Do supervolcanoes form metallic ore deposits? If so, what types of deposits do they form and how large are they?

KEYWORDS: supervolcano, metallic ore deposits, hydrothermal systems, supervolcano life cycle, ash-flow caldera

Metallic ore deposits, the primary source of metals critical to industrialized societies, are rare concentrations of metals that can be economically recovered. The life cycle of supervolcanoes involves magmatic, tectonic, and hydrothermal processes that can form metallic ore deposits. Hot springs, geysers, mud pots, and hydrothermal eruption craters at Yellowstone (Lowenstern and Hurwitz 2008 this issue), for example, are characteristic of shallow ore-forming systems and may indicate that metals are currently being concentrated there. Several types of metallic deposit are related to supervolcanoes, although most deposits form in the eroded cores of these volcanoes, from ~100 ky to >2 My after catastrophic eruption.

The formation of metallic ore deposits requires (1) sources of metals, (2) methods of transporting metals from sources to sites of deposition, and (3) processes to precipitate and concentrate metals. Supervolcanic ores can be sources of metals, in which case the metals are either derived directly from their crystallizing magma through incorporation into a magmatic volatile phase or leached from their eruptive products. Supervolcanic magmas can provide fluids (H₂O, CO₂, ligands (S, Cl), and heat needed to transport metals and to drive fluid circulation. Faults formed during supervolcanic evolution can channel and concentrate ore fluids into sites of ore deposition.

The life cycle of a supervolcano system entails several potential ore-forming stages and structural environments (e.g. Elston 1994). Emplacement of large magma bodies at shallow crustal depths results in broad regional uplift and faults that can channel later ore-forming fluids. The roofs of the shallow magma chambers commonly collapse during eruption, forming calderas that may fill with volcanic rocks, sediments, and water. Caldera-filling lakes can provide the water and salts needed to transport metals (e.g. silver-lead-zinc veins in the Creede district, Colorado; Bethke and Hay 2000). Hydrothermal fluids circulating through caldera fill may leach metals and redeposit them elsewhere, forming ores (e.g. hot spring mercury, uranium and lithium clay deposits at McDermitt, Nevada; Rytuba and Glanzman 1979). Post-collapse injection of new magma into the caldera floor provides heat to drive convective ore-forming hydrothermal systems (e.g. the Long Valley hot spring gold deposit, California; Steininger 2005). The new magma may also uplift the caldera floor, creating faults that provide structural controls on hydrothermal fluid flow and ore deposition (Creede district). More deeply emplaced, late-stage intrusions may form porphyry deposits (e.g. the molybdenum deposit at Questa, New Mexico; Cline and Bodnar 1994).

Magma composition is an important factor in the types of ore deposits formed by supervolcanoes. Alkali-rich magmas, such as at McDermitt and Questa, form deposits rich in lithophile elements like molybdenum, uranium, lithium, and mercury. Less alkalic magmas, such as those at Long Valley and Creede, form deposits rich in gold, silver, lead, zinc, and copper.

The types of ore deposits and sources of fluids (meteoric or magmatic) are also a function of paleodepth and of associated lithologic properties, such as permeability and tensile strength. Hot spring ores, for example, tend to be deposited by meteoric water (with little magmatic input) at the paleosurface, generally within unconsolidated mant sediments (Long Valley and McDermitt). With increasing depth, hot spring deposits grade downward into epithermal vein deposits, which form in faults and breccias hundreds to more than one thousand meters below the paleosurface from mixtures of magmatic and meteoric fluids (Creede). At depths 22–3 km, porphyry copper and molybdenum deposits may form from ore fluids directly exsolved from the crystallizing magma (e.g. Questa).

Like supervolcanoes, metallic ore deposits are uncommon geological occurrences. Although most supervolcanoes have hydrothermal systems and many have genetically related ore deposits, few giant and no supergiant ore deposits (the largest 10 and 1 percent of deposits, respectively; Singer 1995) are known to be related to them. The scarcity of giant and supergiant ore deposits is likely a combination of (1) the explosive nature of supervolcanoes and the consequent dispersion of metal-rich(?) magmatic vapor into the atmosphere during climactic eruptions, and (2) the large number of coincidental processes required to form giant deposits.

REFERENCES
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Round Mountain Mine, Nevada, in 1990. Gold ore is hosted in 26 Ma rhyolite tuff erupted from the Round Mountain caldera, a possible supervolcano, which mostly is buried in the adjacent basin. Gold production from the mine through 2006 is more than 10.4 million troy ounces (320 metric tonnes). Photograph courtesy of the Nevada Bureau of Mines and Geology (WWW.NBMG.UNR.EDU/SIDES/INDEX.HTM)