Supplemental road log 1: Pre-meeting tour of the Molycorp Molybdenum mine and mill

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SUPPLEMENTAL ROAD LOG 1, PRE-MEETING TOUR OF THE MOLYCORP MOLYBDENUM MINE AND MILL

PAUL W. BAUER, ROBERT LEONARDSON and ROBERT S. YOUNG

Assembly point: Main gate of Molycorp mill.

SUMMARY

The Molycorp molybdenum mine is located on NM Highway 38 between Red River and Questa in the Red River valley. Commercial mining of molybdenum began here in 1922. Ore was processed in a 50-ton mill near Red River until 1923, when a 50-ton mill was constructed at the mine site. In 1945, a mile-long tunnel was driven northward from the Red River valley to the underground workings. Both ore and water were removed through this tunnel. Most of the rich moly veins were mined out by 1958, and by 1964 developmental work had begun on an open-pit mine in a massive, low-grade deposit in Sulphur Gulch. By 1969, the new modern mill could process 15,000 tons of ore per day. Exploratory drilling by Molycorp led to the discovery of a deep, high-grade deposit in 1975, and by 1985 the transition from open-pit to underground mining was complete.

An east-northeast-trending zone of Precambrian crustal weakness known as the Jemez lineament controls the position of the present-day Red River valley. A mid- to late Oligocene period of east-northeast-directed crustal extension in the Questa–Red River region produced the north-northwest-trending fault zones that cut across the Red River valley. Together, the two fault systems created a locus for the emplacement of the Questa batholith. This intrusion spawned the subsequent Questa caldera, the southern margin of which is bounded by Jemez lineament structures (see mini-paper by Meyer, this guidebook).

Extension, which accelerated after development of the caldera and eruption of the thick Amalia Tuff rhyolite, continued for nearly two million years or so after development of the molybdenum deposits. Throughout the mine area flat, undulating faults, which together comprise a zone in excess of 2900 ft in thickness over the Goat Hill ore body, created the locus for all of the known molybdenum source intrusions and presently defined economic ore. Crustal extension has resulted in 90°W rotation of most of the intracaldera rocks above 7000 ft elevation. Nearly all of this rotation occurred prior to development of the ore deposits.

External to the caldera, the low-angle fault zone is inferred to be relatively thin, and rotation is much less pronounced, generally less than 45°. Good exposures of the flat fault zone are in a roadcut on NM-38 about 0.75 mi east of the Red River townsite.

This tour begins at the main gate of the Molycorp mill 4.4 mi west of Red River. The tour consists of two parts. Part one is a drive from the main gate of the mill to the open-pit mine; a road log is provided. Mineralized Tertiary intercaldera rocks are well exposed along this road. Part two is a walking tour of the mill; a mini-paper on the operation of the mill is provided. Although we will not visit all phases of the mill operation, the complete milling process is described in the mini-paper. Remember to **wear safety glasses and a hard hat** at all times when on Molycorp property.

Mileage

0.0 At main gate to Molycorp mill. Building on the right is the security office. On left is the assay lab. Large building ahead on left is a warehouse. Garages straight ahead house small vehicles and workshops. To the left are containers of processed molybdenum ore ready for shipping. Containers are either plastic sacks or 55-gallon drums. **0.05**

0.05 At 9:00, 2/3 of way up hill, is an old, timbered portal from the original mining days. At 12:00, 100 ft up the hill, are remains of a wooden flume from the 1950's. Notice the enclosed conveyor system on the hillside. Ore from the underground mine is transported up to the primary crusher building at the top of the hill on this conveyor system. **0.05**

0.1 Fenced equipment storage area on the right sits on the original townsite of Moly. See accompanying guidebook paper by J. Schilling for a taste of life here in the early 1950's. **0.1**

0.2 At 3:00, the large, covered, upright cylindrical objects are replacement rolls of new conveyor belt. Because these rubber belts deteriorate when exposed to UV radiation, they must be kept covered when stored outside at this elevation. Gravel road on left goes up to water tanks. **0.05**

0.25 At 12:00 on the slope is a layered sequence of caldera fill. Precambrian quartz-biotite schist occupies the lower slopes. The schist is bounded by two low-angle fault systems. The lower fault is below the switchback beyond the orange haul truck; the upper fault is about 150 ft vertically higher on the hillside. A third fault is about 250 ft above the second fault; its approximate location is where the lower, darker-colored rhyolite dike crops out. The upper pair of faults bound a block of early Tertiary conglomeratic sandstone. The remainder of the slope above the third fault consists of massive andesite flows. The dark-colored rhyolite dike is an early porphyritic unit related to the Amalia Tuff. The upper, lighter-colored dike is a rhyolite porphyry with >20% phenocrysts that crystallized post-molybdenum ore. Such dikes follow the low-angle fault zones and occupy more steeply dipping tension fractures within and behind the low-angle faults. As we will see at Stop 1, the presence of dikes within the southern margin of the caldera is usually an indication that a low-angle fault is present. **0.15**

0.4 On left is a 120-ton Electra Haul truck. These trucks contain a diesel engine and generator that power an electric motor in each wheel. These trucks were used in the open-pit mine. Only a few now remain on the property. **0.1**

0.5 First switchback. Begin ascent up to open pit. At 2:00 to 3:00 is good view of large, gray, resistant knob of Precambrian quartz-biotite schist that is in fault contact with overlying Tertiary sediments within the southern margin of the caldera. The schist contains disseminated porphyroblasts of magnetite and is intruded by a pre-caldera latite porphyry dike. Both units are cut by magnetite veins and younger shattered zones caused by a low-angle fault strand, most of which occur below road level. **0.1**

0.6 View at 11:00 to 1:00 along road of a 50–100-ft-thick low-angle fault system that dips at approximately the slope of the road and 10° to the north. The fault separates andesite in the hanging wall from sedimentary rocks in the footwall. Young rhyolite porphyry dikes have penetrated up along the flat fault and terminated in tension fractures. A cross fault between this fault and the next fault on the hillside above separates Tertiary rocks to the west from the Precambrian rocks here. **0.15**

0.75 **STOP 1.** Splay of major low-angle fault system in roadcut. Rock is caldera-fill Tertiary sediment that has been intensely sheared during faulting. Andesite flows occupy the hanging wall of the fault. Younger rhyolite-porphyry dikes migrated up the flat fault system and into more steeply dipping tension fractures within and above the fault. Subsequent movement on the low-angle fault sheared and fluidized the zone, including the rhyolite dikes which display drag movement to the northeast. Extensional cross faults curve down, or toe in, to the northeast into the sole of the low-angle fault. Molybdenum mineralization exists downdip on this zone about 3000 ft north of here. **0.05**

0.8 At 11:00 is large mine dump that has filled what was known as Sulphur Gulch. Dump material consists of sub-economic rock derived from the open-pit mine. Before the dumps filled this canyon, rainstorms would send torrents of oxidized, acidic mud into the Red River. These temporary earth dams or debris aprons created relatively flat-lying lake bed deposits upstream from the dams. Two of the six paleo-lakebeds on the Red River drainage are the sites of the Molycorp mill and town of Red River. **0.25**

1.05 Road on left leads to the secondary crusher. Enclosed conveyor system visible. **0.15**

1.2 Old roads visible on south side of the valley were roads built by Molycorp to transport exploration equipment. Dead pine trees on north-facing slopes were killed by a budworm infestation several years ago. **0.1**

1.3 Near top of conveyor system. Rectangular building ahead is the #3 transfer tower. There are three transfer towers in the conveyor system that house machinery for transferring ore from one conveyor belt to another where the conveyor system changes direction. The #3 transfer tower also contains the drive motors for the third, or upper stage, of the conveyor belt as well as the fine and coarse ore stacker belts. **0.1**

1.4 Passing beneath conveyor belt. Large building on left is primary crusher, and first stop of mill tour on our return. On the right is the top of the decline conveyor system and the coarse ore surge pile where ore is stockpiled before running through mill (Fig. S-1.1). An underground conveyor moves ore from the bottom of the surge pile to the primary crusher. On the left is the fine ore surge pile. A vibrating grizzly inside #3 transfer tower separates material for the two piles. **0.3**

FIGURE S-1.1. Coarse ore leaving upper conveyor belt at Molycorp mill. The coarse ore surge pile feeds an underground conveyor belt that carries ore to the primary crusher. Primary crusher is out of view to the right.

1.7 Small structures on left contained ammonium nitrate–fuel oil mixture used as explosive in open-pit operation. Diesel fuel tanks on left. **0.3**

2.0 **STOP 2.** In open-pit mine. **Park near abandoned shovels** and walk past shovels to edge of lower pit. This is a good vista of the open-pit mine. Straight ahead is the 1985 landslide that dumped 5 million tons of rock into the pit (Fig. S-1.2). Most evidence of the benches that formerly encircled the pit is now gone. The two shovels are 10-yard 1900 series P&H shovels. Both 10- and 14-cubic-yard shovels were used in the mine. The blast hole drill is a Bucyrus Erie model 40-R capable of a 40-ft hole, which is identical to the pit bench height. A Bucyrus Erie model 50-R drill was also used.

Above the upper benches on northwest side of the pit are the remnants of the old Sulphur Gulch alteration scar. It is slowly expanding as it migrates toward the pit. Catastrophic earth movement and scar development have been rejuvenated in the Sulphur Gulch scar because of the steep northwest wall of the pit. In time, appearance of the scar and the northwest portion of the pit will resemble the original scar. The entire western wall of the pit is slumping down to the east, toward the viewer, at the rate of several feet per year.

On the north wall can be seen the west-dipping contact of the Sulphur Gulch stock against the overlying andesite. Numerous dikes from the stock penetrate the andesite, with a major east-trending dike occupying the upper pit wall. The same west-dipping stock contact can be seen on the south pit wall with a collapse stope in the stock just under the contact. This is from the old vein mining period which took place in the 1920's and 1930's. This vein, with a shallow (± 15°) westerly dip, would be a lower grade vein of ± 5% MoS_2 when compared to steeply dipping veins (>45°) which would average over 10% MoS_2.

A light-colored, shallowly west-dipping alteration zone occupies the upper south wall of the pit. This represents

FIGURE S-1.2. View northeastward of inactive Molycorp open-pit mine. Wall of pit is site of the 1985 landslide that dropped 5 million tons of rock debris into the pit. Most evidence of benches is now gone from the wall. See text for description of shovels and blast drill.

an up-dip western extension of a low-angle fault zone that contains molybdenum ore downdip under the western wall of the pit. The zone, as exposed, occurs 500 to 2000 ft from ore, and locally contains a characteristic assemblage of orthoclase, specular hematite and green sericite.

A north-trending fault in the western pit wall, with a moderate to steep westerly dip, has offset the low-angle fault zone 200–300 ft down-to-the-west. **Retrace route to mill area. 0.5**

2.5 Ahead is conveyor gallery and coarse and fine surge ore piles. The fine surge ore stockpile contains rock that is <6 inches. In case of shutdown of the primary crusher, this fine ore can be fed directly into the secondary crusher. **0.1**

2.6 **Park near primary crusher** to begin walking tour of the mill.

THE MOLYCORP MILL OPERATION, QUESTA, NEW MEXICO

Robert S. Young

Molycorp Inc., Questa Division, Questa, New Mexico 87556

Molycorp Inc., a wholly owned subsidiary of Unocal, operates an underground molybdenum mine near Questa, approximately 56 km (35 mi) northeast of Taos, New Mexico. Operations commenced at plant scale in December 1965 with a nominal ore-processing capacity of 11,000 tons per day. The mill capacity was upgraded to about 15,000 tons per day in October 1969 by the addition of an additional grinding mill, flotation cells and tailings pipeline. The present mill throughput is in excess of 16,000 tons per day, and production of molybdenum is approximately 1 million pounds per month. The following overview is a step-by-step description of the operation of the mill from crushing and grinding, to flotation, drying and shipping. A detailed description of the mine operation is given by Schilling (1990).

Ore reaching the top of the decline conveyor system from underground (Fig. S-1.3) is separated into coarse and fine piles. Coarse ore is then fed into the primary crusher, a 48 × 74-in. A.C. Superior gyratory crusher with a close-side setting of 5.0–5.5 in. Crushed ore is drawn by a 72-in. pan feeder onto a 54-in. accelerator belt and then by three 48-in. belt conveyors to two coarse ore bins with 6000 tons live storage each. Dust is controlled by an 11,300-cfm wet scrubber dust collector in the primary crusher building and a 6000-cfm unit at the coarse ore bins.

Crushed ore from the two coarse ore bins is drawn by 48-in. pan feeders, one per bin, onto a 36-in. belt conveyor and thence to a 6 × 16-ft double-deck screen. The top deck contains a urethane-coated manganese grizzly section with 1.5 × 22-in. openings. The bottom deck is equipped with 0.5 × 0.5-in. mesh steel wire screen cloths. Approximately 25% of the secondary feed is minus 0.5 in.

Undersize material from the bottom deck goes directly to the fine ore bins whereas the other fractions are sent to a secondary, 7-ft Nordberg crusher with a close-side setting 1.0–1.25 in. This secondary crusher product is split onto two 6 × 10-ft Nordberg rod deck screens that are equipped with $^{5}/_{16}$-in. rods with $^{3}/_{8}$-in. wide openings. Undersize material goes directly to the fine ore bins whereas oversize ore goes into two tertiary, 7-ft, open-circuit Nordberg crushers, with close-side settings of $^{3}/_{16}$ in.

A tripper belt conveyor then feeds crushed and screened ore to four 50-ft diameter by 78-ft high, fine-ore bins with 6000 tons total live storage. Dust control is effected with a 24,300-cfm wet scrubber dust collector in the secondary crusher building and a 16,800-cfm unit at the fine ore bins.

The primary grinding circuit consists of four 13 × 14-ft Marcy grate discharge ball mills and one 15 × 19-ft-2-in. Nordberg overflow discharge ball mill (see Table S-1.1). The mills contain 3-in. forged steel balls. Ball mill discharge is accomplished with 26-in. cyclones. Cyclone U'flow is returned to the mill. Cyclone U'flow, which is approximately 7% + 48 mesh, passes to the flotation circuit. Flotation reagents, with

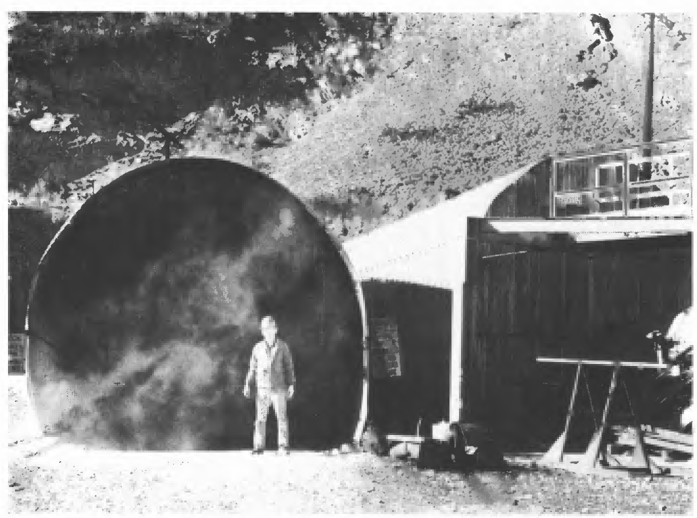

FIGURE S-1.3. View into top of decline at Molycorp mill site. Vehicle entrance to 7000-ft decline is the open corrugated portal. Note condensation that is formed where moist underground air encounters cool, dry air at portal. Enclosed portal on the right houses the conveyor belt. Molycorp metallurgist for scale.

TABLE S-1.1. Molycorp mill grinding machines specifications.

	Primary Mills 1-4	Primary Mill #5	Cleaner Regrinds	Recleaner Regrinds
Mill				
Manufacturer	Marcy	Nordberg	Marcy	Hardinge
Size	13'x14'	15'x19'2"	11'6"x20'	8'x20'
Speed (RPM)	15.8	14.0	N/A	12.8
Speed (% Critical)	72.8	69.7	N/A	46.3
Motor				
Size (HP)	1250	3000	600	200
RPM	240	180	1185	1780
Type	Sync.	Sync.	Sync.	Induction
Power Draw				
HP	1390	2310	N/A	110
KW	1038	1807	N/A	82
KW per ton	8.5	9.30	N/A	--
Grinding Media				
Size	3"	3"	1"-5"	screened rock
Material	Forged	Forged	-	--
Consumption	1.0 lb/ton	1.0 lb/ton	-	--

N/A = Not available
sync. = synchronous

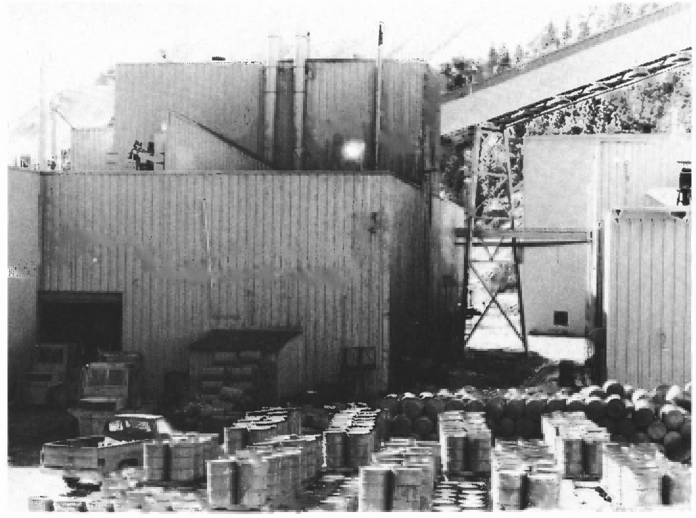

FIGURE S-1.4. Barrels of molybdenite concentrate ready for trucking from mill site. Building on the left houses concentrating-drying-packing operation. Building on the right contains grinders and flotation tanks. Enclosed conveyor system is visible in upper right corner.

the exception of Nokes and Orefoam D-8, are added to the water-ground rock slurry (called pulp) in the ball mills. The pulp is then sent to the flotation machines.

Molybdenite flotation is a physical process. When the ore is ground in the ball mills, a small amount of diesel oil is added to the mixture. The diesel oil coats on the surfaces of moly particles and prevents water adhesion. MIBC and pine oil reagents are also added in the ball mills. When agitated, these reagents make a foam called froth. The flotation machines use large mixers to keep the ground rock particles from settling and to circulate air bubbles through the pulp. Whenever an air bubble contacts a moly particle, the moly particle attaches to it. Oreform D-8 and Nokes Reagent are also added to keep copper and lead from floating with the moly. The net result is that air bubbles collect above the pulp to form a froth that is teeming with moly particles.

The froth then spills over the side of the flotation tank. This moly-rich mixture is called the concentrate. The remainder of the moly-poor pulp is called tailings. The concentrate is repeatedly refloated until it consists of nearly pure moly.

The flotation product is thickened to 20% solids before being filtered to 80% solids. The filter cake is dried to 3% moisture in Holoflite driers powered by natural gas. Gas consumption is about 1370 cubic feet per ton of product. The final product is packaged in either 55-gallon drums, each containing 400 pounds of molybdenum, plastic sacks or bulk trucks (Fig. S-1.4). The moly is then shipped by truck to processing oxidation plants in Washington, Pennsylvania and elsewhere.

Molybdenum is a metal nearly as heavy as lead, with a very high melting point (4730°F). This melting point is 2000° higher than that of steel and 1000° higher than that of most rocks. When alloyed with steel, molybdenum increases the toughness, hardenability, corrosion and heat resistance of the steel.

Nearly 90% of all molybdenum produced is used in the steel industry for high temperature applications such as engine parts and turbines. Additional applications include constructional alloys, stainless steels and tool steels.

Molybdenum disulfide is also used as a solid lubricant that is unaffected by vacuum, solvents or cold. Molybdenum is also a micronutrient essential for life and is added to deficient soils to improve crop productivity. It is also used as a pigment, especially for the color yellow.

The large volumes of water used in the mill operation are obtained from the Red River and from local wells. Water is also reclaimed from the process thickeners. Mill tailings are pumped by two-stage centrifugal pumps through three tailings lines about 17 km (10.5 mi) to the tailings disposal ponds west of Questa. These lines are 14-in. rubber-lined pipe for the first 8 km (5 mi) and 14-in. steel pipe thereafter. The elevation of the pipeline varies from 8100 ft at the mill to 7329 ft at its lowest point, with corresponding pressures of 75 psi and 200 psi, respectively. The slurry velocity varies from 2.0 to 5.7 ft per second. Emergency facilities exist to immediately drain the lines in the event of a leak. Tailings are presently impounded in an 859-acre tailings pond. The dams around the ponds are earthwork, hydraulic-type structures and are lined with an impervious membrane. Rock drains collect any seepage before it reaches the dams. The effluent is treated in a water purification plant before being released back into the Red River drainage basin.

Presently, the mill employs a total of 60 people. This includes 31 production workers, 14 maintenance crew, 11 mill staff and 4 tailings maintenance and construction personnel. Electrical maintenance and assaying are not performed by mill personnel. The mill staff includes personnel for production, maintenance, plant and research metallurgy and metallurgical accounting.

End of Supplemental Road Log 1.