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Item 9

Discussion of the Disseminated-Gold-Ore-Occurrence Model

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INTRODUCTION

The ultimate objective of the 1982 workshop was, if possible, to develop an ore-occurrence model for the disseminated-gold-deposit type. Such a model should assure a common vocabulary and body of factual data that define the common classifiable deposit characteristics and lead to the systematic identification of favorable geologic environments of deposition. Several ore-occurrence models for other types of deposits at various qualitative and quantitative levels have been created to organize data systematically for meeting special-purpose needs (Erickson, 1982; Cox, 1983a, b), but the seeming diversity between sediment- and volcanic-hosted disseminated gold occurrences appeared, at the outset, to pose difficulties in arriving at a simple model. Options for framing a model were considered first, and the elements composing one followed.

Recently, two types of occurrence models have been developed, each of which provides an example of model technology. A genetic-geologic uranium model, for example, encompasses the widely ranging igneous, sedimentary, and metamorphic environments in which uranium forms (Finch and others, 1980). The environment and processes of formation of deposits thought to have a common origin are considered in a time-process sequence. The matrix is intended to consider every event, condition, and process that influenced mineralization, and thus aid in evaluation of the resources. As an example of the second type of model, the computer program "Prospector" (Duda, 1980) was designed for the identification or recognition of specific types of deposits (for example, porphyry copper, massive sulfide) and links field and laboratory observable or inferred evidence with an inference network of plausible rules based on probabilistic reasoning. Such a model provides a systematic methodology for creating a useful resource model and may assist in evaluating geologic terranes and the discovery of unrecognized resources.

The consensus of the workshop was that a definitive or quantitative model, such as those described above, may be premature for disseminated gold deposits; however, documentation of the geologic attributes as well as of existing gaps in data is an important first step in establishing the status of knowledge.

Borealis, Nevada

[Data from H. F. Bonham, Jr., Nevada Bureau of Mines and Geology. n.d., no data available]

A. Name/location ---------------- Borealis district, 19 km south of Hawthorne, Nev.

B. Deposit type ---------------- Volcanic-hosted disseminated gold.

C. Other examples ---------------- Iwato, Kasuga, and Akeshi, Japan; Pueblo Viejo, Dominican Republic; Baguio district, Lepanto, Phillipines; Masonic district, Nev.

D. Regional attributes
1. Presence of gold ---------- Known gold province, along with Bodie, Aurora, and Masonic districts, Nev. Veins and stockworks.
2. Terrane ---------------- Continental margin, mobile-belt volcanic rocks.
3. Basement ---------------- Mesozoic plutonic and metamorphic rocks; possible accreted late Paleozoic volcanic-arc terrane.
4. Igneous association ------- Andesitic composite volcano. Rhyolite flow-domes.
5. Structural regime --------- Subduction-related volcanoes in arc setting.
6. Level of erosion ---------- Favorable.

E. District attributes
1. Host rocks ---------------- Volcanic flows and volcaniclastic rock-types.
2. Traps ---------------- Favorable stratigraphy (see D1 above).
3. Preparation ---------------- Hydrothermal alteration widespread.
4. Size ---------------- Previous minor production of gold.
5. Extensions ---------------- Excellent.

F. Deposit attributes
1. Host rocks ---------------- Subaerial andesitic volcanic rocks, flow-banded rhyolites and volcaniclastics rocks and flows.
2. Size/shape ---------------- Deposit is in quartz-sulfide breccia, irregular; 2 million tons at 0.08 oz Au/ton (1.8 million t at 2.5 g Au/t), which is 160,000 oz Au (4.5 million g Au).
3. Physical characteristics
   a. Ore/gangue mineralogy -- Pyrite, sphalerite, minor bravoite and cobaltite. Geochemically anomalous Ag, As, Au, Hg, and Sb. Hg decreases with depth, whereas Zn increases.
   b. Structures ------------- Silicified hydrothermal breccias cutting volcaniclastic rocks and flows.
   c. Textures --------------- Silicified breccias with multiple periods of brecciation and silicification. Late period of boiling resulted in acid-leached zone (sponge rock of local usage).
   d. Host-rock type/age ----- Miocene andesite and associated volcaniclastic rocks. Mineralization age, 5 m.y.(?).
   e. Paragenesis ------------ Several stages of silicification and brecciation, with associated precious and base-metal mineralization. During late stage, lowering of water table combined with boiling resulted in formation of acid-leached rock in upper part of ore zone.
4. Chemical characteristics
   a. Solution chemistry
      (1) Inclusions --------- n.d.
      (2) Stability ---------- n.d.
      (3) Solubility --------- n.d.
      (4) Isotopes ----------- n.d.
      (5) Cause of deposition Probably, boiling and oxidation of bisulfide species.
   b. Temperature ------------ Silicate and sulfide mineralogy are temperature indicators. Available data not diagnostic at this time; probably 120°C.
   c. Associated anomalies --- Anomalous Ag, Au, and Hg.
   d. Alteration/zonation ---- Wallrock alteration: Silicification, argillization, acid leaching with alunite, and alteration in deeper levels; adjacent to deposit is advanced argillic alteration with pyrophyllite, diaspore, and quartz-alunite ledges.
   e. Oxidized or carbonaceous materials. Late-stage hematite and barite indicate increase of f_{O_2} in hydrothermal system. No carbonaceous material.
   f. Chemical evolution ----- Early quartz-sulfide deposition, late-stage oxidizing environment.
5. Source of elements --------- Not known. Two main possibilities are (1) magmatic and (2) leaching of andesitic pile by convecting meteoric waters.

6. Geophysical signatures	
a. Gravity	n.d.
b. Magnetic	n.d.
c. Induced polarization	n.d.
d. Seismic	n.d.
e. Radiometric	n.d.
7. Summary of apparent depositional environment.	High-level system associated with low-pH hydrothermal solutions (Huang and Strachan, 1981). Argillic and advanced argillic alteration. No evidence of former paleosurface or true sinter, and so not a hot-spring deposit. Ore is in quartz-sulfide breccias, in part oxidized by late-stage hypogene solutions. Has many similarities to other gold deposits associated with advanced argillic alteration--for example, Goldfield, El Indio, and Lepanto--but apparenty lacks typical enargite-luzonite-tennantite assemblages that are characteristic of this group of deposits, although these minerals may be present elsewhere within the district. The Borealis deposit also appears to contain only minor amounts of high-grade (more than 1 oz Au/t (34.3 g Au/t)) ore, whereas Goldfield-type deposits typically contain significant zones of very high-grade Au mineralization. The top of the Borealis deposit probably formed within 100 m of the paleosurface at temperatures of about 200°C. There apparently was a high temperature gradient with depth (pyrophyllite-diaspore assemblage), and the solutions were low pH. The gold was transported as a bisulfide complex and precipitated by boiling and bisulfide oxidation. Late-stage solutions were oxidizing and formed hematite and barite and partially oxidized previously deposited sulfides. The deposit occurs in flow-banded rhyolite domes and marginal breccias and in andesitic volcanic rocks and associated volcaniclastic rocks. High-angle faults were the primary solution channelways. Stockwork mineralization may occur at depth, and a significant increase in base metals at depth is to be expected. Silicified hydrothermal breccias elsewhere in the district may well contain significant Au mineralization in association with enargite-group minerals. The occurrence of a granodiorite porphyry intrusion at depth is indicated. The deposit setting is that of an eroded composite volcano.
8. Byproduct metals	Ag, possibly Cu, elsewhere in the district.
G. Summary, features for resource evaluation.	Faulted and extensively altered volcanic rocks, similar to those in known gold deposits in region geochemical anomalies.

Carlin, Nevada

[Data from C. E. Ekburg, Carlin Gold Mining Co., with additions from W. C. Bagby. n.d., no data available]

A. Name/location	Carlin gold mine, approximately 32 km north of Carlin, Nev.
B. Deposit type	Carbonate-hosted, hydrothermal, disseminated.
C. Other examples	Cortez, northern Nevada; Bell, northern Nevada.
D. Regional attributes	
1. Presence of gold	Carlin is located on a northwestward trend shared by several other loci of gold mineralization. Gold is generally submicroscopic, however, the oldest known occurrences contain coarse (≤0.5 mm) gold. The gold mineralization at Carlin is accompanied by antimony, mercury, and arsenic.
2. Terrane	Sedimentary host rocks of miogeosynclinal origin.
3. Basement	Cambrian sedimentary rocks are exposed, but basement rocks do not crop out.
4. Igneous association	Premineral intrusive dikes of acidic composition. Dikes are indiscriminately mineralized.
5. Structural regime	Carlin is located along a northwest-trending lineament of probable crustal origin in the Antler orogenic belt and below the Roberts Mountains thrust.
6. Level of erosion	No apparent significant supergene enrichment.