Good Afternoon, my name is Mike Magyar and I am the Molybdenum Commodity Specialist with the Minerals Information Team at the U.S. Geological Survey in Reston, Virginia. Today I would like to give you an overview of the world Mo market.
What is molybdenum? It is a silvery-white, refractory metal that is very hard and has an atomic number of 42 and an atomic mass of about 96.
Background

- First identified in Sweden in 1778
- Named for the Greek molybdos, or lead-like
- High density
- Third highest melting point

Molybdenum was discovered by a Swedish chemist, Carl Wilhelm von Scheele in 1778. Its predominant mineral - molybdenite - was surely utilized in the Middle Ages, as a 14th century Japanese sword has been found to contain molybdenum. However, it would have been indistinguishable from other similar materials such as lead, galena, and graphite. Collectively, these substances were known by the Greek word "molybdos", which means lead-like. Scheele followed this convention in naming the new element molybdenum. Mo has a high density (similar to lead) and the third highest melting point of all commonly available metals at 2,623 C, behind only tungsten and tantalum.
Uses

- Alloying agent in steel:
  - adds hardenability to quenched steels
  - improves high temperature strength
- Nickel-base alloys (Hastelloys®) and stainless steel - imparts heat- and corrosion-resistance
- Nuclear energy applications, missile and aircraft parts - where high temperature resistance is vital
- Petroleum refinery catalysts – sulfur removal
- Ti master alloys
- Thermocouples, filament wires
- Electrodes for electrically heated glass furnaces

What is it used for?
Molybdenum’s ability to withstand high temperatures and maintain strength under those conditions is responsible for the fact that molybdenum finds many of its application at elevated temperatures, as shown in this slide. In fact, it can work at temperatures above 1100°C (in non-oxidizing conditions), which is higher than steels and nickel-base superalloys. Molybdenum is used in petroleum refinery catalysts to remove sulfur from crude oil as well as alloying element in Ti Master alloys.
History

- Phase I (1778)—Laboratory curiosity
- Phase II (1891)—Tungsten substitute, armor plate
- Phase III (1930)—Civilian applications

Phase I - From its discovery in 1778 molybdenum remained mainly a laboratory curiosity until the technology for the extraction of commercial quantities became practical. Phase II - In 1891, a French company used molybdenum to replace tungsten as an alloying element in the production of armour plate. World War I caused tungsten demand to soar and severely strained its supply. As a result, molybdenum was substituted for tungsten in many impact resistant steels. The increased demand initiated an intensive search for new sources of molybdenum supply, culminating with the development of the massive Climax deposit in Colorado, in 1918. Phase III - Research efforts in 1930’s developed a number of new low-alloy molybdenum steels for automotive uses and perfected the heat treatment of molybdenum-bearing high-speed steels. The years after WW II to the present have seen a dramatic expansion of applications for molybdenum alloys and compounds in structural steel.
Climax Mine circa 1969

Let's look briefly at the Mo mine that started it all, the Climax Mine. All mining is like a military retreat - you pull back with careful planning all the way. The mining at Climax was once done by *stoping* - caving in the ore from below. By 1969 the mine had collapsed the top of the mountain to produce this "glory hole", looking a little bit like the crater of Mount Saint Helens. The mine sits right on the Continental Divide at 11,300 feet elevation. This picture was taken in *May* so you can see mining at Climax was never easy.
This is the Climax mine in the summer of 1999. The Glory Hole is in the background and the mill in the foreground. From 1918 until 1986 Climax mined 470 million t of molybdenite ore, recovered over 2 million t of concentrate and produced 1.9 billion pounds of molybdenum worth in excess of $4 billion, and that is at year-mined value, not today’s prices. During WW II the Climax Mine supplied virtually all the molybdenum for the war effort. In the 1950’s it was the world’s largest underground mine, with its own community, the highest town in North America, Leadville, CO. The mine has been idle since 1985 except for a few months in 1995. Nevertheless, remaining open pit reserves stand at 137 million tons. At a continuous production level of 20,000 tons per day, the mine life could exceed twenty-five years. Although the average grade remaining is only 0.317%, open pit reserves contain another 400 million pounds of molybdenum metal. Truly Climax is the mother of all Mo mines.
Mineralization

• Does not occur in native state
• Molybdenite (MoS₂)
• Also Wulfenite and Powellite
• Present in ores from 0.01% to about 0.5%
• Primary – from porphyry Mo ore
• Byproduct – from porphyry Cu/Mo ores

How does it occur?

Molybdenum does not occur in its native state, but is obtained principally from molybdenite. Wulfenite, and Powellite are also minor commercial ores. Primary Mo ores range from about 0.3% to 0.5% Mo and by primary I mean Mo is the only product of the mine. Byproduct Cu/Mo ores range from 0.01% to 0.05% Mo; and Cu is the primary product and Mo and possibly Re are the byproducts. Primary Mo mines produce higher-grade concentrates but byproduct mines have the cost advantage as all mining costs are charged against the Cu product. Molybdenum is also recovered in minor quantities as a by-product of tungsten mining operations.
Where does it occur?
The geologic feature where the porphyry moly and copper-moly deposits occur is known in North America as the Western Cordillera. It runs through Alaska, British Columbia, the US and Mexico and down into the Andes Mountains in Peru and Chile in South America. There are presently no operating mines in Alaska as the deposits are located in National Parks and face difficult environmental restrictions, but there are 2 active mines in British Columbia, 7 in the United States, and 1 in Mexico.
Mining

• Primary – porphyry Mo ores
• Beneficiation produces a moly concentrate
• Byproduct – porphyry Cu/Mo ores
• Beneficiation produces a copper concentrate
• Cleaning produces a molybdenum concentrate
• 45% to 58% Mo in molybdenum concentrates

How do we recover it?

With a primary molybdenum deposit, molybdenum is recovered as a concentrate after mining and beneficiation. With a porphyry copper/moly deposit, mining and beneficiation produces a copper concentrate, which when cleaned produces a byproduct molybdenum concentrate. Mo concentrates can contain 45% to 58% molybdenum with the byproduct concentrates on the lower end of the scale and the primary concentrates on the upper end.
How do we process it?

Primary Mo concentrates can be further cleaned chemically to remove impurities and produce a high-purity MoS₂ for use in lubricants and chemicals. Most Mo concentrates are roasted to drive off sulfur and produce molybdenum oxide which is the primary Mo product. The stack gases are scrubbed to reduce sulfur emissions and flue dust. Byproduct concentrates also contain rhenium which reports in the scrubber sludge and can be recovered separately as an additional byproduct. Technical grade Mo oxide can be further converted to FeMo containing up to 80% Mo.
U.S. 2004 Molybdenum Production

- Seven molybdenum mines in the United States
- Four copper/molybdenum mines
- Three primary molybdenum mines
- Three roasters
- Total molybdenum production over 41,500 metric tons (t)

In the US there are operating primary mines in Idaho, Colorado, and New Mexico and byproduct mines in Montana, Utah, and 2 in Arizona. The primary Mo concentrates are roasted in Iowa and Pennsylvania, and the byproduct concentrates in Arizona. U.S. Mo production in 2004 was about 41,500 t maintaining the US position as the largest Mo producer in the world. The U.S. is a net exporter of Mo and can meet all its demand with domestic production.
2004 Estimated World Production

- United States – 41,500 t
- Chile – 41,500 t
- China – 29,000 t
- Peru – 9,600 t
- Canada – 5,700 t
- Mexico – 3,700 t
- Total world production – 141,000 t

These are the major molybdenum producers worldwide. These 6 countries accounted for about 93% of the estimated world production of 141,000 t/yr in 2004. Other significant producers include Russia and Armenia at about 3,000 t/yr each.
Estimated Reserves

• China reserves about 3,300,000 t
• U.S. reserves about 2,700,000 t
• Chile reserves about 1,100,000 t
• World reserves about 8,600,000 t
• U.S. reserve estimate (revised 1990) does not reflect potential new ore bodies

Do we have enough?

China is the dominant player from a Mo reserves perspective with about 38% of the world total. US reserves are about 33% of the estimated world total, and Chile is about 13%. It should be pointed out that the reserve base, which includes unproven or sub-economic reserves, is more than double this total, so adequate supplies are assured. In addition, new ore bodies that would be economic under today’s prices are not reflected in these totals.
What do we use it for?

This slide depicts the typical world molybdenum consumption by end use. The Other Use category includes catalysts, lubricants, chemicals, and pigments. Although steels and cast iron comprise the single biggest market segment, molybdenum has also proven invaluable in nickel base alloys, electronics, master alloys, and many other applications.
In the U.S. our consumption of Mo looked like this for the last 5 years in these major end-use categories. Clearly the alloy groups mirrored the downturn in the economy in 2001 and 2002 following the terrorist attacks. In 2003 they rebounded and the upward trend continued through 2004. The Other category (catalysts, lubricants, chemicals, and pigments) however did not begin its downturn until 2004. In searching for a reason for this behavior I found this.
This single chart probably explains why the molybdenum specialist was asked to speak at a titanium conference, the unprecedented rise in Mo price. Clearly the producers in the Other category (catalysts, lubricants, chemicals, and pigments) are far more price sensitive than the stainless and alloys groups. The Other category is served by one large primary Mo mine which consequently has a virtual monopoly on their business. In addition, the cost of Mo is a significant portion of the operating costs for their particular end products. Lastly, with the rising steel prices of the last 2 years, stainless and alloy producers were able to pass through much of the cost increase due to Mo. These Other category producers were not so fortunate. I suspect producers of Ti master alloys fall into this category.
In an effort to understand the driving forces behind such an unprecedented rise in Mo prices, I plotted worldwide Mo supply and demand since 2002. What this shows is a significant shortfall in supply in the first half of 2002, about 17 million lbs of Mo. The shortfall caused a spike to $8 per pound in June 2002 which gradually fell back to $3 per pound by December. A second shortfall, about 10 million lbs of Mo occurred in the first half of 2003 which drove the price back to $8 per pound by the end of the year. These 2 events removed any surplus Mo from the market. From 2004 to the present supply has barely matched demand leading to the prolonged price run up we saw in the previous chart.

What set the stage for this situation was the cutback in production by Phelps Dodge and Kennecott in the U.S. and Codelco in Chile in the 4th quarter of 2001. At that time Cu was selling for under $0.70 per pound and Mo was selling for under $3 per pound, and both industries were losing money. Reduced supply in 2002, combined with increased demand in the steel industry and robust expansion in China, fueled the run up in Mo prices since 2003. Cu prices also rose increasing the availability of byproduct Mo.
Supply/Demand Issues

- No surplus Mo in the market
- China alternates between net importer/exporter
- Short term buying supports high spot prices

What are the supply/demand issues?
The price spikes in 2002 and 2003 removed any excess inventory from the market. Due to bottlenecks in roasting/converting it takes almost 5 months to get Mo from the mine to the market. As supply and demand are nearly balanced, inventory has not been rebuilt. Complicating this scenario is the fact that in 2004 China’s Mo exports alternated between 2 million lbs to 12 million lbs monthly due to disruptions in their domestic supply. This means that China alternated between being a net importer/exporter on a month-to-month basis. In a tight global market this had a disruptive effect on price. Until several weeks of supply inventory are built up in the market to overcome delivery issues, spot prices will be in effect.
Supply/Demand Issues—Continued

- Over 80% of Mo consumed by steel industry
- Chinese expansion has cooled somewhat
- Chinese production has stabilized
- Incremental production increases in the West

Is there any hope on the horizon?

Over 80% of all Mo consumption in the U.S. and worldwide is in the steel industry. After the rash of bankruptcies and consolidations the steel industry is in better shape and it is projected to grow at about 2% per year. Government efforts have cooled Chinese steel industry expansion from 20% per year to under 10% per year. These factors should provide stable Mo demand going forward.

The disruptions to Chinese Mo production that we saw in 2004 have been resolved and their production has stabilized. The U.S. and Chile have planned incremental production increases in 2005 and 2006. These 2 factors should stabilize Mo supply worldwide at slightly above current levels.

The combination of these 2 effects should allow inventories to be rebuilt gradually and higher inventories usually put downward pressure on price.
This slide gives you the historical perspective on Mo price. The early years reflect the time period when the Climax Mine ruled the Mo world and you can extrapolate that line back to 1918. In the late 1970’s demand outstripped Climax’s supply capacity, prices spiked, and then byproduct mines came online bringing the price down. In the early 1990’s the breakup of the Soviet Union flooded the market with stockpiled material, briefly driving the price down. The small peak in 1995 represents the last time the Climax Mine operated, and the company lost millions in that startup because they missed the spike.

What does this chart tell us? Clearly, we have never seen a spike of the magnitude of the one we are currently in. Will the Mo price return to previous levels? The answer to that question depends on many variables: will the U.S. and E.U. economies continue to recover, will China remain strong, when will demand develop in the former Soviet Union states, and how quickly will emerging economies in India and South America develop. The degree and order in which these markets develop will affect the supply/demand balance and hence the price. Good luck and happy forecasting.