4020 0018

247

Item 31

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.

Round Mountain, Nevada

[Data from D. R. Shawe. n.d., no data available]

A. Name/location	Round Mountain, Nye County, Nev.
B. Deposit type	Volcanic-hosted stockwork-disseminated gold deposits.
C. Other examples	No closely similar gold deposits known elsewhere.
D. Regional attributes	
1. Presence of gold	Within a known gold province that contains a great variety of gold-deposit types: Vein deposits (including bonanza type) in Tertiary volcanic rocks and Paleozoic and Mesozoic sedimentary and volcanic rocks, and replacement and disseminated (stockwork) deposits in Paleozoic and Mesozoic sedimentary and volcanic rocks and Tertiary volcanic rocks. Round Mountain is one of several early Miocene (19-25 m.y. old) gold deposits in a northwest-trending belt centered along the northeast margin of the Walker Lane in southwestern Nevada, associated with rhyolitic-andesitic flows and tuffs of similar geologic age. No relation to regional geochemical anomalies is evident. Minerals and metals in the deposit are nondiagnostic because all are widely and irregularly distributed in the region.
2. Terrane	Accreted terrane of some complexity; mixed oceanic-shelf derivation, emplaced near continent margin. Probably several successive episodes of accretion, beginning with the Antler orogeny (Roberts Mountains allochthon) of Devonian-Mississippian age, and possibly including two or more Mesozoic events.
3. Basement	Lower Paleozoic marine sedimentary rocks, consisting of quartzite, silty argillite, argillite, limy argillite, limestone, dolomite, and chert, locally metamorphosed to schist and calc-silicate carbonate rocks, and Cretaceous granite. Not known whether or not "crystalline" Precambrian rocks underlie the Paleozoic and Mesozoic rocks. Ore deposits of a great variety are widely known in basement rocks throughout the basin-and-range structural province.
4. Igneous association	Silicic volcanic rocks within which the Round Mountain gold deposits formed are favored hosts elsewhere in the region. Closeness in the ages of the gold ore and host volcanic rocks (26-25 m.y.) suggests that the ore deposits are related to magmatic activity. However, no 25-m.y.-old intrusive rocks are known in the near vicinity. Nearby 35-m.y.-old rhyolitic and andesitic dikes and granodiorite stock predated formation of the gold ores.
5. Structural regime	Round Mountain lies close to a major crustal tectonic zone, the northwest-trending Walker Lane, of probable great geologic vintage (Mesozoic or older?). Some northwest-trending faults at Round Mountain had a major influence on the localization of ore. The district also is marginal to a large Cretaceous granitic pluton that may have served as a structural control on localization of the gold mineralization.
6. Level of erosion	Erosion has not progressed sufficiently to remove the relatively shallow and low-temperature environment of the Round Mountain volcanic-hosted stockwork-disseminated deposits. However, the deposits may not have formed just below the surface, as indicated by a temperature of formation (250°-260°C, Nash, 1972) suggesting a depth of 0.5 to 1 km (see data from Broadlands thermal area, New Zealand, Grindley, 1970).
E. District attributes	
1. Host rocks	Silicic (quartz latitic to rhyolitic) ash-flow tuff.
2. Traps	Lower unwelded porous unit of the ash-flow tuff, and similar porous tuff in an underlying volcanic megabreccia, served as a permeable zone that controlled deposition of the main disseminated lower ore body.

3. Preparation ---------------- Silicification of volcanic rock in the welded upper part of the ash-flow tuff, controlled by major mineralized northwest-trending fractures in the core of the district, accounts for the erosion-resistant Round Mountain hill. Early-stage silicification probably increased the brittleness of the silicic ash-flow tuff and permitted extensive fracturing that controlled stockwork mineralization in the upper ore body.

4. Size ----------------------- District is about 2 by 3 km. Early production (1906-59) came from several underground lode mines and surface and underground placer workings. Total production of gold during the early period was about 537,000 oz Au (16.7 million g Au) (Koschmann and Bergendahl, 1968, p. 194). According to Ferguson (1921, p. 395-397), fineness of the gold mined from lodes was 574-696, and that of placer gold only slightly higher. Thus, probably about 250,000 oz Ag (7.8 million g Ag) was produced in the early period. Current production started in about 1977 from the stockwork ore body in silicified welded ash-flow tuff. Through 1983, in addition, more than 300,000 oz Au (9.4 million g Au) (Simpson and Getz, 1981; Paul Sonerholm, written commun, 1984), and more than 150,000 oz Ag (4.7 million g Ag), has been produced.

5. Extensions ---------------- Mining company (Smoky Valley Mining Division of the Copper Range Co., a subsidiary of Louisiana Land and Exploration) is continuing to drill in the district and, in addition to a large new (lower) ore body, has found other new zones of gold-silver-mineralized rock. Large additional potential resources may exist.

F. Deposit attributes

1. Host rocks ---------------- The upper body at Round Mountain (now being mined) lies in welded rhyolitic ash-flow tuff, dated as 26.1 m.y. old. Early-mined lode ore bodies were distributed throughout the total present thickness of the welded tuff, about 250 m vertically from the base of the welded tuff to the top of Round Mountain hill. Presently mined stockwork has a similar distribution. The lower ore body at Round Mountain (explored by drilling but not yet developed for mining) is in underlying porous tuff, and it extends locally into underlying Paleozoic rocks.

2. Size/shape ---------------- Early-mined ore bodies were thin quartz veins, commonly brecciated, along steep east-west- to northwest-striking faults, and on north- and south-dipping low-angle faults. The flat veins were richer in gold than were the steep veins, and richest ore shoots occurred along intersections of the flat faults with the steep faults (Ferguson, 1921). The veins generally were no more than a few centimeters wide but locally were both thicker and thinner. Numerous vertical nearly parallel northwest-striking fissures filled with thin quartz seams formed a "sheeted" zone at the southwest edge of Round Mountain hill that was mined in a large glory hole. More than half (approximately 330,000 oz Au (10.2 million g Au)) of the gold production during the early period (1906-59) came from the lode deposits at Round Mountain. During the first 10 years of production, grade averaged about 2 oz Au/ton (68.6 g Au/t) and generally diminished thereafter. The presently mined ore body is an oval zone, about 0.4 by 0.8 km, centered on northwest-striking faults of the sheeted zone. Numerous mineralized fractures of different orientations, together with the northwest-striking fractures of the sheeted zone, constitute a stockwork. Reserves in this ore body were initially reported as 11 million tons (10 million t) at .06 oz Au/ton (20 g Au/t) or 660,000 oz Au (20 million g Au). The newly discovered, but not yet mined, lower ore body is also an oval zone, about 1.0 by 1.3 km and as much as 250 m thick, containing an announced 193 million ton (175 million t) averaging .043 oz Au/ton (1.5 g Au/t) or 8.3 million oz Au (262 million g Au). This ore body is more silver rich than the upper ore body and contains about 15.7 million oz Ag (488 million g Ag).

3. Physical characteristics

a. Ore/gangue mineralogy -- Veins of the early-mined deposits consisted of a gangue of quartz and accessory adularia, alunite, and, rarely, fluorite; primary metallic minerals were gold (electrum), pyrite, and, rarely, realgar (Ferguson, 1921, p. 391). Chalcedonic silica is a late-stage mineral. Limonite, manganese oxide, and clay minerals are locally abundant, and jarosite is present in places. Limonite is the product of oxidation of pyrite. Ferguson (1921, p. 393) reported widespread supergene mineralization in which fissures, filled with iron and manganese oxides, or clay, and free gold, transected primary quartz veins. B. R. Berger and P. I. Eimon (unpub. data, 1981) attributed the formation of clays and manganese oxide to a second stage of hydrothermal mineralization. The presently mined (upper) ore body encompasses some of the mined-out veins of the earlier period of mining. It is a stockwork that, in effect, is simply an extension of the veins, as thin seams and fracture fillings in the wallrocks between the veins, that, though of low grade, is minable owing to the present high price of gold. Its mineralogy is essentially that of the veins; it is distinguishable, however, by the occurrence outside a zone of strong alunite development, and fluorite is a common component that occurs in pockets in strongly altered rhyolite. The newly discovered (lower) ore body contains disseminated gold-bearing pyrite and minor base-metal sulfides. The mineralogic residence of the silver is not fully known. Geochemical data reported by Berger and others (1981) indicate that a broad zone of arsenic and antimony enrichment lies near the top of the zone of gold and silver mineralization that constitutes the upper and lower ore bodies. The Au/Ag ratio in the upper ore body is about 2:1, whereas that in the lower ore body is about 1:2.

b. Structures ------------- Faults, both high and low angle, commonly bounded by wallrock breccia and locally filled with gouge and displaying anastomosing slickensided shears, localized the quartz veins that were mined during the early period. The high-angle faults are characterized by nearly horizontal slickensides and mullions, attesting to dominantly strike-slip displacement. Other fractures subparallel to the high-angle faults, and myriad fractures of different orientations, localized the stockwork mineralization of the upper ore body. The lower ore body, though centered on conspicuous zone of northwest-striking fractures, is characterized by disseminated mineralization in porous tuff, a feature suggesting that permeability of the porous tuff beneath a cap of densely welded and, in places, silicified ash-flow tuff was a major factor in ore localization.

c. Textures --------------- No specific ore textures are known that are diagnostic evidence of boiling. Many veins show that a period of silicification was followed by rupture (shearing and brecciation) and, in turn, by renewed silicification. A possible corollary is that silicification sealed the system to allow a buildup of pressure, which, after deformation (breaking), was released in an episode of boiling. Alternatively, hydrothermal-pressure buildup, after sealing by silicification, was sufficient to cause rupture (hydrobrecciation) and boiling. Neither mechanism, however, is required by the evidence.

d. Host-rock type/age ----- The rhyolitic welded ash-flow-tuff host rock has been approximately dated at $26.1\underline{+}0.8$ m.y. (Silberman and others, 1975, p. 1). The age of gold mineralization has been established at approximately $25.2\underline{+}0.8$ m.y. (K-Ar age on adularia; Silberman and others, 1975, p. 2). Alunite in thin veins in the core zone of alteration has been dated at about 10 m.y. old (B. R. Berger, oral commun., 1981). Whether these veins are hypogene or supergene is not known.

e. Paragenesis ------------ In view of the uncertainly as to whether some of the late mineralizing events at Round Mountain were hypogene or supergene, the evolution of the mineral system cannot be described with any confidence.

4. Chemical characteristics

a. Solution chemistry

(1) Inclusions --------- Fluid-inclusion studies by Nash (1972, p. C17) indicated that some of the quartz veins (early stage) were deposited from solutions of very low salinity (0.2-1.4 weight percent NaCl equivalent).

(2) Stability ---------- The presence of chalcedonic silica in late-stage (post-primary ore?) veins suggests that the temperature of deposition at that time was no higher than about 200°-230°C, possibly much lower. Little, if any, additional evidence of depositional conditions based on mineral stabilities is available.

(3) Solubility --------- Solubility data for silica do not add significant understanding of the environment of gold deposition at Round Mountain.

(4) Isotopes ----------- No stable-light-isotope data are available from Round Mountain.

(5) Cause of deposition Boiling is a possible mechanism to account for the deposition of gold and associated minerals, but no direct evidence exists for it. Nash (1972, p. C17) stated that "Boiling does not seem to be characteristic of***" a group of Nevada gold-quartz-adularia vein deposits, including Round Mountain. There is insufficient direct evidence to determine the cause of deposition of the gold deposits.

b. Temperature ------------ The temperature of deposition of some of the quartz veins at Round Mountain, based on fluid-inclusion studies, was about 250° to 260°C (Nash, 1972, p. C17). Berger (this volume) reported temperatures in the range 210-268°C.

c. Associated anomalies --- Associated elements that provide geochemical anomalies which are guides to the location of the Round Mountain gold deposits are Ag, As, Cu, K, Mo, Zn (Shawe, 1977), and F, Hg, Sb, Tl, and W (B. R. Berger and P. I. Eimon, unpub. data 1981).

d. Alteration/zonation ---- The work of Tingley (Berger and Tingley, 1980) showed that the northeastern part of the Round Mountain district, encompassing the area of Stebbins Hill to the north and the top and northeast flank of Round Mountain hill farther south, where high-angle west-northwest-trending veins as well as low-angle veins were mined, shows pervasive alteration of tuff in which biotite of the tuff has been altered to chlorite, sericite, and clay. The core of this zone is extensively silicified, and local zones of alunite in veins are present. Peripheral to the altered core is a zone of propylitization of tuff in which biotite of the tuff was altered to chlorite and sericite. Within this peripheral zone southwest of Round Mountain hill are the presently mined upper ore body (stockwork) and newly discovered lower ore body, both centered on the northwest-trending sheeted zone. A patch of breccia at the southeast end of the top of Round Mountain hill and within the altered core, was interpreted by Berger and Tingley (1980) to be a breccia pipe and part of the structural system that localized alteration in the core of the mineralized system. Drill-hole data (Paul Sonerholm, oral commun., 1982), however, do not confirm downward projection of the breccia zone.

e. Oxidized or carbonaceous materials. There is no evidence that oxidized or carbonaceous material in the host rock influenced ore deposition.

f. Chemical evolution ----- Incomplete understanding of and inadequate data on the Round Mountain gold deposits prevent reconstruction of the chemical evolution of the mineral system.

5. Source of elements -------- n.d.

6. Geophysical signatures

a. Gravity ---------------- n.d.

b. Magnetic --------------- Aeromagnetic mapping (U.S. Geological Survey, 1979) indicates west-facing arc of magnetic highs that encloses the Round Mountain district; the ore is similar to areas of magnetic highs that mark the margins of nearby Mount Jefferson and Manhattan calderas. The magnetic highs near Round Mountain may indicate a volcanic--at least igneous--center concealed beneath alluvium and the silicic volcanic rocks exposed at the surface, to which the gold deposits are related.

c. Induced polarization --- n.d.

d. Seismic ---------------- n.d.

e. Radiometric ------------ Gold ore from the presently mined ore body at Round Mountain contains minor uranium, and so the deposit could have a radiometric signature.

7. Summary of apparent depositional environment.

Ore deposition followed emplacement of rhyolitic welded ash-flow tuff, possibly by as much as about 1 m.y. and probably at a depth of about 500 m. The temperature of formation of the early veins was about 250° to 260°C, and deposition was from fluids of low salinity (0.2-1.4 weight percent NaCl equivalent), though not necessarily under boiling conditions. Deposition of veins and the stockwork ore body occurred in brittle rhyolitic welded ash-flow tuff and was controlled by tectonically formed faults and fractures. Deposition of the large disseminated ore body underlying the veins and stockwork occurred in laterally permeable porous ash tuff, although tectonically formed faults probably provided the channels for ingress of hydrothermal fluids from a deeper level. The altered core zone (of silicification and alunitization) northeast of the stockwork and disseminated ore bodies, and coincident with part of the area of vein mineralization, is not clearly related to the stockwork and disseminated ore bodies. If the main ingress of hydrothermal fluids into the district was upward through "flues" (breccia pipes) in the altered core zone, as suggested by Berger and Tingley (1980) and by B. R. Berger and P. I. Eimon (unpub. data, 1981), it is not evident how the bulk (approx. 95 percent) of the gold mineralization occurred outside the altered core and at a lower level than the zone of silicification and alunitization. Moreover, the localization of the stockwork and disseminated ore bodies along a tectonic fault zone outside the altered core zone suggests that the major solution flow that formed those ore bodies was upward from deeper levels along the tectonic fault zone. Further work, including stable-light-isotope studies, will be needed to clarify the nature of the separate mineralizing stages that have been recognized in the vein deposits. These stages will have to be correlated with the formation of the stockwork and disseminated ore bodies, and the ambiguous age (10 m.y.) of the alunite veins in the altered core zone explained. Judged from the nearby presence of several mineral systems of different ages and separated in age by many millions of years (D. R. Shawe and others, unpub. data, 1983), the possibility of multiple ages of gold mineralization at Round Mountain should be considered.

8. Byproduct metals ---------- Silver is the only byproduct metal, but a major one, recovered.

G. Summary, features for resource evaluation.

The geologic setting that appears to be favorable for the occurrence of gold deposits of the type present at Round Mountain is a stack of silicic volcanic rocks underlain by an igneous center (zone of igneous intrusion). Evidence of widespread mineralization recurring throughout geologic time marks the region as a metal-rich province. A relatively near-surface environment seems essential for the formation of epithermal gold-silver deposits, but it is not at all clear that boiling and the near-surface (acid leaching) zone of a hot-spring system are essential to the model. Geochemical characteristics of the Round Mountain gold-silver district include the presence of anomalous Ag, As, Cu, F, Hg, K, Mo, Sb, Tl, W, and Zn. Although the relation of various alteration minerals to the major ore bodies at Round Mountain is unclear, the presence in and around the ores of hydrothermal quartz, adularia, alunite, sericite, chlorite, fluorite, clay, manganese oxide, pyrite, and other (base metal) sulfides appears to be important to recognition of an appropriate alteration and mineralization environment.