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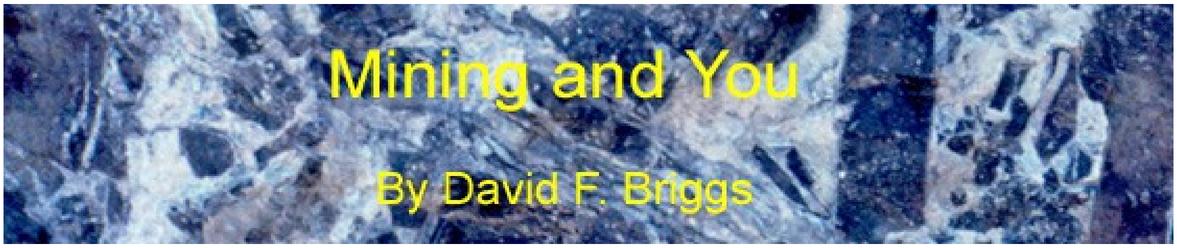
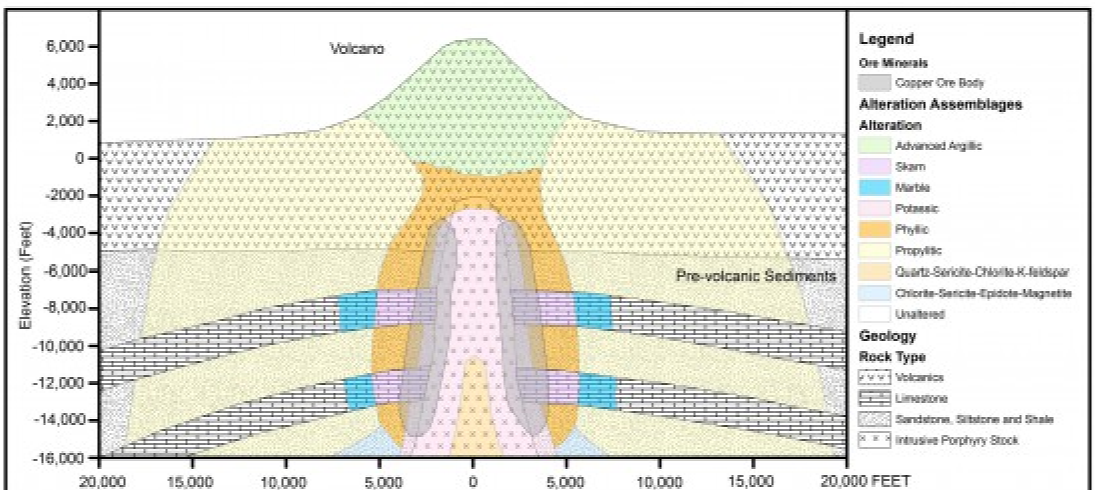


What is a Porphyry Copper Deposit?

by David F. Briggs on Jan. 11, 2014, under Geology

Over the last several years, many of you have probably heard the term "porphyry copper" and wondered what everyone is talking about. Porphyry copper deposits are very large mineralized systems that are typically formed by relatively small intrusions (stocks), which are several thousand feet in diameter. These small intrusions are the solidified remains of a magma chamber from which the volcanic rocks were extruded. Hydrothermal (hot fluids) activity associated with their emplacement affected the wall rocks surrounding these intrusive bodies for a great distance, extending outward as much as 30,000 feet or more from the center of the intrusive system. The simplified cross section shown below, represents a vertical slice (like cutting a slice of cake) through the middle of an idealized porphyry copper system.



Simplified Cross-Section through a Porphyry Copper System (Modified from Lowell and Guilbert, 1970)

The term "porphyry copper" is derived from the texture of the igneous rock that forms these intrusive bodies. Porphyritic texture is characterized by larger crystals of feldspar and quartz, known as phenocrysts, which are surrounded by a matrix of very fine-grained crystals. This texture is commonly found in intrusive bodies that have risen to a shallow level in the earth's crust. They initially cooled slowly, which allowed large crystals of quartz and feldspar to form. At some point during the cooling process, the magma was rapidly quenched, resulting in crystallization of the finely crystalline matrix surrounding the larger phenocrysts.

Porphyry with feldspar and quartz phenocrysts and quartz veining. This 4-inch long sample is from the Rosemont deposit, Pima County, Arizona (Photo taken by Jan Rasmussen, September 2012).

As the intrusive body is emplaced the outer edges of the intrusion are the first to crystallize. This crystalline rind and the surrounding baked zone of sedimentary and volcanic wall rocks are repeatedly broken and fractured by metal-rich volatiles that are released by the crystallizing magma. Heat from the cooling porphyry stock rises resulting in movement of groundwater upward, then downward, in large convection cells within the surrounding volcanic and sedimentary strata. The volatiles from the porphyry stock and the groundwater disperse the metals contained within these solutions and react with the surrounding rocks. This forms a large zoned alteration halo within and around the porphyry stock.

From the center of the porphyry copper system and proceeding outward, the potassic alteration assemblage occurs at the center, the phyllic alteration is next and propylitic alteration assemblage is furthest from the center. The alteration and metallic minerals replace other minerals in the rock. These minerals are disseminated throughout the rock and occur within and/or along the edges of veins cutting the rocks.

Potassic alteration is characterized by the presence of quartz, potassium feldspar, biotite (dark colored mica) and anhydrite. It typically contains only minor amounts of chalcopyrite, pyrite (fool's gold) and molybdenite.

Minerals associated with phyllic alteration include quartz and sericite (a fine-grained colorless mica) with abundant pyrite and lesser amounts of chalcopyrite and bornite.

Looking northwest from top of Red Mountain, Santa Cruz County, Arizona toward the town of Patagonia in the valley. The reddish ridge in foreg oxidized, quartz-sericite-pyrite (phyllic) alteration in the volcanics that overlie the porphyry copper deposit at Red Mountain (Photo taken by D October 2009) .

Propylitic alteration frequently gives the rock a greenish cast as it is characterized by green-colored minerals such as chlorite and epidote, and calcite with minor amounts of pyrite.

Greenish colored propylitic alteration with calcite veining in andesitic volcanics at the Rosemont deposit, Pima County, Arizona (Photo taken Ja
September 2012).

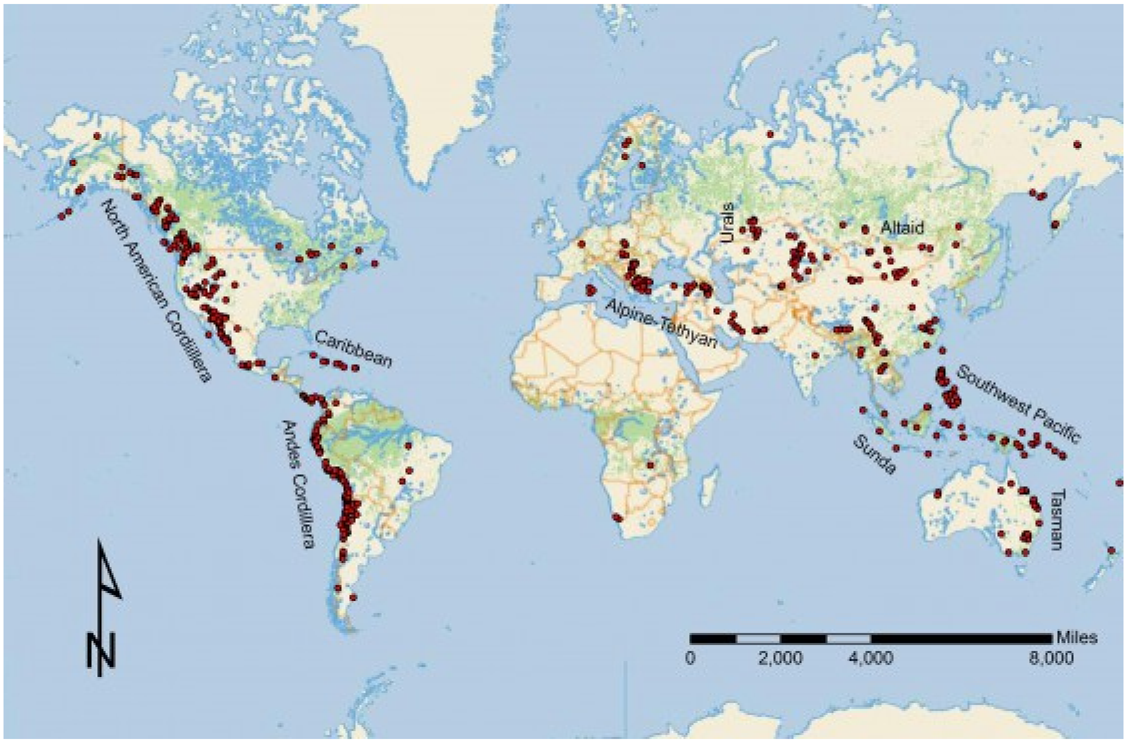
A zone of advanced argillic alteration (quartz, clay, alunite and pyrite) normally overlies the central portion of porphyry copper systems. Limestone beds located immediately adjacent to the intrusive stock are typically altered to a calc-silicate assemblage, known as skarn, which includes garnet, diopside, tremolite and/or serpentine with chalcopyrite and pyrite. The zone separating the skarn and unaltered limestone is normally occupied by recrystallized limestone, which is also known as marble.

Marble from Pima-Mission Mine, Pima County, Arizona (Photo taken by David Briggs).

The copper-bearing ore body typically occupies a shell-like zone that straddles the boundary between the potassic and phyllic zones of alteration and surrounds a low grade core, located at the center of the system. The copper ores are characterized by the following sulfide-bearing minerals: chalcopyrite, bornite and molybdenite (minor) with minor to moderate amounts of pyrite. These ore bodies are very large, generally containing from 100 million to several billion tons of copper ore with a copper content of 0.2% to 2.0%.

Chalcopyrite-Bornite-Quartz Vein from Freeport's Dos Pobres mine near Safford, Arizona (Photo taken by David Briggs)

The majority of porphyry copper deposits occur adjacent to subduction zones (i.e. Ring of Fire around the Pacific Ocean), which form along continental margins (i.e. Andes Mountains) and island arcs (i.e. Aleutian Islands).



Distribution of World's Porphyry Copper Deposits (Modified from Singer et. al., 2008).

Few porphyry copper deposits are greater than 340 million years old. Formed at relatively shallow depths in the earth's crust (less than 15,000 to 30,000 feet) in areas characterized by high rates of uplift, most of the older deposits have been exhumed and eroded away. Most of Arizona's porphyry copper deposits were formed during late Cretaceous to early Eocene time (75 to 51 million years ago). The one exception to this rule is Bisbee, which dates from early Jurassic time (180 million years ago).

Although copper has been mined from a number of different types of mineral deposits, porphyry copper deposits are the most important source for copper, accounting for more than 60 percent of the annual world copper production and approximately 65 percent of the known total copper resource. Since 1970, more than 95 percent of the U. S. copper production has been derived from porphyry copper deposits.

Porphyry copper deposits are also important sources for other metals, including molybdenum, gold and silver. Minor amounts of rhenium, tellurium, arsenic, zinc and platinum group elements are also present in elevated concentrations within these systems and are recovered at some mining operations.

With the commencement of open pit mining operations at Bingham Canyon (Utah) in June 1906, porphyry copper deposits were the first type of metallic mineral deposit to be exploited by large-scale, bulk tonnage, open pit mining methods. Economies of scale and advances in technology have made it possible to profitably mine these deposits despite their relatively low ore grades.

Bingham Canyon, Salt Lake County, Utah (Photo taken by Ken Krahulec, July 2005).

Over the last century porphyry copper mining projects have had significant economic and societal impacts, as a result of the large size of these deposits, their long mine lives and the scale of these mining operations. They will continue to be an important source for the copper we consume for many years to come.

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