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Exploration Guides for Precious-Metal Deposits in Volcanic Domes

By Charles G. Cunningham *and* George E. Ericksen

Volcanic domes are common in intermediate to silicic volcanic fields and are exploration targets for epithermal precious-metal deposits. Domes occur throughout volcanic fields, but they are most common along structural margins and radial faults associated with calderas, within and on the flanks of stratovolcanoes (fig. 1), and along regional faults, especially where an inflection occurs along the fault. Domes generally form late in the magmatic evolution of an eruptive center and typically are cupolas above larger magma bodies at depth that were sources of much of the metals and fluids in addition to the magma.

The Neogene to Quaternary volcanic complex in the Andean Highlands of Peru, Bolivia, and Chile contains many excellent examples of mineralized volcanic domes. These domes have well-preserved features, commonly exposed during mining, that record the evolution of the domes and provide insight into the controls on the distribution of associated hydrothermal ore deposits. Some of these controls are described below and are illustrated in figure 2.

Forceful emplacement of silicic magma may cause development of outward-flaring cone fractures above a magma chamber that serve as natural conduits for hydrothermal fluids. As magma rises toward the surface, interaction with ground water may result in phreatomagmatic explosions that open a conical vent and deposit a surrounding apron of crudely bedded breccia fragments. This explosion breccia generally consists of fragments of the country rock and the carapace of the intrusive body in a tuffaceous matrix. This heterogeneous mixture can be highly porous and, consequently, is a favorable site for mineralization. The breccia commonly is overlain by bedded air-fall tuff resulting from subsequent explosive activity in the vent. Where it is well preserved, the tuff ring is draped over the mound of breccia and dips outward at the periphery as well as inward into the vent.

Viscous, flow-banded magma may then be extruded and expand over, and shoulder aside, the breccia and tuff; these magma movements cause the formation of both radial and concentric faults and fractures. Obsidian rings may

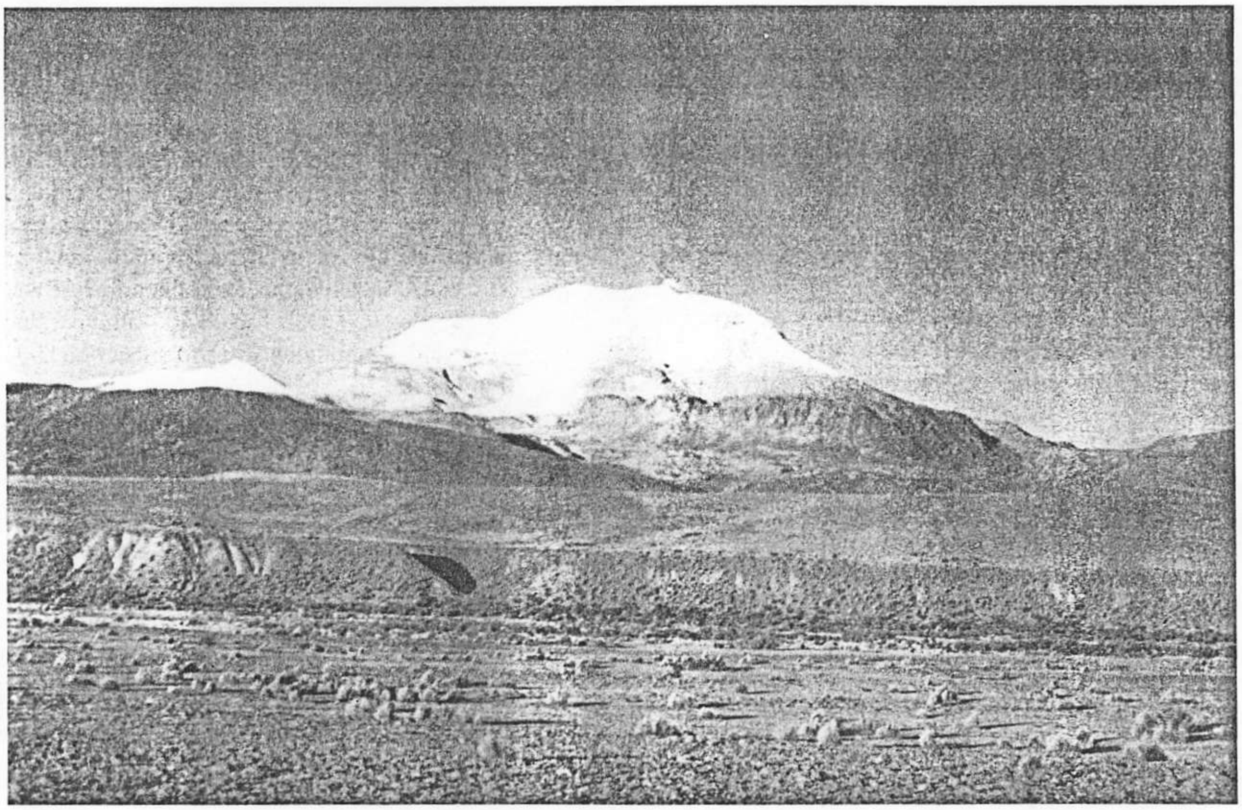

Figure 1 (Cunningham and Ericksen). Volcan Gualatiri, an ice-covered andesitic stratovolcano in northernmost Chile, near the Bolivian border, showing fumarolic activity (tiny white plume at highest point) and active deposition of native sulfur. The distribution of ore deposits in this region indicates that a newly formed or presently forming gold-silver deposit may exist deep within or beneath this volcano. Hydrothermal alteration zones in deeply eroded volcanoes of this type are prime exploration targets for new gold-silver deposits in this part of the Andes. Photograph by George E. Ericksen in 1979.

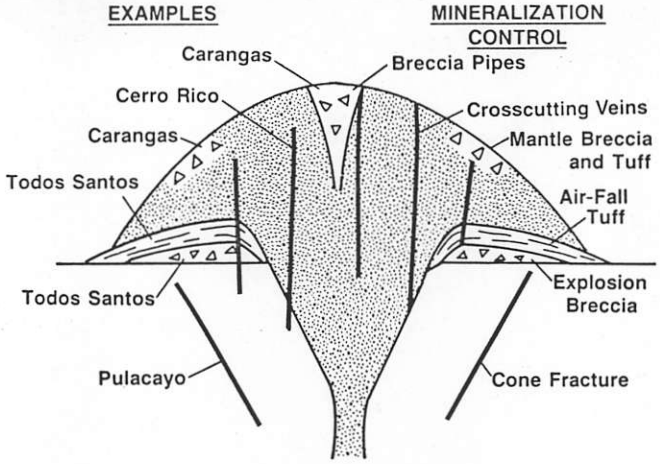

Figure 2 (Cunningham and Ericksen). Exploration guides for precious-metal deposits in volcanic domes, showing examples from Bolivia. Faults, fractures, and breccias are permeable features that are favorable sites for ore deposition.

form at the base of the dome where the magma is quenched as it overrides the cooler tuff ring. Continued extrusion of magma causes the dome to expand and break its solidified carapace to form mantle breccias. Hydrothermal and intrusive breccia pipes may form; they range from those less than a meter in diameter to those that encompass most of the dome. Eroded fragmental material accumulates as porous volcaniclastic sediments and talus along the flanks and base of the dome. Reactivation of faults that initially guided magma emplacement can cause development of fracture systems within the dome in which crosscutting epithermal veins may form.

Origin of Iron, Rare-Earth Elements, Copper, and Gold in Middle Proterozoic Deposits of the Midcontinent Region, U.S.A.

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Middle Proterozoic anorogenic rocks of the midcontinent region of the United States host several magnetite-hematite deposits rich in rare-earth elements (REE) and locally rich in copper and gold. The anorogenic rocks exposed in Missouri represent the root zone of an eroded volcano-plutonic terrane that developed on rocks of the Early Proterozoic Central Plains orogen. Subvolcanic biotite granite massifs are overlain by comagmatic high-silica rhyolite, which erupted from caldera complexes that locally underwent resurgence. The resurgent cauldrons are cored by plutons of high-silica, two-mica granite that have characteristic magnetic lows; amphibole granite and a magnetite-trachyte suite form ring intrusions along the margins of the calderas. The magnetite-hematite ore deposits are cut by aplite and postvolcanic mafic dikes indicating ore emplacement during the waning stages of igneous activity.

A 20-mgal, northwest-trending steep gravity gradient, as well as several smaller (5–10 mgal) en echelon gradients, transects the anorogenic terrane. Most of the magnetite-hematite ore deposits are spatially associated with the gravity gradients. Although the depth and precise geologic cause of the gravity gradients are unknown, the gradients require fairly abrupt density discontinuities over a vertical zone of more than 4 km and may represent a deep-seated fracture system that provided structural conduits for the magmatic and mineralizing systems.

The Pea Ridge magnetite deposit in Missouri is the best studied ore deposit of this class in the midcontinent region. The volcanic-rock-hosted ore body is steeply dipping, lenticular, and zoned outward from a magnetite-rich core through a footwall hematite zone to a quartz-potassium feldspar zone. The hanging wall is an amphibole-quartz-magnetite skarn. REE-rich breccia pipes composed of barite, potassium feldspar, monazite, xenotime, and local gold cut the footwall margins of the magnetite ore body. Total REE oxide and gold contents of the breccia pipes reach 20 percent and several parts per million, respectively; however, gold distribution is erratic.

New major- and trace-element chemical data indicate that the iron-REE±copper±gold deposits are genetically related to the host anorogenic terrane. The rhyolitic and granitic rocks represent lower crustal melts generated in response to mantle upwelling during the Middle Proterozoic. The magnetite-trachyte suite represents either a high degree of partial melting of the lower crust or crust-contaminated mantle melts. The rhyolitic and granitic magmas ascended into the upper crust and formed volcano-plutonic complexes. One scenario allows that the magnetite-trachyte suite underwent fractionation and liquid immiscibility and generated an Fe-P-REE-rich phase and a Si-Al-K-rich phase. The Fe-P-REE-rich phase was the progenitor of the ore deposits, whereas the Si-Al-K-rich phase was the precursor of the quartz-potassium feldspar alteration zone at Pea Ridge. These fluids may have been channeled along the deep-crustal discontinuities and emplaced into the volcano-plutonic complexes.

Anomalous Concentrations of Fine-Grained Native Gold in Stream Sediments of East-Central Lemhi County, Idaho

By George A. Desborough, William H. Raymond, *and* Karl V. Evans

Preliminary reconnaissance studies of heavy minerals in stream sediments show that anomalous amounts of fine-grained (microscopic) native gold in concentrations >0.05 ppm are present in a large area around Salmon, Idaho (fig. 1). Native gold in anomalous amounts was

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