graben: Paleozoic sedimentary rocks and Eocene andesites, pyroclastic rocks, and rhyolites. Graben subsidence began about 48 m.y. ago. Hydrothermal alteration and epithermal mineralization took place about 44 m.y. ago in parts of the graben where there was both silicic intrusive activity and persistent fault movement.

Andesites, rhyolites, and associated pyroclastic rocks host vein and disseminated gold-silver deposits that are localized along discrete northeast- and northwest-trending fracture zones. Ore minerals in vein deposits are electrum, native gold and silver, chalcopyrite, and various sulfosalts in a gangue of pyrite and fine-grained quartz.

At the Sunbeam Mine, near the center of the graben, vein and disseminated gold-silver mineralization occurred in hydrothermally altered rhyolite and pyroclastic rocks. The host rock has been pervasively silicified, and the feldspars altered to clay minerals. Analyses of surface and drill-core samples show that altered rocks are variably enriched in gold, silver, molybdenum, arsenic, zirconium, and selenium. Intense silicification is shown by SiO_2 values as high as 93%.

Northeast-trending fractures, parallel to the graben-bounding fault zones, played an important part in localizing ore at the Sunbeam Mine. Pipe-like masses of silicified breccia, interpreted to be hydrothermal-explosion breccia, were formed along the northeast-trending fractures; the most prominent of these is crudely funnel-shaped and pinches out downward. Movement along some fault zones continued after the period of alteration and mineralization, ultimately juxtaposing altered and unaltered rocks.

Geology and Ore Deposits of the Thunder Mountain Mining District, Valley County, Idaho

OPAL ADAMS

Freeport Exploration Co., Reno, Nevada, U.S.A.

The Thunder Mountain mining district is located in Valley County, central Idaho. Epithermal Au-Ag mineralization occurs in Eocene Challis volcanics and volcaniclastic sediments. Alteration is characterized by pervasive, fracture controlled silicifation and argillization. At the Sunnyside Mine gold and silver occur at a 3:1 ratio along goethite-hematite coated fractures within the upper ash flow tuffs. The mineralization occurs as very fine free gold and electrum. One K-Ar date from quartz-adularia veins over the ore zone yields a date of 41.8 ± 1 million years. This age is no more than two to five million years later than the emplacement of host rocks.

Mineralization at the Dewey Mine occurs as free gold and electrum in siliceous and carbonaceous sediments along shear zones. In limited geochemical sampling, Hg and As are significantly higher in the ore zone of both deposits.

Petrographic and whole-rock analyses indicate the volcanics are rhyolitic to dacitic in composition. A vent area proximal to the mineralized zone has been defined and is characterized by a more mafic composition. Several periods of syn- and post-volcanic normal faulting have resulted in a blocky fault pattern and extensive erosion of portions of the ore deposit.

The volcanic-hosted Sunnyside deposit has an announced grade and tonnage of 2.1 million tons of 0.09 oz gold/ton. The sedimentary hosted Dewey deposit has a reported 1.5 million tons of 0.11 oz gold/ton.

An Exploration Strategy for Hot-Spring Precious-Metal Deposits

BYRON R. BERGER[1] and SAMUEL S. ADAMS[2]

[1] *U.S. Geological Survey, DFS, MS 973, Denver, CO 80225, U.S.A.*

[2] *Consultant, Boulder, CO, U.S.A.*

The discovery of economic precious-metal deposits related to physical-chemical processes in the near-surface portions of high-temperature hot-spring systems has led to intensive exploration efforts for this deposit type. To increase the probability of success, these exploration programs should (1) be based on the most important visually recognizable or readily measurable deposit-model criteria; (2) be able to identify specific targets within the best search areas; and (3) be able to rank the order of priority among the targets.

We propose a process-recognition exploration strategy for hot-spring deposits that has been developed from data from precious-metal occurrences at several localities in the western United States, including Round Mountain, Tonopah Divide, and Sulphur, Nevada; DeLamar, Idaho; and Knoxville district, California. The exploration model is based on the degree to which recognizable geologic and geochemical criteria are favorable or unfavorable to the occurrence of an economic deposit, either through their presence or absence.

In the broadest context, the areas for exploration must contain: (1) evidence for a relatively near-surface heat source; (2) fracturing suitable for the movement of large volumes of meteoric water over extended periods of time; (3) the availability of large volumes of meteoric water; (4) a host rock of sufficiently low permeability to allow the focusing of hot fluids within specific fracture sets; and (5) evidence of the occurrence of processes for transporting and precipitating metals. Near-surface heat sources are best exemplified by volcanic flows and intrusions. The most favorable structures for transporting fluids include caldera-related fractures, rift zones or grabens, and normal fault zones. The absence of these features makes the areas highly unfavorable. Endogenous and/or exogenous domes of quartz latite to rhyolite composition are moderate to highly favorable indicators by their presence, but their absence is only low to moderate "bad news", because intrusive rocks, per se, are not exposed in many important precious-metal districts. Areas with bimodal basalt-rhyolite volcanism are also favorable. The availability of large volumes of meteoric water to make up the ore fluid is indicated by the presence of lacustrine sediments, large mountain edifices, or regionally extensive artesian aquifers. Time periods of high annual rainfall may be reconstructed from the fossil record or from published paleoclimatological data. Because of the need to focus hot fluids into confined fracture volumes, host rocks of low permeability are moderately to highly favorable for the occurrence of higher grade ores. Generally, rocks of high permeability will tend to disperse the thermal waters over large volumes of rock, and are only weakly to moderately favorable hosts for economically mineable grades. The most favorable evidence for the processes needed to transport metals are siliceous sinter and extensive near-surface silicification. The absence of both of these features is a highly unfavorable criterion. The metal precipitation processes are best evidenced by periodic self-sealing, followed by rupturing of the seal. The occurrence of these processes is recognized by multiple episodes of silicification, cross-cutting quartz veins, silica-cemented breccia pipes or breccia veins.

Criteria related to all of the above processes are numerous, and any combination might be chosen for exploration. More effective, however, is the selection of a few criteria that significantly increase the likelihood that a discovery will be an economic deposit rather than a lesser result of a hydrothermal system. Jasperoid and As-Sb anomalies, for example, are widespread; therefore, these features become effective exploration criteria only in areas demonstrated to have had favorable structures and hydrologic systems. Grass roots exploration emphasis is best placed on the development of screening criteria that help assure that detailed mapping, sampling, and claim staking are conducted in areas that have the potential for ore.