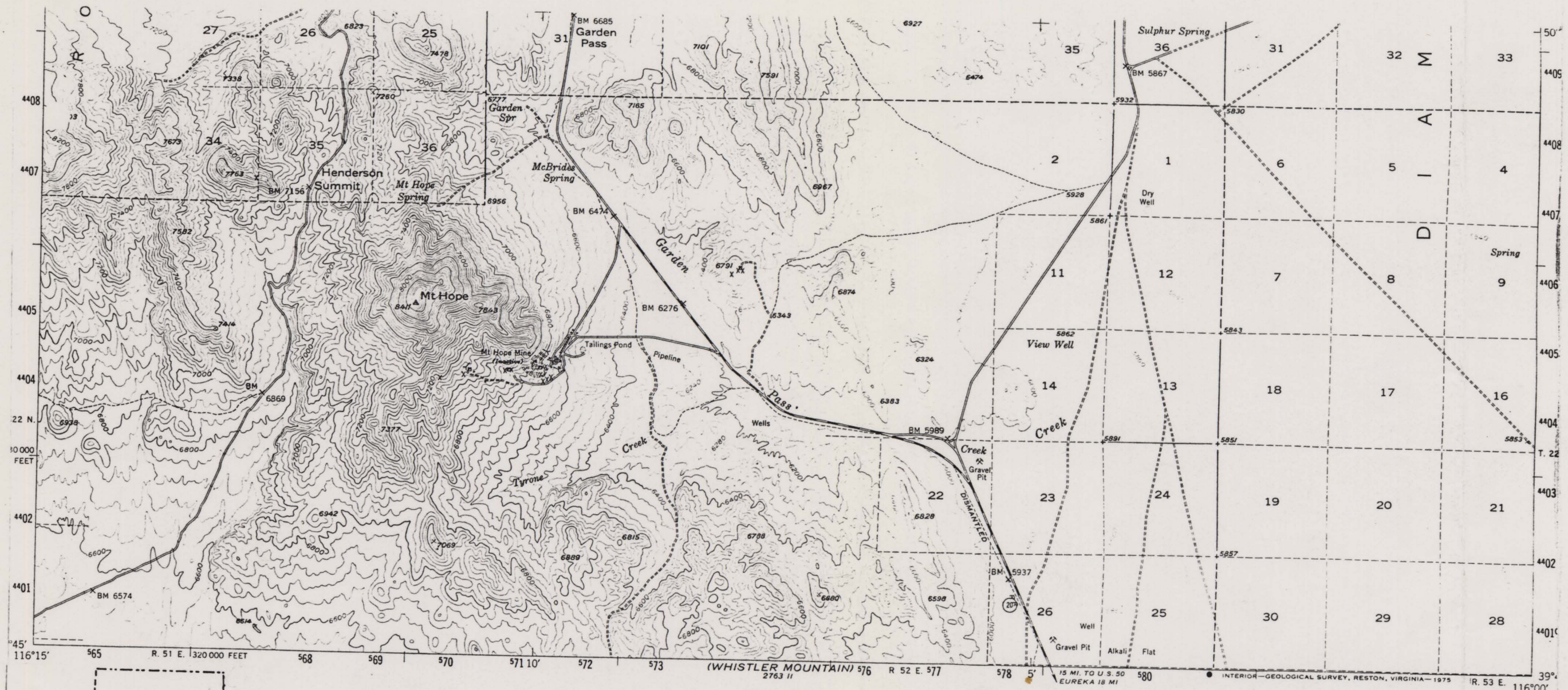


3220 0021

FIELD REVIEW
MT. HOPE PROJECT
OCTOBER 1, 1981

EXXON MINERALS CO.



ROAD CLASSIFICATION

HARD-SURFACE ALL WEATHER ROADS DRY WEATHER ROADS
 Heavy-duty ——— LANE LANE Improved dirt ———
 Medium-duty ——— LANE LANE Unimproved dirt ———
 Loose-surface, graded, or narrow hard-surface ———
 □ U. S. Route ○ State Route

GARDEN VALLEY, NEV.
 N3945-W11600/15

1949

AMS 2763 I-SERIES V796

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
 FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
 A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

32200021

R51E

R52E

MT. HOPE

NEVADA

T
23
NT
23
N

Trade	Bonus/ Claim	End Price/ Claim
M.H.	\$502	\$45,226
TIA	\$607	\$21,428

NO ROYALTY



M.H. \$502 \$45,226



TIA \$607 \$21,428



MINERALIZED ZONE



EXXON LAND

T
22
NT
22
N

MD 37-81

MT. HOPE REVIEW
MANAGEMENT COMMITTEE

June 25, 1981 - R. E. Rohn

**MOUNT HOPE, NEVADA
-OBLIGATIONS-**

Lease Name	Exxon Corporation Claims	Mount Hope Mines, Inc.	Maynard Bisoni, et al	TOTALS
Lease Number	L# 556993	L# 557045	L# 557077	---
Date of Lease or Location	May, June, Oct., Nov., 1978 July, Aug., 1979, and Feb., 1981	July 6, 1978	August 15, 1978	---
Claim Names	Hop #1-5, MH #1-1450, Pass #1-4	Unpatented Claims: Bowser Group, Bowser Fractions, Hope Group, West Incline, Lookout Patented Claims: Parallel, Parallel Ext, Magnolia, Dixon, Lorraine, Silver Butte, San Juan Chief, Good Hope. Mill Sites: Good Hope Mill Site, Bachelder Mill Site.	TIA, TIA #1-13	---
Unpatented Claims	1,459	184	14	1,657
Patented Claims	-0-	13	-0-	13
Mill Sites	-0-	2	-0-	2
Total	1,459	199	14	1,672
Acquisition Capital Cost	\$163,500.00	\$102,500.00	\$11,000.00	\$277,000.00
Annual Assessment Obligation	1981 74,600.00 1982 \$145,900.00	18,400.00 \$18,400.00	1,400.00 \$1,400.00	\$ 94,400.00 \$165,700.00
Royalty	None	5 1/2% NSR until exercise, then -0-	5% NSR until exercise, then -0-	
Annual Payments				
1981	None	\$110,000.00	\$18,000.00	\$128,000.00
1982		120,000.00	20,000.00	140,000.00
1983		180,000.00	25,000.00	205,000.00
1984		180,000.00	35,000.00	215,000.00
1985-87		240,000.00	35,000.00	275,000.00/Yr.
1988		7,440,000.00	35,000.00	7,475,000.00
1989		See Note #7 Below	29,500.00	29,500.00
Total Purchase Price		9,000,000.00	\$300,000.00	9,300,000.00
Spent to Date Toward Purchase Price		\$250,000.00	\$32,500.00	282,500.00

SPECIAL PROVISIONS

1. Exxon must not impede Owner's operations during term of Option. Upon exercise, Owner has six (6) months to remove its plant, facilities, and tailings.
2. No partial release & reduction clause.
3. Conveyance by special warranty.
4. Release by May 1st to avoid assessment obligation.
5. Factual data to Owner on quarterly basis.
6. Must decide to exercise by 1988.
7. May delay exercise payment from 1988 to 1993 by annually paying prime interest rate on balance due.

THE MOUNT HOPE MOLYBDENUM PROSPECT

(Project 2608)

EUREKA COUNTY, NEVADA

A PROGRESS REPORT

by

Gerhard Westra

March 5, 1980

INTRODUCTION

Location

The Mount Hope Mining District is located in Eureka County, in east central Nevada (Figs. 1, 2). Nevada State Highway 51 passes within one mile east of the main mine workings. Palisade, 57 miles north of Mount Hope, is the nearest railhead. The county seat is Eureka and the number of inhabitants in Eureka County was 1,220 in 1965. At Mount Hope the population varies from 6 to 15.

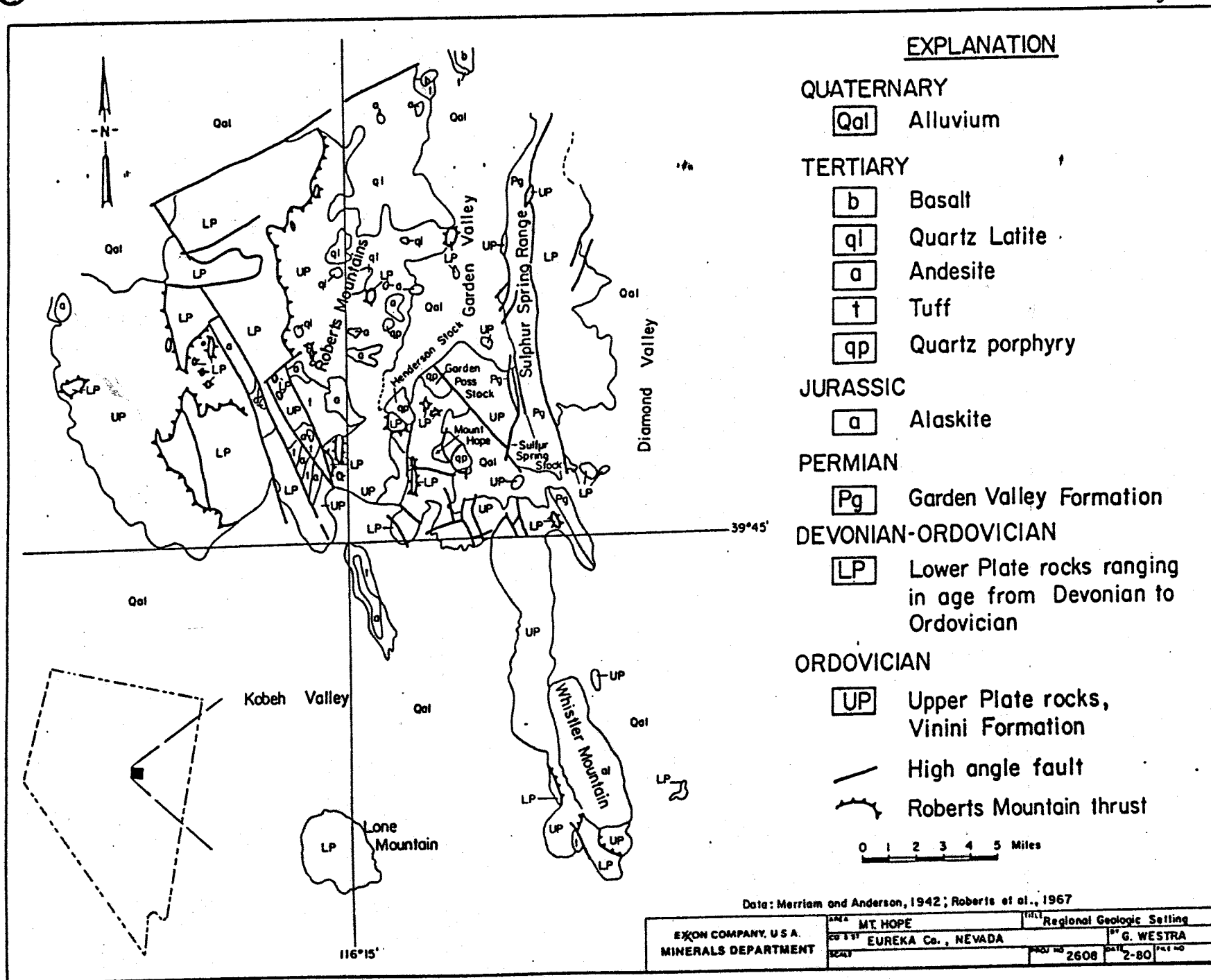
A small mill owned and operated by Mount Hope Mines, Inc. is located on the southeast side of the mountain. This mill has recently been connected to the Mount Wheeler Power Company network by a 14,400 volt powerline. Water for milling purposes is pumped from the mine workings. An additional water supply is available from three untested wells located some two miles east-southeast of the mill. All streams in the area are seasonal, but a major water supply may be found in Diamond Valley.

Mount Hope reaches an elevation of 8,411 feet. The gently sloping areas east and southeast of the mountain vary in elevation from 6800 to 6200 feet. Vegetation consists of grasses and sagebrush at lower elevations and sagebrush, juniper, and piñon pine at higher elevations. Rainfall varies from 10 to 15 inches annually and the temperature ranges from 65° to 75° in July, to 20° to 30° Fahrenheit in winter. Frosts commonly occur from September through June.

The Mount Hope Mining District and direct surroundings are not incorporated in any proposed Wilderness or Forest Service withdrawal areas.

Mining History

A detailed account of the mining history is given by Matson (1946). Zinc-lead replacement ore in altered Permian limestones of the Garden Valley



formation was first discovered in the area in 1870.

The property was purchased by Mr. Hal Jensen in 1967 who sold part of his interest to Mr. Harold L. Drimmer. Mount Hope Mines, Inc. drilled 5 short angle holes from the No. 1 adit level and discovered a small, high grade copper-silver orebody in skarn. A small crusher-mill complex was erected and some zinc ore was mined and treated. Mining was discontinued and the mill presently (1978) treats tungsten ores from several sources.

Until 1965 (Roberts et al., 1967), the district had produced 10,189,454 lbs. of zinc, 441,104 lbs. of lead, 63,967 ounces of silver, 57,675 lbs. of copper, and 83 ounces of gold with a historic metal value of \$1,335,393. Exploration activities during World War II by the U.S. Bureau of Mines outlined 175,874 tons of 9.9% zinc with significant cadmium credits. According to Mount Hope, Inc. inferred reserves now stand at 500,000 tons of 8% zinc and 0.1% cadmium.

Exploration History

Between the fall of 1928 and January, 1930, the Universal Exploration Company completed 3,413 feet of drilling. In 1944 the Callahan Zinc-Lead Company drilled 51 underground holes (5,536 feet). At this time, the U. S. Bureau of Mines completed 18 surface holes totalling 7,215 feet. In addition, mineralization has been tested by 7,659 feet of drifting, shaft sinking, and raising, and by about 20,000 cubic feet of stoping.

Phillips Petroleum Company optioned the property in 1970. Between 1970 and 1971, Phillips conducted an extensive geological, geophysical and drilling program to test high grade base metal skarn and replacement potential in sediments along the southern and western contact of the Mount Hope igneous complex. Following I.P. and aeromagnetic surveys, Phillips drilled 15 core holes (17,058 feet) and 14 rotary holes (~4200 feet). Although widespread significant base metal mineralization was found, no economic deposit was located. In 1971, after spending in excess of \$1 million, Phillips terminated its option agreement with Mount Hope Mines, Inc.

Between 1972 and 1978 several major mining companies, including Amax, Asarco, Phelps Dodge and Gulf Mineral Resources tried without success, to negotiate an option agreement with Mount Hope Mines. In 1974 Asarco did take an option on the TIA property which straddles the southwestern contact zone of the stock. Asarco completed a detailed soil geochemical survey and drilled two holes (1,138 feet) to test the base metal potential of the sediments before abandoning the property.

Gulf Mineral Resources staked a large area east of Mount Hope, conducted an I.P. survey and drilled three holes (3226 feet), two of which test Exxon's Sulphur Springs target area, approximately 1.5 miles due east of the Mount Hope workings. Abco Oil may also have drilled three holes in the Sulphur Springs target area. Known drill hole locations are indicated on plate 1A. Both Bear Creek Mining Company and Phelps Dodge have conducted I.P. surveys in the area east of Mount Hope.

Exxon Activity in the Mount Hope Area

The skarn potential of the Mount Hope Mining District was brought to the attention of management by Mr. Paul W. Zimmer in 1969 and investigated by Stevens (1969), who recommended acquisition of the property. The area was again assessed by Lavery (1974) who investigated the copper potential of the intrusive body. He did not find encouragement in the samples collected and recommended against additional work in this district. Weaver (1975) suggested that potential might exist for high grade copper mineralization in sediments adjacent to the rhyolite stock. Westra, (1978) recognized, and recommended to management, the molybdenum potential of the project. Land acquisition and subsequent work to present has followed.

SUMMARY

The Mount Hope molybdenum prospect is located along the leading edge of the Roberts Mountain thrust. Deep water siliceous sediments of Ordovician age (Vinini Formation) were thrust over Devonian carbonates during the Antler orogeny. Drilling indicates that the upper plate is at least 2890 feet thick. During the Permian, calcareous sandstones, conglomerates and limestones were deposited in the area. These rocks were folded and faulted during the Sonoma orogeny.

In Oligocene time, Mount Hope became the site of an intrusive-extrusive center that has now been eroded to a subvolcanic level. The northwest-trending Mount Hope igneous complex measures 6,800 by 4,500 feet and is made up of intrusive and extrusive (?) rhyolitic to alkali granitic igneous rocks that have been emplaced along the southwest side of a much larger circular structure. Within the complex, cauldron subsidence along the Mount Hope fault resulted in a small cauldron 4,000 feet in diameter filled with rhyolite crystal tuffs and explosion breccias. The rhyolite is intruded by a quartz porphyry stock with a border phase transition to rhyolite. Based on groundmass crystal sizes, two main quartz porphyry cooling units can be recognized, a quenched border phase and a coarser aplitic quartz porphyry phase that occupies the core of the stock. These rocks in turn are intruded at depth by a biotite granite to granite porphyry stock and a coarse crystalline quartz-K-feldspar porphyry. Plagioclase is absent and biotite is exceedingly scarce in the quartz porphyry stock but both are present at depth in the biotite granite and coarse quartz-K-feldspar porphyry phases below the ore zone. Directly east of the stock a large altered dike of biotite granodiorite porphyry is exposed.

Several levels of erosion in the igneous complex are reflected in the alteration distribution and the surface geochemistry. Alteration from the

periphery inward ranges from weak argillization, clay-carbonate, argillic, K-feldspar-quartz-fluorite-sericite to K-feldspar-quartz-fluorite. At depth the potassic zone grades into a K-feldspar-quartz-magnetite assemblage and fresh rocks. Quartz-sericite-pyrite alteration is scarce and fracture controlled. The dominant surface alteration assemblage consists of clays (montmorillonite, nontronite, kaolinite), carbonates (calcite, dolomite, ankerite), sulfides (pyrite, pyrrhotite and sphalerite) and locally sericite. The alteration minerals commonly occur in orbicular aggregates. Clay-carbonate alteration assemblages are abundant in rhyolite, explosion breccias and locally in Vinini hornfels but have not been found in the quartz porphyry. Quartz veins on the other hand are restricted to quartz porphyry phases and have not been found in the rhyolite. The top of a quartz vein stockwork occurs at depth well within the quartz porphyry stock east of the Mount Hope Fault and is exposed west of the Mount Hope fault. Molybdenite occurs in a quartz vein stockwork that cuts pervasively K-feldspathized quartz porphyry. K_2O values often exceed 10 percent. Total sulfide content in the ore zone is low (≤ 1 wt%) but a strong pyrite halo (≥ 5 wt%) is present in the rhyolite above the ore zone in EMH-3.

Vinini Formation in the contact zone has been converted to a biotite hornfels and away from the contact consists of quartz, sericite and pyrite. A quartz vein stockwork with fluorite cuts biotite hornfels in the southern contact zone. A small syncline of Garden Valley formation along the southeast side of the stock has been recrystallized to marble and also contains zones of grossularite skarn with basemetal sulfides. Metal content changes from lead-zinc in the upper horizon through zinc in the middle horizon to zinc-silver-copper in the lower horizon. In addition, high grade copper-silver mineralization is present in a pyrrhotite skarn found along the igneous contact.

Metal zoning patterns are well developed in the Mount Hope system. Surface molybdenum values range from 1 to 10 ppm and form a pronounced

anomaly along the southwestern contact of the quartz porphyry stock. A large fluorine anomaly (highest value 6600 ppm) coincides with, and occurs south of, the molybdenum anomaly. This structurally deep environment contrasts markedly with the area east of the Mount Hope fault where surface samples contain highly anomalous lead, zinc and silver values. High zinc, lead, copper and tin values have also been detected in the contact zone of the northern apophyse in target area IV.

Vertical metal zoning patterns are well defined. The upper halo is characterized by strongly anomalous lead values (to 935 ppm) followed at greater depth by a strong zinc-silver-tin halo. Zinc reaches values of 2% in ten foot samples and 300 feet of $>0.5\%$ zinc is present in EMH-3. Tin values reach 0.52% over 50 feet and silver values in excess of 0.3 ounces are present over hundreds of vertical feet. Copper forms a halo directly above the molybdenum ore shell and values range from 200 to 1500 ppm. The highest fluorine concentrations (> 5000 ppm) are found directly above the molybdenum ore shell. Tungsten is found in strongly anomalous concentrations (up to 275 ppm W) in the lower part of the molybdenite zone and directly below it. Alteration, trace element distribution patterns and drillhole results best fit a single large molybdenite ore shell. This ore shell has the shape of an inverted cup with surface dimensions of 3,800 by 1,900 feet and a true thickness of 600 to 800 feet. The systems axis has been tilted 20° east and the eastern part of the ore shell has been downfaulted 1200 feet along the Mount Hope fault.

A total footage of 11,551 feet was drilled in five holes during the 1978-1979 drilling program. The drilling program established the presence of a very large molybdenum-rich hydrothermal system. Conservative reserve estimates are 527 million tons of 0.1902% MoS_2 . These reserves include significantly higher grade portions. The following mineralized intercepts were obtained:

anomaly along the southwestern contact of the quartz porphyry stock. A large fluorine anomaly (highest value 6600 ppm) coincides with, and occurs south of, the molybdenum anomaly. This structurally deep environment contrasts markedly with the area east of the Mount Hope fault where surface samples contain highly anomalous lead, zinc and silver values. High zinc, lead, copper and tin values have also been detected in the contact zone of the northern apophyse in target area IV.

Vertical metal zoning patterns are well defined. The upper halo is characterized by strongly anomalous lead values (to 935 ppm) followed at greater depth by a strong zinc-silver-tin halo. Zinc reaches values of 2% in ten foot samples and 300 feet of $>0.5\%$ zinc is present in EMH-3. Tin values reach 0.52% over 50 feet and silver values in excess of 0.3 ounces are present over hundreds of vertical feet. Copper forms a halo directly above the molybdenum ore shell and values range from 200 to 1500 ppm. The highest fluorine concentrations (> 5000 ppm) are found directly above the molybdenum ore shell. Tungsten is found in strongly anomalous concentrations (up to 275 ppm W) in the lower part of the molybdenite zone and directly below it. Alteration, trace element distribution patterns and drillhole results best fit a single large molybdenite ore shell. This ore shell has the shape of an inverted cup with surface dimensions of 3,800 by 1,900 feet and a true thickness of 600 to 800 feet. The systems axis has been tilted 20° east and the eastern part of the ore shell has been downfaulted 1200 feet along the Mount Hope fault.

A total footage of 11,551 feet was drilled in five holes during the 1978-1979 drilling program. The drilling program established the presence of a very large molybdenum-rich hydrothermal system. Conservative reserve estimates are 527 million tons of $0.1902\% \text{ MoS}_2$. These reserves include significantly higher grade portions. The following mineralized intercepts were obtained:

EMH-1 (T.D. 2867):	1750-2450	700 feet of 0.138% MoS ₂
	1800-2000	200 feet of 0.206% MoS ₂ + 0.012% WO ₃
EMH-2 (T.D. 2734):	360-2350	1900 feet of 0.187% MoS ₂
	350-1800	1450 feet of 0.213% MoS ₂
	720-980	260 feet of 0.30% MoS ₂
	1350-1400	50 feet of 0.329% MoS ₂
EMH-3 (T.D. 2888):	1450-2000	750 feet of 0.161% MoS ₂
	1570-1810	240 feet of 0.202% MoS ₂
EMH-4 (T.D. 1883):	0-1883	less than 0.1% MoS ₂
EMH-15 (T.D. 3146):	2180-3146	966 feet of 0.185% MoS ₂
	2340-2940	600 feet of 0.205% MoS ₂

These drill holes only test part of the main molybdenum system and significant untested potential remains within the area tested and in areas east, north and northwest of EMH-1; the area east, north and northwest of EMH-3; the zone west of EMH-2; and an area north of the Mount Hope summit. In addition, bulk silver potential along the Silver fault and bulk zinc-silver-tin potential in the area around EMH-3 and within the explosion breccia along the southeast side of the stock deserve attention.

CONCLUSIONS

Alteration and metal distribution patterns documented in surface exposures and drillcore in the Mount Hope molybdenum prospect indicate the presence of a large molybdenum-bearing system. After completion of five drillholes (11,551 feet) possible reserves stand at 500 million tons of 0.1902% MoS_2 . The top of the ore zone occurs 360 to 2180 feet below the surface. Drillhole EMH-2 intercepted 310 feet of 0.305% MoS_2 suggesting that a significant tonnage of $>0.30\%$ MoS_2 may be present. Presently known mineralization best fits a single large inverted cup-shaped ore shell with a diameter of 3,800 feet and a true ore thickness of 600 to 800 feet. The eastern part of this ore shell has been downfaulted 1200 feet along the Mount Hope fault.

The number of drillholes that test the ore zone and the drillhole spacing are totally inadequate to evaluate the economic potential of the prospect. At present the odds appear better than even that an economic molybdenum deposit will be found at Mount Hope. A minimum of ten drillholes will be needed to test the exploration potential. The petrochemistry of cogenetic igneous phases strongly suggests that this is a Climax-type molybdenum system which implies that molybdenite grades could be significantly higher than 0.3% MoS_2 .

MOLYBDENUM

By Andrew Kuklis¹

Molybdenum, a very important additive metal, is used in increasingly greater quantities in the manufacture of steels, iron castings, and alloys. Additionally, molybdenum is a refractory metal and has gained prominence as one of the new nuclear and space age metals. It is of increasing value to the chemical industry where extensive applications were discovered for molybdenum chemicals.

The United States supplied nearly 59 percent of the total world output in 1974. About 66 percent is recovered as a primary product from molybdenite, a molybdenum sulfide mineral. The remainder is obtained as a byproduct of copper.

No economically competitive substitutes are available for molybdenum in some critical alloy applications; but tungsten and other elements can be utilized as alternate materials in certain applications. Many elements are used in various formulations to achieve desired effects.

Demand for molybdenum has increased steadily during the past decade, and the outlook is for continued growth. The most promising growth areas are in transportation, industrial machinery, and the oil and gas sectors.

A contingency forecast by end uses indicate that U.S. molybdenum requirements will increase at an annual average rate between 3.7 to 4.7 percent through the year 2000. Domestic demand is expected to rise from 73 million pounds in 1973 to between 165 and 215 million pounds in 2000. Cumulative requirements for 1973 to 2000 will total 2.9 to 3.4 billion pounds. It is expected that domestic production will continue to provide the U.S. molybdenum demand.

The demand in the rest of the world from 1973 to 2000 is forecast to increase at a rate of 4.0 to 5.0 percent annually and to total 346 to 448 million pounds. Cumulative requirements for 1973 to 2000 will range between 5.9 and 6.9 billion pounds. Supply for the rest of the world is expected to be more than adequate through 2000.

INDUSTRY STRUCTURE

Background

Molybdenite, the principal molybdenum mineral, was identified as molybdenum sulfide by a Swedish chemist, Karl Scheele, in 1778. Four years later, J. J. Hjelm isolated the element molybdenum. More than 100 years elapsed before an impure molybdenum metal was produced by reducing calcium molybdate with carbon and separating the lime with hydrochloric acid. This impure metal was reported to have been used experimentally in tool steel in 1893 as a replacement for tungsten. A short time later, Henri Moissan, a French chemist, produced a virtually pure metal by reducing molybdenite in an electric furnace.

Moissan conducted extensive studies on the chemical properties of molybdenum and established its atomic weight and many other physical properties of the metal. These early experiments stimulated interest in the element and led to its applications in steel and chemicals.

The Knaben mine in Norway reportedly mined the first molybdenite-bearing ore in the late 18th century. The mine operated intermittently because molybdenum demand was small.

Molybdenum was first produced commercially in the United States in the latter part of the 19th century, but output was very small. In 1917, the Climax molybdenite deposit in Lake County, Colo., and the Questa molybdenite deposit in Taos County, N. Mex., were developed to meet the increased demand for molybdenum during World War I. U.S. production since this time has come largely from the Climax deposit, which is the largest known molybdenum deposit in the world.

In 1933, the Greene Cananea Copper Co. began recovering molybdenite as a byproduct from its copper-mining operations at Cananea, Mexico. Molybdenum-bearing copper ores have since become an important source of molybdenum, supplying from one-third to one-half of the world output of molybdenum.

¹Physical scientist, Division of Ferrous Metals.

Size, Organization, and Geographic Distribution

Five large corporations are predominant in the domestic molybdenum producing industry, two of them mine primary ore, and three recover molybdenum as a byproduct of copper ore.

Primary molybdenite ore was mined at the Climax and Urad mines in Colorado operated by AMAX Inc. and at the Questa mine in New Mexico operated by Molybdenum Corp. of America. The two companies accounted for over 66 percent of domestic production and nearly 40 percent of the world's output in 1974. Both companies processed the concentrate to molybdic oxide, ferromolybdenum, and other molybdenum-related products. They also sold concentrate to other companies that produced a variety of molybdenum products.

Duval Sierrita Corp., Duval Corp., and Kennecott Copper Corp. are significant producers of molybdenum as a byproduct of copper mining. The Pennzoil Co., owner of Duval Sierrita Corp. and Duval Corp., is the largest domestic producer of byproduct molybdenum. The material is recovered at the Sierrita, Esperanza, and Mineral Park mining facilities in Arizona.

Kennecott Copper Corp., ranking second in byproduct molybdenum production, operated mines near Salt Lake City, Utah, Hurley, N. Mex., McGill, Nev., and Ray, Ariz. Other large producers of molybdenum from copper ores were the Magma Copper Co. and the Anamax Mining Co. Five other companies recovered molybdenum from copper ores. Most of the companies producing byproduct molybdenum sold their output as molybdenite concentrate or molybdic oxide.

Molybdenum was recovered from tungsten ore by the Union Carbide Corp. at a mine in Inyo County, Calif. A small quantity of byproduct molybdenum also was recovered from processing uranium ores near Grants, N. Mex., by Kerr-McGee Corp.

Eight companies, including five producers of concentrate, roast molybdenite concentrate (MoS_2) to molybdic oxide (MoO_3), from which intermediate products such as ferromolybdenum, metal powder, and various chemicals are produced.

It is estimated that at least 1,200 companies, situated principally in the Eastern and Midwestern States, consumed molybdenum in 1974. About 85 percent was used in the production of alloys, stainless steel, and cast iron.

All the molybdenum produced in Chile and Peru was a byproduct of copper mining operations. The mines in Chile were nationalized by

Table 1.—World molybdenum production, 1973, and capacity, 1973, 1974, and 1980

(Thousand pounds)				
	Production in 1973	Capacity		
		1973	1974	1980
North America:				
United States	115,859	134,000	140,000	195,000
Canada	27,450	42,200	42,200	50,000
Other	90	500	500	2,000
Total ¹	143,399	177,000	183,000	247,000
South America:				
Chile	12,974	16,200	22,200	25,200
Peru	1,592	2,800	3,000	4,000
Other	0	200	200	1,000
Total ¹	14,566	19,200	25,400	30,200
Europe:				
U.S.S.R.	18,700	23,000	24,500	27,000
Bulgaria	310	500	500	1,000
Norway	289	500	500	---
Other	0	200	200	1,000
Total ¹	19,299	24,200	25,700	29,000
Africa:				
Nigeria	0	100	100	100
Republic of South Africa ..	0	100	100	100
Other	0	100	100	100
Total ¹	0	300	300	300
Asia:				
People's Republic of China ..	3,300	5,200	5,200	6,000
Japan	346	500	500	500
Republic of Korea	112	500	500	500
Philippines	0	200	200	200
Other	0	100	100	500
Total ¹	3,758	6,500	6,500	7,700
Oceania:				
Australia	130	300	300	400
Other	0	200	200	300
Total ¹	130	500	500	700
World total ¹	181,152	228,000	241,000	315,000

¹ Data may not add to totals shown because of rounding.

the Government in 1971. Canadian molybdenum production is mainly controlled by large international mining concerns.

World molybdenum production and capacity for 1973 and projected capacity for the years 1974 and 1980 are shown in table 1.

Definitions, Grades, Specifications

Molybdenum is a silvery-white metallic element having a specific gravity of 10.2 and a very high melting point. Only carbon, rhenium, osmium, tantalum, and tungsten have higher melting points. Molybdenum has good thermal conductivity and a corresponding low coefficient of thermal expansion. Like chromium and tungsten, which are in the same periodic chart group, molybdenum is characterized by the ability to function as both a metal and nonmetal.

Molybdenite (MoS_2) is the principal mineral from which molybdenum is obtained. Its specific gravity ranges from 4.6 to 4.8, and its lead-gray color is similar to that of graphite. Molybdenite concentrate is a term applied to the product obtained from the milling of crude ore containing molybdenum. Industry specifications vary widely, although a 90-percent molybdenum disulfide (MoS_2) content is the usual basis for price quotations.

Virtually all molybdenite concentrate is converted to technical-grade molybdic oxide (MoO_3), which is the base material for producing chemical compounds, ferromolybdenum, and purified molybdenum. However, some lubricant-grade molybdenum disulfide is prepared by passing commercial-grade molybdenite concentrate through several successive circuits of grinding and flotation.

Molybdenum, in the form of molybdic oxide, also can be recovered from selected ores sufficiently rich in the oxides of molybdenum by chemical processing, but such processing is not presently economical.

Technical-grade molybdic oxide (MoO_3) is usually produced by roasting sulfide concentrate in a multiple-hearth furnace at temperatures up to 600°C in the presence of excess air. It contains most of the impurities present in the concentrate and has a molybdic oxide content of about 90 to 95 percent. Technical-grade molybdic oxide is added as a charge material or directly to cast iron and to a large proportion of steels and other alloys.

Pure molybdic oxide is prepared by sublimation or selective recrystallization of technical-grade molybdic oxide at about $1,000^\circ\text{C}$ to $1,100^\circ\text{C}$. It is used as a base material for metallic molybdenum and for sodium and ammonium molybdates.

Molybdic oxide briquets are compacted forms prepared from a mixture of technical-grade molybdic oxide and air-floated pitch, a distillation product of coal tar used as binding material. Molybdic oxide briquets are added to the charge material in producing cast iron and alloy steel.

Ferromolybdenum is produced by reduction of technical-grade molybdic oxide and iron oxide in an electric furnace or by the silicothermit or aluminothermit process. The metallic mass formed by the reaction is crushed and marketed in a number of sizes. The molybdenum content ranges from 58 to 64 percent. Two grades—a high carbon and a low-carbon ferromolybdenum—are produced by the industry. Ferromolybdenum is an alternate molybdenum

additive to a charge material in producing non-ferrous alloys, cast iron, and alloy steel.

Ammonium molybdate is produced by reacting ammonium hydroxide with high-purity molybdic oxide; sodium and calcium molybdenum compounds are produced in a similar manner by the reaction of sodium hydroxide and calcium carbonate with molybdic oxide. All are commercial molybdenum products which are used as chemical reagents.

Molybdenum metal powder is produced by reducing ammonium molybdate or pure molybdic oxide with hydrogen. Metal powder is pressed hydraulically into small ingots, which after sintering are converted into rod, wire, or sheet by hot rolling, swaging, or forging. Large ingots are produced by arc-casting powder in a vacuum or inert-gas atmosphere.

Figure 1 illustrates the principal commercial forms and uses of molybdenum from ore to end products.

USES

Molybdenum is used principally as an alloying element to impart hardenability, strength, toughness, and corrosion resistance to steel, cast iron, and nonferrous metals. It is used either as the sole alloy material, or in combination with such alloys as chromium, manganese, nickel, and tungsten. Molybdenum is used also in the production of a variety of products ranging from cutting and wear-resistant materials to electronic semiconductor devices. Molybdenum compounds are used as chemical reagents, catalysts, and lubricants, in paints and pigments, and in several other applications.

End use applications for molybdenum in 1973 are shown in figure 2. An estimated 27 percent of molybdenum consumption was in the manufacture of transportation equipment. This quantity includes principally the molybdenum contained in alloy steel used in the manufacture of automobiles, rail transportation equipment, aircraft, and space systems. Also, it includes that contained in high-temperature alloys used in aircraft engines and aerospace propulsion devices.

About one-fourth of the molybdenum consumption was in manufacturing industrial machinery. This general end use category includes the molybdenum used in producing iron castings, steel, tool steels, and nonferrous alloys required for the manufacture of agricultural, mining, and electrical machinery and tools.

Molybdenum-containing alloy and stainless steels are consumed in the production of a wide variety of line pipe, tubing, and tubular assem-

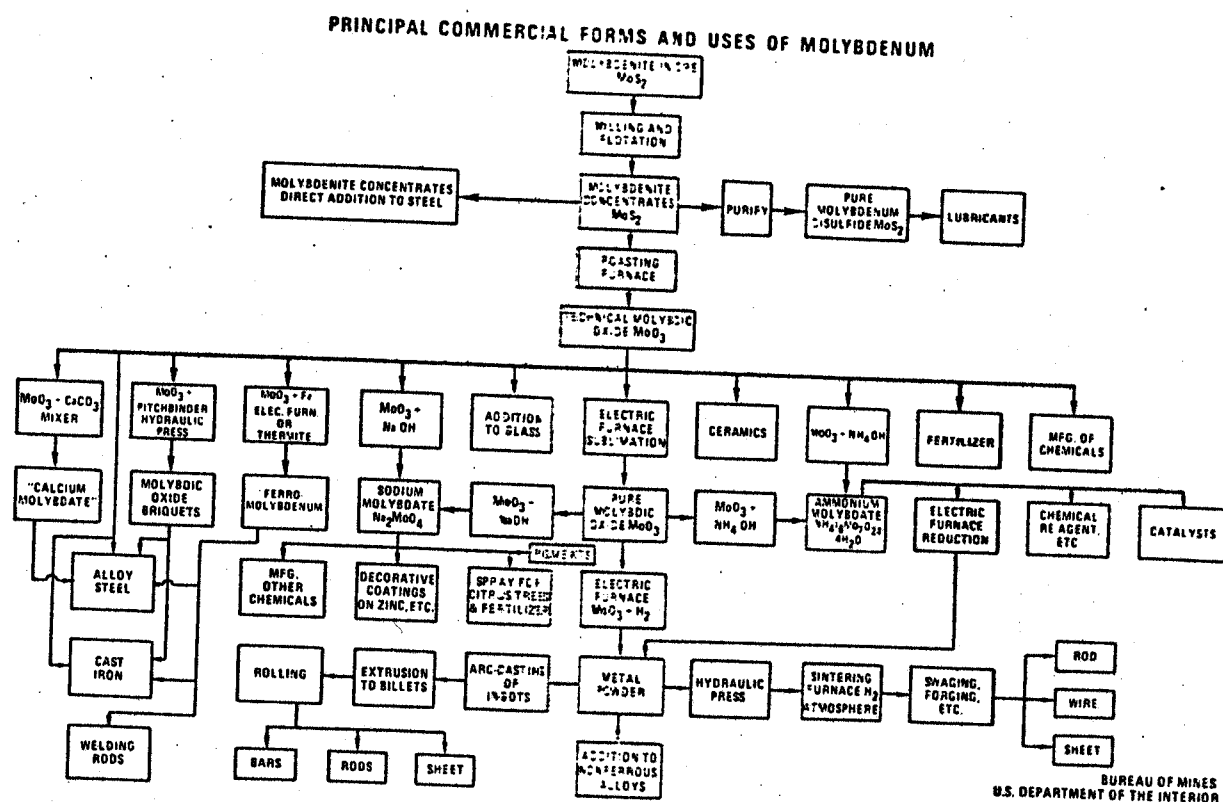


Figure 1.—Principal commercial forms and end uses of molybdenum.

blies that are used extensively in boilers, superheaters, heat exchangers, condensers, and distillation, transmission, and refining equipment, particularly by the oil and gas industries.

Food-processing and electrical-power generating companies are also large consumers of molybdenum-containing alloy and stainless steel tubular products. An estimated 28 percent of the total molybdenum consumed was used in these products.

Chemical uses of molybdenum compounds range from pigments in paint primer coatings to catalytic applications in the cracking and reforming of petroleum. Molybdenum compounds are used also as laboratory reagents, in ceramic manufacture, and in various types of chemical processing.

Molybdenum disulfide is finding increased use as a lubricant. About 10 percent of the total molybdenum consumed in 1973 was used in chemical, catalytic, pigment, and lubricant applications.

An estimated 4 percent of molybdenum was consumed as metal in the production of electrical and electronic components such as electric furnace heating elements, electrical contacts, electrodes, anodes, power transistors, and semi-

conductor devices such as power and control rectifiers. For some applications, molybdenum was used in the form of billets, sheet, or wire. In others, such as semiconductor devices, molybdenum parts were plated with materials such as silver, gold, and nickel.

An estimated 9 percent of molybdenum was consumed in products including cutting and wear-resistance materials, alloy hardfacing rods and materials, permanent magnet alloys, metal-to-glass seal materials, friction materials, cast carbide dies or parts, and fertilizers.

RESERVES-RESOURCES

The Bureau of Mines estimates world recoverable molybdenum reserves at about 13.2 billion pounds. The figure includes reserves in many countries where only fragmentary information is available on molybdenum. The general distribution by country and the order of magnitude of reserves and resources are shown in table 2. Total identified molybdenum resources are estimated at 63.1 billion pounds.

The United States has almost one-half of the known world molybdenum reserve. Most of the remainder is in the U.S.S.R., Canada, Chile, and

Table 2.—Identified world molybdenum resources

(Million pounds)			
	Reserves	Other	Total ¹
North America:			
United States:			
Arizona	932	1,070	2,000
Colorado	4,820	15,200	20,000
New Mexico	357	7,640	8,000
Other States	419	4,690	5,100
Total ²	6,530	28,600	35,100
Canada	1,900	8,100	10,000
Mexico	100	900	1,000
Other ³	100	1,600	1,700
Total ²	2,100	10,600	12,700
South America:			
Chile	1,800	3,700	5,500
Peru	250	1,050	1,300
Other	(⁴)	300	300
Total ²	2,050	5,050	7,100
Europe:			
U.S.S.R.	2,000	3,000	5,000
Bulgaria	10	90	100
Yugoslavia	(⁴)	1,000	1,000
Other	(⁴)	200	200
Total ²	2,010	4,290	6,300
Africa:			
Morocco	0	50	50
Other	(⁴)	50	50
Total ²	(⁴)	100	100
Asia:			
People's Republic of China	500	500	1,000
Japan	10	90	100
Other	10	340	350
Total ²	520	930	1,450
Oceania:			
Australia	10	90	100
Other ⁵	15	235	250
Total ²	25	325	350
World total ²	13,200	49,900	63,100

¹ Revised from Geological Survey Professional Paper 820, p. 431.

² Data may not add to totals shown because of rounding.

³ Includes Greenland, Central America, and Puerto Rico.

⁴ Negligible.

⁵ Includes Antarctica.

the People's Republic of China. Canadian reserves have increased recently because of copper-molybdenum discoveries in the Western Provinces.

About 80 percent of the U.S. reserve occurs in molybdenite deposits, principally in two deposits in Colorado and one in New Mexico. The remaining reserve is almost entirely in porphyry copper ores in Arizona, Nevada, New Mexico, and Utah. Molybdenum in small quantities occurs in a tungsten deposit in California, in uraniferous lignite deposits in North and South Dakota, and in uraniferous ore in New Mexico. Also small amounts of molybdenum are contained in the vanadiferous shale deposits of Montana, Idaho, and Wyoming.

Canadian molybdenum reserves, which are predominantly in British Columbia, are in copper porphyry ores.

Countries with centrally controlled economies are currently considered to be self-sufficient in molybdenum. Reserves of the U.S.S.R. are estimated at 2 billion pounds, and there are reserves of molybdenum in the People's Republic of China, Yugoslavia, and Bulgaria.

Most of the molybdenum reserves in Chile are in four large copper porphyry deposits. Peru also has substantial reserves in copper ore.

Molybdenum has been discovered on all continents. Some production was reported in 1974 in Australia, Japan, Mexico, and Republic of Korea; but ore reserves are small.

Because molybdenum is generally available in adequate supply, there probably are economically recoverable deposits in the world that await discovery. For example, the Henderson deposit, discovered in Colorado by AMAX Inc. in 1967 and currently under development, reportedly contains nearly 2 billion pounds of molybdenum.

Geology

Mineralogy.—Molybdenum does not occur in nature in its free or native state, but is found only chemically combined with other elements. Small deposits of molybdenum-bearing minerals occur throughout the world, but the only molybdenum mineral of commercial importance is molybdenite. Wulfenite, powellite, and ferrimolybdate are common but have supplied very little molybdenum.

Molybdenite (MoS_2) is a lead-gray, metallic mineral that characteristically occurs in thin, tabular, commonly hexagonal plates and also disseminated as fine specks. The plates have a basal cleavage and may split into thin flakes which bend readily although they are not elastic. It has a specific gravity of 4.6 to 4.7, a hardness of 1 to 1.5, and a greasy feel, and it soils the fingers. Superficially it resembles graphite, for which it commonly has been mistaken.

Wulfenite (PbMoO_4), a molybdate of lead, is a heavy metallic mineral characterized by red, orange, yellow, gray, and white colors. The mineral has a resinous or adamantine luster, a hardness of 2.75 to 3, a specific gravity of 6.5 to 7, and a white streak. It generally occurs in well-formed crystals, chiefly square tabular ranging in size from microscopic to more than an inch along the edge. Deposits are found almost entirely in veins, mostly in the oxidized parts of lead deposits. Occurrences of wulfenite are numerous, but none are of economic importance.

Powellite (CaMoWO_4), a calcium molybdate, is usually formed from the alteration of molybdenite. It is nearly always impure; tungsten substitutes for molybdenum up to about 10 percent. The mineral has a hardness of 3.5, a specific gravity of 4.3, and a variable color which includes dirty white, gray, straw yellow, greenish yellow, pale greenish blue, and brown. Powellite is found with scheelite, and this association helps to identify the mineral because it fluoresces a golden yellow.

Ferrimolybdate ($\text{Fe}_2\text{Mo}_3\text{O}_{12} \cdot 8\text{H}_2\text{O}$) is a very soft, hydrous mineral of distinctive canary-yellow color. It occurs as fine, needlelike crystals and has a hardness of 1.5 and a specific gravity of 2.99 to 4.5.

Other molybdenum minerals include chillagite, ilsemanite, koechlinite, lindgrenite, achrematite, belonesite, eosite, pateraite, and jordisite.

Should demand for molybdenum continue to rise, wulfenite, powellite, and ferrimolybdate may become economically important source materials.

Type of Deposits.—Molybdenum deposits are of five genetic types: (1) porphyry or disseminated deposits including stockworks and breccia pipes in which metallic sulfides are dispersed through relatively large volumes of altered and fractured rock, (2) contact-metamorphic zones and tacite bodies of silicated limestone adjacent to intrusive granitic rocks, (3) quartz veins, (4) pegmatites and aplite dikes, and (5) bedded deposits in sedimentary rocks.

The first three genetic type deposits are hydrothermal in origin and as such represent nearly all the known molybdenum resource currently mined in the world. The remaining types do not represent a great volume of molybdenum but are of certain economic importance only when molybdenum is associated with other minerals.

In the hydrothermal deposits, metallic minerals are precipitated from high-temperature aqueous solutions either by changes in temperature and pressure or by evaporation of the liquid. Minerals are deposited in the cavities, cracks, or interstices of the matrix rock. Favorable host intrusive rocks with which the metallic minerals are genetically related range from intermediate to acidic and include diorite, quartz monzonite, granite, and their porphyritic equivalents. Metallization commonly takes place both in the host intrusive and in the surrounding or overlying country rock. The following are specific examples of hydrothermal mineralization at deposits currently mined.

The most important stockworks deposit at Climax, Colo., was formed by an intrusion of a quartz-monzonite magma into granite, schist, and porphyry rocks. The aqueous solutions

penetrated the smallest fractures and deposited quartz-molybdenite in the form of small veinlets which made the host rock appear like a breccia.

Molybdenite occurs in veins and stringers of porphyry-type rock at the Questa deposit of New Mexico. The vein filling in quartz and molybdenite with minor amounts of pyrite, chalcopyrite, and chlorite. The veins vary from a fraction of an inch to several feet wide. The mineral content varies widely; most of the molybdenite is fairly fine grained and appears to be concentrated along the vein walls or along joints and seams.

Most of the porphyry coppers in the Western United States contain small quantities of molybdenite disseminated with the copper minerals through large bodies of granitic rock. The chief minerals are chalcopyrite and chalcocite, with pyrite and small amounts of other sulfides including molybdenum. In addition, minor amounts of other base-metal minerals, specular hematite, fluorite, and secondary silicate minerals are present. Chalcocite replaces pyrite and chalcopyrite in the zone of secondary enrichment. The copper-to-molybdenum ratio ranges from about 50:1 to perhaps 150:1.

Small quantities of molybdenite are widely distributed in lime-silicate deposits along the contacts between granitic intrusive rocks and lime-rich sedimentary rocks. Molybdenite is commonly associated with scheelite, bismuthinite, or copper sulfides in zones of silicated limestone near granitic intrusive rocks. The only domestic production from this type of mineralization has been as a byproduct from the Pine Creek tungsten deposit in California. The mineral formation is metasomatic since it originates by replacement of the rock with additional material transported from the intruding magma.

In the pegmatite-type and aplite-type deposits, the principal geological process is igneous activity with subsequent solidification of the magma and crystallization of its mineral components. The pegmatites contain coarse crystallization and consist almost exclusively of quartz and feldspar. Molybdenite occurs as an accessory mineral, and the individual crystals are generally large and usually euhedral. Many pegmatites contain magnetite, ilmenite, cassiterite, wolfram, columbite, zircon, apatite, rutile, and beryl. The average grade of these types of deposits is low, hence, they are not important potential producers of molybdenum. A pegmatite-type deposit that contains disseminated molybdenum associated with bismuth was mined in recent times at Val d'Or and Preissac, Quebec, Canada.

Molybdenum minerals occur in bedded deposits of sedimentary rock such as coals, shales, phosphorites, lignitic sandstones, and some arko-

sis sandstone. The molybdenum in these sedimentary rocks has not been included in the estimates of reserves because it is uncertain whether technology will be developed to permit their mining.

TECHNOLOGY

Exploration and Development

Metallogenic provinces in which molybdenum is known to occur are the most favorable areas for prospecting and exploration. Molybdenum mineralization usually is found along contact zones between granitic masses and crystalline sedimentary rock. Green pyroxenite commonly occurs in granite and granite-gneiss rocks and is an indicator of molybdenum.

Basically, prospecting and exploration for molybdenum mineralization is similar to that used for deposits of other minerals. The principal method employed includes geological mapping of rock units and structures to evaluate the structural conditions, mineralizing solutions, reactive gangue, and other control factors. The precise position and extent of an underground deposit are determined by penetrating it. This is usually done by diamond core drills, rotary drills, and churn drills. Driving an exploration drift into the ore horizon is another method employed in evaluating a newly discovered molybdenum deposit.

Most molybdenum output comes from large-scale mining operations. Exploration, development, and preparation of the deposit for production requires considerable investment. It is estimated that, even on a crash basis, an underground mine may require 7 years of lead time to get into production, while an open pit mine requires about 3 years. Some recent capital investments in new molybdenum production facilities indicate a cost investment factor ranging from \$4,000 to \$8,000 per ton of molybdenum output.

Mining

Molybdenum ore is mined by open pit and underground methods. The choice of method is determined by the size, configuration, and depth of the ore body. In an open pit mining operation, the ore is exposed by removal of waste rock. The cut in the ore takes the form of benches, which vary in height and width from mine to mine. Holes are drilled vertically into the ore and loaded with a blasting agent (either dynamite or ammonium nitrate). The broken

ore is mechanically loaded into either railcars or trucks for transportation to the concentrator.

Block caving, a low-cost underground mining method in which the ore body is undercut to induce caving, is commonly employed. The broken ore is drawn off from the caved mass through finger raises into concrete-lined slusher drifts. The ore is then scraped through the draw holes into cars on the haulage level located just below the slusher drifts. Draw control is essential to avoid ore dilution and development of excessive ground stresses to mine openings.

Open pit mining is used in most copper mines currently recovering byproduct molybdenum. The cycle of open pit extractions consists of drilling, blasting, loading, and transportation. Primary drilling consists of driving a vertical blasting hole into the ore. Secondary drilling and blasting are required to break large boulders. Ore is loaded by mechanical shovels into rail cars or trucks. Haulage is conducted by either diesel- or electric-powered trucks for short distances and by train for long distances. Skipways and belt conveyors are employed at some mines for transporting ore to the concentrator.

In a recent development, AMAX Inc., operator of the world's largest underground molybdenum mine, commenced open pit mining operations at Climax in conjunction with underground practices.

Beneficiation

Because of their low molybdenum content, all molybdenum-bearing ores require beneficiation. The method depends upon the type of ore and impurities. Both the primary molybdenite and the copper sulfide ore are beneficiated by flotation. Mine-run ore is subjected to several stages of crushing and grinding processes conducted in closed circuit with vibrating and trommel screens and classifiers. With primary ores, a final concentrate of about 90 percent or more molybdenite is produced by treating the primary float product to several stages of regrind and refloatation processes.

Separation of the molybdenite from copper ores is more difficult, however, because molybdenite constitutes less than 0.1 percent of the ore. The method employed varies from plant to plant, but the technique of selective flotation of molybdenite and/or copper is more commonly used by the producers. In the selective flotation process, the ore is subjected to special treatment such as close control of the pH, use of specific reagents, and several regrind and refloatation cycles. The yield of molybdenite from copper

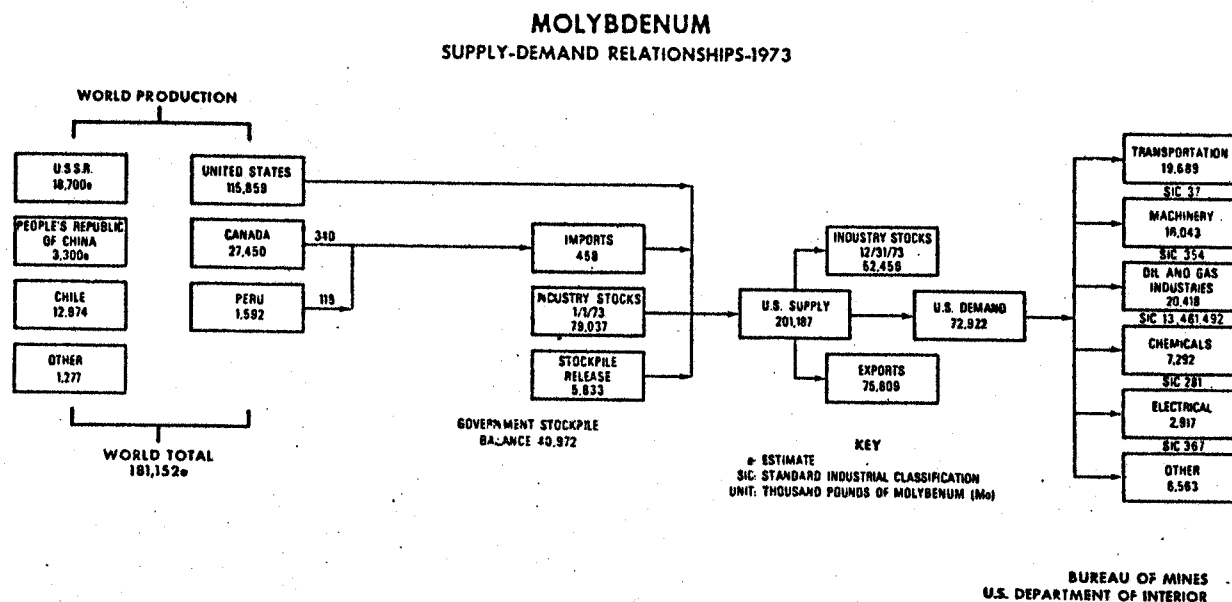


Figure 2.—Supply-demand relationships for molybdenum, 1973.

ores varies, but at some operations 85 percent of the molybdenum in the ore is recovered.

Research

The properties of molybdenum have been studied extensively, and experimental research has developed a wide variety of industrial applications. The requirements for austenitic and ferritic stainless steel and reliability requirements in the electronic industry offer particularly attractive markets, and research is continuing in these areas.

Recent efforts have centered on development of molybdenum-base alloys suitable for use in the aerospace, chemical, petroleum, and electrical power generating industries. The trend in industrial plants is to operate at higher temperatures and pressures and with larger, stronger, and more reliable equipment.

In recent years, a tough, weldable, low-carbon manganese-molybdenum-columbium steel was developed for use in pipeline construction in geographical areas of subzero temperature. The steel has good resistance to cracking at low temperatures and high tensile strength.

Other recent investigations have resulted in the development of new molybdenum-containing alloys and stainless steel having corrosion-resistant properties, specifically to chloride and oxychloride media used in pulp and paper mills. A new type of stainless steel has been developed that contains molybdenum and chromium but

no nickel; it can be produced at a relatively low cost in the new Airco-type vacuum furnace.

Much research has been directed, both by industry and the Federal Government, toward improving beneficiation processes, and numerous patents have been granted for various processes for facilitating and improving yields of molybdenum recovery. Bureau of Mines investigations have generally concerned mining, milling, and concentrating procedures, but more recent studies have concerned extractive metallurgy, fabrication techniques, and more diversified uses for molybdenum.

SUPPLY-DEMAND RELATIONSHIPS

Components of Supply

Mine Production.—Reported production of molybdenum in the United States in 1974 was 112.0 million pounds. Roughly two-thirds of the total was the output of primary producers, and most of the remainder was produced as a byproduct of copper.

The United States furnished over 59 percent of the total world output in 1974. Most of the remainder came from Canada, the U.S.S.R., Chile, and the People's Republic of China.

Over the past decade, domestic mine output of molybdenum has increased at an average annual rate of 3.7 percent per year. For the same period, the U.S. share of world mine production of molybdenum from domestic

Table 3.—Molybdenum supply-demand relationships, 1964-74

(The—sand pounds)

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974 *
World mine production:											
United States	65,605	77,372	90,532	90,097	93,447	99,807	111,352	109,592	112,138	115,859	112,011
Rest of the world	27,803	37,659	52,056	54,676	54,624	62,963	70,078	61,472	66,285	65,293	76,263
Total	93,408	115,031	142,588	144,773	148,071	162,770	181,430	171,064	178,423	181,152	188,274
Components of U.S. supply:											
Domestic mine production	65,605	77,372	90,532	90,097	93,447	99,807	111,352	109,592	112,138	115,859	112,011
Net Government release (purchase)	8,048	2,999	8,863	2,800	2,659	2,832	4,751	318	0	5,833	35,142
Imports .....	.....	142	5	179	1	.....	25	854	385	458	155
Industry stocks, Jan. 1	12,411	13,358	13,684	22,329	27,349	37,879	31,716	41,325	64,135	79,037	52,511
Total U.S. supply	86,064	93,871	113,081	114,405	123,466	140,518	147,844	152,089	176,658	201,187	199,819
Distribution of U.S. supply:											
Industry stocks, Dec. 31	13,358	13,684	20,329	27,349	37,879	31,716	41,325	64,135	79,037	52,511	41,600
Exports	26,326	26,008	31,327	31,205	29,634	51,315	57,370	47,308	46,117	75,809	81,802
Industrial demand (apparent U.S. consumption)	46,380	54,179	61,425	55,851	55,953	57,487	49,149	40,646	51,504	72,867	76,417
U.S. demand pattern:											
Transportation	13,928	16,119	18,308	17,467	16,709	16,957	13,548	11,035	14,498	19,634	21,328
Machinery	10,888	12,975	14,501	13,086	13,386	13,749	12,325	8,325	11,063	16,043	19,227
Oil and gas industries	8,635	9,677	11,039	9,760	9,983	10,254	8,593	9,572	12,773	20,418	21,061
Chemicals	3,674	4,379	4,996	4,415	4,518	4,641	4,419	4,120	4,410	7,292	7,779
Electrical	1,134	1,352	1,542	1,363	1,394	1,432	1,424	1,524	1,624	2,917	2,957
Other	8,121	9,677	11,039	9,760	9,953	10,454	8,840	6,070	7,136	6,563	4,065
Total U.S. demand	46,380	54,179	61,425	55,851	55,953	57,487	49,149	40,646	51,504	72,867	76,417

* Preliminary.

sources has ranged from 72 percent in 1963 to 59 percent in 1974. In 1953, the United States produced 80 percent of the world's output.

Imports.—Although the nation is self-sufficient in molybdenum, small quantities of the material enter the United States from numerous countries. High tariff rates preclude the importation of such material in large amounts. Currently, a tariff of 12 cents per pound is imposed on imports of molybdenum in concentrate. Importation of other molybdenum products is subject to a tariff of 10 cents per pound and/or an ad valorem tax ranging from 3 to 12.5 percent of its value. In 1967, a reduction in tariff rates on molybdenum products was negotiated under the Kennedy round of General Agreements on Tariff and Trade (GATT) in Geneva, Switzerland. Lower tariff rates have not resulted in an increase in imports of molybdenum and related products. Tariff rates have remained unchanged since 1972.

In 1973, imports of concentrate totaled 458,000 pounds of molybdenum or about 0.5 percent of U.S. demand. For 1965-74, annual imports of concentrate averaged around 320,000 pounds of contained molybdenum.

The components of domestic supply-demand relationships for 1964-74 are shown in table 3.

U.S. and World Consumption

Molybdenum requirements in the United States in 1973 and 1974 were 72.9 and 76.4

million pounds, respectively. As in other past years, virtually all was supplied from domestic sources. Less than one-half million pounds was imported in 1973, principally from Canada. Approximately 85 percent of the total was consumed by the ferrous metal industry.

For 1973 and 1974, requirements in the rest of the world were estimated at 120.0 and 128.6 million pounds, respectively. As in the United States, requirements parallel steel production because most of the molybdenum was consumed in the production of alloy steel.

Over the past decade, U.S. apparent consumption of molybdenum increased at an average annual rate of 3.5 percent, compared with 5.1 percent for the rest of the world.

World Trade

Molybdenum enters world trade as a concentrate and as various primary products; the most important include molybdic oxide, ammonium and calcium molybdate, ferromolybdenum, and metal. The concentrate is traded in terms of contained molybdenum grading 90 percent or more molybdenum disulfide.

The standard units of weight used in marketing molybdenum are pounds in the United States, Canada, and the United Kingdom and kilograms in Latin America and mainland Europe.

Since the United States is a major producer and a large exporter of molybdenum, it establishes the marketing price in world trade since it

MOLYBDENUM SCRAP FLOW DIAGRAM

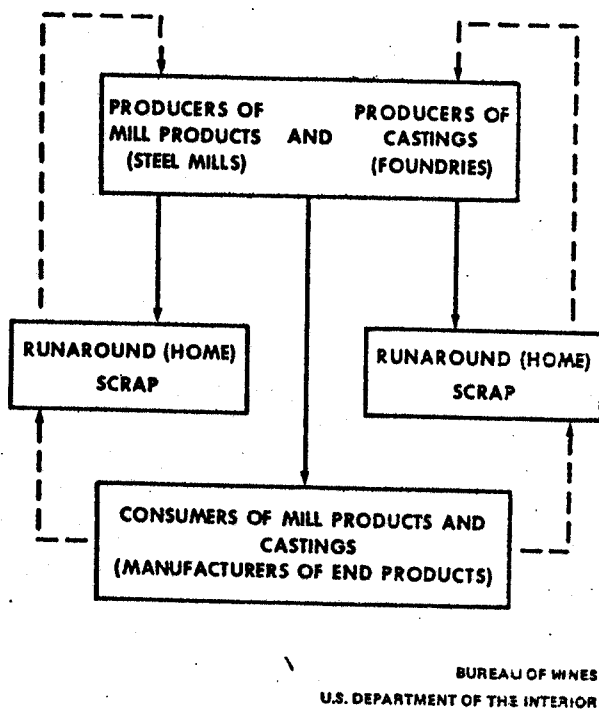


Figure 3.—Molybdenum scrap flow diagram.

is the major supplier for the world. In 1974, 73 percent of domestic output, or 81.8 million pounds, was exported. The principal destinations were the Netherlands, Japan, West Germany, Belgium-Luxembourg, Sweden, and the United Kingdom. About 45 percent of the total molybdenum concentrate exports went to the Netherlands for conversion into technical-grade molybdc oxide and reshipment largely to other European countries.

Secondary Sources and Recovery

Some molybdenum is recycled in the form of scrap material, but data on quantities are incomplete and inconclusive. The scrap is consumed by companies that generate it and hence may be classified as "runaround scrap." The flow of such scrap material is indicated in figure 3.

Substitutes

Because of an adequate supply of molybdenum and its versatility as an alloying element, there has been little substitution or replacement of molybdenum. At operating temperatures of over 1,200°C, tungsten and tantalum are used

Table 4.—Domestic molybdenum byproduct and coproduct relationship in 1973

Source	Product	Unit	Quantity of total output	Percent of total output
Molybdenum	Tin	Long ton	W	W
Do	Tungsten	1,000 pounds	2,000	26.4
Do	Sulfur	1,000 long tons	W	W
Do	Iron	1,000 short tons	W	W
Do	Molybdenum	1,000 pounds	67,061	57.9
Do	Rhenium	do	7	100
Copper	Molybdenum	do	48,070	41.5
Tungsten	do	do	W	W
Uranium	do	do	W	W

W Withheld to avoid disclosing individual company data.

instead of molybdenum, but at higher cost. Tungsten is much heavier and more difficult to fabricate than molybdenum. Boron can replace molybdenum in some steels where hardenability is the only desired effect. Chromium and manganese also impart hardenability in varying degrees. However, in view of the foreseeable supply relationship of these elements, such replacement would not be justified, especially during a national emergency. Other materials, such as plastics, are competitive but do not have the properties to withstand high temperatures.

Chrome orange, cadmium red, and other organic orange pigment can replace molybdate orange in certain applications. Cost considerations usually are the determining factor in selecting which material to use.

In refractory materials for electric furnaces operating in the range of 1,100° to 1,600°C, molybdenum can be replaced by graphite. However, molybdenum furnaces are easier to operate and control.

BYPRODUCTS-COPRODUCTS

Molybdenum is recovered as a byproduct from copper, tungsten, and uranium ores. Iron, rare earths, sulfur, tin, and tungsten are recovered as byproducts from molybdenum ores. Rhenium is extracted from flue gases and dust produced by roasting molybdenite concentrate.

The relative quantities of molybdenum recovered from molybdenum and other ores and the byproducts recovered from molybdenum ores in the United States in 1973 are shown in table 4.

ECONOMIC FACTORS AND PROBLEMS

Prices of molybdenum products are quoted in dollars per pound of contained molybdenum. Usually the price for processed material is dependent upon the purity of the product and the form in which it is sold. Prices for particular

Table 5.—Time-price relationship for molybdenum¹

Year	Average annual price, dollars per pound	
	Actual prices	Constant 1973 dollars
1954	1.05	1.81
1955	1.10	1.86
1956	1.18	1.94
1957	1.18	1.88
1958	1.25	1.93
1959	1.25	1.90
1960	1.25	1.87
1961	1.40	2.06
1962	1.40	2.04
1963	1.40	2.01
1964	1.55	2.20
1965	1.55	2.16
1966	1.55	2.10
1967	1.62	2.13
1968	1.62	2.04
1969	1.72	2.07
1970	1.72	1.96
1971	1.72	1.88
1972	1.72	1.82
1973	1.72	1.72
1974	2.02	1.83

¹ Price changes in 1974 and 1975: March 1, 1974, \$1.87; July 1, 1974, \$2.08; Sept. 8, 1974, \$2.30; Jan. 1, 1975, \$2.43; and Sept. 29, 1975, \$2.62

products also vary slightly according to whether they are briquetted or packaged in bags or cans.

The United States, a major exporter of molybdenum, sets the pricing pattern for the world markets. Except in time of short supply, the price has been stable though trending upward. With relatively few primary molybdenum mines, labor problems have periodically created short supply situations.

The published prices for molybdenum in concentrate at yearend 1973 was \$1.72 per pound, unchanged since May 1969. During periods of oversupply of molybdenum, some discounting was prevalent, particularly in the byproduct markets. Prices rose substantially during 1974 and 1975. The published price for molybdenum disulfide on September 29, 1975 was \$2.62 per pound.

Data on the average price per pound of molybdenum contained in molybdenite concentrate on the basis of 1973 dollars for the period 1954-74 appear in table 5.

At the average price of \$1.99 per pound for molybdenum in concentrate in 1974, the total value of domestic production in 1974 was \$222.9 million, while the total value of domestic demand was \$152.0.

No special taxes are imposed on the domestic molybdenum industry. Producers are granted a depletion allowance of 22 percent on domestic and 14 percent on foreign production.

The Office of Minerals Exploration (OME) encourages exploration for molybdenum in the United States and its territories by providing financial assistance to private industry at the rate of 50 percent of approved costs for exploration,

repaid on the basis of the sale of production from discovered deposits.

Molybdenum concentrates, molybdic oxide, and ferromolybdenum acquired for the Government stockpile in the 1950's were declared surplus by the Office of Emergency Preparedness in 1972. Legislation authorizing disposal of the products was approved by Presidential and Congressional action in 1973. The molybdenum remaining for disposal in the stockpile at yearend 1974, in terms of molybdenum content, totaled about 2.0 million pounds. The General Services Administration sold over 35.0 million pounds during 1974. Heavy sales continued into 1975, and the stockpiled excess material is expected to be exhausted.

OPERATING FACTORS AND PROBLEMS

The cost of producing molybdenite concentrate varies according to the mining and milling methods employed. For operations utilizing similar methods, costs may vary because of local physical characteristics of the ore body and the type of ore in the deposit.

Because of the low grade of most primary deposits, high-tonnage producing methods (open pit and underground block caving) are necessary to extract the ore profitably.

An estimated 2,400 men were employed in 1973 in the mining and milling of primary molybdenum ores in the United States. When related to production, the average annual output of molybdenum per production employee was 28,000 pounds in 1973. A number of additional employees associated with the molybdenum-producing industry are engaged in product control and development, basic research, marketing activities, exploration, and development of molybdenum resources.

The mining of primary molybdenum ore disturbs some land areas which, in the future, may require reclamation. The problem is small; only a few mines are active. Molybdenum recovered in conjunction with copper production entails the disturbance of significantly larger land areas.

The conversion of molybdenite to molybdic oxide involves roasting which releases sulfur oxides into the atmosphere. Pollution from roasting is relatively widespread geographically because molybdenite is shipped to a number of consumers in other parts of the country for processing. The growing national concern for air pollution and intensification of research will probably result in changes in molybdenite processing practices.

Table 6.—Projections and forecasts for U.S. molybdenum demand by end use, 1973 and 2000
(Thousand pounds)

End use	1973	2000			
		Contingency forecast for United States			
		Forecast base	Forecast range		Probable
			Low	High	
Transportation	19 730	50,000	48,500	60,000	56,000
Machinery	16 000	48,000	45,000	53,000	52,000
Oil and gas industries	20 430	49,000	41,000	55,000	44,000
Chemicals	7 330	16,500	16,500	24,000	22,000
Electrical	3 000	7,000	5,000	8,000	7,000
Other	6 500	10,000	9,000	15,000	12,000
Total	72 900	....	165,000	215,000	193,000

Large quantities of raw materials and chemicals are consumed in processing molybdenum ore to its end use products. Also, energy requirements are similar to those of comparable industries.

The bulk of the molybdenum production in the United States is shipped as a concentrate by rail from mines in the West to processing plants in the East, but some concentrate is shipped to the gulf and west coasts. Transportation costs are reflected in the price of molybdenum primary products, but the high value of the concentrate per unit shipped makes transportation costs relatively insignificant when related to the total value of the product.

OUTLOOK

Barring major technological or economic shifts, U.S. molybdenum requirements are expected to increase at a rate of approximately 4.3 percent annually through the year 2000. This rate is related to the projections of iron and steel requirements in 2000, but is substantially higher because of expected increased demands for alloy and stainless steel, particularly the high-strength, high-temperature, alloy types, many of which contain significant amounts of molybdenum.

With an established producing industry that currently supplies virtually all domestic demand, and known reserves of 6.5 billion pounds, more than double the projected maximum cumulative domestic requirement, it is expected that domestic production will provide the bulk of U.S. molybdenum demand through 2000.

Demand

Overall demand for molybdenum in the United States has increased steadily during the past decade, and the outlook for the rest of the century is one of continued growth. The most promising growth areas are expected to be in

the transportation, industrial machinery, and oil and gas production and distribution sectors.

The U.S. contingency forecasts for each end use in 2000, shown in table 6, were developed from a forecast base established by relating current demand to the projected growth of a particular economic indicator which is expected to have a growth rate that will parallel future demand for the end use. The quantity of molybdenum indicated by this relationship was then modified to obtain a demand contingent upon changes or influences which may alter demand requirements in the year 2000.

Contingency Forecast

A contingency forecast of future demand by end uses indicates that molybdenum requirements of the United States will increase from the 1973 level of 72.9 million pounds at a rate of 3.7 to 4.7 percent annually through the year 2000, resulting in domestic demand of 165 to 215 million pounds in 2000. At these rates of increase, cumulative requirements for the period 1973-2000 will be 2.9 to 3.4 billion pounds, respectively.

This contingency forecast is based upon an analysis of possible economic, technological, and sociological influences and changes that may affect demand, and the assumption that molybdenum will find continuing applications as an alloying element necessary for imparting certain desirable properties to cast iron, and steel, and as a chemical compound that will be used in increasing quantities as a catalyst, lubricant, and chemical reagent. The median of the forecast range is 190 million pounds. The high and low of the forecast range for each major end use were projected from a forecast base which was established on the basis of forecasts for selected relevant indicators such as iron and steel production, population, gross national product (GNP), and gross domestic private investment (GDPI).

Table 7.—Summary of forecasts of U.S. and rest-of-world molybdenum demand, 1973–2000
(Thousand pounds)

	1973	2000 Forecast range		Probable		Probable average annual growth rate 1973–2000 (percent)
		Low	High	1985	2000	
United States:						
Total	72,900	165,000	215,000	102,000	193,000	4.3
Cumulative	---	2,870,000	3,360,000	980,000	3,160,000	
Rest of the world:						
Total	120,000	345,000	445,000	204,000	393,000	4.5
Cumulative	---	5,630,000	6,590,000	1,940,000	6,360,000	
World:						
Total	192,900	511,000	660,000	306,000	586,000	4.4
Cumulative	---	8,750,000	10,250,000	2,920,000	9,520,000	

¹ Calculated from a 20-year primary demand trend of 61,500 for 1973.

The high of the forecast range of domestic demand in 2000 anticipates an increased demand for molybdenum for the production of stainless and high-strength, low-alloy steel for use in transportation, industrial machinery, and oil and gas industry products. The high rate would be influenced also by greater-than-anticipated increases in the standard of living, which would increase demand for molybdenum-containing consumer products. The low of the range is based principally upon lower-than-expected transportation requirements and the use of substitute materials in sectors that presently employ steel.

Demand in the rest of the world in 2000 is forecast to increase at a rate of 4.0 to 5.0 percent annually and to reach 346 to 448 million pounds. Cumulative requirements for the period 1973–2000 will be between 5.9 to 6.9 billion pounds. Requirements are expected to increase at a higher rate in other countries than in the United States because of the present trend toward the production of more molybdenum-containing steel and the increasing replacement of tungsten by molybdenum in alloys. Supply for the rest of the world is expected to be more than adequate through 2000 because known world reserves are approximately 3.7 billion pounds greater than the combined projected requirements for the United States and the rest of the world. World market economies will continue to draw upon U.S. supply, but requirements of some countries are expected to be met in increasingly greater amounts by production from Canada.

As in the United States, demand will be contingent largely upon the level of steel production because probably as much as 90 percent of all molybdenum consumed in other countries is used in the production of alloy and stainless steel and cast iron.

U.S. and rest-of-the-world demand in 1973 and forecasts for 1985 and 2000 are shown in table 7.

End-Use Trends

Transportation.—Molybdenum requirements for transportation are forecast to more than double and account for over one-quarter of the total consumption by the end of the century, based on Bureau of Mines projections of iron requirements for transportation equipment. However, the forecast was modified to reflect expected increased usage of molybdenum-containing steels, particularly in the manufacture of automobiles, railroad transportation equipment, aircraft, and aerospace systems. It is expected, also, that there will be substantially larger requirements for molybdenum as an alloying material in high-temperature alloys and precipitation-hardenable stainless steels. These materials have extensive applications in the production of components for jet engines and, to a lesser extent, airframes.

Machinery.—An average annual growth rate of 4.2 percent is projected for the machinery sector and reflects the increasing use of high-speed, hot work, and other tool steels and other molybdenum-containing alloy steels. The forecast is predicated on the assumption that the bulk of the molybdenum will be consumed in the production of machine tools and metalworking machinery and that requirements will increase at a rate more than triple that projected for iron and steel in 2000.

Oil and Gas Industries.—Molybdenum requirements for the oil and gas industries will increase at an average annual rate of 3.3 percent, equivalent to the gross private domestic investment. This growth rate is expected because of the increasing use being made of alloy and stainless tubular products in petroleum refining and chemical processing equipment. Increased chemicals demand and increase in the expected number of gasoline-powered motor vehicles could substantially increase the demand for tubular products for oil and gas transmission, and consequently the demand for molybdenum.

Chemicals.—Demand for molybdenum compounds for chemical, catalytic, pigment, and lubricant applications is projected to increase at an average annual growth rate of 3.5 percent, approximately equivalent to the medium forecast for GNP. Most of the molybdenum will be consumed in catalyst, particularly for the reforming and desulfurization of petroleum. However, increasing quantities of molybdenum are being consumed also as lubricants, particularly in greases and oils for automobiles.

Electrical.—Molybdenum demand for electrical and electronic equipment is forecast to increase at an average annual rate of 3.2 percent, equivalent to about the GNP rate of growth. Many of the electrical and electronic components are used in consumer products, and more expected increases in standard of living would increase molybdenum demand for their manufacture.

Other.—Requirements for this end use sector will increase at an average annual growth rate of about 1.6 percent, twice the rate projected for population. It is expected that molybdenum will be consumed for such diversified uses as cutting and wear-resistance materials, cast carbide dies and parts, permanent magnet alloys, hard-facing rods and materials, fertilizer, and miscellaneous other uses not accounted for in the other categories.

Supply

Domestic reserves of molybdenum recoverable in terms of 1973 dollars at the yearend 1973 price of \$1.72 per pound of contained molybdenum in molybdenite concentrate are estimated at 6.5 billion pounds. Although deposits mined in 2000 may be deeper or require more beneficiation, the increased extractive difficulties are expected to be offset by greater efficiencies in mining and beneficiation so that the projected unit price in terms of 1973 dollars will be relatively stable.

At current prices, about 4.9 billion pounds are economically recoverable for the molybdenum content alone. An additional 1.6 billion pounds will probably be recovered by the year 2000 as a byproduct of copper and tungsten, depending on rates of production of these minerals.

World molybdenum supply that can be mined profitably at the current price is estimated at 13.2 billion pounds. Exploration currently underway in the market economy countries particularly in Canada, could substantially increase the present reserves.

Table 8.—Comparison of domestic primary molybdenum production and demand 1954-74, 1985, and 2000

(Thousand pounds)			
Year	Demand	Production	
1954	31,794	58,668	
1955	18,950	61,781	
1956	41,322	57,462	
1957	27,242	60,753	
1958	25,155	41,069	
1959	34,118	50,956	
1960	36,696	68,237	
1961	34,439	66,563	
1962	36,414	51,244	
1963	42,374	65,011	
1964	46,380	65,605	
1965	54,179	77,372	
1966	61,425	90,532	
1967	55,851	90,097	
1968	55,953	93,447	
1969	57,487	99,807	
1970	49,149	111,352	
1971	40,646	109,592	
1972	51,504	112,138	
1973	72,922	115,859	
1974	76,417	112,011	
1985	² 102,000	³ 154,000	⁴ 202,600
2000	² 193,000	³ 208,000	⁴ 383,400

¹ Estimate.

² Preliminary, not used in forecasts.

³ Probable forecast from table 6.

⁴ 20-year trend.

The present primary-byproduct molybdenum production relationship will be maintained through this century, but it is expected that byproduct production will increase at a greater rate than primary production. As much as 45 percent of the production may come from byproduct-coproduct sources in the year 2000.

Contingency-Type Analysis of Production.—For the base period 1954-73, mine production of molybdenum increased at an average annual rate of about 3.4 percent. Sufficient molybdenum resources are available to maintain this growth rate for the rest of the century. A straight-line projection of the data indicates that molybdenum output in 1985 and 2000 would be 154 and 208 million pounds, respectively.

For speculative purposes, these data may be compared with those obtained by calculating the ratio of production to consumption for 1969-74 and applying this ratio to the demand forecast for 1985 and 2000. Should that ratio prevail then U.S. molybdenum production in 1985 and 2000 could be 202.6 and 383.4 million pounds, respectively (table 8).

Possible Supply-Demand Changes

No major changes in the molybdenum supply are foreseen at present. Currently mined primary deposits and one scheduled for production in 1976 are expected to continue to provide the larger part of domestic demand, but production

from byproduct copper, tungsten, and uranium deposits also will increase.

Since the United States has been self-sufficient in molybdenum and has supplied most of the world's market economy requirements, no Government price incentives are anticipated.

Because of molybdenum's availability in excess of domestic demand, it has enjoyed a competitive advantage over alternate materials. Substitution of other metals for molybdenum is not anticipated because of the unique characteristics of hardness, strength, toughness, and corrosion resistance that molybdenum imparts to various alloys.

The current trend in the molybdenum mining industry is for multiple land use of mining sites and for control of water pollution. Future mine development will require more consideration of air and water pollution and of multiple land use, which will tend to increase extraction costs.

The United States and other countries undoubtedly have large undiscovered resources which add to the total supply. These, however, are essentially undelineated and probably will not be needed in this century.

Increased competition because of expansion of existing productive capacities in Chile, Canada, and the United States and expected developments in mining and milling technologies are factors that should keep molybdenum prices in 2000 at moderate levels.

Possible Technological Progress

Molybdenum metal and molybdenum-base alloys have been the subject of research for a number of years in an effort to develop a material suitable for nuclear reactors, jet engines, and rocket nozzles operating at high temperatures. A breakthrough in a coating, alloying, or surface diffusion treatment would renew interest of still higher temperature designs.

There has been considerable effort in recent years to die-cast the higher-melting-point materials such as cast iron. If the effort becomes commercially successful, it is expected that there will be a significant requirement for die materials with very high molybdenum contents.

There is a need to develop a manufacturing process that reduces scrap losses. For example, in the use of molybdenum metal, the present ratio between material input and output of the finished component is as high as 10 to 1. Much of the scrap material is lost either because it is unsuitable for remelting into high-quality material, or because large losses of molybdenum are incurred during remelting.

Beneficiation processes for increasing recovery

yields from copper ores require improvement. Because the molybdenum content of ore is extremely low (roughly 2 to 4 pounds of molybdenum per ton of primary ores, and less than 1 pound of molybdenum in copper ores), there will undoubtedly be continued effort to improve beneficiating techniques. Such improvements will result in increased recoveries of molybdenum and convert more of the low-grade resources to reserves.

Little improvement can be expected in the mining sector to reduce cost and increase supply because both primary and byproduct producers employ high-volume, low-cost mining systems. Technological end use change could alter the future consumption pattern. Technological improvement in processing will probably reduce production costs.

Continuing research on preparation of high-purity metal and resistance to oxidation at elevated temperatures will tend to broaden the scope of potential end uses for molybdenum.

The development of new molybdenum alloys with improved properties for presently known and yet to be developed applications can be expected by the year 2000.

REFERENCES

1. American Metal Market. Molybdenum Section. Dec. 16, 1974, p. 1A-12A.
2. American Society For Metals. Fabrication of Molybdenum. Cleveland, Ohio, 1959, 221 pp.
3. American Society for Metals. The Metal Molybdenum. Proceedings of a Symposium, the Office of Naval Research, Detroit, Mich. Sept. 18-19, 1956, 696 pp.
4. Archer, R. S., J. S. Briggs, and C. M. Loeb, Jr. Molybdenum (Steels, Irons, Alloys). Climax Molybdenum Co., New York, N.Y., 1948, 391 pp.
5. Bieniewski, C. L. Demand and Supply of Molybdenum in the United States. BuMines IC 8446, 1970, 61 pp.
6. Butler B. S. and J. W. Vanderwilt. The Climax Molybdenum Deposits, Colorado, U.S. Geol. Survey Bull. 846-C, 1933, 235 pp.
7. Carmen, J.B. Mining Methods of Molybdenum Corporation of America at Questa, N. Mex. BuMines IC 6514, 1931, 15 pp.
8. Climax Molybdenum Co. Molybdenum for Nuclear Energy Applications. New York, N.Y., 1965, 111 pp.
9. Holliday, R.W. Molybdenum. Ch. in Mineral Facts and Problems. BuMines Bull. 630, 1965, pp. 595-606.
10. King, R. U., D. R. Shawe, and E. M. MacKevett Jr. Molybdenum. U.S. Geol. Survey Prof. Paper 820, 1973, pp. 425-435.
11. Kirkemo, H., C. A. Anderson, and S. C. Creasey. Investigation of Molybdenum Deposits in The Conterminous United States, 1942-1960. U.S. Geol. Survey Bull. 1182-E, 1965, 90 pp.
12. Krushchov, N. A. Molybdenum in the Tirny Auz Ores. Tsvetnye Metally, No. 2, February 1949.
13. McInnis, W. Molybdenum. A Material Survey. BuMines IC 7784, 1957, 77 pp.
14. Petar, A. V. Molybdenum. BuMines Economic Paper 15, 1932, 38 pp.

15. Schilling, J. H. Geology of the Questa Molybdenum Mine Area, Taos County, N. Mex. N.M. Inst. of Mining and Technol., Bull. 51, 1956, 87 pp.
16. Schneider, V. B. Molybdenum. Canadian Dept. Mines and Tech. Surveys, Mineral Report 6, 1963, 176 pp.
17. Sheridan, E. T., Molybdenum. Ch. in Mineral Facts and Problems. BuMines Bull. 650, 1970, pp. 333-346.
18. Sutulov, A. Molybdenum Extractive Metallurgy. University of Concepcion, Santiago, Chile, 1964, 239 pp.
19. Titley, S. R., and C. L. Hicks. Geology of the Porphyry Copper Deposits, Southwestern North America. Arizona University Press, Tucson, Ariz., Wilson Volume, Edition 1966, 287 pp.
20. Vokes, F. M. Molybdenum Deposits of Canada. Geol. Survey of Canada, Econ. Geol. Rept. 20, 1963, 332 pp.

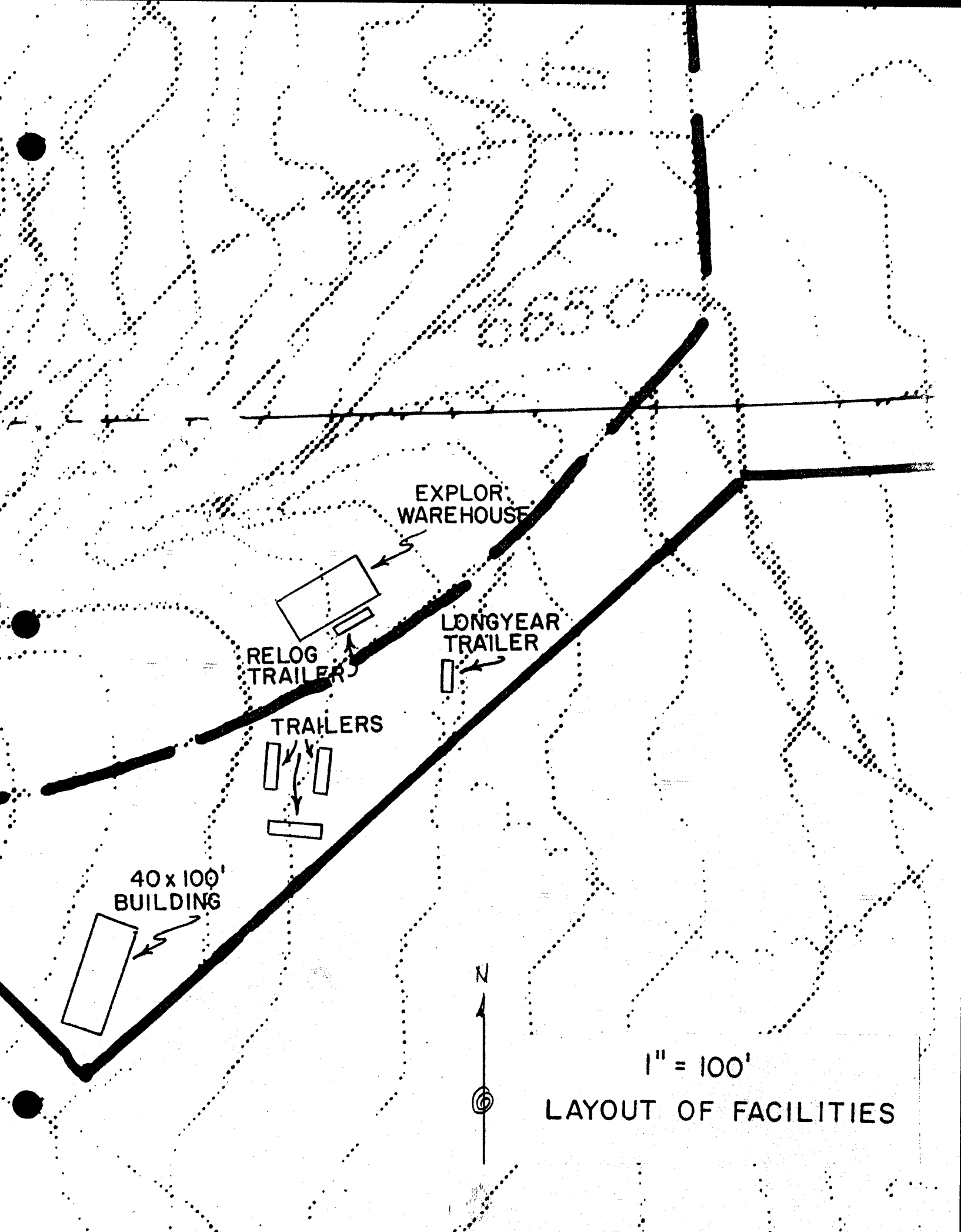
SOURCES OF CURRENT INFORMATION

U.S. Bureau of Mines publications:

Molybdenum. Ch. in Commodity Data Summaries, annual.
Molybdenum. Ch. in Minerals Yearbook, annual.
Molybdenum. Reported monthly and annually in Mineral Industry Surveys.
Mineral Trade Notes. Issued monthly.

Other sources:

Airgrams, Department of State.
American Metal Market.
Annual Reports of various companies.
Metals Week.
Metallurgical Transactions.
Mining Record.



EXPLOR
WAREHOUSE

RELOG
TRAILER

LONGYEAR
TRAILER

TRAILERS

40 x 100
BUILDING



1" = 100'

LAYOUT OF FACILITIES

MT. HOPE DEPOSIT - PRELIMINARY ECONOMICS

• RECOVER 267M TONNES • 2:1 STRIPPING RATIO • 30 YEARS

• \$5.80/lb. Mo. (1980\$), 1981 P&B PRICE FORECAST

	<u>CONSTANT 1980 \$</u>	<u>CURRENT \$</u>
GROSS REVENUE	3,600M	22,203M
OPERATING EXPENSES	1,549M	11,251M
CAPITAL	331M	1,303M
NET AFIT	1,268M	7,223M
DCF RETURN	19%	23%
CASH COST	\$2.80/LB.	
TOTAL COST	\$3.40/LB.	

48-81MD

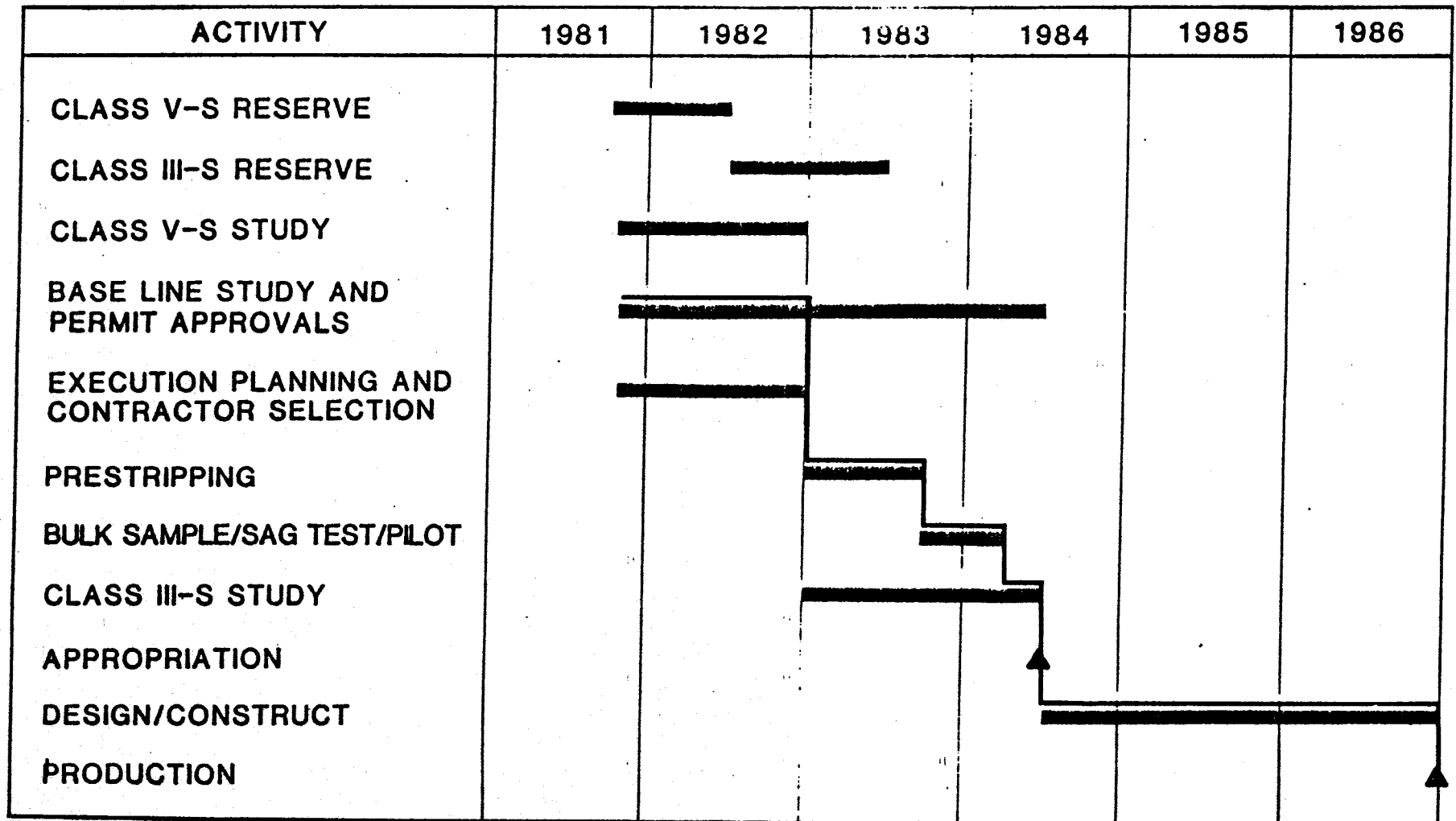
MT. HOPE REVIEW
MANAGEMENT COMMITTEE

June 25, 1981 - R. E. Rohn

MT. HOPE PROJECT

BASE CASE SCHEDULE

1981 P & B



CRITICAL PATH

M81-305X