Berkeley Pit, Butte, Montana

Montana Geology 2008

January

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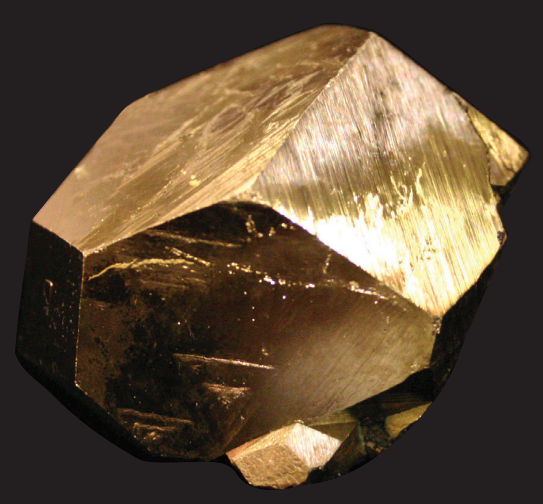
Minerals found in the Butte mines

rhodochrosite

gypsum (selenite) with pyrite on quartz



pyrite

chalcocite with pyrite on quartz

bornite with quartz and pyrite

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The Berkeley Pit

Introduction

The Berkeley Pit has become a Montana landmark. To some it represents a key element in the evolution of mining in Butte; to others it is a symbol of problems inherent in mining. To most Butte residents it is just "The Pit," a normal part of everyday life in a mining town.

The site of the Berkeley Pit is the center of the Butte (or Summit Valley) mining district, which covers about 25 square miles. The district has produced a great volume of various metals almost continuously since 1864, but it was the extremely large, high-grade veins of copper minerals beneath the Butte Hill that earned the title "The Richest Hill on Earth."

The Berkeley Pit was actually a relatively recent and short-lived effort in Butte's 144 years of mining. The first miners in 1864 focused on shallow gold placers, followed by silver mining in 1866. In 1882 the first major discovery of copper mineralization was made on the Anaconda claim. Mining in Butte took off, focused mostly on those high-grade copper veins and driven by new uses for copper as America became electrified. The underground workings from the hundreds of mines that operated in Butte have been reliably estimated at approximately 10,000 miles. One mine, the Mountain Con, is over a mile deep (5,291 feet), hence the phrase "Butte—a mile high and a mile deep." The production is astonishing—over 21 billion pounds of copper have been recovered from the Butte Hill. That's enough copper to pave a four-lane highway, 4 inches thick, for 450 miles.

Headframe at the Anselmo Mine. This mine went to 4,301 feet deep and produced primarily copper and zinc. Photo by Michael Barth.

Geology

The granitic rock hosting the Butte ore body is one of several igneous bodies that rose as molten masses to fairly shallow levels in the earth's crust, where they solidified about 75 million years ago to form the Boulder Batholith. The batholith stretches about 70 miles from the Highland Mountains, south of Butte, northward to Helena. Various parts of the batholith were subsequently enriched with metals transported by hot waters associated with the batholith and younger igneous rocks. But it was only at Butte that metal deposition formed the incredible high-grade veins several miles long, up to 120 feet wide, and some over a mile deep. Geologists have deciphered a history that indicates mineralization occurred in several pulses and resulted in a huge ore body made up of mineral zones. The mineral zones locally are so distinct that mine workings separated by only a few hundred feet produced completely different metals, such as copper, silver, zinc, or manganese.

Natural chemical reactions between ground water and mineralized rock on the Butte Hill began long ago, as soon as the Butte ore body was exposed at the surface. In the walls of the Berkeley and Continental Pits, a red-brown layer of rock (leached cap) overlies more uniformly colored massive gray-blue rocks (see picture below). As oxygen-rich ground water percolated downward through the uppermost rocks, it caused oxidation of iron contained in pyrite (iron sulfide) and yielded the red and brown colors; at the same time, copper in these rocks was dissolved and carried downward to the water table where it was redeposited. Although underground mines exploited the original high-grade veins, much of the ore mined in the Berkeley Pit was enriched in copper by this ground-water action.

Above: *Butte mining operations, looking west. At left center is the water-filled Berkeley Pit and the city of Butte beyond it. The Continental Pit is hidden between the Berkeley Pit and waste rock piles in the foreground. The Yankee Doodle tailings pond in the upper right is covered by very shallow water. Photo by Larry Smith.*

Front photos: *View of the Berkeley Pit looking east, photo by Pete Norbeck. Minerals from the Butte collection in the Mineral Museum at Montana Tech, photos by Susan Barth.*

Below: *Northeast wall of the Continental Pit. Overburden overlies gray-blue rocks that retain the original copper. Photo by Susan Barth.*

Production for the Butte Mining District 1880—2005

Copper	21,635,294,319 lbs
Zinc	4,909,202,540 lbs
Manganese	3,702,787,341 lbs
Lead	854,797,405 lbs
Molybdenum	197,007,798 lbs
Silver	715,976,036 oz
Gold	2,922,446 oz
Total value, Fall 2007 prices	$114.5 billion

Source: Steve Czehura, Montana Resources

The Berkeley Pit

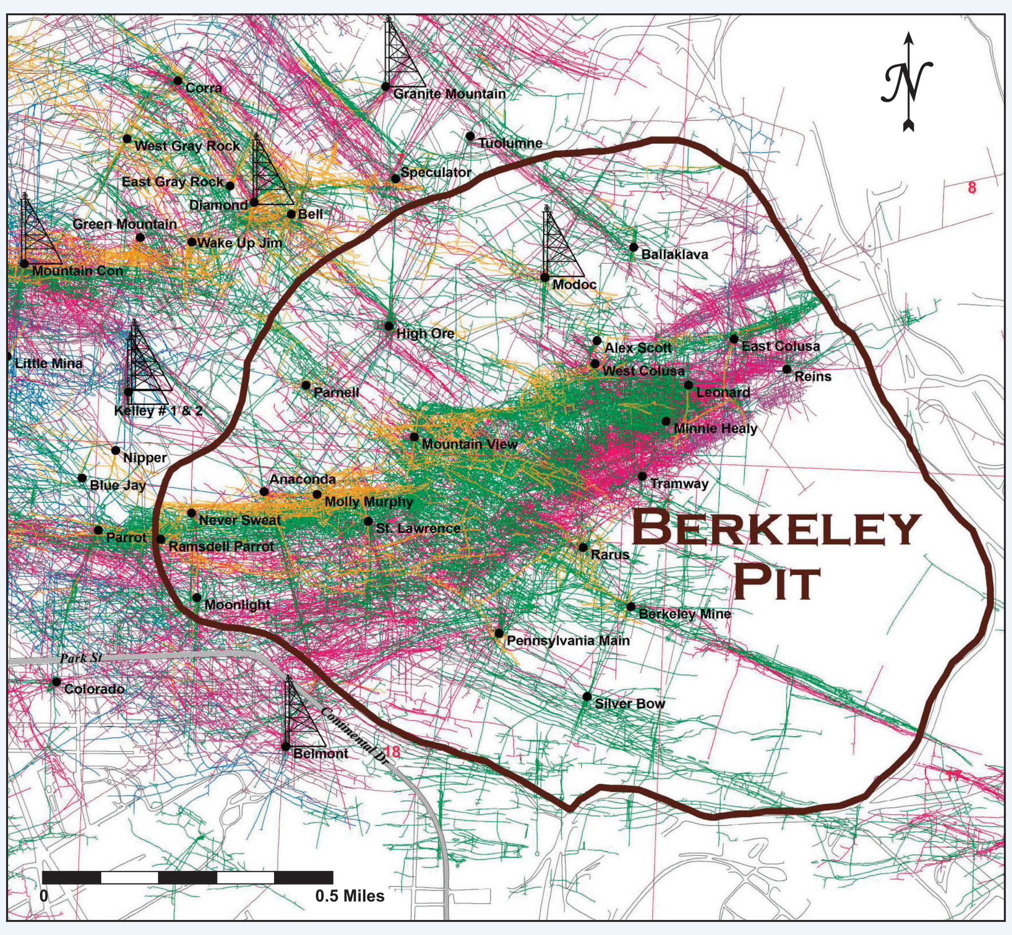
With the development of larger trucks, shovels, and other equipment, open-pit mining offered not only lower costs per ton of mining rock, but also more efficient and complete recovery of the available resource than in the past. Lower-grade material that would have been bypassed in underground mining could be mined by open-pit methods. Although underground mining continued until 1975, the transition to open-pit mining began much earlier, in 1955. At peak production, about 250,000 tons of rock were moved each day, including ore, low-grade rock destined for leach pads, and waste rock. The Anaconda Copper Mining Company suspended mining in the Berkeley Pit in May 1982.

While the Berkeley Pit is huge (5,000 feet by 7,000 feet rim-to-rim, and 1,800 feet deep), it is far from being the largest open-pit mine in the world. The fame of the pit is the chemistry of the water in the 900-foot-deep lake that fills it. The same process that created the red-brown rock layer seen at the top of the pit rim, a reaction of water and oxygen with abundant pyrite in rocks in the pit walls, makes the lake acidic. The pH of the pit water is between 2.5 and 2.7 (about the same as a carbonated cola) and readily dissolves many metals, particularly iron, from the wall rocks. The high metals content makes the water unfit for release into streams or local ground water, as the pH and concentrations of many metals exceed regulatory standards.

For this reason the Montana Bureau of Mines and Geology (MBMG) monitors water levels and water quality in the lake and the bedrock surrounding the Berkeley Pit under agreements with the Montana Department of Environmental Quality (DEQ) and the U.S. Environmental Protection Agency (EPA). The Berkeley Pit is designed to be what is referred to as a "terminal pit"; its water level is lower than in the surrounding rocks, so all bedrock ground water drains into the pit. The EPA and DEQ have established a maximum ground-water level (5,410 feet) that cannot be exceeded. This ensures that ground water continues to flow towards the pit rather than outward into the surrounding rock.

Large-scale mining in the Continental Pit, east of the Berkeley Pit, began in 1980 and continues today. Ores at the Continental Pit are lower grade than those mined at the Berkeley Pit, but contain higher percentages of molybdenum; depending on metals prices, at times the Continental Pit is a molybdenum mine with a copper by-product. Montana Resources moves an average of 100,000 tons of rock per day at the Continental Pit, with approximately 52,000 tons per day going to the mill. Additional copper is recovered by reacting copper-rich water from the Berkeley Pit with scrap steel cans.

In the past few years the Berkeley Pit has been prospected from a different direction. Extreme environments such as the hot springs and geyser pools at Yellowstone National Park harbor uniquely adapted microbes from which new compounds can be extracted that are tested as anticancer drugs. Recently, researchers at Montana Tech have confirmed that Berkeley Pit water also hosts exotic microbes and are working to isolate compounds that may prove to be beneficial.



This map shows ~ 10,000 miles of underground mine workings. Colors indicate the depth of the workings. The original map is available from the Montana Bureau of Mines and Geology as a postcard or wall map.

Common questions about the Berkeley Pit:

Will it overflow?
No. Ground-water levels under the Butte Hill were artificially lowered by nearly a century of constant pumping to keep the underground mines, and later the Berkeley Pit, from flooding. When pumping ceased in April 1982, the natural flow of ground water began refilling the voids in the rock. When the water levels rose high enough, a lake formed in the Berkeley Pit. Water levels in the pit are currently rising at a rate of about 7 feet per year. A water-treatment facility, required by the EPA, will allow pit water to be pumped, treated, and released into streams, ensuring that bedrock water levels will not exceed 5,410 feet. This plant is currently operating, but the treated water is being used in mining operations rather than being released.

Then why is the water level in the pit lake of such concern?
A shallow alluvial aquifer containing good quality water overlies the bedrock aquifer, so metals-laden water in the pit lake and bedrock must not be allowed to contaminate it. The critical water level (5,410 feet) is 50 feet below the alluvial aquifer.

What does the monitoring program do?
The MBMG's monitoring includes monthly water-level measurements and semi-annual water-quality sampling of the pit lake and nearby bedrock wells. Selected physical parameters, e.g., pH, dissolved oxygen, temperature, and specific conductance, are measured throughout the upper 300 feet of the lake's water column, and samples are collected at a minimum of three depths for inorganic chemical analysis. The overall trends in the concentrations of most dissolved constituents in the Berkeley Pit have changed little over time. Exceptions are arsenic and iron, which have decreased throughout portions of the water column; concentrations of copper and zinc increase with depth. All data are reported to regulatory agencies and other involved parties.

When will the critical water level be reached?
Water levels are affected not only by ground-water inflow, but also by precipitation and surface-water inflows, and water that is extracted for use in mining operations. The current projection is that the critical water level will be reached in June 2021. This projection is reviewed annually and adjusted based on current water-level trends.

What happens then?
Excess water will be treated and released as surface water.

Would a large earthquake rupture the pit and allow the water to flood out?
No. Any fractures created by an earthquake would fill, but only as high as lake level.

How can I find out more about the Berkeley Pit?
The Montana Bureau of Mines and Geology maintains an informational page on our website, at ***http://www.mbmg.mtech.edu/env/env-berkeley.asp***.

PitWatch, a regular publication published by the Berkeley Pit Public Education Committee, is available online at ***http://www.pitwatch.org***.

Numerous scientific references on Butte's mines and geology are available in libraries, and many articles in popular publications can be accessed by an internet search.

References:
Czehura, S.J., 2006, Butte: a world class ore deposit: Mining Engineering, v. 58, p. 14–19.
Czehura, S.J., 2007, Manager of Engineering, Montana Resources, personal communication.

Acknowledgments:
Map from: *Butte, Montana: Richest Hill on Earth, 100 years of underground mining, Duaime, T.E., Kennelly, P.J., Thale, P.R., 2004, Montana Bureau of Mines and Geology: Miscellaneous Contribution 19.*
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Edited by Susan Barth; layout by Susan Smith.

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Montana Bureau of Mines and Geology

Montana Tech of The University of Montana

Scope and Organization

The Montana Bureau of Mines and Geology (MBMG) was established in 1919 as a public service agency and research entity for the State of Montana, *to conduct and publish investigations of Montana geology, including mineral and fuel resources, geologic mapping, and ground-water quality and quantity.* In accordance with the enabling act, MBMG conducts research and provides information but has no regulatory functions.

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