2940 0021

115

Item 23

Discussion of the Disseminated-Gold-Ore-Occurrence Model

By Edwin W. Tooker (USGS Bul. 1646)

CONTENTS

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.

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.
C. 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.

E. District attributes

1. Host rocks	Porous, permeable sedimentary rocks.
2. Traps	Favorable stratigraphic horizon, with unaltered massive limestone unit lying stratigraphically above.
3. Preparation	Carbonate removal, addition of clay minerals and silica.
4. Size	Five mines, all gold.
5. Extensions	n.d.

F. Deposit attributes

1. Host rocks	Gold mineralization is in top 90 m of the Roberts Mountains Formation (stratiform).
2. Size/shape	Strike of 1675 m on a N. 45 E. trend dipping 30°-40° NW. As of 1977, 3 million oz Au (93 million g Au) produced from 9.4 million tons (8.5 million t) milled.
3. Physical characteristics	
a. Ore/gangue mineralogy.	Oxidized gold ore major minerals: clay, silica, quartz (detrital); minor minerals: oxides, some exotic sulfates. Carbon gold ore major minerals: clay, silica, quartz (detrital); minor minerals: carbon, pyrite, realgar, cinnabar, other minor sulfides.
b. Structures	Replacement and dissemination.
c. Textures	Acid leaching(?).
d. Host-rock type/age	Silurian and Devonian Roberts Mountains Formation. Mineralization is Tertiary.
e. Paragenesis	Radtke (1981) indicated early introduction of silica, pyrite, illite, and sericite, followed by Au associated with Hg, As, Sb, and Tl minerals. Early stage of silicification was preceded and (or) accompanied by removal of dolomite and calcite. Minor Pb, Zn, and Cu sulfides were introduced slightly later than the Au. Late acid-leaching oxidation included carbonate, sulfide, and organic-carbon removal, introduction of barite and quartz veins and anhydrite, and kaolinite alteration.
4. Chemical characteristics	
a. Solution chemistry	
(1) Inclusions	Type I: 0.0-17 weight percent NaCl equivalent, 152°-338°C; type II: less than 1 weight percent NaCl equivalent, 198°->350°C; type III: rarely containing liquid CO_2. Radtke (1981) indicated that the solutions evolved from low-temperature (175°-200°C) nonboiling solutions during main-stage activity to high-temperature (200°-300°C) boiling during the acid-leaching stage.
(2) Stability	Experimental work on the stabilities of pyrite, cinnabar, mercury, orpiment, realgar, and gold suggests that the solutions were low temperature (150°-200°C) and that total sulfide was low (0.001-0.0001 m) (Rytuba, this volume).
(3) Solubility	Rytuba (this volume) suggests that gold solubility was controlled by sulfide complexing under low temperature, low ionic strength, low total sulfide, and low f_{O_2} and f_{S_2}.
(4) Isotopes	δD=-153 to -139 permil; stage I, $\delta^{18}O$=-6 to +3 permil; stage II, $\delta^{18}O$=+3 to +6 permil; stage III, $\delta^{18}O$=+6 to +10 permil; stage IV, $\delta^{18}O$=-15 to -10 permil. Rye (this volume) noted that the fluid isotopes indicate meteoric-dominated water and that substantial exchange with carbonate or igneous rocks occurred in a low water-rock system.
(5) Cause of deposition	Radtke (1981) suggested that a combination of factors, including changes in ionic strength and pH due to boiling, and supersaturation due to temperature decrease, caused deposition of sulfide and sulfosalt minerals. Deposition of gold was presumably controlled by these same processes.
b. Temperature	200°-400°C (?)
c. Associated anomalies	As, Hg, Sb, Tl.
d. Alteration/zonation	Carbonate removal, clay introduction, silica introduction.
e. Oxidized or carbonaceous materials.	The Roberts Mountains Formation contains trace amounts of syngenetic carbon. In altered parts of the Roberts Mountains Formation, carbonaceous material has been remobilized, and additional carbon introduced. A small proportion of the gold was precipitated on carbon particles.

f. Chemical evolution -----	See 4a(1) above.
5. Source of elements --------	Leached from deep-seated intrusive(?) and (or) surrounding sedimentary rocks.
6. Geophysical signatures	
a. Gravity ----------	n.d.
b. Magnetic ----------	The Lynn window (locus of the Roberts Mountains Formation) is situated at a magnetic "high".
c. Induced polarization ---	n.d.
d. Seismic ----------	n.d.
e. Radiometric ----------	n.d.
7. Summary of apparent depositional environment.	Low-pressure low-temperature near-surface deposition.
8. Byproduct metals ----------	Hg.
G. Summary, features for resource evaluation.	Anomalously high geochemical values for As, Au, Hg, Sb, and Tl in a carbonate sedimentary sequence that contains silicification and argillization as the major alteration types.

Cortez, Nevada

[Data from J. J. Rytuba. n.d., no data available]

A. Name/location ----------	Cortez. T. 27 N., R. 47, 48 E., Lander County, Nev.
B. Deposit type ----------	Carbonate-hosted, disseminated.
C. Other examples ----------	Horse Canyon and Gold Acres, Nev.
D. Regional attributes	
1. Presence of gold ----------	Ag-Au district.
2. Terrane ----------	Tectonostratigraphic accreted oceanic crust over miogeoclinal shelf of craton.
3. Basement ----------	Concealed.
4. Igneous association -------	Several felsic dikes of biotite-quartz-sanidine porphyry of age and composition to those of the Caetano Tuff.
5. Structural regime ---------	North-northwest-striking normal faults.
6. Level of erosion ----------	Apparently near-surface, as evidenced by open breccia and vein.
E. District attributes	
1. Host rocks ----------	Finely laminated carbonaceous siltstone beds of the Roberts Mountains Formation.
2. Traps ----------	Ore bodies follow general strike and dip of dikes.
3. Preparation ----------	Silicification; brecciation and fracturing, formation of jasperiod.
4. Size ----------	0.8 by 6.4 km. Cortez main production: 4.5 million oz Ag, 24,000 oz Au (139.9 million g Ag, 146,000 g Au) and some minor Pb, Cu, and Zn from mantos in the Hamburg dolomite.
5. Extensions ----------	New discovery in district being put into production at Horse Canyon, which holds 3.4 million ton (3.08 million t) of ore containing .05 oz Au/t (1.9 g Au/t).
F. Deposit attributes	
1. Host rocks ----------	Deposit occurs in thin bedded siltstone of the Roberts Mountains Formation (Wells and others, 1969).
2. Size/shape ----------	3.4 million st of ore containing 0.29 oz Au/t (3.1 million mt at 9 g Au/t) in irregular to tabular ore bodies striking north-northwest and dipping 30°-40° SW.
3. Physical characteristics	
a. Ore/gangue mineralogy --	Native gold, pyrite, Au-, As-, Sb-, and Hg-bearing pyrite and gangue minerals of quartz, calcite, and very minor barite.
b. Structures ----------	Disseminated and fracture controlled. Some minor quartz-gold veins.
c. Textures ----------	Fine-grained, locally open breccias and fractures.
d. Host-rock type/age -----	Silurian and Devonian Roberts Mountains Formation and 34-m.y.-old felsic dikes.
e. Paragenesis ----------	n.d.