

Mining, Minerals, and Public Land Policy
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Abstract

This paper is about mining, minerals, and the policy regarding it on public lands. It discusses a history of mining in the Sierra Nevada mountain range, what types of rocks and minerals are mined (precious, industrial, aggregate, and dimension stones), what processes concentrate ores into deposits that are economically worth extracting (hydrothermal, epithermal, placer, evaporitic, sedimentary, and volcanic deposits) with additional information about the Long Valley Caldera hydrothermal system, and it also discusses several mining processes (hard rock, hydraulic mining, placer, leaching) and the life-cycle of mines (exploratory phase, development of infrastructure, extraction, processing, reclamation). In addition there is a discussion of the laws and regulations concerning mining on Forest Service and Bureau of Land Management lands and the environmental impact that the mines leave on the land and the author's assessment of the best method to balance the competing demands of the environment and mining products.

Introduction

Mining is the process of taking minerals, ores, rocks, and metals from the ground. It is important because those are the building blocks of much of civilization-without mined goods there would be no computers, cars, streets, skyscrapers, wires, or many other products. Mining has moved vast amounts of people in short amounts of time, as in the California Gold Rush; it has supplied the world's governments with currency for millennia, and its products have supplied sculptors with stones, artists with paints, and

writers with graphite-fueling the world's creative enterprises. This paper will focus on the non-fossil-fuel products of mining.

Mining has taken place for tens of thousands of years, however, of specific importance to this class is the mining in the Sierra Nevada range which began over 150 years ago. James Marshall discovered gold in 1848 and brought about the 49ers and placer mining. George McKnight discovered gold near Grass Valley in 1850-Grass Valley was filled with veins of gold and became honeycombed with countless mines. The mines continued working until World War 2, when gold mines were closed down by law. The law was lifted afterwards but few continued production and those that did went bankrupt by the 50s because the government regulated the price of gold and when the price wasn't increased, the companies couldn't afford to stay in business any longer. There are several other minerals in the area, such as nephrite jade, but gold was the most important (Hill, 2006). An example of a gold mine is the one at Bodie. Waterman Bodie and Black Taylor discovered the gold in 1859 and the town they formed was initially named Bodie but the name was changed so people would be less likely to mispronounce it. Production was slow at first due to nearby competition, but then Standard Mining Company made a large strike in '77 and miners rushed in. The population grew to around 10,000 by 1881 and the town was known for having a murder almost daily. Along with gold, there was a thriving business importing wood since there was none nearby. Mining decreased quickly though after 1881, cyanide and electricity gave it new life when they came out but not enough to equal the town's heyday. Fires occurred in 1892 and 1932, destroying much of the town, and eventually the mines were just shut down (California State Parks).



Image of Bodie as it is today (Explore Historic California).

Characteristics of the Rocks and Minerals

There are several varieties of stones, minerals, and ores that are mined. These are precious materials, aggregate materials, industrial minerals, and dimension stones.

Dimension stones are rocks that are mined in order to obtain stones of specific shapes or sizes. Granite, limestone, and marble are good examples of rocks that are dimension stones. This type of material has been used for construction and decorative purposes for hundreds of years, however in recent times steel and concrete have taken over much of its role as a construction material, instead relegating it to a mostly decorative role (Virginia Division of Mineral Resources). Industrial minerals are rocks that have some sort of industrial use, but which are not fossil fuels. Clays, such as kaolin, limestone and dolomite, sand, iron, etc. are just a small example of some industrial minerals (Kentucky Geological Survey). Aggregate minerals are crushed rocks used in construction projects- chief examples of aggregates are sand, gravel, and crushed stones. By volume, more than

half of all mining in the US is for aggregate minerals. The chief materials in asphalt and concrete are aggregate materials, mixed with a bit of binder materials. It's very cheap to produce them at the mine-the main expense involved is transportation so in order to compete, aggregate mines try to be as close as possible to population centers (Wyoming State Geological Survey). Finally, the other type of rock mined is for precious materials. Precious materials are rare and have a high monetary value. Silver, gold, and platinum are the most obvious precious materials, though rhodium is roughly ten times as expensive as gold (Kitco).

The following are several minerals found in the Sierra Nevada range. Gold is one of the precious metals and has been used for currency, for artistic purposes, and in many different technologies. It takes a fair amount of work to get it to oxidize, because it's a noble metal, but it's soft, malleable, and dense. It's often extracted from rocks by mixing it with mercury because when the two mix they form a solution together called an amalgam, and then the mercury can be removed leaving just the gold behind. Due to its softness it's mixed with other metals for jewelry and other times when it needs to be harder. The amount of gold in the mix is referred to as the karat or fineness of the product. Gold tends to be found in placer or lode deposits-lode deposits are formed by hydrothermal systems and both types of deposits will be mentioned in greater detail below (Kirkemo et al., 97).



Gold, one of the precious materials (Wikipedia).

Kaolin is an industrial mineral and is also referred to as Kaolinite. It has microscopic triclinic crystallization, which means that the crystals are very small and there's no symmetry in the crystallization (Bangert, A.). It's formed through hydrothermal alteration and is a common clay. It's used in ceramics and as a filler in paper production (Basic Soil Science). As learned from Professor Hamburger, at some kaolin mines they also produce a large quantity of chert as a waste product. Chert is composed of fine-grained silica, and is sometimes known as flint, which is a variety of chert. It can be found in all colors and can be found in extensive sedimentary beds or mixed with limestone and dolomite (Eardley, 1965).

Dolomite, another industrial mineral, is glassy, coarsely crystalline, and whitish or gray (Mineralogy Database). Dolomite and limestone consist of $\text{CaMg}(\text{CO}_3)_2$ and CaCO_3 , respectively, when pure. They are formed when the shells of clams, snails, and skeletons of coral are precipitated by bacteria, though evaporation is also a mode of precipitation (Eardley, 1965). They are used in the making of steel, they're burned and used as fluxing agents, and also in the production of rubber, "sugar refining, agriculture,...water purification, construction,...carpeting, chalk,...fiberglass, paint", etc (Ohio Department of Natural Resources).

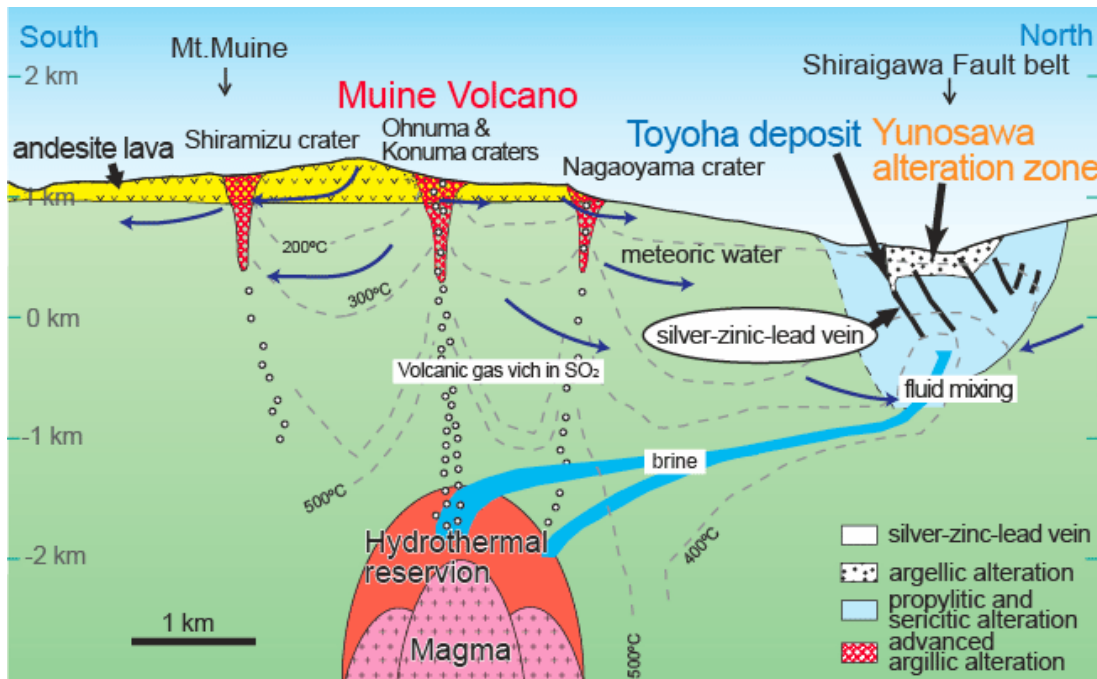
Ore Concentration

There are several different processes that can concentrate ores. These include hydrothermal systems, epithermal, evaporitic, sedimentary, placer, and volcanic deposits (Australian Museum Online).

Hydrothermal systems which form mineral deposits consist of water as the primary ingredient along with some dissolved salts, which make it into a brine. Water by itself is incapable of dissolving metals but the salts along with the high temperatures enable small amounts to be dissolved. The water can come from magma when it cools, or by groundwater or seawater that came near a magma source and was heated up by it. The water can form deposits because as it moves upwards it gradually cools and when it cools the minerals precipitate. If a fracture is present, a lot of water will move upwards in that limited space and cool near each other, forming veins of ore. As the hot water passes through an area, it also alters the rock that it passes-this is called hydrothermal alteration and is the way that clays such as kaolin are made. Epithermal deposits are a type of hydrothermal deposit and tend to be near fumaroles or hot springs. They form relatively near the surface and are formed due to the boiling and mixing of liquids. Gold and silver are most often associated with them (Whitehead, 2003).

An example of an area with an active hydrothermal system is the Long Valley Caldera area in California. Within this system there are two aquifers-one of them begins by the Bishop Tuff and another is in the Casa Diablo/Hot Creek Gorge area. The water in the one by Casa Diablo moves about 100-200 meters per year (Blackwell, D.). Hot springs are found mostly in the eastern part of the caldera and fumaroles are mostly in the west, where the elevation is greater. The resurgent dome, Hot Creek Gorge, and other

areas in the southern and eastern moats are the locations where most of the minerals formed by thermal activity have been found. Around 80% of the discharge from the hydrothermal system is let out into the Hot Creek Gorge, this is 250 liters per second. The water for the system comes from snow that melted in the mountains, which sinks down several kilometers and gets heated up by relatively young magmatic intrusions. Mostly the melted snow that comes into the Caldera comes from mountains on the western side, the water then flows through faults underground in a south-eastern direction until around Hot Creek and Crowley Lake. The Inyo Craters have underground water temperatures of around 220 degrees Celsius, which goes down until around Crowley Lake the temperatures are around 50 degrees Celsius (USGS-Long Valley Observatory).



Showing a hydrothermal system which results in mineral formation through alteration (AIST).

Sedimentary deposits were formed millions of years ago in areas that were probably covered by shallow seas (Australian Museum Online). Organic matter or sediment, created from the weathering of larger rocks and which was washed into the

seas by rivers or streams, floated to the bottom of the sea floors and were cemented together over time to create them (Dawson, J.). Evaporitic deposits are a type of sedimentary deposit that are formed when a lake evaporates and leaves its salts and minerals behind (Whitehead, 2001). Badwater is an example of a place with evaporitic deposits since it is covered by salts but used to be covered by a lake.

Placer deposits form when weathering breaks down rocks and the minerals within it are washed downstream and the flow sorts them into deposits. It's more common for heavier minerals to form placer deposits because they'll tend to accumulate at bends in rivers, where the water flow isn't intense enough to continue lifting them (Whitehead, 2003).

Volcanic deposits are rocks that form due to volcanic processes. Black smokers are vents at the bottom of the ocean which create a local hydrothermal system because of the heat coming from the vent, which is magmatic in source, and this hydrothermal system takes minerals out of any nearby volcanic rocks and concentrates it into deposits (Australian Museum Online).

Mining Processes

In order to extract any resources, first companies need to find them in a phase called the exploration phase. Most of the easy ore sites have already been discovered in the continental US so new sites tend to be either deeper underground, where it's hidden under other rocks, or from extensions of old sites because when the main vein in a site has been exhausted there still tend to be trace amounts of material in the surrounding rocks-material that got to that location from the same hydrothermal system that concentrated the initial vein. When material is found in trace amounts like this it is called

disseminated mineralization. Also, sometimes resources are found by mining the heaps of material left by previous mines, in order to extract the trace minerals remaining. In order to find out the extent of a deposit, testing holes are drilled, the amount and distance between them is decided based on the geology of the deposit (Committee on Hardrock Mining on Federal Lands [henceforth referred to as Hardrock Committee]).

If a deposit is judged to be worth extracting there are various mining methods used, depending on what created it-sedimentary rocks like limestone tend to be in flatter deposits so they can be mined horizontally whereas materials that are formed by magmatic and hydrothermal systems tend to be more complex and require vertical mining. Infrastructure, support buildings, processing buildings, and waste locations are decided upon and built. Shafts are built underground, if it's going to be mined vertically, or if it's going to be mined horizontally the soil and material on top of the deposit is taken off and placed in waste dumps-once the mine has been exhausted the waste is placed into the hole to fill it in (Hardrock Committee).



Vertical mining results in underground mines (Virtual Science Fair).

After exploration and development the companies can finally begin extraction. In order to extract material, holes are drilled and explosives detonated in the holes. The blasted material is then transported to the processing buildings. At the processing buildings the rocks are ground up into small pieces and go through various chemical and/or physical processes in order to separate the desired minerals from the surrounding rock. Naturally, depending on the individual mineral or rock, there may be differences to this process, but that's a rough generalization of the routine (Hardrock Committee).

After the mine has been exhausted there is a further process called reclamation, where the mine is supposed to be cleaned up and the environment returned closer to its

natural state. Sometimes this isn't done and in the worst cases the mine can become a Superfund cleanup site (Hardrock Committee).

Another mining practice, besides just subsurface and pit mining, is hydraulic mining-where water is highly pressurized and shot out through hoses to wash gravel and other sediment into extraction facilities. This method is rarely practiced anymore though, due to the immense environmental damage it could cause-during the gold rush it destroyed hills and built up sediment in rivers which resulted in more flooding (MJC Geology Department).



Hydraulic mining in California during the 1800s (Wikipedia).

Modern placer mining involves diverting a section of a stream through a new route, digging out the rocks from the old route, processing it to remove the sought after minerals, and then returning the unwanted rocks to the old section, and diverting the stream again so it flows through the original location. It can also be done by using a suction-device to pump up sediment from the stream's bottom and having it go through a floating sluice (Hardrock Committee).

Another major mining technique is mining through leaching. This is done when an ore is in an aquifer-chemicals are added to the aquifer to make a solution called a leachate. The solution dissolves the mineral to be mined, which is then extracted from the aquifer, the mineral is taken out from the solution and the leachate is put back in to dissolve more ore (Minerals Downunder Teacher Guide).

Public Lands

The General Mining Law of 1872 affects public lands that are not closed off to mining. The law allows anybody to stake a claim in a public area and reserve the minerals in that area for exclusively his/her own use. Once minerals are being extracted the person doesn't need to pay any royalties to the government or pay to own the land that is being used. If the person who claims the land can prove that there are substantial amounts of minerals on it, the title of the land can be bought for \$2.50-\$5 an acre. The BLM and Forest Service own 38% of the land in the Western US and 76% of the land in Nevada-this is 99% of the land that the BLM administers and 85% of the Forest Service's land (Hardrock Committee).

On BLM land, mining operations of more than 5 acres must submit an operation plan to be approved by the BLM and post a variable amount of money to assure they reclaim the land, while operations of less than 5 acres are not required to post financial assurance and though they need to post a plan of operation-the BLM doesn't approve the plans to insure they fit any kinds of standards. The Forest Service generally requires financial assurance and a plan of operation for all mining operations, regardless of their size. The mining operation must also fill out an Environmental Impact Statement under the National Environmental Policy Act (NEPA), which must be filed with the relevant

agency that is managing the land (either the Forest Service or the BLM). This document tells what impacts the operation will entail and helps the agency come up with operation and reclamation requirements that the mine must fulfill in order to be approved.

However, if the title to the land has been bought then the mining land is treated as if it was owned by a private individual, and isn't required to file an operation plan or file a NEPA statement (Hardrock Committee).

In addition to federal laws, mines must comply with state laws. Many states have their own reclamation laws, in California individual counties regulate reclamation and are overseen by a state mining board. In addition, they often have laws regarding air and water quality and to protect the fish and wildlife (Hardrock Committee).

Though it is theoretically possible for a mining operation to fill out all the permits and forms and begin working in six months' time, for large companies it usually takes between 18 months and 8 years for the process to be completed. There are over 200,000 abandoned or otherwise inactive mines, which are the main cause of mining related environmental damage, however mines in current operation also occasionally don't meet the requirements of environmental protection laws (Hardrock Committee).

The Forest Service's mission is to manage the land under its authority with an emphasis on using the land in multiple ways in order to satisfy diverse groups of people. Some of the multiple ways that they use their land is for conservation, improving scientific knowledge, improving rural economies, and providing work for the needy. (USDA Forest Service) In recent years it has focused its attention on preserving the lands under its care and the amount of timber that has been cut has decreased considerably as a result. The mission of the Service has been governed by the Organic Act of 1897, the

Multiple-Use Sustained-Yield Act of 1960, the 1974 Act for Forest and Rangeland Renewable Resources Planning, and the National Forest Management Act of 1976, which, when combined, tell the Service that it needs to sustain the forest indefinitely to provide recreation, environmental protection, and goods to the American public. None of those Acts however tell the Forest Service which of those priorities should come first when they conflict, however after the passage of the Endangered Species Act and Congress's recent emphasis on marking more and more federal lands as wilderness-designation, the Service came to the conclusion that environmental protection was the role that the government and public as a whole were interested in the most and thus decided to give it the highest priority (GAO).

When mines operate they inevitably leave their mark on the environment. Cyanide and other chemicals used in the processing stage are often present in waste rock or tailings from mining operations and if they come into contact with water they can contaminate ground and surface waters. If contaminated waters go into a lake like Mono Lake, that have no outputs, they can build up and eventually start killing birds or other animals that come there. Sometimes, when mines run deep enough, they start getting below the water table and start flooding and pumps are installed to pump out the excess water. If the water is dumped into streams it can result in a different, and unnatural, flow pattern which would harm the river ecosystem. One of the goals that the Mono Lake Committee was trying to get the LADWP to accomplish, which was mentioned in class when we toured the aqueduct's dams, was to have water released from the dams in a natural way to try and repair the damage that had previously been done to it. This shows how important it is to have a natural flow pattern. Also, mines sometimes withdraw

water from the local groundwater supply for processing and to prevent the mines from getting flooded and this can lower the water table, which can result in less input for rivers and, in extreme cases, can result in rivers starting to dry up. With mines, come paved roads and other paved areas which leads to more runoff than natural. Though most new mines are by sites of already existing mines, they're also sometimes made in pristine environments where large amounts of human activity has never been seen before. Naturally, large scale human activities result in substantial disruption to these areas. Smelter exhausts result in air pollution, heavy machinery results in noise pollution, erosion increases as natural surfaces are disturbed, and dust levels increase as vegetation holding down topsoil is disturbed (Hardrock Committee).



Example of river pollution, possibly caused by mining (Encarta).

Interpretation

Mining is a critical facet of civilization. Without mining and its products humanity would have been stuck in the Stone Age, for better or worse-that's a simple fact, for copper, bronze, and iron would never have been worked. Mankind would be left scraping flint and obsidian to make bows and arrows, though perhaps a rudimentary form of agriculture would be possible without the products of mining. Assuming that civilization is desirable then, mining must be accepted. However, with its boons comes its banes, and the chief bane of mining is the mess it leaves the environment in. Mines use up fuel and thus contribute to global warming, they put dangerous chemicals and metals into the air, soil, and water, and they harm the environment in other ways mentioned in greater detail in its appropriate section within this paper. Having a healthy environment is critical in ensuring that the world can continue to support healthy organisms, humans included.

Since they are both critical to our well-being a balance needs to be struck between mining and the environment. This can be done in several ways-placing more regulations on mines to minimize as much as possible their environmental mark and increasing the number of checks to make sure that the regulations are being followed, but this would cost both the mining companies and the government more money and it would give the government more control over a section of the economy-never the best idea and rarely a good one. Another way to strike a balance would be to decrease the demand for minerals, then mines would close of their own accord because the price would go down and make it uneconomical for some of them to continue functioning. Demand can be decreased in several ways-either each person would only be allowed to purchase a certain quantity of

mineral-products a year, a very hard thing to regulate, or the number of people could decrease, which would be easier but perhaps hard to do in a non-coercive manner since humans seem to have a tendency to multiply.

None of the above are particularly savory, however as I mentioned above, more than half of all mining in the US, by volume, is for aggregate materials which are used in construction projects. To decrease construction people would need to either get poorer, and not be able to afford to build more, or else there would need to be fewer people. Nobody wants to get poorer so that leaves getting fewer people, which many people would like. This can be done non-coercively by having the government increase funding of campaigns to educate people about the danger the environment is in and of all the benefits of having fewer children and perhaps with some positive reinforcement by giving tax credits to people without children.

Conclusion

In conclusion, mining is a critical activity for civilization because it extracts minerals from the ground which are used to produce a large variety of important goods to help sustain our quality of life. The minerals can be grouped into several groups based on their uses-aggregate, industrial, precious, or dimension stones. They are made into concentrations that are economically viable to extract by a number of different processes such as hydrothermal systems, volcanic, sedimentary, evaporitic, etc, and are mined by various techniques such as pit, subsurface, placer mining, etc. Much of the mining in the US takes place on federally administered lands, where mines have to obey environmental regulations set by the administering agency and usually also by the state the mine is located in. In order to help the West expand, the Mining Law of 1872 allowed mines to

purchase rights to the mineral content of an area for a very cheap price, and that law is still in effect. The BLM has a more relaxed attitude toward mines and small amounts of environmental damage, since only relatively large operations need to get their plans of operation approved, while Forest Service lands have stricter regulations as they try to balance the competing demands of numerous interests, which they consider important because their mission is to have multiple uses for their lands. Despite environmental regulations, mines still have an impact on the environment, and in the author's analysis the best way to balance the needs of the world for mineral-based goods and of the environment is to encourage people to reproduce less in an attempt to lower the world's population, and thus its consumption.

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