has not retained any strategic reserve of the metal.*

Mexico was briefly a major world supplier during the Second World War, but lost ground quickly to Chile as the world's second largest producing country. The Soviet Union developed a molybdenum industry of world scale in the early 1950's. Since then Soviet output has been comparable to that from Chile.

Canada appeared as a major world molybdenum producer in the mid-1960's with the development of major porphyry deposits in British Columbia (see below for further discussion of historical BC output). Prior to that time the country's output had been sporadic, peaking during the world wars when molybdenum became a strategic commodity. Sources had been mainly Quebec and Ontario deposits in the Ottawa Valley. The rise in production from the insignificant levels of the post-war years to world importance by the late 1960's was dramatic. By 1966 Canada had passed the U.S.S.R. as the world's second largest producer and has been unchallenged in this position since then (see Table II-2).

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* U.S. government stockpile releases, 1969-77 (Metric tonnes).

1969 - 1285	1972 - 37	1975 - 1970
1970 - 2157	1973 - 2609	1976 - 723
1971 - 145	1974 -15940	1977 - 10

Source: U.S. Bureau of Mines, Molybdenum Commodity Profile.

TABLE II-2

PROPORTIONAL SHARE OF WORLD MOLYBDENUM PRODUCTION

1901 - 1978

	CANADA	USA	CHILE	USSR	OTHER
1901 - 1910	-	3.2	-	-	96.4
1911 - 1920	9.2	32.4	-	-	58.4
1921 - 1930	0.3	88.0	-	-	11.7
1931 - 1940	-	88.9	0.3	0.3	10.5
1941 - 1950	0.8	87.0	3.5	1.8	6.7
1951 - 1960	1.0	85.3	5.4	8.4	2.9
1961 - 1970	11.4	65.7	7.7	11.2	3.9
1971 - 1978	15.7	60.4	10.4	10.3	3.1

Sources: U.S. Bureau of Mines, Minerals Yearbook, Molybdenum preprints.
__________________, Commodity Profile, Molybdenum, May, 1979.
Canada; Energy, Mines and Resources, Minerals Yearbooks, Molybdenum preprints.

TABLE II-3

PROPORTIONAL SHARE OF WORLD MOLYBDENUM PRODUCTION

1971 - 1978

	1971	1972	1973	1974	1975	1976	1977	1978 (p)
CANADA	13.3	15.9	16.5	16.2	15.9	16.5	17.4	14.0
USA	64.2	62.7	62.9	59.1	58.8	58.0	58.3	60.2
CHILE	8.2	7.3	7.1	11.4	11.1	12.3	11.6	13.3
USSR (e)	10.3	10.1	10.2	10.2	11.1	10.6	10.2	10.1
CHINA (e)	1.9	1.9	1.8	1.7	1.8	1.7	1.6	1.5
PERU	1.0	1.0	0.9	0.9	0.8	0.5	0.5	0.5
JAPAN	0.4	0.5	0.2	0.1	0.2	0.2	0.2	0.2
BULGARIA (e)	-	0.2	0.2	0.2	0.2	0.2	0.2	0.1
NORWAY	0.4	0.2	0.2	-	-	-	-	-
AUSTRALIA	*	*	*	*	*	*	*	*
SOUTH KOREA	0.1	*	*	*	*	0.1	0.1	0.1
MEXICO (e)	0.1	0.1	*	*	*	*	*	*
PHILLIPINES	*	-	-	-	*	*	*	*

(Columns may not add to 100% due to rounding)

* = Less than 0.1%

p = preliminary

e = estimate

Other Countries

Since the early 1940's countries other than the United States, Canada, Chile and the Soviet Union have accounted for less and less of the world's molybdenum production. Of these other sources Peru and China have alternated as the world's fifth largest producers over the last 25 years, with the latter taking the lead in the last decade. Other notable producing countries are listed in Table II-3.

The historical rate of change in world molybdenum supply is profiled in Table II-4 below. The 1930's were the years of most dramatic growth in production, about 30% per year in that period. In the 1970's production has increased 6.4% per annum from the 1960's average. Between 1958 and 1978 world production has shown a 7.1% annual rate of increase, between the years 1968 and 1978 this figure is 4.2%.

2.2 Current World Supply Structure

World Supply is dominated by four countries, the United States, Canada, Chile and the Soviet Union, which together accounted for more than 97 percent of world molybdenum in 1978 (see Tables II-2 and II-3). Brief profiles of each country as a molybdenum producer are presented below.

TABLE II-4

Rate of Increase in World Molybdenum Production; Percent Change in Average Output Between Indicated Periods and Growth Rate:

PERIOD	AVERAGE YEARLY OUTPUT (1000 tonnes)	% CHANGE BETWEEN PERIODS	GROWTH RATE DURING PERIOD
1901-10	67.8		
1911-20	269.8	278	16.6
1921-30	840.8	212	13.5
1931-40	8 975.6	967	30.1
1941-50	18 321.3	104	8.7
1951-60	28 603.1	56	5.0
1961-70	55 967.6	96	9.7
1971-78	86 614.6	54	6.4

Source: Table II-1 above

2.2.1 United States

Since 1971 the United States has accounted for about 60 percent of world molybdenum output with a 1978 production of about 60 000 metric tonnes of the metal.

Table II-5 gives a breakdown of American molybdenum production by company and mine. The country's four largest producing companies accounted for about 92 percent of domestic mine output in both 1977 and 1978.

AMAX Inc. has been the United States' largest producer since the country became the world's leading world molybdenum source in the 1920's. The company operates two primary molybdenum mines in Colorado, Climax and Henderson, mill capacity at Climax is about 27-29 thousand tonnes of molybdenum annually. Henderson began production in 1976 and is expected to reach capacity output of 24 000 metric tonnes per year by 1980-81.[2]

AMAX thus dominates both world and domestic U.S. molybdenum supply. The company is vertically integrated and operates its own oxide, ferromolybdenum and chemical plants in Pennsylvania and Iowa. These plants have a combined annual conversion capacity of 32 000 metric tonnes of molybdenum per year. Overseas, the company operates conversion facilities in the Netherlands, Italy and England.

TABLE II-5

COMPANY / MINE OUTPUT - U.S.A., CANADA AND CHILE

COUNTRY	COMPANY	COMPANY SHARE IN DOMESTIC OUTPUT %		COMPANY SHARE IN WORLD OUTPUT %		MINES (*-PRIMARY)	MINE PRODUCTION (1000 TONNES)	
		77	78	77	78		77	78
UNITED STATES	AMAX	61.4	64.1	35.7	38.6	*CLIMAX	23.1	23.5
						*HENDERSON	10.9	14.7
	DUVAL	18.2	15.9	10.6	9.6	SIERRITA	8.6	8.2
						MINERAL PARK	1.5	1.4
	KENNECOTT	6.4	8.2	3.7	4.9	BINGHAM	2.9	4.2
						OTHERS	0.6	0.7
	MOLYCORP	6.6	4.2	3.9	1.9	*QUESTA	3.7	2.5
	ANAMAX	3.0	2.3	1.8	1.4	TWIN BUTTES	1.7	1.4
	MAGMA	2.2	2.3	1.3	1.4	SAN MANUEL	1.2	1.4
	OTHERS [1]	2.2	3.0	1.3	1.7	OTHERS	1.2	1.7
CANADA [2]	PLACER	47.3	44.3	8.2	6.2	*ENDAKO	7.7	6.0
						GIBRALTAR	0.1	0.1
	NORANDA	35.5	35.1	6.2	4.9	BRENDA	3.9	3.3
						*BOSS	1.0	0.8
						GASPE	1.0	0.8
	RIO ALGOM	11.2	13.3	1.9	1.9	LORNEX	1.9	1.9
	UTAH	6.0	5.2	1.0	0.9	ISLAND COPPER	1.0	0.9
	BETHLEHEM	-	0.9	-	0.1	BETHLEHEM	-	0.1
CHILE	CODELCO	100.0	100.0	25.3	29.3	CHUQUICAMATA	15.3	19.7
						TENIENTE	4.8	6.1
						SALVADOR	3.2	2.7
						ANDINA	0.8	0.6

* 1. Includes Cyprus, Asarco Cities Service, Inspiration, Union Carbide.

2. Shipments

Duval is the United States' second largest producer as a result of by-product production from the Sierrita mine in Arizona. As well as owning two other Arizona copper-molybdenum mines, Duval operates oxide and ferromolybdenum plants in the state.

Molycorp, Inc. (which was acquired by Union Oil in 1977) operates a primary molybdenum mine at Questa in New Mexico. Since producing a record 5200 metric tonnes of molybdenum in 1976, this mine has encountered lower grades and will likely be replaced by an underground mine in the same area (the Goat Hill deposit) in the mid-1980's. Molycorp's vertical integration includes an oxide/ferro molybdenum plant in Pennsylvania.

Kennecott produces molybdenum as a by-product at its Bingham, Ray, and Chino copper mines in Utah, Arizona, and New Mexico respectively. Of these only the Bingham mine is a major producer, with an output of from 3 to 5 thousand metric tonnes of molybdenum per year. Roasting of concentrates takes place at a plant near Salt Lake City.

Of the remaining producing firms in the United States, six others, accounting for about 8 percent of U.S. output, recover molybdenum as a by-product from copper mines in Arizona. These are, in order of declining output, Anamax, (a partnership between Anaconda and AMAX), Magma Copper Co. (a Newmont Subsidiary), Cyprus Mines Corp., Cities Service

Co., Inspiration Consolidated Copper Co., and Asarco Inc. Most of these firms' production is sold in concentrate form to dealers or other companies for further processing.

Recently improved copper markets have allowed resumed production at the Inspiration and Silver Bell (Asarco) mines, in addition Molycorp has announced its intention to produce from its Goat Hill deposit with start-up in 1983. A small amount of American production (less than half of one percent of total domestic output) comes from tungsten production at Union Carbide's Pine Creek mine in California. Kerr McGee Corp. also recovers a minor quantity of molybdenum from its New Mexico uranium operations.

Trade

The United States is the world's largest exporter of molybdenum. Exports over the last ten years constituted 56 percent of domestic mine output in that period. Major destinations for U.S. molybdenum output in 1978 were the Netherlands (about half of total exports) and Japan (about one-sixth). Other major customers for U.S. molybdenum were Belgium-Luxembourg, West Germany and the U.S.S.R. (see Appendix Table A-1). About 97 percent of molybdenum exports in 1978 were in the form of concentrate or molybdic oxide.

Summary of U.S. Supply Structure

The United States is the world's largest supplier of molybdenum, exporting over half of domestic output to world markets. The country's molybdenum output is dominated by four firms which have consistently accounted for about 90 percent of total production. These firms, led by AMAX, are for the most part vertically integrated into conversion of molybdenum to end-use products such as molybdic oxide, ferromolybdenum and ammonium and sodium molybdate. These products can be used directly in the production of steel, alloys and chemicals. Vertical integration among major molybdenum mining companies in the United States thus extends to the point of their final industrial consumption by steel and chemical producers.

2.2.2 Chile

Chile strengthened its position as the world's third largest molybdenum producer with a 1978 output of 13 000 metric tonnes of the metal. All Chilean molybdenum production is recovered as a by-product from four porphyry-type copper mines operated by the National Copper Corporation of Chile (Codelco-Chile).

State-owned Codelco was born from the 1971 nationalization of copper mines operated by Anaconda, Kennecott and Cerro. The company's largest mine, Chuquicamata, is also the largest copper producer in the world, with a capacity of 500 000 metric tonnes of ore per year. The operation recovers the greatest amount of molybdenum as a by-product from copper production of any world mine.

El Teniente, El Salvador and Andina are the other Codelco-owned Chilean molybdenum-producing mines (see Table I-5 for production breakdown); Andina began production in 1975, the other two mines in 1976. One has recently used a Noranda-patented leaching process in the expansion of its recovery plant.

Trade

Over 95 percent of Chilean molybdenum production is exported. The major market, accounting for more than half of Chilean exports, is Western Europe. (see Appendix Table A-2).

Japan is an area of increasing export trade, the Chilean exports to that country rising in 1978 to about 1400 metric tonnes of molybdenum from 689 in 1977.

Chilean exports are either handled directly by the producer, Codelco, or through a processing company, Molibdenos Y Metales S.A. (Molymet). Molymet converts the molybdenite concentrate it purchases from Codelco into molybdenum oxide (with by product recovery of rhenium) or ferromolybdenum.

Summary of Chilean Supply Structure

Chilean molybdenum production is monopoly controlled, with state-owned Codelco the only producer. Output is mainly exported, with Western Europe, and, more recently, Japan, the major customers.

About two-thirds of Chilean molybdenum exports are in forms other than molybdenite concentrate. Codelco has recently been oriented toward converting its molybdenite concentrates into more valuable products before export. Conversion to further processed forms is done by Molymet, a company which possesses conversion facilities but no mineral properties.

2.2.3 U.S.S.R.

The Soviet Union ranks fourth in world molybdenum production with an output of about 10 000 metric tonnes of the metal per year. Most of the country's resources and producing facilities are concentrated along its southern border, in Armenia and Central Asia.

Soviet production data is kept confidential because strategic metals are involved. Based on data compiled by Sutulov[3], however, a reasonable profile of the Soviet industry can be obtained.

Almost all molybdenum produced is recovered as a by-product from copper production. The Balkhash Copper complex at Kazakhstan in Central Asia is the largest operation with an output of 1500 to 2000 metric tonnes per year. Ore is milled from two mine sites, a primary porphyry molybdenum deposit and a large copper-molybdenum porphyry. Another Central Asian facility, the Almalyk plant in Uzbekstan, also produces by-product molybdenum. Using ore from the Kalmakyr copper-molybdenum porphyry, this operation yields about 1000 metric tonnes per year of contained molybdenum.

Several low-grade copper porphyry deposits, in Armenia, yield molybdenum as a by-product. These facilities apparently bear some similarity to the by-product molybdenum recovery operations in British Columbia copper mines. Armenian output totals about 3000 metric tonnes per year.

Another area of small by-product operations is Eastern Siberia, near the Chinese border. Production from several mines in the region totals about 1800 metric tonnes per year.

Trade

While molybdenum production in the Soviet Union has grown at a comparable rate to the expansion of the domestic steel industry, the country currently has a considerable trade deficit in the metal resulting in imports of about 6000 metric tonnes per year. Direct imports from the United States accounted for about a third of this total in 1978. The remaining two-thirds of imports are mainly American, Chilean and Canadian molybdenum that has been processed in Western Europe. Canadian molybdenum exports to the U.S.S.R. in 1978 were about 400 metric tonnes.

Summary of U.S.S.R. Supply Structure

Soviet molybdenum production is divided among many fairly small mines. Almost all output comes from by-product recovery of the metal at low-grade copper molybdenum porphyry deposits.

The country relies on the Free World for about 40 percent of her domestic molybdenum requirements. The bulk of imported molybdenum is produced in the Americas and processed in Western Europe.

2.2.4 Canada

Canada is second only to the United States as a world producer of molybdenum. The country's rise to this position of world importance began in the 1960's with the development of large, porphyry-type molybdenum and copper-molybdenum deposits in British Columbia. While Canada produced less than one percent of the world's molybdenum in 1960, by 1966 the country had passed both Chile and the Soviet Union in production, with a world share of 14.4% (see Table II-2).

Almost all of pre-1960 Canadian molybdenum production came from deposits in Quebec and Ontario. Today, however, British Columbia accounts for over 95 percent of domestic production. Of the 8 molybdenum-producing mines in Canada today, 7 are in British Columbia (the only producer not in that province being the Gaspe Copper mine operating in Quebec). Table II-6 gives a breakdown of Canadian molybdenum production over the past decade by mine (for a more comprehensive discussion of BC producers and prospects, see Section III, below).

Two companies dominate Canadian molybdenum production - Placer Development Limited, with a 44 percent share of domestic output in 1978 and controlling interest in two producing mines; and Noranda Mines Limited with a 35 percent share in 1978 and control of three producers. Noranda also has a 31.4% interest in Placer. Two of Canada's five molybdenum-producing companies thus accounted for about 80 percent of its output in 1978 (See Table II-5).

Molybdenum is converted to molybdic oxide at two roasting plants in the country, one at Placer's Endako mine in British Columbia and the other at *Eldorado Gold Mines' Duparquet,

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* - formerly Fundy Chemical International Ltd.

Table II-6

CANADA

MOLYBDENUM PRODUCTION BY MINE, 1969-78
(metric tons contained molybdenum)

COMPANY	MINE	LOCATION	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
EXISTING PRODUCERS												
PLACER DEVELOPMENT LIMITED	ENDAKO	ENDAKO, BC	8 530	8 273	6 525	4 190	5 388	5 466	6 849	6 838	6 928	6 359
	GIBRALTAR	McLEESE LAKE, BC	-	-	-	-	223	338	35	-	141	129
NORANDA MINES LIMITED	BRENDA	PEACHLAND, BC	-	3 675	4 355	4 557	3 786	3 466	3 837	3 636	3 810	3 311
	BOSS MTN.	WILLIAMS LAKE, BC	1 062	1 114	912	-	-	826	1 094	1 033	993	753
	GASPE COPPER	GASPE, PQ	123	170	185	211	126	25	142	300e	1 039	973
RIO ALGOM LTD.	LORNEX	HIGHLAND VALLEY BC	-	-	-	264	1 579	1 832	1 399	1 710	1 721	1 808
UTAH INTERNATIONAL LIMITED	ISLAND COPPER	PORT HARDY, BC	-	-	-	350e	200e	700e	650e	550e	910	923
BETHLEHEM COPPER CORPORATION	BETHLEHEM	HIGHLAND VALLEY BC	-	-	-	-	-	-	-	-	-	194
PREVIOUS PRODUCERS												
ANGLO-AMERICAN MINING COMPANY	PREISSAC	PREISSAC, PQ	500e	500e	300e	-	-	-	-	-	-	-
RED MOUNTAIN MINES LIMITED	RED MTN.	ROSSLAND, BC	335	266	365	-	-	-	-	-	-	-
CADILLAC MOLY MINES LIMITED	CADILLAC	CADILLAC, PQ	332	120e	-	-	-	-	-	-	-	-
KRC OPERATORS LIMITED	MT. COPELAND	REVELSTOKE, BC	-	200e	400e	350e	250e	-	-	-	-	-
KENNECOTT COPPER CORPORATION	B.C. MOLY	ALICE ARM, BC	1 363	1 504	1 250	265	-	-	-	-	-	-
TOTAL			14 771	18 608	16 606	10 668	11 552	12 653	14 006	14 067	15 542	14 450

Quebec plant. The Duparquet operation and Masterloy of Ottawa produce ferromolybdenum. (see Section V for more on further processing of molybdenum in Canada).

Trade

Canada exports about four-fifths of its molybdenum production making it the second largest exporter of the metal, behind the United States. Japan and Western Europe are the main markets for Canadian exports (see Section I). The United States is also a major destination for Canadian shipments. Canadian production is often sent to the U.S. for further processing and most is subsequently transferred to foreign markets.*

2.3 Factors Affecting World Supply

2.3.1 Primary Molybdenum Production

Primary molybdenum mines are those whose main or major output is molybdenum concentrate or ore. There are only six such mines among the 55-odd current world molybdenum producers, but these operations accounted for 50.1 percent of world production of the metal in 1977 and 49.2 percent in 1978. AMAX operates the Climax and Henderson mines, the

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* the actual quantities consumed in the U.S. and/or transferred to foreign markets are difficult to determine, however.

two largest primary operations in the world. Placer Development's Endako mine is the world's third largest.

Primary molybdenum ores have on average from 2 - 50 times the molybdenum content of ores used in the recovery of molybdenum as a by-product from copper production, however primary porphyry molybdenum deposits are often of comparable tonnage to copper porphyries. Primary moly-mines thus produce, on average, much more of the metal than by-product operations, and therefore the development of techniques for the exploitation of primary deposits has had an important effect on historical world molybdenum supply.

A major breakthrough of this nature occurred at the Climax mine in Colorado, when the old shrinkage stope method of mining was replaced by the block caving method in the mid-1930's. By the war years mill capacity had increased to 18 000 metric tonnes per day of ore from 1200 in 1932. The introduction of block caving, and the expanded recovery capacity that was associated with it, thus enabled molybdenum output to meet demand when the Second World War broke out, and established the Climax mine as the world production leader.

2.3.2 By-Product and Co-Product Production

A by-product is a secondary or additional product yielded in the process of production. A co-product is an output produced in conjunction with, and at a comparable rate as, another. In mining, these concepts are based primarily on the underlying economics. By-products are seen as outputs that have a minor contribution to the economics of an operation, and co-products are those which have a relatively large impact. In the pure sense, a by-product is yielded without the exertion of extra effort. In mining, by-product recovery requires extra effort and capital but outputs are still considered "by-products" if this impact is insignificant.

Production of molybdenum as a by-product or co-product (hereafter just "by-product") of other metals has had significant impact on molybdenum supply. Today, over 50 percent of the world's molybdenum output is recovered as a by-product, primarily from porphyry copper deposits (see Table II-7) While minor amounts of molybdenum are recovered from tungsten, uranium and bismuth-containing ores, over 95 percent of the by-product output of the metal comes from about 50 copper mines around the world.

The breakthrough in molybdenum by-product recovery took place at Anaconda's Green Cananea Copper Mine in Sonora, Mexico in the mid-1930's when a process for the separation of molybdenite from copper ore was pioneered. The new technology quickly vaulted Mexico to second place in world molybdenum production.

TABLE II - 7

WORLD MOLYBDENUM PRODUCTION BY TYPE 1977-78
(1000 Metric tons contained Mo)

	PRIMARY		BY-PRODUCT OR CO-PRODUCT	
	1977	1978	1977	1978
U.S.	37.7	40.8	17.8	19.0
CANADA	8.7	6.8	7.9	7.1
S. AMERICA	-	-	11.1	13.2
OTHER	1.2	1.2	10.8	11.1
TOTALS	47.6	48.8	47.5	50.4
%	50.1	49.2	49.9	50.8

The development at Green Cananea was of considerable importance to significant copper producers in the Southeast United States, where many porphyry copper deposits contained substantial amounts of molybdenite. Kennecott, holder of several such deposits, had soon developed a molybdenum recovery process for its Bingham and El Teniente mines in Utah and Chile respectively. The Kennecott process provided the basis for molybdenum recovery systems used today. As mining technology progressed and larger shovels, bigger trucks and other technological advances in earth moving, open pit mining and molybdenum recovery occurred, by-product molybdenum increased its share of total output. In 1957 molybdenum by-product production was only 17 percent of world output; today it has a greater than 50 percent share.[4]

2.4 Economic Effects of By-Product Production

With more than half of the world's molybdenum output coming from copper mines today, molybdenum supply has to some degree become dependent on copper markets. Poor markets for copper have been identified as a factor contributing to the short supply of molybdenum in recent years.[5]

This is undeniably a factor in United States supply, with poor copper markets in 1977 forcing the closure of the Cyprus Pima and Esperanza mines and reducing production at Sierrita, Mineral Park and several Kennecott operations, all by-product producers of molybdenum. The decrease in molybdenum output caused by copper production cutbacks in 1977 was more than offset by production increases at the Henderson primary mine in Colorado, however.

While by-product production is important in an aggregate sense, it must be remembered that by-product mines usually produce much less on an individual basis than primary operations and their independent impact is thus much less than that of primary mines.[6] A copper market slump would have to be devastating to have a quantum impact on molybdenum supply similar to, say, a strike at AMAX's primary mines. Nonetheless, copper markets are an undeniable factor in molybdenum supply, although one industry representative has expressed the view that less than 50% of the world's molybdenum production will come from by-product in the near future.

Some copper-molybdenum producers are equally as dependent on molybdenum as on copper in their production economics, especially in light of recent molybdenum prices. At Duval's Sierritta mine in Arizona and BC's Brenda operation, for example, high molybdenum and low copper heads make molybdenum indispensible to the mines' operation. In such cases copper and molybdenum are "true" co-products.

In some cases of by-product molybdenum recovery, molybdenum may actually have had a greater effect on cash flow than copper, as long as high molybdenum prices were gained for production. The addition of a by-product molybdenum recovery circuit can have very attractive economics, because most other costs of operation at the mine/mill (such as coarse and fine crushing, grinding and rougher and cleaner flotation) can be charged to copper production, and are thus sunk costs.

In addition, when copper prices are low the reduction in copper output which results from molybdenum recovery is a smaller opportunity cost than it would be if copper prices rose.* Thus a molybdenum recovery circuit can be added with the possibility of a profitable return on investment.

When molybdenum prices are high, by-product production of the metal may actually have a major effect on copper supply. Molybdenum content, even if it is minor, may help rationalize the development of otherwise economically marginal copper deposits, and stabilize the income of copper mines when copper markets falter.

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* The relationship between molybdenum and copper recovery is quite complex and subject to the content of each in ore milled.[7]

2.5 International Molybdenum Reserves*

2.5.1 Physical Resources

Molybdenum is contained in the earth's crust at an average concentration of 1.3 ppm (parts per million). This is comparable to concentrations of tungsten, tin, and uranium but is much lower than many other metals including copper, aluminum and iron (see below).

TABLE II - 8

CRUSTAL CONCENTRATION OF VARIOUS MINERALS

MINERAL	CONCENTRATION (ppm)
Gold	0.0035
Silver	0.075
Tungsten	1.1
Molybdenum	1.3
Tin	1.7
Uranium	1.7
Cobalt	25.0
Copper	63.0
Nickel	87.0
Iron	58 000.0
Aluminum	83 000.0

Source: Tilton, J.E., The future of Non-Fuel Minerals.

* See appendix I for discussion of methodology used in this section.

Total physical resources (obtained by multiplying crustal concentration by the weight of the earth's crust) are $2.83 \times 10'^{3}$ metric tonnes of molybdenum. It should be noted that of this amount the vast majority is not available under any current economic or technical scheme.

Distribution is mainly in three geological belts:

The Circumpacific Mountain Belt - the major area of molybdenum reserves, this belt begins in the Aleutian Islands of Alaska and runs down the western cordillera of the Americas to Tierra del Fuego in the south. Concentrations occur in north-central Chile and in the lower United States as an almost continuous belt from Texas to Idaho and Montana. Clusters of deposits occur in North America within the Colorado mineral belt, in Central British Columbia from Endako, through Alice Arm to Quartz Hill in southeast Alaska.

The Alpine Cancasian Cenozoic Belt - runs through southern Europe from Spain to Yugoslavia. Peak concentrations occur in Yugoslavia.

The Paleozoic Belt of the Siberian Shield - runs along the U.S.S.R./China border, with high values only in central Kazakhstan in the south-central Soviet Union. Important molybdenum deposits have also been reported in central and southern parts of China.

2.5.2 Deposit Characteristics

Five general types of molybdenum ore deposits can be identified:

1. Disseminated porphyry deposits
2. Contact-metamorphic deposits
3. Quartz veins
4. Pegmatite and aplite dykes
5. Bedded deposits in sedimentary rocks.

The first category is by far the most important to world physical resources and production, accounting for about 90 - 95 percent of the former and almost all of the latter. These deposits are generally low-grade and large volume and thus are appropriately exploited using large-scale open pit or underground block caving methods.

The primary economic mineralization of such deposits is mainly molybdenum or copper. In primary molybdenum porphyries, accompanying minerals are often tungsten, tin, bismuth, lead, zinc, and uranium. In copper porphyries, molybdenum presence is often minor and difficult to detect by visual inspection. There are many more identified copper-molybdenum than primary molybdenum porphyries, though world production from each type is roughly comparable today.

Several world mines have exploited the other types of deposits listed above. The world's first molybdenum mine at Knaben, Norway, worked a contact metamorphic deposit. The Questa mine in New Mexico first began mining a quartz-vein deposit. Quebec molybdenum-bismuth producers in the Cadillac area have mined pegmatite-type orebodies. Generally speaking, however, these types of deposits have little importance to the reserves and supply of the metal in comparison to porphyries.

2.5.3 Political Distribution:

Physical resources of molybdenum have been estimated by Sutulov (1978) by totalling the confirmed reserves of the world's major deposits. These deposits include operating mines (whether or not they recover molybdenum currently) and other known deposits or discoveries.

TABLE II - 9

Identified World Molybdenum Resources, 1977

Country	Average Grade (% Mo.)	Mo content (100 metric tonnes)
Canada	0.049	2 080
United States	0.039	5 559
Latin America	0.02	4 369
Asia	0.02	600
U.S.S.R.	0.026	640
Europe	0.06	1 400
Australia & Oceania	0.033	200
World Total		14 848

Source: Sutulov, A. World Molybdenum Encyclopaedia, 1978.

The distribution of resources closely parallels the pattern of world output, with the United States, Canada, and Chile as the leaders. The Soviet Union is an exception, with a tenth of the world output and only 4 percent of resources as identified above.

Canada, with 7.5 percent of the world's land area, has about 14 percent of global molybdenum resources. British Columbia accounts for over 85 percent of Canada's molybdenum resources. Canada's porphyry copper, particularly those in British Columbia, show on average a considerably higher molybdenum-to-copper ratio than those in the Soviet Union and the United States. This suggests molybdenum content is more important to the economics of their exploitation than it is to copper deposits in other areas of the world.

South Central American resources are contained mainly in the large copper porphyries of Chile and Peru. Some major deposits (none currently mined) are also found in Argentina, Equador,Columbia, and Panama. Elsewhere in Latin America, Mexico contains a number of noteworthy copper-molybdenum deposits along its border with the United States.

United States deposits are mainly in Colorado,Arizona, New Mexico and Utah. Other massive porphyries are found in Washington, Montana, Idaho and Alaska.

Australian deposits are minor in comparison to those in the Americas. North Korea, Japan, Burma, China and Iran have deposits of some importance. In the southwestern Pacific, the Phillipines, New Guinea and Australia have some resources of the metal.

Europe, except for deposits in Yugoslavia, Rumania and Bulgaria, is practically devoid of molybdenum resources. The same is true of Africa, in which only Morocco and Sierra Leone have, at best, poor deposits. The African continent is almost a "blank spot" on a map of world molybdenum resources.

The concentration of resources in the non-communist world is thus great, with western industrial countries controlling over two-thirds of the total. Underdeveloped countries, especially those in Africa, have almost no resources of the metal. Among communist nations, the Soviet Bloc has resources but is dependent on outside sources of supply. China's resources, while undefined, could be quite large.

2.6 Economic Reserves

Reserves are defined as those resources of the metal thought to be economically exploitable given today's prices and technology. Table II-10 gives a breakdown of world reserves, as defined by existing mines and prospects. Prospect reserves are included at their expected date of development. (Under the definition of economic reserves used in this report,

TABLE II - 10

WORLD MOLYBDENUM RESERVES : EXISTING AND PROSPECTIVE MINES

(thousands of metric tons)

COUNTRY	RESERVES OF EXISTING MINES	RESERVES OF PROSPECTS BY EXPECTED STARTUP DATE			
	1979	1980-85	1986-90	1991 +	PROSPECTS TOTAL
U.S.A.	2 999	846	1 338	103	2 287
Chile	2 253	-	100	-	100
U.S.S.R.[1]	594	N.A.	N.A.	N.A.	N.A.
Canada	357	269	121	450	840
China[2]	227	N.A.	N.A.	N.A.	N.A.
Peru	140	251	-	-	251
Other[3]	193	275	330	194	799
TOTAL	6 763				

1 - Sutulov, Molybdenum Encyclopedia, Vol 1 (1978).

2 - U.S. Bureau of Mines, Molybdenum Commodity Profile (1979)

3 - Includes Bulgaria, Greenland, Iran, Japan, Korea, Mexico, New Guinea, The Phillipines, Yugoslavia.

N.A. - not available.

a deposit should not be considered in a reserve total until it is exploited as a mine - see Appendix I).

A different picture of molybdenum resources is given than by the physical resource data in Table II-9. While the United States still leads, Chile is close behind on the weight of the massive reserves of the Chuquicamata and El Teniente copper porphyries. Canada lags behind the Soviet Union in reserves.

It is important to remember that reserves are calculated on the basis of the known metal content and not on recoverable material. This has major implications in the case of Chile, for example, where molybdenum reserves are all contained in copper porphyries. Since recovery of molybdenum contained in copper porphyries (at 50-60 percent of contained Mo) is much lower than from primary molybdenum porphyries (at 75-90 percent), Chilean molybdenum reserves are less proportionally than indicated. Canada and the United States, with significant reserves in primary deposits, will have proportionally greater recoverable molybdenum than is indicated in Tables II-9 and II-10.

The data on reserves at prospective mines show that the United States is likely to retain its position as the world's reserve leader for many years to come. Chile will likely continue to be important on the basis of existing reserves, while Canada will solidify its position through the reserves of new producers. In the "other" category, substantial new deposits, especially in Latin America, will increase the share of world reserves contained in less developed countries.

Section II Footnotes

1. World Production Figures are from the following sources:

   (a) 1970 and before: Sutulov, A., International Molybdenum Encyclopaedia, Vol. I, 1978, pp. 298-304

   (b) 1971 and later:

   - United States Bureau of Mines, Mineral Commodity Summaries, 1979, Molybdenum Commodity Profile May 1979, Minerals Yearbook, various years, molybdenum section.

   - Canada, Energy, Mines and Resources Minerals Yearbook, Molybdenum reprints, various years from 1971 on.

   - British Columbia, Ministry of Energy Mines and Petroleum Resources, Annual Reports

2. AMAX, Annual Report 1978

3. Sutulov, A. Molybdenum and Rhenium, Concepcion, 1976, pp. 116-117

4. Tex Report, January 19, 1979

5. See, for example, Goth, J.W., "Molybdenum", E.&.M.J. March 1979, or Dept. of Energy, Mines and Petroleum, Molybdenum preprint 1977, or Sutulov, A. "Molybdenum, The Energy Metal...", World Mining, March 1978

6. Energy, Mines and Resources, Molybdenum Preprint, 1977 and Sutulov, A., op.cit.

7. See Shirley, Joseph F, "Optimizing the By-Product Circuit", World Mining, July 1978.

3. B.C. SOURCES OF SUPPLY

3. B.C. SOURCES OF SUPPLY

British Columbia currently accounts for about 95 percent of Canadian production of molybdenum from five by-product and two primary molybdenum mines. The province is a major world producer in its own right, with a 13 percent share of world molybdenum output in 1978.

3.1 Historical Profile

The province's first molybdenum output came from five small high-grade deposits (Golconda, Index, Molly, Tidewater and Victoria) mined between 1914 and 1918. It was not until the 1960's, however, when the mining of large, low-grade molybdenum and copper molybdenum porphyry deposits began, that BC molybdenum production grew to significant levels.

The Bethlehem copper mine in the Highland Valley recovered molybdenum from its copper ores between 1964 and 1966. Large scale production first occurred in 1965, when two primary mines, Endako and Boss Mountain, began operations. In 1966, Coxey, a small 400 mtpd (metric tonnes per day) open-pit mine began operations near Rossland. The operating company, Red Mountain Mines, never ran the mine without a loss and it closed in 1972 after producing about 1650 mt of molybdenum.

The BC Molybdenum mine, at Kitsault on BC's north coast, began production in 1967. The mine, owned by Kennecott Copper Ltd., encountered problems of lead content in its concentrates. In 1972 Kennecott closed BC Moly after it had produced more than 10 000 mt of concentrates in its 6 years of operations. Weak market conditions were blamed for the closure.

Another short-lived producer was King Resources' Mt. Copeland mine, which worked a small high-grade molybdenum deposit from 1970 to 1973. In its 4 years of operation, about 1 200 mt of molybdenum were produced.

Endako's capacity was doubled in 1968, and by 1970, with the startup of Noranda's Brenda Mine and the Mt. Copeland and BC Moly mines in operation, British Columbia molybdenum production reached an all-time peak of 17 800 mt (shipments peaked later, in 1977 - see Table III-1).

In the early 1970's, weak markets saw the closure of the BC Moly, Mt. Copeland and Boss Mtn. mines - all primary molybdenum producers. At the same time, two copper-moly mines, Lornex and Island Copper, began production in 1972 and a third Gibraltar, started in 1973. Thus, while molybdenum markets were slumping in that period, copper showed promise and by-product production increased.

Since 1971-3, when mine closures and reduced output at other mines like Endako caused a decrease in production, British Columbia molybdenum output has climbed steadily, chiefly through increased recovery by copper by-product producers of the metal. Lornex and Island Copper, for example, had initial difficulties with molybdenum recovery but were able to resolve them and have consistently increased output since startup. Gibraltar actually closed its molybdenum recovery circuit in 1975 when it was deemed uneconomic, but resumed recovery of the metal in 1977.

In 1974 the Boss Mtn. mine was re-opened and by 1975 production had reached near-peak levels of about 1 000 mtpy. Other than the re-opening of Gibraltar in 1977, the only additional producer since 1974 has been Bethlehem, where a molybdenum recovery circuit was added and began production by mid-1978.

The province's production was down in 1978, due primarily to decreased output at the largest producers, Endako and Brenda. A strike at Gibraltar,and lower ore grades and hence output at Boss Mtn. were also contributing factors in this decrease.

3.2 Performance of the BC Molybdenum Industry

Table III-1 shows BC molybdenum shipments since 1960 and their associated values. (see following page)

Table III-1

British Columbia - Shipments of Molybdenum 1960-78

Year	Quantity (metric tons)	Value (1 000 $)	% of BC metal prod.	% of BC mineral prod.
1960	2.5	9.5	*	*
1961	-	-	-	-
1962	-	-	-	-
1963	-	-	-	-
1964	12.8	47.0	*	*
1965	3 306.3	12 405.3	7.0	4.4
1966	7 754.1	27 606.1	13.2	8.2
1967	7 945.8	31 183.1	13.2	8.1
1968	8 981.0	32 552.7	13.0	8.0
1969	12 064.4	47 999.4	19.1	10.3
1970	14 168.7	52 561.8	17.0	10.8
1971	9 926.7	36 954.9	12.3	7.0
1972	12 719.4	43 260.3	11.6	6.8
1973	13 785.3	51 851.5	6.5	4.7
1974	13 789.8	60 791.6	8.0	4.8
1975	13 026.6	71 201.4	12.1	5.2
1976	14 088.7	94 109.1	14.6	6.2
1977	15 522.0	142 058.0	19.9	7.9
1978	13 055.2	167 714.2	20.5	8.4

Source: B.C. Ministry of Energy, Mines and Petroleum Resources, Annual Report, 1978.

In terms of the total value of metals and minerals produced in the province yearly, revenues from molybdenum sales quickly reached a level of significance in 1965. In 1970 the value of molybdenum produced reached a peak share of provincial mineral output, at 10.8 percent.

Among metals, molybdenum had passed both iron and silver in value of production by 1966. The metal surpassed lead in 1967 and zinc in 1974. By 1976 molybdenum was the province's second leading metal by value next to copper, and it has held and strengthened that position since then.

In 1978 molybdenum, with production valued at $167.7 million, was the province's fourth most important mineral next to coal ($382.9 million), natural gas ($401.4 million) and copper ($431.7 million).

3.2.1 By-Production and Co-Production

Four of British Columbia's molybdenum producers, Bethlehem, Gibraltar, Island Copper and Lornex, received less revenue from molybdenum than for their copper concentrate outputs in 1978. These mines can thus be classified as by-product producers. The Brenda mine received greater revenues from molybdenum than copper production and thus must be considered a co-producer. The other producers, Endako and Boss Mtn., produce only molybdenum.

3.2.2 Impacts on Production

A number of impacts of molybdenum production in BC have been listed below. Since it would be inappropriate to attribute the impacts of a by-product molybdenum producer solely to molybdenum production, co-product and primary producer impacts are listed separately from by-product producer impacts.

3.2.3 Direct Employment

By-product producers employed a 1978 average 2 250 persons at the four operations, or 21 percent of total employment in the province's metals production sector[1]. Employment at co-product and primary mines was a 1978 average 1 398 persons, 13 percent of metal sector employment. The average hourly wage for mine/mill workers from all BC molybdenum producers was $9.05 in 1978.

3.2.4 Energy Use

Use of selected energy inputs in 1978 is summarized below:

Table III-2

Energy Use by Molybdenum Producers, 1978

	Mine Type	
Energy Input	By-Product	Co-Product & Primary
Gasoline (1 000 Imp.Gals)	773	239
Diesel (1 000 Imp.gals)	10 935	2 545
Electricity (Millions kwh)	991	404

Electricity consumption shown above constitutes 5.5 percent of BC Hydro's non-residential electrical output for the year for by-product producers, and 2.4 percent for co-product and primary producers[2].

3.2.5 Consumption of Mining/Milling Inputs

In 1978 by-product molybdenum producers consumed $78 million worth of materials, containers, supplies and other non-energy inputs used in the mining and milling processes. This figure was $36 million for co-product and primary producers in the same year.

Table III-3

Taxes Paid by BC Molybdenum Producers, 1978

Type of Tax	(Payment ($ millions) By-Product	Co-Product & Primary
Municipal	4.1	0.9
Provincial	4.9	14.7
Federal	3.4	15.3

Co-products and primary producers paid significantly more provincial and federal taxes than by-product producers. By-product producers paid more municipal taxes.

3.3 Current BC Molybdenum Producers Profiled

Brief profiles of British Columbia's existing molybdenum producers appear below. Total reserves of the metal in BC were 303.1 thousand metric tonnes in 1978, or 88.2% of total Canadian producer reserves. (See Table III-4).

3.3.1 Bethlehem (Bethlehem Copper Corporation)

The Bethlehem mine began operation in 1962 and recovered molybdenum from its copper ore briefly, from 1964 to 1966. In 1977 a molybdenum recovery circuit was added at a cost of about $1 million. Capacity of the circuit, which began production in 1978, is between 300 and 350 mtpy of molybdenum.

Bethlehem workers live mainly in Ashcroft with some in Cache Creek, the Nicola Valley and Kamloops. Ashcroft relies on mining for only 30 percent of resident employment, with ranching and services providing the main source of work [5].

Ore reserves were expanded in 1978 with the discovery of additional reserves on the edge of the Jersey Pit.

Earning per share fell from $1.39 in 1974 to $0.14 in 1977, recovering to $0.70 in 1978 [3]. The company's earnings have shown considerable growth since the addition of the molybdenum circuit and increased metal prices, with six-month share earnings to June 30 1979 quadrupling to 70.5¢ per share, as opposed to 15.8¢ per share in the same period in 1978 [4].

3.3.2 Boss Mountain (Noranda Mines Ltd.)

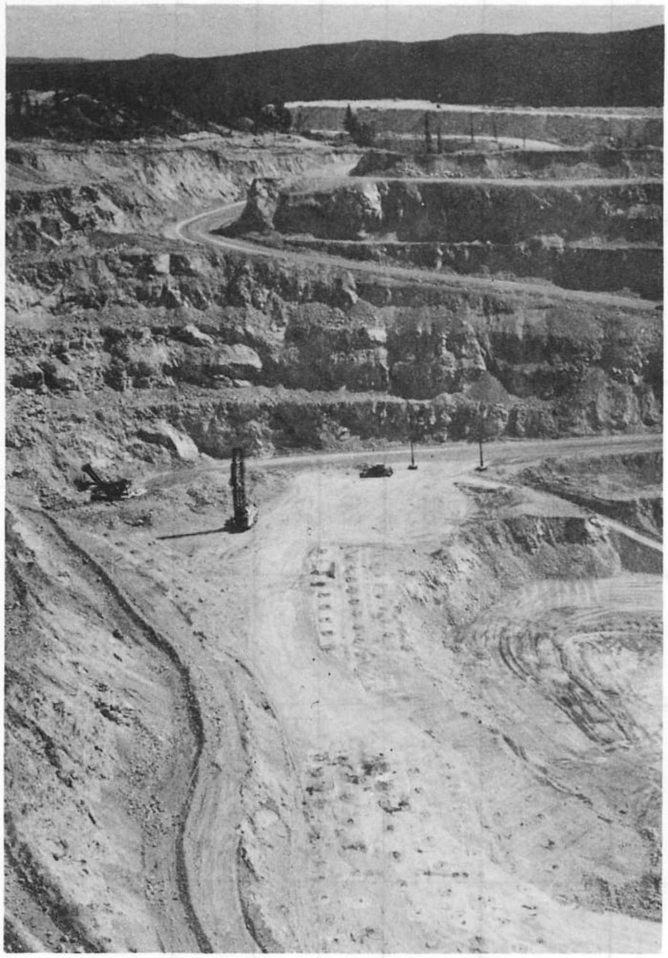
This primary molybdenum operation started in 1965 but the mine was closed between 1971 and 1974 due to poor market conditions.

Table III - 4

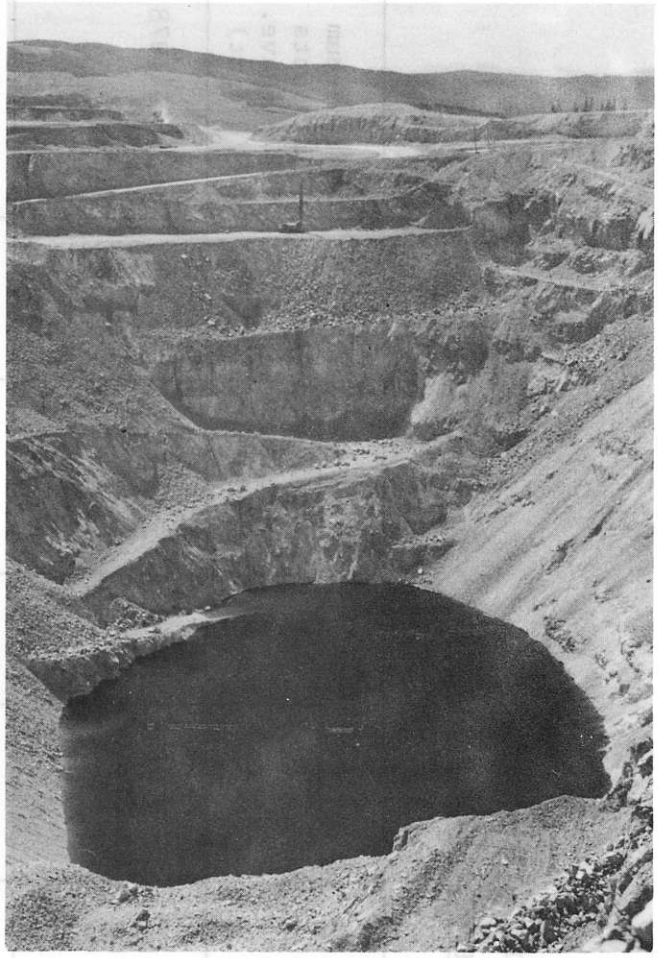
B.C. Molybdenum Producers Profile

Mine	Ownership	Type	Ore Reserves			Mill Capacity (mtpd)	Molybdenum Shipments 1977-78 ave. (1 000 mt)
			Mo %	Cu %	Contained Molybdenum (1 000 mt)		
Bethlehem	Bethlehem Copper Corp. 100%: Newmont 22.8% Gulf Res. 25.8% Cominco 39.3%	By-Product Open Pit	0.01 (estimate)	0.42	6.1	18 600	started 1978
Boss Mountain	Noranda Mines 100%	Primary Underground/Open Pit	0.186	-	4.6	1 590	879
Brenda	Brenda Mines Ltd: Noranda 50.9% Nippon 7.6% Mitsui 0.3%	Co-Product Open Pit	0.04	0.165	32.1	27 200	3 589
Endako	Placer Development Ltd. 100%: Noranda 31.4%	Primary Open Pit	0.082	-	162.9	24 500	6 861
Gibraltar	Placer Development Ltd. 71.9%	By-Product Open Pit	0.009	0.36	20.8	36 300	128
Island Copper	Utah Mines Ltd. 100%	By-Product Open Pit	0.015	0.5	27.7	34 500	924
Lornex	Rio Algom Ltd. 68.1% Teck Corp. 20.8%	By-Product Open Pit	0.012	0.406	48.9	40 900	1 855

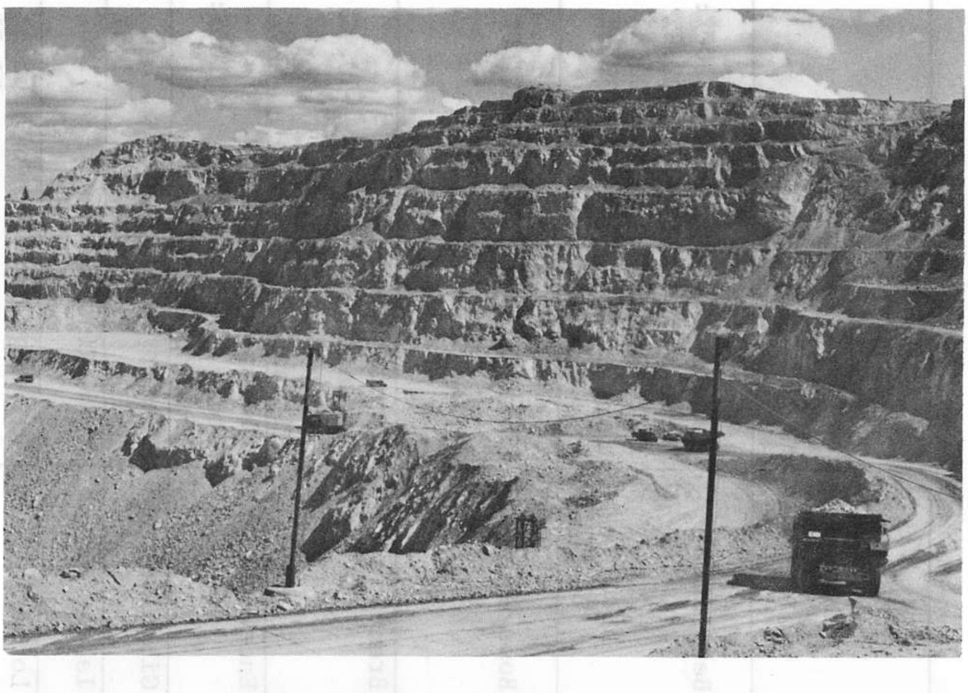
BETHLEHEM MINE, HIGHLAND VALLEY, B.C.



Drilling in the Iona Pit



Ground water in the Jersey Pit



Ore Trucks in the Iona Pit

Due to falling ore reserves a small open pit was added to the original underground operations in 1978. Production of molybdenum is currently about 50% from underground and 50% from open-pit but the latter is not expected to produce after 1980.

Workers live in the company town of Hendrix Lake, five miles from the minesite.

3.3.3 Brenda (Noranda Mines Ltd.)

Brenda is a true co-product producer of molybdenum, deriving a greater, but comparable, amount of its revenues from its molybdenum than its copper output. Mining, which began in 1969, is by open-pit methods. The mill includes a leaching plant, necessitated by lead and copper content in molybdenum concentrates produced.

Most workers live in Peachland, 18 miles from the mine on the shore of Okanagan Lake. Many live in Kelowna and Penticton.

Earnings per share rose from $2.21 in 1977 to $3.14 in 1978. Increased molybdenum prices will push this higher in 1979.[6]

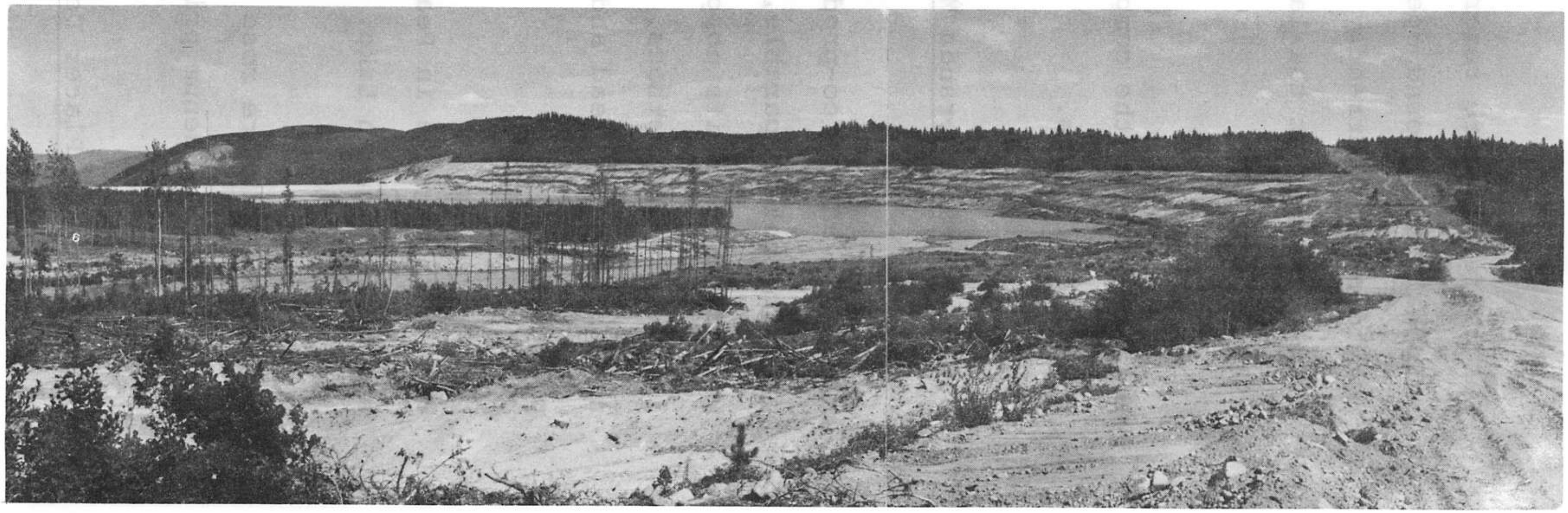
3.3.4 Endako (Placer Development Ltd)

The Endako mine is British Columbia's largest molybdenum producer, and fourth largest in world production. Operations, which include

BRENDA MINE, OKANAGAN AREA, B.C.

Brenda Mine from access road

Ore trucks and shovel working a bench in the Brenda pit



Brenda Tailings Pond

the mining and milling of molybdenite ore and the roasting of concentrates, began in 1965. Roasting capacity has been increased steadily since startup to its present level of 7 700 mtpy of contained molybdenum. Plans are to increase this to 10 800 mtpy by 1981.

Most Endako workers live in Fraser Lake, where about three quarters of employment is provided by the mine and the remainder being in forestry and services. A few workers live in Burns Lake and Vanderhoof.

The Endako mine has been very important to Placer's earnings in recent years, providing $1.54 of Placer's 1977 net earnings per share of $1.78, and $1.62 of $1.67 in 1978. In the first six months of 1979 Placer earnings per share tripled to $3.01 from 92¢ in the same period in 1978.

A work stoppage began at the mine on February 15, 1979, and continued until November 2, 1979. The consequent disruption of supply aggravated the already serious world shortage of molybdenum since the mine was operated at one third capacity during that period (see Section IV).

3.3.5 Gibraltar (Placer Development Ltd.)

Gibraltar is a minor by-product producer of molybdenum. Recovery of the metal was resumed in 1977 after closure of the molybdenum circuit for most of 1975 and all of 1976. A 31-week strike, lasting until February 1979, has reduced recent production.

The operation has had financial difficulties in recent years, operating at a loss in both 1977 and 1978.

In the first six months of 1979 the company reported earnings of 60 cents a share, however, largely due to record high prices for its molybdenum extract, which Placer sold by tender. Prices paid for this output have been close to spot market levels.[7]

3.3.6 Island Copper (Utah International)

First shipments from this by-product molybdenum producer were in 1971 and production has increased quite steadily since then. Port Hardy is the mine townsite, but the town relies on mining for less than half of its employment, with the balance taken up by logging, fishing and services. The District of Port Hardy, incorporated in 1965, includes the minesite.

The mine's ore reserves are characterized by a high rhenium content (up to 0.2% on 100% MoS_2). Molybdenum concentrates are exported to the United States where they are roasted and the rhenium extracted. Utah experimented with on-site roasting but elected to export for further processing.

3.3.7 Lornex (Rio Algom)

Currently Canada's largest metal mine and BC's largest producer of by-product molybdenum, Lornex began operations in 1972. Design milling capacity of 34 470 mtpd of ore was reached by 1973 and since 1976 the milling rate has averaged 42 600 mtpd of ore.

The townsite of Logan Lake was built as part of the mine development. Logan Lake is 11 miles east of the mine and was incorporated in 1970. A few workers, about 10 percent of the mine workforce, live in the centres of Ashcroft, Merritt and Kamloops, each about 30 miles from the mine.

Lornex earnings per share dropped to $0.08 in 1975 but recovered to $1.93 in 1976, $0.94 in 1977 and $1.74 in 1978. Healthy gains were shown in 1979, with six-month earnings per share of $1.91 (compared to $0.54 in the first half of 1978) reported [8].

Lornex plans to have its concentrates toll-roasted at Endako once expansion in roasting capacity there is completed. Concentrates are currently sold directly to Phillip Bros., an international metals company.

3.4. Theoretical Geological Potential [9]

British Columbia is one of the world's major areas of molybdenum mineralization. The Canadian Cordillera, in which BC's deposits are

LORNEX OPEN PIT, HIGHLAND VALLEY B.C.

found, is part of the Circumpacific Mountain Belt, which stretches south to Tierra del Fuego. The world's major molybdenum deposits in Colorado, Arizona and Chile, are located in this belt.

3.4.1 Types of BC Molybdenum Deposits

Molybdenum deposits in the province are of four major types - porphyry, pegmatite, quartz vein and skarn.

Porphyry-type molybdenum deposits and copper-molybdenum deposits dominate the province's molybdenum resource. A porphyry deposit is a large low to medium grade deposit related to volcanic or igneous rock, in which conspicuous crystals are usually set in a fine-grained ground mass. All the the current molybdenum-producing mines in the province work such deposits. Generally, the distribution of major porphyry molybdenum and copper-molybdenum deposits in the Province is similar.

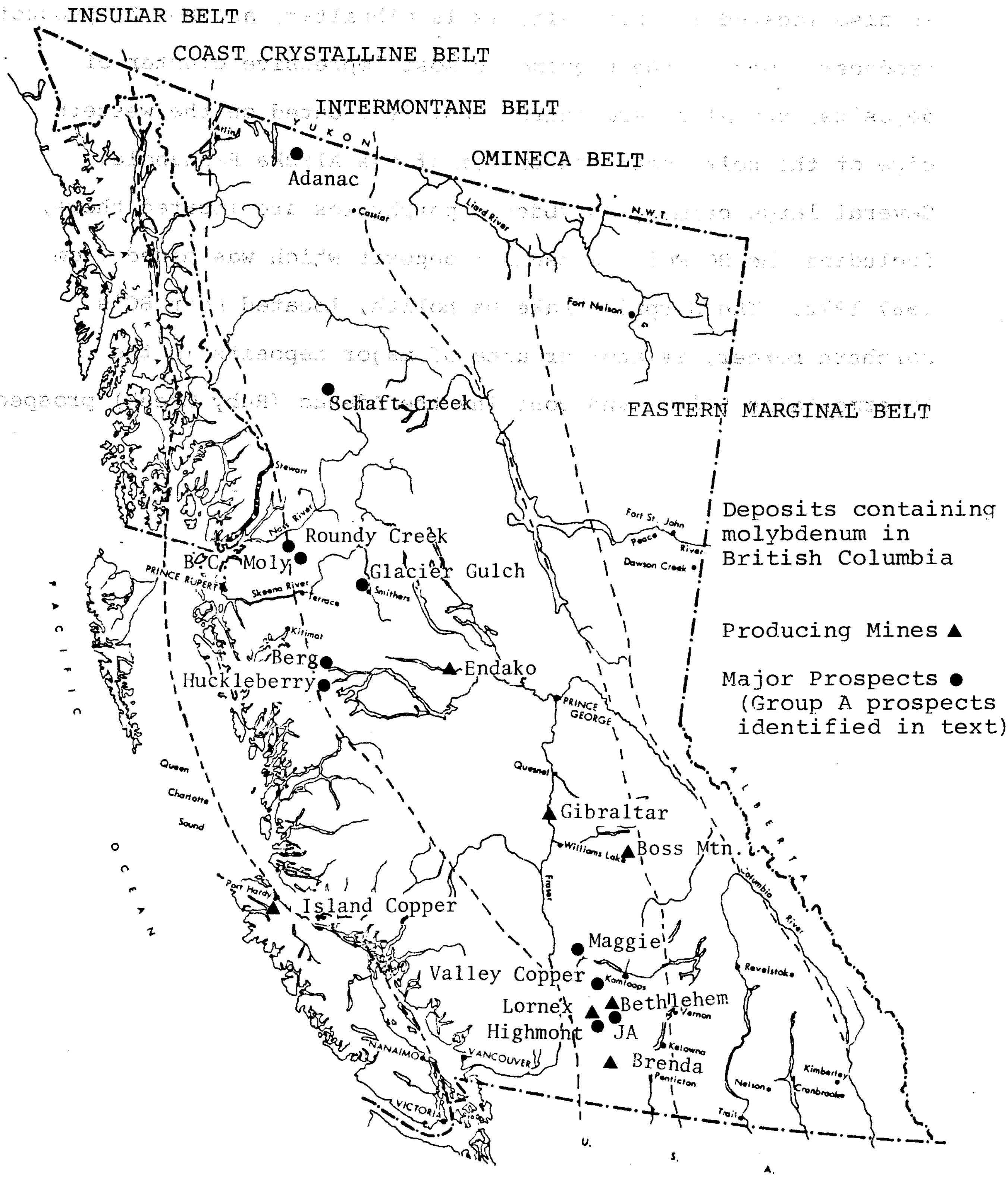
The only major pegmatite deposit to have been identified and/or exploited is the Mt. Copeland mine, which operated from 1970 to 1973. Quartz-vein type deposits are often found in the proximity of a porphyry deposit. An example is the Endako deposit, which has several such veins associated with it. Minor molybdenum producers that worked such deposits in the pre-1960 period were the Golconda mine at Ollola, the Index mine near Lilloett, and the Molly mine near Salmo. The only skarn-type to have been worked is the Red Mountain (Loxey) mine near Rossland, which produced 1655 mt of molybdenum between 1966 and 1972.

3.4.2 Distribution of BC Molybdenum Deposits

The Canadian Cordillera contains five tectonic (structural) belts within which the geology is dominated by rocks of a similar age, evolution and history. In addition, each belt shows a characteristic molybdenum mineralization. Figure III-1 shows these belts and the major molybdenum and copper-molybdenum deposits contained within each. Currently operating producers and prospects (as identified below) are also shown.

The Eastern Marginal Belt (occupying the general area of the Rocky Mountains) contains no identified molybdenum deposits. Moving west, the Omineca Belt contains several deposits in the northern and southern regions. Near Revelstoke, for example, the Mt. Copeland mine worked a pegmatic-type deposit. Omineca is the only belt to contain skarn-type deposits of any magnitude.

The Intermontane Belt, which runs down the interior of the province, contains most of British Columbia's porphyry-type molybdenum and copper-molybdenum deposits, including six of the seven producing mines. In the Highland Valley area near Kamloops, molybdenum occurs in varying grades with copper in large porphyry deposits and is currently recovered as a by-product at the area's Lornex and Bethlehem open-pit mines. The belt also contains the Brenda mine, with its high molybdenum to copper content, and the Endako mine, the third largest primary producer in the world. The province's only other primary molybdenum mine, Boss Mountain,


INSULAR BELT
COAST CRYSTALLINE BELT
INTERMONTANE BELT
OMINECA BELT
EASTERN MARGINAL BELT
Deposits containing molybdenum in British Columbia
Producing Mines ▲
Major Prospects ●
(Group A prospects identified in text)
Adanac
Schaft Creek
Roundy Creek
B.C. Moly
Glacier Gulch
Berg
Huckleberry
Endako
Gibraltar
Boss Mtn.
Island Copper
Maggie
Valley Copper
Lornex
Bethlehem
Highmont
JA
Brenda
YUKON
N.W.T.
Atlin
Cassiar
Liard River
Fort Nelson
Stewart
Nass River
PRINCE RUPERT
Skeena River
Terrace
Smithers
Kitimat
Fort St. John
Peace River
Dawson Creek
PRINCE GEORGE
Quesnel
Williams Lake
Fraser
Queen Charlotte Sound
PACIFIC OCEAN
Port Hardy
Kamloops
Vernon
Kelowna
Penticton
Revelstoke
Columbia River
ALBERTA
Kimberley
Cranbrook
Nelson
Trail
NANAIMO
VANCOUVER
VICTORIA
U. S. A.

is also located in this belt, as is Gibraltar, another by-product producer. One of the province's most impressive cluster of deposits, the Alice Arm intrusions, is located on the western edge of the belt, near the bottom of the Alaska Panhandle. Several large primary molybdenum porphyries are located there, including the BC Moly (Kitsault) deposit which was mined from 1967-1972. The Surprise Lake batholith, located near BC's northern border, is another area of major deposits in the Intermontaine Belt, and contains the Adanac (Ruby Creek) prospect.

In the Coast and Insular Belts molybdenum mineralization is more sporadic, but several large porphyry deposits are identified. Island Copper, recovering molybdenum as a by-product, is the largest such deposit and the only molybdenum producer in these regions.

3.5. BC Molybdenum Prospects

3.5.1 Committed for Production

Deposit	Company	Reserves	Expected Startup	Annual Output (mt contined Mo)
Highmont	Teck	132 million mt 0.047% Mo. 0.027% Cu.	1980-81	2000 - 2300
Kitsault (BC Moly)	AMAX	95 million mt 0.115% Mo.	1982	4000 - 4500

3.5.1.1 Highmont (Highmont Mining Corporation)

Teck Corporation, with a 53% interest in Highmont Mining and a 30% interest in the Highmont property, plans to spend $125-150 million to develop this copper/molybdenum mine in the Highland Valley of BC. Preparatory work on the deposit, which borders the Lornex Mine property on the south and west, began in May of 1979. Planned milling rate is 25 000 tonnes per day, and the operation is expected to employ 400. Molybdenum output will be sold to Metallgesellschaft of Germany, a company which recently became Teck's second largest shareholder. The planned annual production of 227 000 mt of copper concentrates will be sold through Marc Rich of New York. A mine life of 13 to 15 years is anticipated by the amount of indicated reserves [11].

3.5.1.2 Kitsault (Amax of Canada)

AMAX plans to reopen this primary molybdenum mine which was operated by Kennecott from 1967 to 1972. The original plant, designed to process 6 000 tonnes of ore per day, will be expanded to 12 000 tonnes per day and a concentrate leaching plant will be installed to reduce lead content. Access to Terrace will be made possible through a proposed road inland. Total investment required to develop this property, which AMAX bought from Kennecott at a cost of $2.62 million is estimated at $135 million (U.S.) While AMAX believes the access road is important to reduce the isolation of the community, the company also plans to use it for trucking concentrate inland to Endako for roasting. Heavy snowfall, as is characteristic for the area, may restrict winter access in any case.

3.5.2 Prospects

A list of the province's major molybdenum prospects appears below. Prospect categories are described as follows:

1. Substantial Development

   Prospects for which extensive drilling and geological exploration has taken place. Most have undergone an economic feasibility study. Ore reserves are well documented and potential is clearly established.

2. Partial Development

   Less development than Group A prospects. Available information indicates less development potential than Group A prospects, but more information required.

3. Less Development or Undocumented

   Ore reserves less documented, or less indicated potential than Group B prospects. Apparent potential in some cases but more exploration and documentation required.

3.5.2.1 Substantial Development

+	J.A. Zone	Bethlehem Copper Corp.
	Glacier Gulch	Climax Molybdenum Corporation of British Columbia
	Ruby Creek (Adanac)	Placer Development Ltd.
	Trout Lake	Newmont-Esso Minerals
*	Valley Copper	Cominco-Bethlehem
+	Berg	Placer Development Ltd.
+	Huckleberry	Kennco Exploration (Western) Ltd.
+	Maggie	Bethlehem Copper Corp.
	Roundy Creek	AMAX of Canada
+	Schaft Creek	Teck Corporation
+	Schaft Creek II	Paramount Mines Ltd.

3.5.2.2 Partial Development

	Ajax	Newmont M.L.
*	Axe	Adonis M.L.
	Bell Moly	AMAX of Canada
	Carmi	Vestor Exploration Ltd.
+	Catface	Catface M.L. (Falconbridge)
+	Krain	Initial Development Ltd.
	Lucky Ship	AMAX Exploration Ltd.
	Mt. Haskins	Della M.L.
	Mt. Thomlinson	AMAX Exploration Ltd.
+	OK	Golden Granite M.L.
+	Ox Kae	Silver Standard M.L.

Partial Development cont

+	Poison Mountain	Copper Giant M. Corp. (Long Lac)
+	Poplar	Utah M.L.
	Red Bird	Ashfork M.L. (Phelps-Dodge)
	Salal Creek	BP Minerals - Utah M.L.
	Storie (Huntsman)	New Jersey Zinc Expl.(Canada) Ltd.

3.5.2.3 Less Development or Undocumented

+	Canam	GM Resources
	Cascade Moly	New Cascade M.L. (Maloney Steel)
+	Eagle	Nuspar M.L. - Imperial Oil
	Gem	Gemex
	Giant	Chandalar Res. - Scurry-Rainbow
+	Karen	Hesca Resources Corp.
	Moly (Atlin)	Cominco
	Moly Taku	Omni Resources
	Mt. Reed	Canadian Superior Exploration
	Serb Creek	AMAX
+	Whit	Kennco Explor. (Western) Ltd.

+ - Copper-molybdenum deposit

* - Copper-molybdenum deposit, minor molybdenum mineralization.

Brief descriptions of Group A prospects appear below (reserve and historical data are in Appendix II).

3.5.2.1.1 J.A. Zone (Bethlehem Copper Corp.)

Bethlehem is examining this property as a new source of ore for its existing mill in the Highland Valley. Molybdenum mineralization is higher than currently used Bethlehem deposits and tonnage is good, but the deposit has a high (3.41:1) stripping ratio [12].

3.5.2.1.2 Glacier Gulch (Climax Molybdenum Corporation of BC)

Extensive drilling and surveying of this property was undertaken in the early 1970's. A development constraint is environmental impact; the deposit is 2 to 3 km north of a Smithers ski hill facing the airport. Underground mining is favoured, but the economics of the project are such that development is not anticipated in the near future.[13]

3.5.2.1.3 Ruby Creek (Adanac-Placer Development Ltd)

Placer recently reached an agreement with Adanac Mining and Exploration for the ultimate purchase of a 70 percent interest in this molybdenum property near Atlin. Placer has expressed interest in bringing the property into production by 1983 if markets are available [14]. Planned output is 3 600 mt of contained molybdenum per year, with a 17-year mine life. Concentrates would be converted to oxide at the Endako roaster. A final production decision is expected by 1980.

3.5.2.1.4 Trout Lake (Newmont-Esso Minerals)

Newmont Exploration of Canada (55%) and Esso Minerals Canada (45%) are planning a 1979/80 underground exploration and sampling program costing $4.5 million for this deposit located 35 miles southeast of Revelstoke. While reports of "an economic deposit" have been made, no grade or tonnage figures have yet been released [15].

3.5.2.1.5 Valley Copper (Valley Copper Mines Ltd.)

This deposit, located in the Highland Valley, touches the Bethlehem mine property on the northeast and Lornex on the southeast. Cominco has 81.7% ownership of Valley Copper, Bethlehem a 5.1% interest. 20% of the copper-molybdenum deposit is in Bethlehem property as well. Molybdenum mineralization is minor and erratic; molybdenum production would likely be similar to Bethlehem's (300 mtpy). Cominco plans to make a decision by the end of 1979, and has expressed interest in development. Mill capacity would be 55-60 000 tons of ore per day, investment in the order of $350 million. $0.90-$1.00/lb. are said to be required for development [16].

3.5.2.1.6 Berg (Kennco Exploration (Western) Ltd)

Placer Development Ltd. acquired the option to this copper-molybdenum property in 1972 and has continued exploration since then. Infrastructure costs of development are great, however; the mine would require an access road from Houston, BC,a townsite would probably have to be built and power transmission lines strung. One source of power might be Alcan's Kemano generating station to the west - Alcan has plans for its expansion [17].

3.5.2.1.7 Huckleberry (Kennco Exploration (Western) Ltd.)

This copper-molybdenum deposit is located in the same area as Berg and suffers from the same infrastructure-cost drawbacks. While copper grades are similar to those at Berg, molybdenum grades are lower and tonnage significantly less.

3.5.2.1.8 Roundy Creek (AMAX of Canada)

This property was acquired by Amax shortly after the purchase of the Kitsault mine from Kennecott. Its proximity to the Kitsault development suggests that it could be a source of further reserves once the existing Kitsault mine runs out of ore. It might also be developed in conjunction with Kitsault given the infrastructure costs already incurred. The major constraint is size - the deposit may not be large enough to rationalize development.

3.5.2.1.9 Schaft Creek I & II (Teck Corporation)

Teck recently acquired the majority interest in the massive Schaft Creek copper-molybdenum deposit northeast of Stewart, BC. Teck has expressed interest in development but infrastructure costs are immense. They include access roads, possibly a 20 - 30 mile tunnel, power transmission and townsite construction [18].

3.5.3 Expansion at Existing BC Mines

3.5.3.1 Granisle (Zapata-Granby Corp.)

A molybdenum recovery circuit is planned for this 14 000 tonne per day mill. Molybdenum will be produced intermittently, starting next summer. Annual output will likely be about 100 mt of contained molybdenum per year [19].

3.5.3.2 Lornex (Rio Algom Ltd.)

Feasibility studies are underway for 50% expansion of the mine and mill. Management feels that such an expansion would still leave the mine with a greater-than 20 year mine life [20].

3.5.3.3 Boss Mountain (Noranda Mines Ltd.)

Expansion of the open pit at this combined underground-open pit mine has been considered for some time. If such pit and mill expansion occurs, output could be increased to 3 600 mt per year of contained molybdenum by as early as 1980 [21]. A factor constraining such development currently is uncertain molybdenum content of reserves.

SECTION III FOOTNOTES

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10. This table is the result of consultations with Dr. N.C. Carter, J.A. Garnett and Dr. A. Sutherland Brown of the Ministry of Energy, Mines and Petroleum Resources, Geological Division, and reference research (see Appendix B) by J. Tyhurst, Economics and Planning Division.
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SECTION 4

MARKET STRUCTURE, PRICES, PROJECTIONS

4. Market Structure, Prices, Projections

4.1 Industrial Organizations and Market History

The industrial organization of western world molybdenum producers is characterized by the dominance of one firm - the Climax Molybdenum Company, a Division of AMAX. Climax was the only company to hold a greater than 10 percent share of world output in 1978 - with an impressive 38.6 percent in that year (see Table II-5). The company has also been successful in establishing processing facilities in W. Europe, the area of largest world consumption of the metal, thereby stabilizing demand for its products. Climax has also been instrumental in developing many of the new applications for the metal through its research and development activities.

Climax has been the traditional leader in establishing price and marketing patterns among producers. Prior to 1978 the Climax price was basically matched by other major world producers and thus pricing took on the appearance of oligopolistic price leadership. Up until 1974 price stability was great, with Climax prices remaining unchanged for years at a time (see Table and Figure IV-1). It is understandable in an economic sense that Climax, the largest seller, should want to maintain this situation since stable prices encourage growth in demand and ensure profitable operations. It was the climate required to enable the metal to establish a solid and diversified end-use pattern. Generally speaking price competition in molybdenum markets has thus far been absent -

competition has been aimed mainly at the markets of substitute metals. The strategy of stable pricing and ensured supply has proven to be an important selling point for the metal, and was one of the factors that has enabled molybdenum to out-compete its substitutes, eg. tungsten, which suffer from wide price and supply fluctuations. Substitution took place as new applications for the metal were developed and consequently, demand rose rapidly. World molybdenum pricing has thus far been basically producer-controlled - most sales of the metal being made at contract or "producer" prices. Strong buyer-seller ties, between molybdenum producers and large iron and steel manufacturers, for example, have allowed this pricing structure to persist, as long as a dependable supply was available.

Molybdenum is also sold at "dealer" or spot-market prices by international metal trading companies like Phillip Bros. and Associated Metals. Before 1978, such sales accounted for a minor (15% or less) amount of the total, with the balance being at contract or producer prices. Also, until recently, spot-market prices for molybdenum were very close to producer prices, within a range of two times the latter.

An exception was a period in the early 1960's when spot-market prices rose to 5 times the producer price as a result of growing demand for the metal and consumption that exceeded supply. These increased prices prompted several new producers to enter the market, including several in British Columbia (Endako and Kitsault among them). By the late 60's there was a world oversupply of the

TABLE IV - 1

HISTORICAL MOLYBDENUM PRICES, 1955-1978

YEAR	ACTUAL PRICE*	1977 $
1955	1.10	2.55
1956	1.18	2.66
1957	1.18	2.57
1958	1.25	2.68
1959	1.25	2.62
1960	1.25	2.58
1961	1.40	2.86
1962	1.40	2.81
1963	1.40	2.77
1964	1.55	3.02
1965	1.55	2.95
1966	1.55	2.86
1967	1.62	2.90
1968	1.62	2.78
1969	1.72	2.81
1970	1.72	2.67
1971	1.72	2.54
1972	1.72	2.44
1973	1.72	2.30
1974	2.02	2.47
1975	2.48	2.76
1976	2.94	3.11
1977	3.68	3.68
1978	4.52	4.21

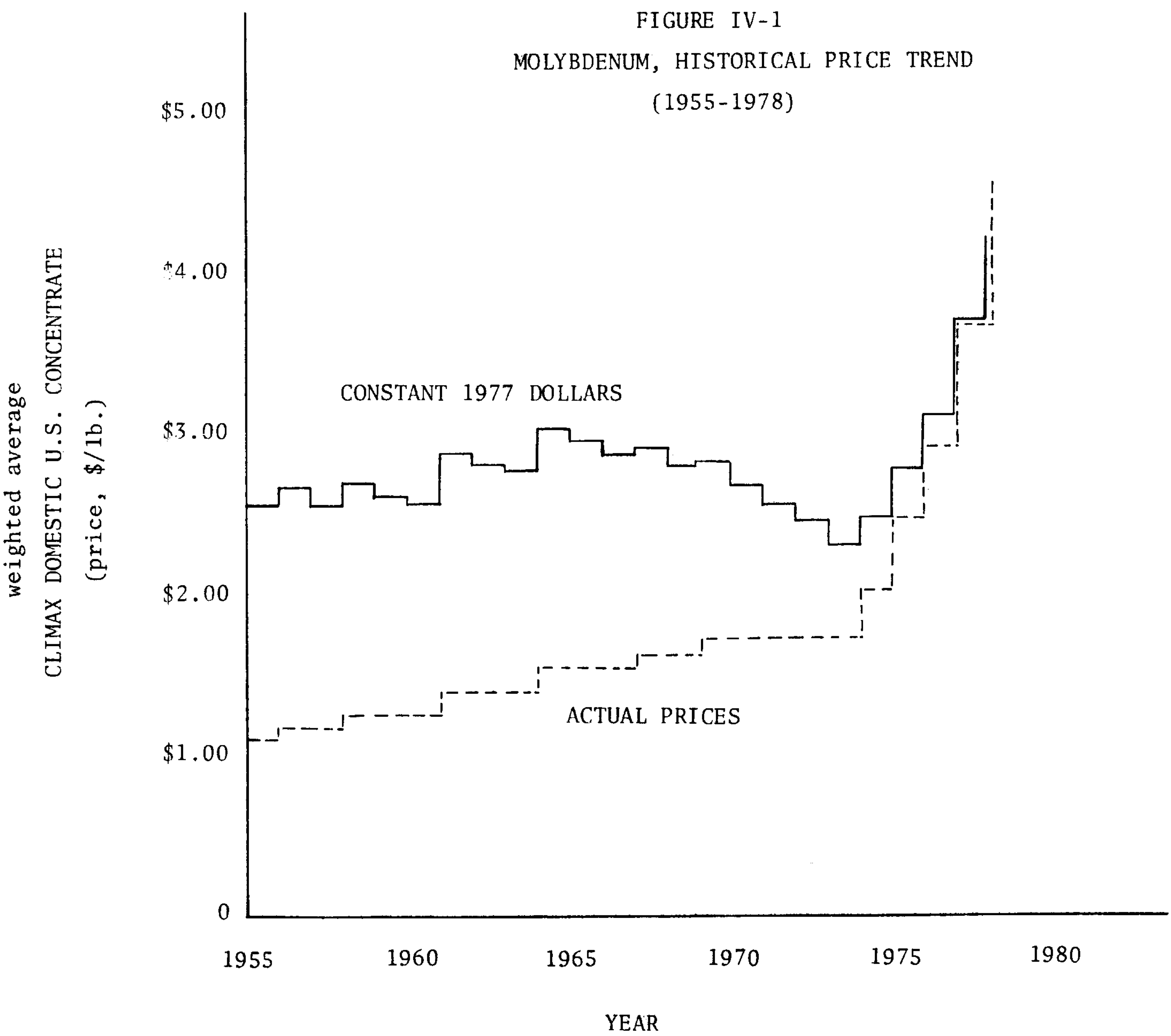
* Climax concentrate in U.S. $/lb. weighted average in each year.

Source: U.S. Bureau of Mines.

FIGURE IV-1

MOLYBDENUM, HISTORICAL PRICE TREND

(1955-1978)



SOURCE: Table IV-1

metal that persisted until the early 1970's (see Table IV-2). In 1971 and 1972 spot market prices actually fell below published Climax prices. Industry profits suffered and there were production cutbacks and closures.

British Columbia was hard hit in this period, with the Boss Mountain and Coxey mines closing in 1971, followed by Kitsault in 1972; Placer Development cut back production at Endako at this time.

By 1973 consumption was rising rapidly again and in 1974 the traditional price stability of the metal had started to break down. AMAX (which had taken over marketing for Climax) began announcing more frequent and substantial price increases. The company's pricing leadership continued, however, with other major producers matching Climax changes closely.

Industry stocks have been falling steadily since 1973, with western world consumption of the metal being greater than supply in every year since then. U.S. General Services Administration stockpile releases cushioned the supply shortfall, but these slowed to a trickle in 1977 and the stockpile was exhausted by 1978.

4.1.2 Recent Trends

In 1977 the supply tightness in the western world was aggravated when the U.S. began in-direct exports of molybdenum to the Soviet

TABLE IV - 2

WESTERN WORLD SUPPLY/DEMAND BALANCE
(1000 metric tons)

	69	70	71	72	73	74	75	76	77	78
Mine Production	67	78	74	74	72	75	74	78	82	85
Consumption	64	66	59	67	82	94	76	80	83	88
U.S. Industry stocks (Dec. 31)	14	19	29	36	24	21	18	15	13	12
U.S. Stockpile Releases	1.3	2.2	0.2	*	2.6	15.9	2.0	0.7	*	-

* Less than 0.1

Sources: Production & Consumption, AMAX from EM&J Annual Reviews
Stocks & Stockpile Releases, U.S. Bureau of Mines.

Union. In addition, construction of the Trans-Siberian pipeline significantly increased demand for the metal in W. Europe and Japan where the pipe was manufactured. By the middle of the year U.S. steel producers, alarmed by continuing shortages of molybdenum, petitioned the Department of Commerce through the American Iron and Steel Institute (AISI) to monitor exports and eventually license and control them. No such action was taken by the U.S. Government. Demand remained strong in 1978, particularly for specialty and stainless steel applications. Production increased during the year, but growth was limited when poor markets forced cut-backs on by-product producers in the United States. Other factors limiting supply were strikes at the Questa mine in N. Mexico, and Gibraltar and Gaspe in Canada, a slide at the Questa mine and power shortages at AMAX's Langeloth roasting facilities.

In response to the strong world-wide demand shown in 1978, other molybdenum producers started to initiate price increases independent of Climax price changes and to post prices in excess of the Climax level. In April 1978 Noranda hiked its export prices by 15% and "stunned the industry ... because it so quickly followed the industry's 10% increase in March" [1]. Later in the year Duval jumped the gun on Climax again and posted a 15% increase on its products.

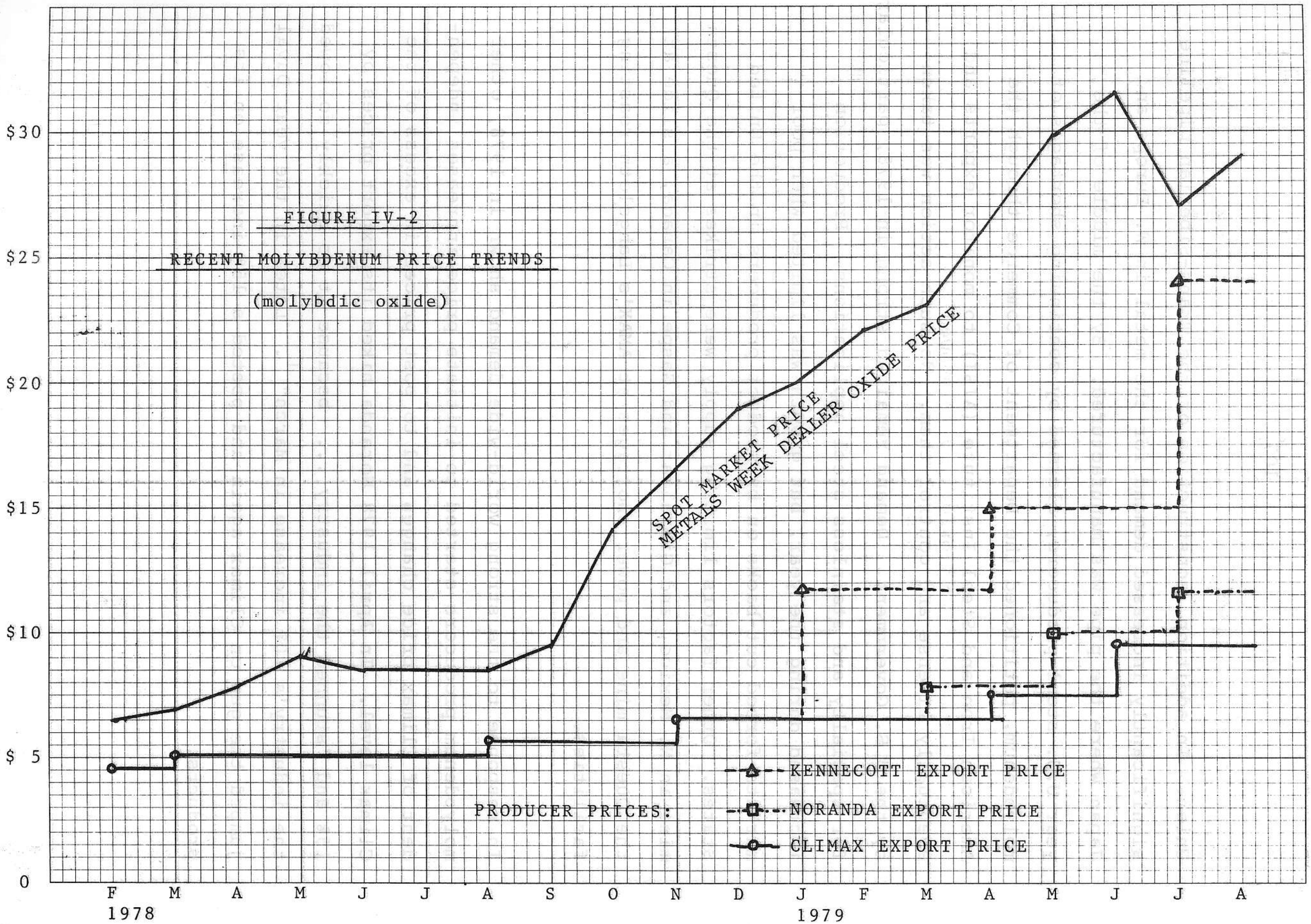


FIGURE IV-2

RECENT MOLYBDENUM PRICE TRENDS

(molybdic oxide)

Spot market prices began to move away from producer prices in mid-1978. Figure IV-2 shows the dramatic price changes that occurred from the fall of 1978 to the summer of 1979. Molybdic oxide is profiled and both contract and spot prices are available because it is the most widely traded form of molybdenum.

In January of 1978 spot oxide prices showed a 26% premium on Climax export prices. This had increased to 77% by May of that year and 174% by December.

In 1979 an already tight supply situation was aggravated by a cold winter in the United States which caused a 10-15% cutback in Climax shipments to Europe and Japan. Then, on February 15, workers struck at Placer Development's Endako mine, the world's fourth largest producer. In the intervening months molybdenum markets underwent fundamental changes. Spot market sales increased greatly, as consumers, fearing further shortages had to look past the traditional long-term contract and producer price system in order to find supplies. As a result, spot market prices soared, peaking at $32.50 U.S. in June 1979 and since then falling to about $15 at the time of writing.

Producer pricing also underwent significant changes. As a result of the Carter administration's control of domestic prices through the council on wage and price stability, pricing by American producers is two-tiered with domestic and export prices quoted.

Export prices began to diverge significantly from U.S. domestic prices when Kennecott hiked its export price 105% from $5.70 to $11.70 U.S. per lb. c.i.f. Japan. Since then other major U.S. producers have followed this pattern. Climax, for example, hiked its domestic oxide price from $4.76 U.S./lb. in July of 1978 to $5.80 U.S. in July of 1979, while the export price went from $5.08 to $9.54 in the same period (see Table IV-3) Climax prices have actually not shown the increases of other companies however; Climax has continued its traditional tendency of protecting its market share rather than raising prices to levels the market will bear. In contrast, Kennecott raised its export oxide price to $24.00 in July 1979.

4.1.3 Summary

Molybdenum marketing has changed drastically in the past 2 years; spot market sales have increased as a proportion of total sales of the metal and spot prices have risen to incredible heights. Producer or contract sales have decreased in importance and price stability, a previous characteristic of the molybdenum producer pricing system, has given way to ever increasing prices. Climax, the historical price leader, has resisted matching the price increases of the spot market but some producers, like Kennecott, have set their producer price at high levels in an attempt to "cash-in" on the buoyant market. Climax is not the current price-setter in the export market, other companies are authoring both the timing and scale of price changes.

4.2 Current Market Structure

4.2.1 Japan

Molybdenum was in short supply in Japan, and this shortage was intensified in 1979 as the Endako strike progressed. Endako accounts for about 40 percent of Japan's imports. Japanese consumers were forced to buy from the spot market (or grey market as it is known in Japan), and this was a factor in the skyrocketing spot price.

Demand for molybdenum in Japan has increased in both metallurgical and chemical applications. Japan's specialty steel industry is growing at near-boom levels.

Direct sales to Japanese steelmakers by North and South American producers have increased in recent years and currently constitutes 30 - 40% of sales.

4.2.2 Soviet Bloc

Soviet and Eastern European imports have increased through both direct trade with producing countries like the United States and increased purchases on the spot market. The U.S.S.R. began buying on the spot market after China stopped selling to it and these purchases have accentuated the world-wide shortage.[2]

Table IV-3

Recent Trends in Producer and Spot Prices
($U.S./lb. molybdic oxide)

Month	Climax Domestic	Climax Export	Duval Export	Kennco Export	Noranda Export	Codelco Export	Spot Market
1978 Feb	4.31	4.60	4.60				6.30- 6.40
Mar	4.76	5.08	5.08	5.08	4.96	5.08	5.75- 6.85
Apr	"	"	"	"	5.83	"	6.85- 7.80
May	"	"	"	"	"	5.80	8.00- 9.00
Jun	"	"	"	"	"	"	8.25- 8.50
Jul	"	"	"	"	"	"	8.25- 8.50
Aug	"	"	"	"	"	"	8.00- 8.50
Sep	5.30	5.70	5.85	5.70	"	"	9.00- 9.50
Oct	"	"	"	"	"	"	11.80-14.25
Nov	"	"	"	"	"	"	15.00-16.50
Dec	"	6.56	6.94	"	6.89	"	16.50-18.00
1979 Jan	5.55	"	"	11.70	"	6.85	17.00-20.00
Feb	"	"	"	"	"	"	21.50-22.00
Mar	5.67	"	7.64	"	7.94	8.91	22.00-23.00
Apr	"	7.54	"	15.00	"	"	23.00-26.50
May	"	"	9.64	"	10.00	"	26.50-29.75
Jun	"	9.54	"	"	"	"	28.00-32.50
Jul	5.80	"	11.34	24.00	11.56	11.59	21.00-27.00
Aug	"	"	"	"	"	"	23.00-29.00

Sources: Metals Week, Tex Report
export prices c.i.f. Japan or Europe

4.2.3 U.S.A.

Domestic producers of specialty steels, and other consumers who normally rely on short-term purchases of molybdenum on the spot market for their supplies, have been hard-hit by escalating world prices. While domestic producer prices have remained relatively stable, only the large integrated steel companies and others with long-term supply contracts are fortunate enough to pay these prices. Thus, despite a massive American trade surplus in the metal, many U.S. consumers have had to suffer short supply at domestic prices and high prices for additional supplies. Some specialty steel makers in the U.S. have been charging 5 to 10 cents per pound surcharge for each percent of contained molybdenum in steel produced [3].

Even major steel producers with long-term contracts had to turn to the spot market in 1979 for 10 to 30 percent of their supplies. There has been growing dissatisfaction among such producers concerning the shortage of molybdenum especially in light of the scale of U.S. exports of the metal. Although protests have been made to the Department of Commerce, no action to control exports of the metal has been taken.

4.2.4 Europe

Europe felt the molybdenum shortage later than other areas, but its scale is now similar to that in Japan. Despite the high cost of the metal, specialty and tool steel producers in Europe have tried to hold their prices for moly-bearing grades near pre-shortage levels by taking lower profits or reducing output of moly-bearing grades, rather than price themselves out of hard-won steel export markets.

4.2.5 Canada

Despite the work-stoppage at their Endako mine, Placer Development was able to meet over 90 percent of its sales commitments for the first four months of the strike. However, once inventories were used up the company could guarantee only 35 percent of shipments required, the level at which the mine can be operated by management. This strike terminated in early November 1979 and the mine has returned to normal output of molybdenum. Placer has been successful in attracting rich prices for output from its Gibraltar mine by selling it by open tender. Tender prices reached $30.00 U.S. in June [4].

Noranda sales, responsible for marketing the output of the Boss Mountain and Brenda Mines in BC, has resisted the Kennecott-scale price increases but has priced molybdic oxide $2.00 U.S. above Climax prices, at levels comparable to Duval.

Lornex has been able to benefit from spot market prices by selling to Phillip Bros., a metal brokerage firm.

On the demand side in Canada, shortages are similar to those in the United States. Since the beginning of the tight domestic supply situation Canadian molybdenum producers, in cooperation with Industry, Trade and Commerce and Energy, Mines and Resources, have been operating a voluntary supply allocation to ensure that the needs of the Canadian steel industry are more equitably shared by all Canadian producers. Despite this move, Canadian molybdenum has been in extremely short supply, especially since the strike at Endako, and Canadian steelmakers are increasingly unhappy about supply availability [5].

4.3 Projected Supply

4.3.1 BC Supply

British Columbia molybdenum supply has been projected on the basis of estimated startup dates for committed and probable projects, and on the projected output from existing producers, taking planned and probable expansion into account. Prospect projections are based on the discussions in Section III above on BC molybdenum deposits.

Table IV-4

Projected British Columbia Molybdenum Supply
(1 000 metric tons contained Mo)

1979	1980	1981	1982	1983	1984	1985	1985-90
10.1	14.9	14.5	17.2	19.1	20.9	22.7	29.0

4.3.2 Non-Communist World Supply

Non-Communist world molybdenum production to 1995 has been estimated by totalling the committed, planned and indicated expansion at existing mines and prospects. A list of prospects, with their expected startup dates and capacity was made, and these capacity increments and additions aggregated to produce projections by country and/or region. The raw tables appear in Appendix III (Tables A-3 to A-6). Table IV-5 lists major prospects with details of reserves, capacity, investment, etc.

Non-communist world supply projections, based on the prospects listed in Table IV-5 and production increments at existing mines, is shown in Table IV-6, Projection I. This projection should be interpreted as a maximum, since only 5 percent has been taken off the total to take account of production-limiting factors and delays in development. Four other supply projections are listed for comparative purposes. All projections except IV are dependent on present conditions and information - it would thus be unwise to place much weight on projections past 1985.

The United States will continue its dominance of supply into the late 1980's with continued output from major producers and the addition of new capacity. Canada should maintain a roughly 16 percent share of non-communist world output, though production will not begin to increase until 1982. Further labour problems at Canadian mines could continue to stall the growth in production.

South American production will increase largely on the weight of expanded capacity at Codelco's Chilean copper mines. Copper markets are projected to improve by 1981-83 with world consumption of copper to stabilize at about 4% growth per year after that [7]. This should help by-product producers throughout the world, with Chile one of the main beneficiaries.

Other countries will increase their share of world output by the late 1980's, mainly through the development of large by-product copper-molybdenum porphyries.

Growth rates implicit in the five projections shown are compared in Table IV-7. Projection IV, a linear regression trend line based on non-communist world output for 1958-78, yields the lowest rates. Given the massive real price increases of the past year and conditions of short supply over the past six years, growth in supply will almost certainly exceed this estimate. Projection II by Placer Development is somewhat pessimistic about certain prospects, but may be a good "low estimate" of supply growth. Projection III is quite optimistic and should thus be considered a "high estimate". Projection I may be a better high estimate, however, since it is a little more realistic but still biased upward.

Table IV-5

Non-Communist World Molybdenum Prospects

Location	Company	Deposit	Ore Grades Cu %	Ore Grades Mo %	Contained Molybdenum (1000 metric tons)	Expected Capacity (mtpy mo)	Startup Date	Investment U.S.$ (millions)	Comments
UNITED STATES									
New Mexico	Union Oil	Goat Hill	-	0.20	32.1	9100	1983-4	$200	Adjacent to exitsing Questa Mine. Will be phased in as Questa ouput drops.
New Mexico	Phelps-Dodge	Tyrone	0.8	0.013	64.9	300-550	1979-81	...	Byproduct copper
Utah	Anaconda	Carr Fork	...	...	...	250	1980	$200	Byproduct copper
Idaho	Cyprus	Thompson Creek	-	0.186	393.2	9100	1983-85	$227	
Washington	AMAX	Mt. Tolman	0.13	0.078	211.9	6800-11300	1985-88	$400	On Colville Indian Reservation. Amax made an initial $8.5 million payment to tribe, with $8.5 to come for exploration rights.
Colorado	AMAX	Mt. Emmons	-	0.258	385.6	13600	1987-90	$450	Local opposition may hinder development.Socio-economic impact of 1300 workforce on Crested Butte currently under investigation.
Alaska	U.S. Borax	Quartz Hill	-	0.0899-0.132	570.6-836.8	11300	1989-1995	$400	Development may be held up because deposit is in Misty Fjords National Monument, an ecological reserve.
Utah	Phelps-Dodge	Pine Grove		0.17-0.23	103.0-182.3	6800	1990's		Still in exploration stages
Nevada	The Hall	Anaconda	...	...	...	4500	1990's		Possibility of two surface mines.
SOUTH AMERICA									
Chile	Anaconda	Los Delambras	0.78	0.03	126.6	910	1986-1990	...	Bought by Anaconda April'79
Chile	Nippon Mines	Cerro Colorado	1.2	0.015	9.0	150	1986-1990	...	
Chile	Exxon	Disputada	0.9	0.008	64.0	600	1986	...	Possible expansion of copper mine.
Peru	S. Peru	Caujone	1.1	0.03	136.1	900-1450	1980-1981	$10	Addition of molybdenum recovery circuit.
Peru	Minero Peru	Michiquillay	0.7	0.02	114.9	1250	1984-1990	$700	
Argentina	St.Joe	El Pachon	0.6	0.016	116.1	730-910	1988-1995	$1000	
OTHER									
Panama	Texas Gulf	Cerro Colorado	0.8	0.01	230.0	2000	1986-1990	...	Joint venture with Panama government
Mexico	Mexicana de Cobre-Asarco	La Caridad	0.75	0.016	96.0	2300	1979-1981	$900	Began copper output 1979
Phillipines	CDCP	CDCP	...	...	...	550	1979-1980	...	
Iran	NICIC	Sar Chesmeh	1.12	0.027	105.3	1810	1980-81	$1400	Political situation may delay startup further.
New Guinea	Bougainville	Bougainville	0.74	0.009	73.5	1810	1980's	$435	

Table IV - 6

Non-Communist World Molybdenum Supply Projections
(1 000 metric tons contained Mo)

	1978[1]	1979	1980	1981	1982	1983	1984	1985	1986-90 ("1988")	1991-95 ("1993")
Projection I:										
Canada	13.9	11.3	16.0	15.8	18.8	20.4	22.0	23.6	29.9	38.4
U.S.A.	59.8	66.2	70.3	72.7	74.6	81.9	84.6	91.2	115.8	140.7
South America	13.4	13.5	14.0	15.0	15.5	16.7	18.6	20.3	25.2	26.6
Others	0.7	0.9	3.2	7.3	11.3	14.3	14.3	14.3	18.3	33.3
Total	87.8	91.9	103.5	110.8	120.2	133.3	139.5	149.4	189.2	239.0
Less 5%*		87.3	98.3	105.3	114.2	126.6	132.5	141.9	179.7	227.1
									(1986-90)	
Projection II[2]		86.4	98.0	106.5	110.5	116.1	119.4	128.0	130.5 -	137.2
Projection III[3]		93.0	99.8	111.6	122.0	138.3	140.2	152.0	-	
Projection IV[4]		92.2	95.4	98.7	102.0	105.3	108.5	111.8	115.1 -	128.2
Projection V[5]		98.6	104.8			(1985 = 137.2-166.5)				

1 Actual data

2 Placer Development, June, 1979

3 Japanese Marketing Report[6]

4 Trend-Line Projections based on data from 1958-1978 (simple linear regression)

5 Energy, Mines & Resources, Molybdenum preprint 1977

* For losses, strikes, etc. - this is Projection I

Table IV - 7

Comparison of Projection Growth Rates
(growth rates in percent)

	1978-1985	1985-1988	1988-1993
Projection I	7.1	8.2	4.8
Projection II	5.5	1.8	-
Projection III	8.2	-	-
Projection IV	3.3	2.9	2.6
Projection V	7.9	-	-

Forecast*

Non-communist world supply is projected to increase at a rate of between 5.5 to 7.1 percent to 1985.

4.4 Projected Demand

4.4.1 Demand Elasticity Substitution

It was originally thought by molybdenum producers that prices of $8 to $10 a pound for molybdic oxide would be enough to start substitution of the metal at wholesale levels. Substitution has taken place in large diameter pipe although demand has remained strong in specialty steels. The short run demand curve for molybdenum has proved to be price-inelastic (in these areas) - demand has continued to grow as prices have risen.

4.4.2 Expanded end-use applications

As the energy crises continues, so will the demand for molybdenum. The unique properties of the metal that combine strength with resistance to the elements have historically broadened its

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* It would be misleading to extend a projection past 1985 since prices, technology, etc. may change conditions greatly. Since mine development usually takes at least six years from "coming public" with a deposit, 1985 is seen as "within the sights" of forecasts.

applications. The need for these properties in industries which involve the synthesis, acquisition and consumption of energy will continue to broaden its demand.

In the automotive industry, for example, the need for steels that combine lightness with strength will increase with gasoline mileage requirements. Oil and gas pipelines, consuming large quantities of the metal in their construction, will be stretched to more remote areas as the price of energy rises. Energy exploration efforts will increase, and will be reflected in demand for drill bits and corrosive-resistant casing consumed in such exploration. The need for superalloys that can tolerate high temperatures will continue as turbines and reactors are built for efficiency and safety. In the chemical market, molybdenum catalysts are consumed at increasing rates with decreasing quality of crude petroleum and are finding new applications in coal liquification and gasification; these areas could become very important if North American pledges of energy self-sufficiency are to be realized.[8] The worldwide increase in rail traffic associated with coal and ore hauling has created a demand for stronger and more wear-resistant steels. A new molybdenum-chromium rail has been developed with an experimental life 60-100% greater than standard carbon steel rails. Initial production of such rails has begun around the world [9].

One prospective application for molybdenum with great potential has been developed at the University of BC Physics Department by Dr. R. Haering and others. It is a battery which uses molybdenum disulphide (molybdenum concentrate), as produced by domestic mines.

A prototype of Dr. Haering's "intercolation" *-type battery was developed by Exxon in 1976 using titanium disulphide, and Bell Labs followed with a vandium disulphide battery.[10] It occurred to Haering to use molybdenum disulphide since it, unlike the other disulphides, is present in its natural form and does not have to be made synthetically at great expense. The battery design has been patented and research continues.

The most promising feature about the battery is its potential low capacity to weight ration in comparison to others (see Table IV-8). The possibility for the use of such a lightweight battery in electric cars occurs to one immediately. The weight of current electric batteries is often a limiting factor, exceeding 1 000 pounds. Another possible application is as a load-levelling storage cell for use by utility companies. This can have very attractive economics for utilities, which must provide enough electrical supply to meet peak demand. BC Hydro has subsidized lab space for the battery's development in exchange for certain rights relating to this application.

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* Intercolation is the process of acceptance or storage of electrons in gaps in "sandwich-structure" molecules such as molybdenum and titanium disulphide.

The effects on demand for molybdenum of this application may be staggering if one considers Haering's estimate of 300 lbs. of molybdenum disulphide required for each electric car.

Table IV-8

Performance of Several Battery Systems

System	Capacity (approximate) Watt-Hours/kilogram
Lead-Acid	40
Nickel-Cadmium	55
Sodium-Sulphur*	90 - 100
Intercolation System MX_2**	500 in experimental cells 100 - 150 anticipated in practical cells.

* Operates at approximately 400°C

** Where M is a transition metal and X is one of Sulphur, Selenium or Delurium

Source: Dr. R. Haering, University of British Columbia Department of Physics.

Other non-metallurgical applications include lubricants, smoke and flame retardants in plastics, and in pigments and paints. A closed-circuit water cooling system containing a soluble molybdenum compound in its corrosion inhibition system received a prestigious engineering award in 1978.

In summary, demand for the metal is expected to develop and broaden as further applications are found.

4.4.3 Forecasts

The major growth area for molybdenum consumption is in H.S.L.A. steels - those used in pipeline and other transportation applications. Placer Development forecast an approximate 6% annual consumption growth rate for molybdenum in this application. Other growth rates to 1984 are forecast as follows: (3-5%) specialty and stainless steel, (10-15%) catalyst applications, (2-3%) carbon steels and cast irons, and (4-6%) tool steels. Placer arrived at an over-all consumption growth rate for the non-communist world of 5.5 - 6% to 1985 (see Appendix Table A-1).

AMAX's demand-growth prediction of 6 percent yearly is comparable with Placer's. AMAX stresses the continued demand for molybdenum in Eastern Europe, which is estimated at 6800-9100 metric tonnes per year (direct demand - not including imports of molybdenum-bearing steels) [11].

A linear regression using non-communist world comsumption data available (1966-78) predicts a 3.7% growth rate in consumption to 1985. This is used as the "low estimate" with AMAX and Placer predictions the "high estimate" growth rates. Non-communist world consumption is projected to 1985 below on the basis of this range of growth rates.

Non-Communist World Consumption Projections
(000 Metric Tons contained Mo)

Rate of Growth	1979	1980	1981	1982	1983	1984	1985
3.7%[1]	95.0	98.8	102.5	106.2	110.0	113.7	117.4
6.0%[2]	93.3	98.9	104.8	111.1	117.8	124.8	132.3
7.0%[3]	94.2	100.8	107.8	115.4	123.4	132.1	141.3

[1] Figures shown are linear regression predictions using 1966-78 consumption data

[2] AMAX forecast

[3] Placer Development forecast

AMAX and Placer forecasts based on consumption of 88 000 metric tons in 1978.

4.4.3.1 Canada

Canadian consumption of molybdenum not associated with pipeline construction is expected to grow at a rate of from 5 to 7 percent until 1984 [12]. In addition to this consumption of between 1800 and 2500 mt per year until 1984, the construction of the Canadian portion of the Alaska gas pipeline will create a great demand for molybdenum. The pipeline is expected to consume about 5500-6000 mt of molybdenum over its 4-year construction period. This means an additional demand of between 3175 and 4000 mt of molybdenum per year during the construction years.

The pipeline's 1.5 million tonnes of pipe will be manufactured by the Steel Co. of Canada (Stelco) and Interprovincial Steel (Ipsco), at a molybdenum content of about 0.3 to 0.4 percent; pipe manufacturing will begin a few months before pipeline construction begins.

If the National Energy Board (NEB) authorizes further sales of natural gas to the United States from Canada, so-called "pre-building" will occur and construction will likely start in late 1980. With these additional sales of gas to the U.S., further trunkline systems required to transport the gas to the main line will be necessary and molybdenum demand will increase by perhaps 200 mt per year. If the NEB rules against extra sales, construction will likely not start until mid-1981 and this additional molybdenum demand will not occur [13].

Despite the hurdles in the way of its development, the Alaska gas pipeline is a priority of the Carter administration and will very likely be started by 1981 at the latest. The pre-building question may have an effect on its timing, however.

4.5 Supply/Demand Balance and Prices

4.5.1 Non-Communist World

A number of different supply/demand scenarios are developed below on the basis of the various projections reached above, and the results examined.

4.5.1.1 Low Supply, High Demand

If we assume that the slowest supply growth projection from Table IV-6 and the high demand growth projection from Table IV-9 are correct, we must adopt :

- Supply projection IV, the linear regression projections
- Demand growth of 7% per year

The supply/demand balance results of this assumption appear in Table IV-9 as scenario 4.7.1.1.

4.5.1.2 High Supply, Low Demand

This scenario adopts the following assumptions

- Supply Projection III
- Demand growth based on a trend-line of consumption data

4.5.1.3 "Most Likely"

The "most likely" scenario chosen is

- Supply Projection I
- Demand growth of 6%

Supply/demand balance results appear in Table IV-10 below:

Table IV-10

Non-Communist World* Molybdenum
Supply/Demand Balance given Different Scenarios
(1 000 metric tons)

	(actual)				(projected)						
Scenario	75	76	77	78	79	80	81	82	83	84	85
actual**	(0)	(1.3)	(1.0)	(3.0)							
(i)					(2.0)	(4.0)	(9.1)	(13.4)	(8.1)	(23.6)	(29.5)
(ii)					(2.0)	1.0	9.1	15.8	28.3	26.5	34.6
(iii)					(6.0)	(0.6)	0.5	3.1	8.8	7.7	17.1

Note: - bracketed figures indicate excess of demand over supply
- unbracketed figures indicate excess of supply over demand

* Including net exports to communist world

** Stockpile releases included as supply.

Scenarios 4.7.1.1 and 4.7.1.2 produce huge shortages and deficits by 1985 respectively.

"Most likely" scenario 4.7.1.3 appears realistic because strong demand for the metal has been demonstrated, along with recently increased prices that should create the incentive to bring new mines into production.* According to this projection, supply and demand should balance by 1981, with the current shortage situation easing off by 1983. If this is correct, molybdenum prices, in constant $'s, should remain strong throughout 1979, level off in the period 1980 to 1982 and begin to fall by 1983.

Exports of the metal from non-communist countries to the Eastern bloc may affect the projected over-supply situation to the point where the apparent surplus disappears. It is difficult to predict the effects of this market for two reasons; firstly, the exports are often contained in finished steel products and, secondly, unforeseen political developments may reduce trade in molybdenum and molybdenum-containing products.

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* It must be remembered that such a projection can identify only the "next turn" of the cycle and nothing past this, since no information has been introduced to allow an analysis of the basis of the cycle. Therefore only supply/demand and accompanying price changes that are affected by today's events can be projected [14].

4.6 Overview - Conclusion

The current shortage of molybdenum is the result of an interaction between increasing demand and decreasing supply for the metal. Demand has increased due to increases in pipeline construction worldwide and increased specialty steel applications for the metal; simultaneously, supply has been reduced by a number of factors including strikes, un-natural climatic conditions and poor copper markets.

The industrial organization of the molybdenum industry has been one of historical market dominance by the Climax Molybdenum Company, resulting in price leadership, stable prices and assumed supply. The industry was not prepared to absorb the jolt it received from shortages in late 1978 and 1979, as a result prices have sky-rocketed and Climax's leadership broken down.

Capacity will now be increased in response to current high prices. Entry into the industry will occur, and the additions to supply will gradually exert downward pressure on prices. At that point, which could be in the period 1985-8, the molybdenum industry may enter a new phase in which capacity is greater than demand. It is difficult to predict whether or not molybdenum will then enter into the cyclical pattern of over-supply accompanied by drastic price reduction which typify many of the other metals. It would be most unusual if this does not occur, since entry into the industry is not restricted, price leadership is no longer a dominant feature, and molybdenum deposits are internationally distributed.

In the longer term the noted interlocks between molybdenum use and incremental energy supplies can be expected to sustain continuing demand for the metal.

Section IV - FOOTNOTES

1. Metals Week, April 14, 1978

2. American Metal Market, July 6, 1979, molybdenum supplement.

3. ibid

4. Metals Week, various issues in 1979 reporting Gibraltar output tenders.

5. Interviews with Ipsco and Stelco Management, Foothills Pipelines Ltd.

6. Obtained from Department of Energy, Mines and Petroleum Resources, author unknown.

7. See, for projected copper prices:
   U.S. Department of Commerce, 1979 U.S. Industrial Outlook, With Projections to 1983 and 2000, January 1979, Wash., D.C.

   The World Bank, Price Prospects for Major Primary Commodities, June 1978, Wash., D.C.

   The Economist Intellegence Unit Ltd., World Commodity Outlook 78/79 Industrial Raw Materials, November 1978, London.

8. See Ellington, R.T., Liquid Fuels from Coal, Academic Press, Inc., Houston, Texas, 1977.

9. Goth, J.W., Amax, "Molybdenum Outlook", E.&M.J., March 1979.

10. See Science, Vol. 192, p. 112G (1976) for article on the Exxon battery.

11. Goth, J.W., Amax, op.cit.

12. Department of Energy, Mines and Resources.

13. Foothills Pipelines Ltd., Interview.

14. More sophisticated analysis of supply and demand balance for metals worldwide is possible using econometric models rather than simple data aggregation, as is done in this report. See, for example,

    Ontario, Ministry of Natural Resources, Mineral Resources Branch, World Mineral Markets, an Econometric Simulation Analysis, May, 1979.

A molybdenum model could be set up using a similar format, employing some of the demand-related variables like energy consumption and pipeline construction which were identified in this section. Long-term projections, impossible under the methodology used in this report, have more validity using such an econometric model.

5. FURTHER PROCESSING

5. FURTHER PROCESSING

5.1 AREAS OF FURTHER PROCESSING

With the exception of high quality molybdenum disulphide concentrate which may be directly purified for molysulphide lubricant production (as Endako plans to do at its new lubricant grade concentrate plant), all concentrate must be roasted to obtain molybdic oxide (MoO_3) before any end use application or further processing can take place. About 75% of end-use consumption in steel is in molybdic oxide, which is added directly to the steel making furnace. The other 25% is in ferromolybdenum which is a final addition to the furnace or ladle. (See Figure I-1, above).

Ferromolybdenum is also used by foundries in the production of certain high-quality iron alloys where control of molybdenum content is critical and losses are important. Usage of ferromolybdenum has declined in favour of oxide.

Technical grade (99.95% pure) oxide is produced by intensive roasting, then is densified with water and dried. This product is chemically refined to produce various forms of molybdates which are used directly by pigment, chemical and catalyst producers.

Pure molybdenum metal is manufactured by reducing pure molybdic oxide or ammonium molybdate with hydrogen gas. Metal powder is pressed and sintered into small metal ingots for conversion into rod, wire or sheet by hot rolling, swaging or forging.

Summary

The vast majority (97%) of molybdenum is converted into oxide with only a small amount of purified concentrate used in lubricants (2½%). The oxide is then used directly in steel (75%), or converted to ferromolybdenum for similar metallurgical applications (25%). Chemical applications use oxide after conversion to molybdates. Pure metal is also manufactured from oxide.

5.2 Industry Trends in Further Processing

Climax (AMAX) is fully integrated, with no other producer close in conversion capacity. Climax identified the ability to establish direct sales contacts with final consumers, which further processing enables, as an important market strategy. At present, the company has roasting capacity in Pennsylvania, Iowa, Holland, Italy and England. Molybdenum metal is produced at a plant in Michigan and lubricant-grade molydisulphide at a plant in Pennsylvania. Climax thus has a full range of processing facilities and does not sell concentrate.

Other U.S. producers have followed Climax's strategy. Duval and Kennecott roast the bulk of their molybdenum production at the minesite. Both companies also produce ferromolybdenum. Molycorp has conversion facilities at its minesite and in Pennsylvania, and sells only oxide and ferromolybdenum.

In the United States molybdenum is generally shipped by rail in concentrate form from the Western States to conversion plants in the East and Midwest, the favoured strategy is to have conversion facilities close to the market. U.S. exports to Europe are both in concentrate, for conversion in Climax-owned plants there, and in oxide form. Exports to Japan are mainly shipments of oxide or ferromolybdenum.

Smaller U.S. producers sell their output as concentrate to domestic and foreign firms with conversion capacity, or to dealers.

Chilean exports have historically been mainly in concentrate, but this is changing. Codelco, the state-owned copper giant, has recently acquired roasting capacity and has used this to gain better access to the Japanese market. (Before this capacity was available, Codelco had an export switching arrangement with Endako for the export of Endako oxide to Japan in exchange for Codelco exports of concentrate to Europe). Molymet of Chile also has expanding roasting facilities.

In Canada, Endako has moved from 30% conversion of its concentrate to oxide when operations began in 1965 to 100% in 1978. This was in response to the industry-wide change identified above toward roasting by producers rather than users, which resulted in a more stable market for oxide than for concentrates. The wisdom of the move was evident when, during the market slump in the early 1970's, Placer was able to move oxides with less difficulty than concentrates.

Noranda, the other Canadian producer, has identified the same trend. The company has an agreement with Sadacem in Belgium for the roasting of concentrate to oxide there and is searching for ways of expanding its roasting capabilities.

Minor by-product producers like Bethlehem sell their concentrate to metal dealers. Lornex sells its output through Phillip Bros. one such dealer, at spot prices. Some of Lornex's concentrates are roasted in Europe and returned to Canada for domestic consumption.

Island Copper's molybdenum concentrates are all processed in the United States, where rhenium is extracted.

5.3 BC Further Processing Opportunities

5.3.1 Current Situation

Of BC molybdenum shipments in 1978, 53% were in concentrate form, 46% were as oxide roasted at Endako and 1% was ferromolybdenum produced by Masterloy in Ottawa from Endako concentrates.

The only facilities for the processing of molybdenum beyond the concentrate stage in Canada are the Endako roaster and recently to be added lubricant-grade plant, the Eldorado Gold Roaster and ferromolybdenum plant at Duparquet, Quebec and the Masterloy ferroalloy plant in Ottawa. Roasting capacity at Endako is about 7000 metric tonnes per year of contained molybdenum, Duparquet capacity is about 800 metric tonnes per year. Ferromolybdenum capacity is about 1500 metric tonnes per year of product at each conversion plant.

Despite this conversion capacity which is easily adequate for domestic needs, Canada imported at least a third of molybdenum consumed in the country in 1977. (See tables I-3 and I-5.)

5.3.2 Opportunities

There is much room for further processing of Canadian molybdenum for export markets, but the problem is to decide on how much is appropriate and in what areas of processing.

The international tariff structure (See table I-5) favours the export of concentrates, since all are accepted free, with the exception of the United States. Canadian exports of oxide currently enter Japan tariff-free - that country changed its policy in 1976. The EEC has a restrictive tariff on oxide, as does the United States. Canada is particularly protective against oxide imports.

British Columbia and Canada lag in the production of oxide probably as a result of the tariff structure against that product. Despite the tariff, Placer has been very successful in marketing oxide directly to Japanese consumers since acquiring adequate roasting capacities. The possession of roasting facilities enables this direct producer-consumer interaction - a type of marketing developed by Climax and apparently now well accepted. Placer has also found that the oxide market is more stable.

Ferromolybdenum also has restrictive tariffs attached to its import, although the use of this product is declining in comparison to oxide. Canadian capacity is reasonable on a world scale and a facility in BC would not benefit the domestic market.

Other molybdenum products are subject to prohibitive tariffs in all major markets. Further processing into the areas of molybdates, technical grade oxide and molybdenum metal is restricted by small markets and is dominated by existing producers like Climax. It is therefore apparent that expansion of roasting facilities in British Columbia offers the best opportunity for further processing of molybdenum. Placer has recognized this and is committed to an expansion which will be operational by early 1981.

5.4 Evaluation of Processing Alternatives

5.4.1 Minimum Economic Throughput

The minimum economic throughput for a roasting facility is between 3600 and 4500 metric tonnes per year of contained molybdenum in concentrates (Placer Development). The Brenda and Endako mines have this level of output, although Brenda's output is borderline.

Should a centralized facility be considered, BC's total unroasted output in 1978 would rationalize only one such facility for the province.

5.4.2 Evaluation Criteria

A framework is set out below for the evaluation of further roasting capacity for BC:

Benefits	Costs
1. Marketing flexibility	1. Venture Capital
2. Market stability of output	2. Pollution
3. Added Values	3. Infrastructure Requirements

Benefits

1. Marketing Flexibility - as mentioned above, Climax has established a pattern of direct producer-consumer ties that is well accepted. The trend world-wide is toward producer-roasting of concentrates. Placer has been successful in penetrating the Japanese market since acquiring adequate roasting capacity.

2. Market Stability - oxide markets are more stable than those for concentrates due to the direct producer-consumer ties available through 1. Weak markets in the 1970's demonstrated that oxides were easier to market than concentrates.

3. Added Values - More study is needed, but these appear limited. An additional roaster sufficient to convert all available BC concentrates would probably employ no more than 30 persons

(Wright Engineers). Oxide-concentrate price differentials have been kept low by Climax over the years and are currently about 7% or \$8.84 U.S./lb concentrate and \$9.54 U.S./lb. oxide (export prices, August 1979).

Costs

1. Capital Cost - Capital costs of a 4 500 metric tonne per year (contained Mo) roaster were estimated by Wright Engineers at \$C5 million in 1975. This translates to almost \$C7 million today.

2. Pollution - Pollution from a roasting facility is in the form of discharged sulphur dioxide. The Pollution Control Branch's objectives for the mining industry in British Columbia result in a range between 1 000 parts per million (ppm) and 250 ppm of sulphur dioxide. A fairly elaborate cleaning system is used in the stacks at the Endako roaster to keep pollution to these levels. Pollution from Endako translates to a range of from 7 000 lb/day sulphur dioxide to 10 000 lb/day maximum.

3. Infrastructure Requirements - Availability of sufficient power is the only major requirement for a roasting facility over and above the normal infrastructure needs of the mining sector.

5.4.3 Locational Considerations

1. Economic

Location should achieve the maximum cost efficiency in freight, containers, handling, molybdenum costs, etc. A location near a minesite is obviously favoured, but BC producers, with the exception of Endako, produce too little and are too scattered for any one existing producer to be an obvious choice.

The Highland Valley is one possibility, given that Highmont and Valley Copper go ahead. Total output from all Highland Valley producers will be about 4 000 - 4 500 metric tonnes per year - enough for one roaster. The area is attractive given the other infrastructure costs already incurred; this attractiveness would increase were Brenda's production of molybdenum to be transferred to the Highland Valley site.

Endako is planning expansion to 10 800 metric tonnes per annum and will roast both the output of Lornex and Kitsault. This will improve the BC processing situation, in addition Endako's existing marketing ties can be taken advantage of. The Endako site is more isolated than the Highland Valley and pollution should therefore be less of a problem.

A tidewater site such as Prince Rupert has handling disadvantages, although a roaster on the north coast could make some borderline deposits in the province's northeast more attractive. For the time being, however, mine production in the area does not rationalize this development. Kitsault's output would be enough to rationalize a small roaster should it not ship to Endako, and the prospect of the deposit being developed makes such a location more attractive. Transportation between Atlin and Prince Rupert remains a problem.

Generally the Endako site appears to be favoured because of its central location in the province, the economics of the expansion of the existing facility against building anew, (thereby incurring separate pollution and infrastructure costs) and the ability to take advantage of Placer's marketing knowledge and successes. A large, central marketing network for oxide is well accepted by steel consumers and producers alike. One obvious difficulty however is the risk inherent in concentrating production in one large facility, the recent strike at Endako has illustrated one aspect of this risk.

APPENDIX 1

DEFINITION OF RESERVES

Definition of Reserves

Before any discussion of the reserves of a given metal can take place, it is important that the concept of reserves be defined. There are two main ways of defining reserves, either in a physical or in an economic sense.

Physical Reserves (Resources)

The physical measurement of reserves attempts to evaluate all the existing resources of a given mineral in the earth's crust. No attempt is made to differentiate between those reserves which are more or less difficult to extract.

Economic Reserves

Economic reserves are those which are "economical" to extract given today's prices, costs and technologies. These reserves expand as a result of increasing prices, decreasing costs, expanding technology or a combination of all three factors.

The known resources of existing and committed properties are totalled to calculate economic reserves. The underlying assumptions of this calculation are:

a. These resources are 100% recoverable
b. Perfect knowledge of the deposit is possible.

The dependence on these assumptions leaves much to be desired, therefore this measure of resources may be regarded as the "best guess" of economically recoverable resources of the mineral in question.

In this report, economic reserves of molybdenum are defined around existing and prospective producers. The latter are included in the reserves calculation at their expected startup dates, to gain an idea of the change in reserves over time. This is the methodology used in Table I-9.

For further discussion of the concept of reserves, see:

Energy, Mines and Resources Canada, Mineral Bulletin MR178, Ottawa, 1979.

Tilton, John E., The Future of Non-Fuel Minerals, Brookings, Washington, D.C., 1977, Chapter 2.

Zwartendyk, Dr. J., "The Life Index of Mineral Reserves - A Statistical Mirage", CIM Bulletin, October 1974, page 67-70.

APPENDIX II

BC PROSPECTS - RESERVES, HISTORY & REFERENCES

COMMITTED FOR PRODUCTION

DEPOSIT	OWNER	LOCATION, SITE	COMMODITIES	TONNAGES AND GRADES	SOURCE	COMMENTS
HIGHMONT	Highmont Mining Corp. (Teck Corp 50.29%)	Highland Valley 921/7				
		Highmont -	Cu	0.27%, 145 000 000 tons	5 (1979)	1955 discovery
			Mo	0.047%		1966-69 Highmont acquires property 1970 agreement with Teck Corp for financing, exploration & development.
		Gnawed Mtn -	Cu	0.27%, 48 000 000 tons	5 (1979)	1971-75 Financing, economic studies by Teck.
			Mo	0.04%	5 (1979)	1979 April announcement of development
			Cu	0.27%, 130 000 000 tons	W.M.June79	1981 Projected startup of 25 000 tpd 5 million Mo lbs/year operation.
			MoS_2	0.05%		B.X. development previous owner of Gnawed Mountain. Mo to be sold to Metallgeschaft. Cost $150 Mn.
ALICE (Lime Creek) Kitsault BC Moly	Climax Moly Corp. of BC (AMAX 100%)	Alice Arm 103 P/G	MoS_2	0.20% 75 000 000 tons	9 (1969)	1916 discovery
			Mo	0.115% 110 000 000 tons (proven probable(	13 (1978)	1967-71 6000 tpd mill operated by Kennco
			MoS_2	0.20% 40 000 000	14 (1972)	1972 closed and purchased by AMAX at cost of $135 Mn, startup 1982, at 9-10 Mn lbs per year. Could also use Bell Moly-Roundy Crk. in this development. 12 000 tpd
VALLEY COPPER	COMINCO-BETHLEHEM		Cu	0.48% 850 000 000 tons		
			Mo	n.a.		

PROSPECTS

DEPOSIT	OWNER	LOCATION, SITE	COMMODITIES	TONNAGES AND GRADES	SOURCE	COMMENTS
J.A. ZONE	BETHLEHEM COPPER CORP. (Cominco 39.25%)	Highland Valley 92 I/7W	Cu Mo	0.45%, 400 000 000 tons 0.01%	2	1971 discovery by drilling 1976 original planned production date for 25 000 tpd mill. BC mineral land and royalty tax indefinately postponed. 1978 Bethlehem introduces molybdenum circuit, JA development contemplated (11) Constraints: High stripping ratio
			Cu Mo	0.43% 286 000 000 tons 0.017% (cutoff grade=0.25% Cu waste:ore = 3.42:1	A, 11(1978)	
			Cu MoS2	0.43% 286 000 000 tons 0.03%	14(Table)	
MAGGIE	BETHLEHEM Copper Corp. (Cominco 39.25%)	9 miles NW of Cache Creek. 92 I/14W	Cu Mo	0.34% 200 000 000 tons 0.022%	4, 7(1971)	1890 discovery 1968 Bethlehem acquires drilling 1969-71 continued drilling 1978-9 Evaluation continues Constraints - Environmental problems. Deposit close to highway, stream on top of deposit.
			Cu MoS2	0.28% 200 000 000 tons 0.017%	14 (p.442)	
			Cu Mo	0.28% 200 000 000 tons 0.029%	14 (text)	
BELL MOLY	CLIMAX MOLY CORP.(AMAX 100%)	6 miles E of Alice Arm 103 P/6W	Mo	0.07% 36 000 000 tons	4	1965 discovery
			MoS2	0.11% 35 860 000 tons	7 (1967),14	1966-75 exploration and drilling by Bell Molybdenum M.L. 1975 Bell sells to Climax. Climax to spend $1 Mn on exploration to Dec.31/80 & make production decision by Dec.31/90. 1976 Drilling by Climax (9 000 ft)
ROUNDY CREEK	CLIMAX	Alice Arm (103 P/6	MoS2	0.32% 1 296 000 tons	6 (1979)	1965-71 drilling, surface exploration 1975 sold to Climax by United Chiefton Res. for $325 000 plus 5% royalty per lb. contained Mo production over 1.5Mn tons.
			MoS2	0.347% 1 447 800 tons	7	
			MoS2	0.36% 1 400 000 tons	14 (table)	
			MoS2 (a) (b) (c)	0.32% 1 296 000 tons 0.668% 39 000 tons 0.12-0.15% 8 000 000 tons	8	

DEPOSIT	OWNER	LOCATION, SITE	COMMODITIES	TONNAGES AND GRADES	SOURCE	COMMENTS
ROUNDY CREEK cont			MoS2 (a) (b) (c)	0.11% 8 000 000 tons 0.347% 1 488 000 tons 0.668% 39 000 tons		
SCHAFT CREEK	LIARD COPPER M.L. (Silver Standard 65%)	85 miles S of Telegraph Crk. 104 G/6E, 7W	Cu MoS2	0.40% 300 000 000 tons 0.36%	6	1957 discovery 1966-74 Liard Copper drilling and surveys. 1970 Hecla mining Co. optioned 1975-78 Hecla drilling. Exploration by Hecla $2 919 900 1978 Feasibility study by Hecla. Not feasible. Majority rights acquired by Teck for 3.1Mn U.S. Hecla retains 5% net profits. Constraints Transportation, power availability about 80Mn power required Could depend on STIKINE Copper.
			Cu MoS2	(350 - Annual Report) 0.40% 364 000 000 tons 0.036% (stripping ratio= 1.5:1)	14 (text) (1975)	
			Cu Mo	0.40 % 270 000 000 tons 0.022% 350	9	
SCHAFT CREEK II	Paramount M.L.	Adjoins Hard Property 104 E/6	Cu Mo	0.329% 100 000 000 tons 0.048%	6 (1973)	1969-70 optioned to Hecla dropped 1973
			Cu Mo	0.33% 90 000 000 0.0238%	9	
ADANAC (Ruby Creek) ADERA	Adanac Mining & Exploration L. Placer	Ruby Creek BC 104 N/11W	MoS2	0.16% 104 000 000 tons	6	1905 discovery 1967 drilling by Adanac 1973-4 optioned to AMAX 1976-7 optioned to Noranda Expl.Co. L. to 1978, approx. $4 200 000 spent on exploration and study 1979 70% interest sold by Adanac to Placer Dev -payment of $80 000 +$300 000 work for 1979. -payment of $100 000 + $300 000 work for 1980 production to begin by 1983,or further payments to be made by Placer. 14 000 mtpd mill comtemplated. prod. by 1981 end. or early 1982/
			MoS2	0.14% 111 000 000 tons (cut-off = 0.10% MoS2	14 (table) (1971)	
			MoS2	0.129% 66 600 000 tons range 0.16% 104 200 000 tons	11(news release)	
			MoS2	0.122% 75 050 155 tons 0.06% MoS2 cut-off	Prospectus (1979)	

DEPOSIT	OWNER	LOCATION, SITE	COMMODITIES	TONNAGES AND GRADES	SOURCE	COMMENTS
BERG	KENNCO EXPLOR (Western) Ltd.	20 miles NW of Tahtsa Reach 93 E/14W (10 miles SE of Houston)	Cu Mo	0.40% 400 000 000 tons 0.05%	6 (1975)	1961-71 exploration, drilling 1972 optioned to Placer Development 1974-5 Placer continues exploration Constraints Require access road from Houston; townsite would probably have to be built. Power requires building of grid from Houston or Kemano.
			Cu Mo	0.40% 360 000 000 tons 0.05%	9	
			Cu MoS_2	0.40% 394 000 000 tons 0.054% (0.25% cutoff; 250 000 000 tons with stripping ratio 2.75:1.)	14(p.422)	
POISON MOUNTAIN	Copper Giant Moly Corp. (Long Lac Min. Explor. Ltd. 50.64%)	70 miles NW of Lillooet. 920/2E	Cu MoS_2	0.37% 85 000 000 tons 0.022%	4,7 (1967) 14 (p.422)	1935-67 drilling, mapping, surveying 1970 tests, surveys Copper Giant has 30% share. Property idle since 1971 (7) 1979 activitiy
			Cu MoS_2 Au	0.33% 193 000 000 tons 0.025% .3 ppm	14 (Table)	
GLACIER GULCH Yorke-Hardy Hudson Bay Mtn.	AMAX EXPLOR. LTD. (Climax of BC)	Smithers Area 93L/14W	MoS_2 WO_3	0.30 70 000 000 tons 0.06	12	1958-66 surface 1966-69 d.d drifts, adits 1970-71 extensive drilling Company has expressed interest in development large tungsten potential Constraints deposit favors underground development, open pit options may be more favorable.
			MoS_2	0.29% 100 000 000 tons	8,14(p422)	
			Mo	0.15% 100 000 000 tons	9,6	
HUCKLEBERRY	KENNCO EXPLOR (Western) LTD.	50 miles SW of Houston on Oosta Lake 93 E/11E	Cu MoS_2	0.417% 85 600 000 tons 0.025%	15 (1976) 14 (p.422)	1961 discovery 1972 Kennco optioned to Granby M.L. can earn 50% int. if spend 1.5 Mn by 1989 - had spent $1 Mn by 1974 1974-76 feasibility studies indicate not economical. Est. cost of dev $100 Mn Constraints - similar to BERG. Townsite/power/roads

DEPOSIT	OWNER	LOCATION, SITE	COMMODITIES	TONNAGES AND GRADES	SOURCE	COMMENTS
OX LAKE	SILVER STANDARD M.L.	75 miles S of Smithers 93 E/11E	Cu Mo	n.a. 30 000 000 tons m.a.	7 91969)	1968-9 discovery drilling, geo. surveys Property owned 50% by Asarco. Idle since 1969. Constraints: see Berg and Huckleberry
			Cu MoS2	0.26% 30 000 000 tons 0.07%	14 (p.422)	
AJAX	NEWMONT M.L.	Alice Arm 103 P/11E	MoS2 or	0.12% 190 800 000 tons 0.09% 460 000 000 tons	14 (p.422)	1960's discovery, drilling Constraints: very high stripping ratio
RED BIRD	ASHFORK ML (Phelps Dodge Corp. 100%)	Red Bird Mtn. 93 E/6E	MoS2	0.24% 20 000 000 tons	7 (1970)	1929 discovery 1959 re-stating by Phelps Corp of Canada 1963-68 drilling Constraints: remote location, infrastructure limited.
			Mo	0.144% 20 000 000 tons	4	
					16 - #59	
CATFACE	CATFACE COPPER M.L. (Falconbridge Mines 97.4%)	Tofino 92 F/5	Cu Mo	0.48% 115 000 000 tons n.a.	1,4	1909-10 exploration 1960-68 drilling, mapping, geophysics 1963 Catface incorporated 1970-72 drilling, preproduction planning Constraints: low ore value to operating costs availability of electrical power.
			Cu Mo	0.45 - 0.50% n.a.	7	
AXE (Adonis)	Adonis M.L.	12 miles N of Princeton 92 H/10	Cu Mo	0.45% 50 000 000 tons 0.012%	7 (1972)	1900 discovery 1967-72 mapping, tests, drilling 1972-73 drilling 1977 Adonis changes name to Global Energy Corp.
			Cu (a) (b) (c) Mo	0.48% 41 000 000 tons 0.56% 16 000 000 tons 0.47% 6 400 000 tons (a)*0.012% (b)*0.012% (c) na	6 (1983) *13 est.	

DEPOSIT	OWNER	LOCATION, SITE	COMMODITIES	TONNAGES AND GRADES	SOURCE	COMMENTS
HUNTSMAN (Storie)	New Jersey Zinc Explor. Canada Ltd.	4 miles S of Cassiar 104 P/5W	Mo	0.115% 110 000 000 tons	15	1965 initial exploration 1968-71 drilling 1976 drilling large sulphide deposit. Could use Cassiar as townsite. Constraints: power supply, transportation would probably be by truck to Stewart. Need higher Mo price.
MT. HASKINS (JOEM)	DELLA ML	Cassiar Area 104 P/5	MoS2 Ag, Zn	0.15% 13 500 000 tons na	14 (p.422)	1968-69 drilling 1971-4 underground tunneling and drilling 1976 drilling resumed Financed by R&P Metals Corp, Iso Mines Ltd and Ashland Oil.
			MoS2	0.17% 13 000 000 tons	3	
O.K.	GOLDEN GRANITE ML (Prev. Granite Mtn. ML)	18 miles NW of Powell River 92K/2E	Cu MoS2	0.30% 100 000 000 tons 0.03%	14 (p.422)	1916 discovery 1965 re-discovered, exploration 1972 surveys, drilling 1973-4 optioned to Western ML (65% if prod). Drilling so Western earns 50% interest. 1976 Western agreement changed so can earn 80% - 90% interest if expands in 2 years.
			Cu MoS2	0.33% 90 000 000 tons 0.02%	6	
			Cu MoS2	0.30% 75 000 000 tons 0.016% (cutoff 0.2% Cu)	14 (Table)	
KRAIN	Initial Develop Ltd.	Highland Valley	Cu Mo	0.56% ;5 530 000 tons 0.01%	14 (text)	1907 discovery 1955 porphyry discovery, exploration 1971 exploration and development option to Getty ML-drilling 1974 Getty drops option Comet Industries owns some claims, optioned to I.D.
			Cu Mo	0.45% 20 000 000 tons na	6	
			Cu MoS2	0.55% 16 535 000 tons 0.02%	14 (Table)	

DEPOSIT	OWNER	LOCATION, SITE	COMMODITIES	TONNAGES AND GRADES	SOURCE	COMMENTS
CARMI	VESTOR EXPLOR. LTD.	Kelowna Area 82 E/11E	MoS2 Mo	0.15% 40 000 000 tons 0.09% 35 000 000 tons	8 9 (14 #1)	1974-5 optioned to Granby Mining. Drilled and option dropped. 1976-7 optioned to Craigmont M.L. Maps and drilling dropped. 1978 Vestor signs agreement with Union Oil on development.
MT. THOMLINSON	AMAX EXPLOR.	30 miles N of Houston 93M/12W	Mo MoS2	0.072% 36 000 000 tons 0.12% 45 000 000 tons	9 14 (p.422)	Little information 14. #94.
LUCKY SHIP	AMAX EXPLOR. 95% Wharf Res. 5%.	59 miles SW of Houston 93L/3W	MoS2 Mo MoS2	0.14% 19 600 000 tons 0.09% 15 430 000 tons 0.17% 19 800 000 tons	8,6 14(Table #72)	1965 restaked by AMAX, drilling 1966-7 drilling 1971-5 no work reported. AMAX acquires 95% interest. Constraints: small, low grade deposit AMAX has better prospects.
POPLAR	UTAH ML Option	30 miles SW of Houston	Cu MoS2	0.42% 80 000 000 tons 0.025% (Similar to Huckleberry)	3 (est) 14 #74	1971 Located for El Pasa Mining originally. 1972 El Pasa exploration 1974 Optioned to Utah Mines 1975-6 Active drilling Constraints: needs proven tonnage and grade, higher Cu price.
WHIT	KENNCO EXPLOR (Western) Ltd	70 miles SSW of Houston (near Huckleberry)	Cu MoS2	0.3% na 0.04%	3	1963 discovery by Kennco 1964-5 drilling 1972 drilling Not a major prospect.
MOLLY (ATLIN)	COMINCO	SE end of Atlin Lk.	MoS2	n.a.	3	1970 surface mapping 1972-4 drilling (little) Cominco has dropped.

DEPOSIT	OWNER	LOCATION, SITE	COMMODITIES	TONNAGES AND GRADES	SOURCE	COMMENTS
GEM (MEG)	GEMEX	N of Harrison L.	Mo	46 500 tons contained Mo	14(p.422)	14 #19
SERB CREEK	AMAX	Smithers Area 93L/12W	MoS2	0.08% 500 000 000 tons	14 (p.422)	
SALAL CREEK	BP MINERALS	92J/14W	Mo	n.a.	14 (p.422)	Low grade potential. Craigmont drilled in 1975.
EAGLE	NUSPAR MIN 40% IMPERIAL OIL 60%	33 miles E of Dease Lake.	Cu Mo	n.a. n.a.	3,6	
KAREN	HE6CA RES.CORP	48 miles N of Grand Forks	Cu Mo	n.a. 60 000 000 tons n.a.		
CASCADE MOLY	NEW CASCADE M.L.		Mo	0.14% 1 078 283 tons	7	Amenable to open pit, but small (7) New Cascade acquired by Maloney Steel 1976. Adjacent to Red Mtn.
			MoS2 Au	0.27% 1 500 000 tons 0.034 oz/ton	14 (p.422)	
GIANT (ST.ELMO)	CHANDALAR RES. 50% SCURRY RAINBOW 50%	Rossland Area	MoS2	0.39% 810 540 tons	6 (1972)	Open pit prospect drilled in the 1970's, split with Scurry.
			MoS2	0.33% 73 000 tons	6	
			MoS2	0.39% 804 700 tons	14 (p.422)	
CANAM	GIANT MASCOT ML (GM RES.)	27 miles SW of Hope 93 11/3	Cu Ag Au Mo	1.28% 2 600 000 tons 0.65% 0.015% 0.03%	6 (1970) 7	1903-70 extensive drilling and development. Work suspended late 1970.

DEPOSIT	OWNER	LOCATION, SITE	COMMODITIES	TONNAGES AND GRADES	SOURCE	COMMENTS
TROUT LAKE	NEWMONT MINING CORP. 55% ESSO MINERALS 45%	35 miles SE of Revelstoke	MoS_2	0.40% - 0.915%	18,17	1979 "several million dollars" spent on drilling; encouraging prospect; no reserves to date.
MOLY TAKU	OMNI RESOURCES	Mt. Ogden, Atlin Region 104 K/6	Mo	0.30% average sample 242 300 000 tons	Prospectus and Annual Report	1978 discovery, chip sampling 1979 drilling program
MT. REED	CANADIAN SUPERIOR EXP.	Near Mt. Haskin				
<u>Y U K O N</u>						
LOGJAM	AMAX POTASH L	100 miles W of Watson Lk. Y.T. (on BC-Yukon border)	WO_3 MoS_2 WO_3 MoS_2	0.12% 179 000 000 tons 0.052% contains: 0.16% 58 000 000 tons 0.062%	17	1977 9 300 ft. drilled 1978 13 700 ft. drilled, road improvement, mapping, 1979 preliminary economic analysis drilling program planned. $1 140 000 has been spent. AMAX can earn 60% interest if spend $2 Mn.
CASINO	CASINO SILVER ML (Brameda Res. Ltd. 38% Teck subs)	190 miles NW of Whitehorse	Cu MoS_2	0.37% 179 000 000 tons 0.039%	3,6	1969-73 extensive evaluation 1973 Brameda had spent $2.8 Mn by this time. No work since. Must bring to production or lose option.
TINTINA	TINTINA SILVER MINES LTD	50 miles E of Whitehorse	MoS_2	0.07% - 0.19% no tonnage	19 (1978)	1978 Amoco Canada Petroleum takes option can earn 70% interest.

FORMER PRODUCERS

DEPOSIT	OWNER	LOCATION, SITE	COMMODITIES	TONNAGES AND GRADES	SOURCE	COMMENTS
COXEY	RED MTN. MINES (Transferred to INCO)	Rossland Area BC 82 F/4W	MoS2	0.51% 992 000 tons	14 (p.420	1966- 1972 open pit mine, 400 ton mill increased 1968 to 600 tons. Production ranged from 900 000 to 1 232 000 lbs annually. operated at loss, Co inactive Charter surrendered 1977. production 1966-72= 3 644 000 lb. Mo
MT. COPELAND	KING RES. KRC OPERATORS LTD.	N of Revelstoke 82 M/1W	MoS2	1.82% 180 000 tons more than 1 Mn tons	6 (1070) 14 (p.420)	production started at 200 tpd - 230 tpd 1971. Ceased May 31, 1973. production 1970-73=2 623 735 lbs Mo.
BC MOLY	BC MOLY (now Climax)	Alice Arm 103 P/6W	MoS2 Mo	0.23% 49 600 000 tons 0.115% 105 000 000 tons proven and probable.	14 (p.420) 13	

YEAR	ORE MINE TONS	WASTE TONS	CONC MoS2 LBS.
1967	88 719	83 450	132 231
1968	2 147 994	4 632 094	5 089 969
1969	2 356 514	3 416 618	5 567 709
1970	2 693 228	4 229 730	6 141 305
1971	2 476 175	2 510 590	5 106 964
1972	521 625	585 511	1 085 204
	10 284 255	15 507 993	23 123 382

WASTE/ORE RATIO = 1.508:1

1967 open pit began production.
mill capacity 6 500-10 000 tpd.
1972 2 000 000 lbs of MoS2 concentrate in inventory
mine, mill, townsite sold to AMAX for $2 622 074
due to lack of market for concentrate.
1973-79 AMAX drilling, feasibility studies.

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APPENDIX III

APPENDIX TABLES

APPENDIX TABLE A-1

NON-COMMUNIST WORLD MOLYBDENUM CONSUMPTION BY END-USE, 1976

END-USE	1000 m.t. Mo	%	EXPECTED GROWTH RATE TO 1984 (%)	% IN 1984*
Carbon Steels	2.0	2.5	0	1.4
HSLA Steels	33.9	42.3	9.5	50.8
Stainless Steels	15.1	18.8	7.0	18.9
Tool Steels	6.0	7.5	3.0	5.5
Managing Steels	1.5	1.8	3.0	1.3
High-Temperature Steels	1.8	2.2	4.0	1.7
Cast Irons	3.6	4.5	2.0	3.0
Superalloys	4.1	5.1	3.5	3.9
Mo Metal	5.0	6.3	5.0	5.4
Pigments	2.3	2.8	6.0	2.6
Catalysts	3.2	3.9	7.0	3.9
Lubricants	1.9	2.3	2.0	1.6
TOTALS	80.0	100.0	7.0	100.0

* given stated growth rates.

Source: Butterfield, J.A., and Ganshorn J.A., Placer Development Limited, "Molybdenum Supply and Demand Forecast", CIM, Annual Volume, 1977.

APPENDIX TABLE A - 2

IMPORTS OF MOLYBDENUM OXIDE BY JAPAN*
(in metric tons)

	1976	1977	1978
Canada	7 168	7 703	6 322
U.S.	9 187	7 822	8 473
Chile	736	652	1 373
S. Korea	70	13	-
W. Germany	229	-	20
Belgium	349	83	-
Netherlands	20	-	13
Sweden	-	-	-
U.K.	30	148	-
Portugal	-	-	24
Australia	-	-	-
Total	17 789	16 421	16 234

* 0.60% Molybdenum on average.

FERROMOLYBDENUM IMPORTS BY JAPAN
(in metric tons)

	1976	1977	1978
Austria	395	64	81
U.S.	500	158	343
W. Germany	9	-	10
Sweden	-	-	-
Belgium	34	-	-
Netherlands	-	-	30
Chile	26	-	10
France	-	-	-
Luxemburg	-	-	-
U.K.	-	-	17
Canada	72	-	21
Brazil	-	-	139
Total	1 036	222	651

Source: Compiled from Finance Ministry figures.

APPENDIX TABLE A - 3

CANADA

CURRENT AND PROJECTED MOLYBDENUM PRODUCTION
(millions of Kg)

COMPANY	MINE	1977	1978	1979	1980	1981	1982	1983	1984	1985	86-90	91-95	1996+
EXISTING MINES													
PLACER	*ENDAKO	7.69	6.03	3.7	6.0	6.0	6.3	6.3	6.3	6.3	6.3	6.3	6.3
	GIBRALTAR	0.14	0.12	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
NORANDA	BRENDA	3.87	3.31	3.0	2.6	2.6	2.7	2.7	2.7	2.7	2.7	-	-
	*BOSS	1.00	0.76	0.7	1.3	1.3	0.6	-	-	-	-	-	-
	GASPE	1.01	0.81	1.0	1.2	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
RIO ALGOM	LORNEX	1.85	1.87	1.5	1.8	1.8	1.8	1.8	1.8	1.8	2.7	2.7	2.7
UTAH	ISLAND COPPER	1.00	0.86	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	-
BETHLEHEM	BETHLEHEM	-	0.13	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-	-	-
ZAPATA	GRANISLE	-	-	-	0.1	0.2	0.2	0.2	0.2	0.2	0.2	-	-
SUBTOTAL		16.56	13.89	11.6	14.7	14.4	14.1	13.5	13.5	13.5	14.1	11.2	10.3
PROSPECTS													
NORANDA	*DUMAGAMI	-	-	-	0.2	0.4	0.4	0.4	0.2	-	-	-	-
TECK	HIGHMONT	-	-	-	-	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
AMAX	*KITSAULT	-	-	-	-	-	2.3	4.5	4.5	4.5	4.5	4.5	4.5
PLACER	*ADANAC	-	-	-	-	-	-	-	1.8	3.6	3.6	3.6	3.6
COMINCO	VALLEY COPPER	-	-	-	-	-	-	-	-	-	0.5	0.7	0.7
BETHLEHEM	JA ZONE	-	-	-	-	-	-	-	-	-	0.7	0.7	0.7
ESSO	*TROUT LAKE	-	-	-	-	-	-	-	-	-	4.5	4.5	7.5
AMAX	*GLACIER GULCH	-	-	-	-	-	-	-	-	-	-	7.0	7.0

COMPANY	MINE												
PROSPECTS		1977	1978	1979	1980	1981	1982	1983	1984	1985	86-90	91-95	1996+
PLACER	BERG	-	-	-	-	-	-	-	-	-	-	1.7	1.7
TECK	SCHAFT CREEK	-	-	-	-	-	-	-	-	-	-	2.5	2.5
KENNCO	HUCKLEBERRY	-	-	-	-	-	-	-	-	-	-	-	0.5
BETHLEHEM	MAGGIE	-	-	-	-	-	-	-	-	-	-	-	1.0
SUBTOTAL		-	-	-	0.2	1.4	4.7	6.9	8.2	9.5	15.2	26.6	28.1
TOTAL		16.56	13.89	11.3	16.0	15.8	18.8	20.4	22.0	23.6	29.9	38.4	40.0

* Primary mines

Note: Projections for existing producers are from Noranda Sales Corporation.

APPENDIX TABLE A - 4

PROJECTED MOLYBDENUM SUPPLY: UNITED STATES

(millions of pounds contained molybdenum)

* primary mines

COMPANY	MINE	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986-1990	1991-1995
EXISTING MINES												
AMAX	* CLIMAX	51.0	52.0	50.0	53.0	53.0	53.0	53.0	53.0	53.0	55.0	55.0
	* HENDERSON	24.0	32.5	45.0	48.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
DUVAL	SIERRITA	19.0	18.0	18.0	18.0	20.0	25.0	25.0	25.0	25.0	25.0	25.0
	MINERAL PARK	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	ESPERANZA	-	-	1.5	3.0	3.5	3.5	3.5	-	-	-	-
KENNECOTT	BINGHAM	6.5	9.2	9.5	10.0	10.5	10.5	10.5	10.5	10.5	10.5	10.5
	RAY	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1.0	1.0
	McGILL	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	CHINO	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
MOLYCORP*	* QUESTA	8.1	5.5	5.0	4.5	4.0	3.0	-	-	-	-	-
ANAMAX	TWIN BUTTES	3.7	3.1	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
MAGMA	SAN MANUEL	2.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
CYPRUS	BAGDAD	0.4	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	PIMA	1.2	-	0.6	1.2	1.8	1.8	1.8	1.8	1.8	1.8	1.8
ASARCO	MISSION	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	SILVERBELL	-	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
CITIES	PINTO VALLEY	0.3	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
INSPIRATION	INSPIRATION	-	-	0.3	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
UNION CARBIDE	PINE CREEK	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
SUBTOTAL		122.1	131.8	145.3	153.7	158.9	162.9	159.9	156.4	156.4	158.7	158.7
PROSPECTS												
PHELPS DODGE	TYRONE	-	-	0.6	0.8	1.0	1.2	1.2	1.2	1.2	1.2	1.2
ANACONDA	CARR FORK	-	-	-	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
CYPRUS	* THOMPSON CREEK	-	-	-	-	-	-	10.0	15.0	20.0	20.0	20.0
MOLYCORP	* GOAT HILL	-	-	-	-	-	-	9.0	13.5	18.0	20.0	20.0
AMAX	MT. TOLMAN	-	-	-	-	-	-	-	-	5.0	25.0	25.0
AMAX	* MT. EMMONS	-	-	-	-	-	-	-	-	-	5.0	30.0
US BORAX	* QUARTZ HILL	-	-	-	-	-	-	-	-	-	25.0	25.0
PHELPS DODGE	* PINE GROVE	-	-	-	-	-	-	-	-	-	-	20.0
ANACONDA	THE HALL	-	-	-	-	-	-	-	-	-	-	10.0
SUBTOTAL		-	-	0.6	1.2	1.4	1.6	20.6	30.1	49.6	96.6	151.6
TOTAL		122.1	131.8	145.9	154.9	160.3	164.5	180.5	186.4	201.0	255.3	310.3

APPENDIX TABLE A - 5

SOUTH AMERICA CURRENT AND PROJECTED MOLYBDENUM PRODUCTION
(millions of pounds)

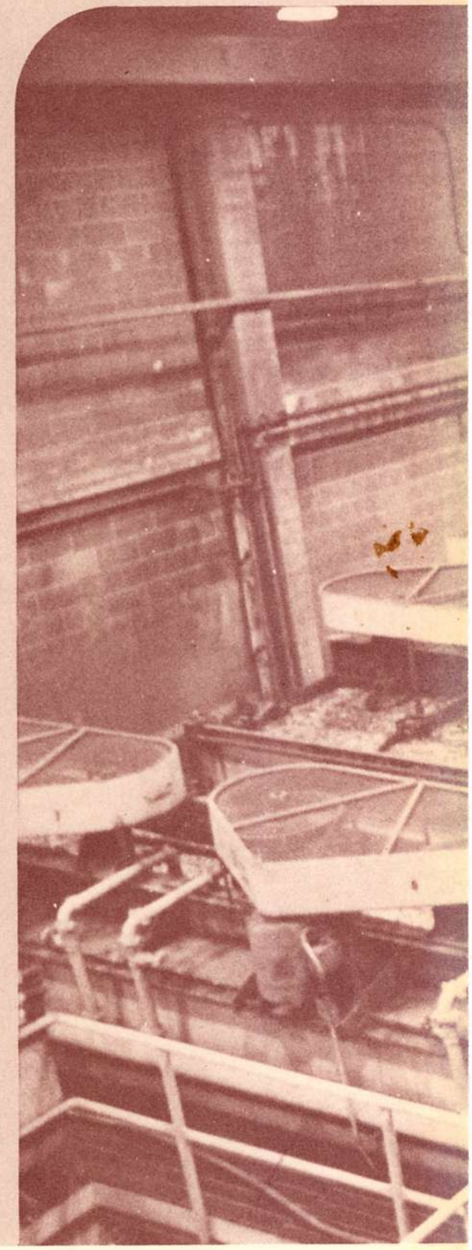
COMPANY	MINE	1977	1978	1979	1980	1981	1982	1983	1984	1985	86-90	91-95	RESERVES 1000 tons M
CHILE													
Codelco	Chuquicamata	15.34	19.70	19.4	19.4	19.4	19.4	21.0	23.0	25.0	25.5	25.4	814.0
	El Tennente	4.79	6.11	6.0	6.0	6.0	6.0	7.0	8.0	9.0	11.0	12.0	1521.2
	El Salvador	3.20	2.71	3.0	3.7	4.0	4.0	4.0	4.0	4.0	4.0	4.0	78.8
	Andina	0.77	0.58	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1.0	1.0	69.5
Anaconda	Los Pelambras	-	-	-	-	-	-	-	-	-	2.0	2.0	139.5
Nippon Mines	Cerro Colorado	-	-	-	-	-	-	-	-	-	2.2	2.5	9.9
Exxon	Dispatada	-	-	-	-	-	-	-	-	-	0.3	0.3	70.6
CHILE TOTAL		24.10	29.09	29.1	29.8	30.1	30.1	32.7	35.7	38.7	45.9	47.2	2703.5
PERU													
South Peru	Toquepala	0.50	0.55	0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.8	1.8	154.3
	Caujone	-	-	-	-	2.0	3.0	3.2	3.2	3.2	3.2	3.2	150.0
Minero Peru	Michiquillay	-	-	-	-	-	-	-	1.0	2.0	3.0	4.4	126.8
PERU TOTAL		0.50	0.55	0.6	1.0	3.0	4.0	4.2	5.2	6.2	8.0	9.4	458.6
ARGENTINA													
St. Joe	El Pachon	-	-	-	-	-	-	-	-	-	1.6	2.0	128.0
SOUTH AMERICA TOTAL		24.60	29.64	29.7	30.8	33.1	34.1	36.9	40.9	44.9	55.5	58.6	

APPENDIX TABLE A - 6

OTHER COUNTRIES CURRENT AND PROJECTED MOLYBDENUM PRODUCTION

(millions of pounds)

COMPANY	MINE	1977	1978	1979	1980	1981	1982	1983	1984	1985	86-90	91-95	RESERVES 1000 tons Mo
PHILLIPINES													
Marinduque	Sipalay	0.10	0.10	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	108.0
CDCP	CDCP	-	-	0.2	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	?
JAPAN													
All Mines		0.30	0.33	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	?
KOREA													
Korean Tungsten	DAEGU	0.22	0.22	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	?
MEXICO													
Cumobabi &	Cananea	0.04	0.04	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	100.0
La Caridad	-	-	-	-	1.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0	105.8
PANAMA													
Texas Gulf	Cerro Colorado	-	-	-	-	-	-	-	-	-	4.0	4.0	253.5
IRAN													
Nicic	Sar Chesmeh	-	-	-	1.0	2.0	4.0	4.0	4.0	4.0	4.0	4.0	116.1
NEW QUINEA													
Rio Tinto	Bouganville	-	-	-	-	1.0	2.0	4.0	4.0	4.0	4.0	4.0	81.0
GREENLAND													
Artish-Amax	Malmbjerg	-	-	-	-	-	-	-	-	-	-	15.0	192.0
TOTAL		0.66	0.69	0.9	3.2	7.3	11.3	14.3	14.3	14.3	18.3	33.3	956.4



Province of British Columbia

Ministry of
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