

EVIDENCE FOR A DEEP GEOLOGIC SETTING DURING ORE FORMATION
AT THE CARLIN DISSEMINATED GOLD DEPOSIT

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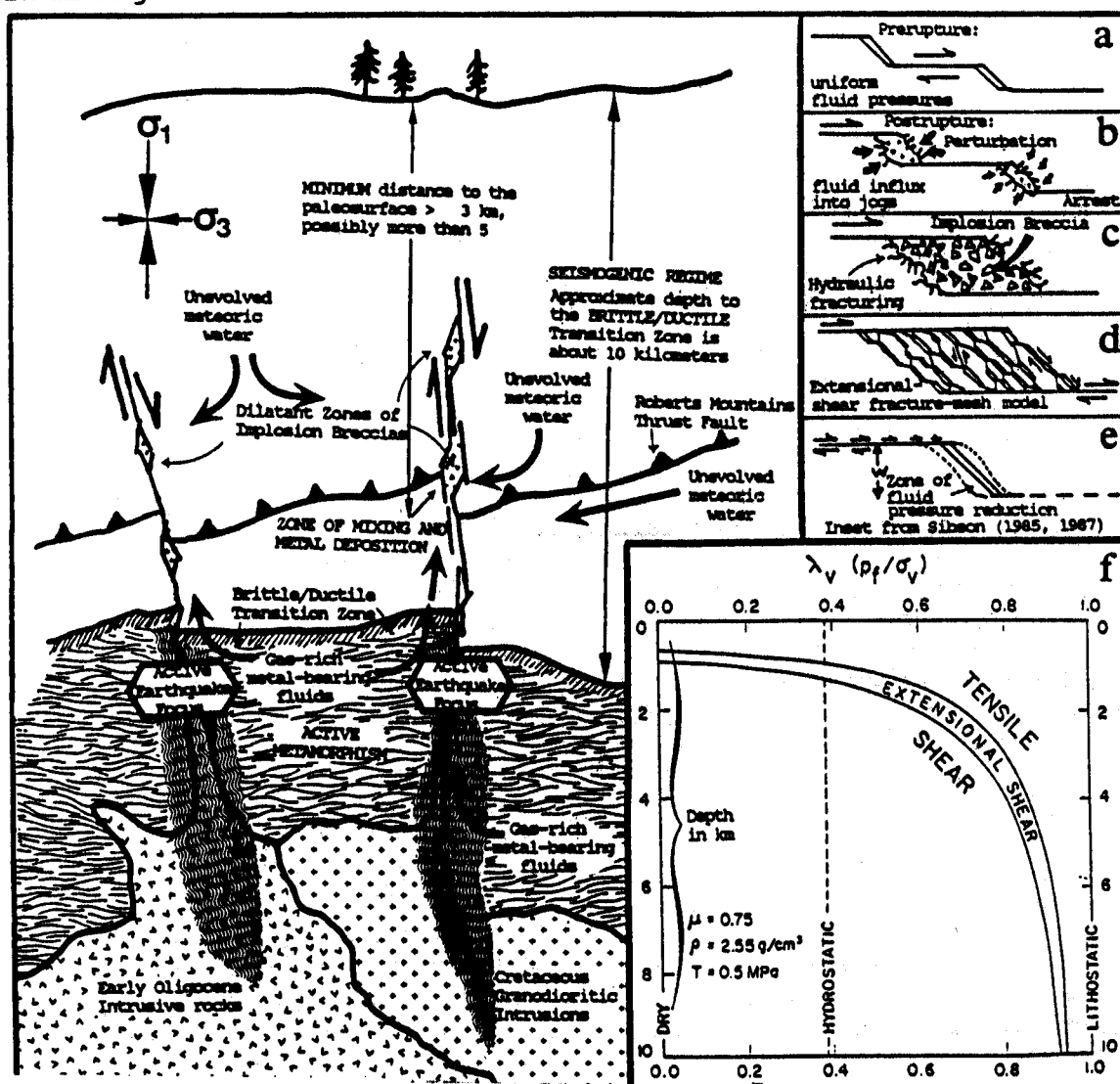
The Carlin disseminated gold deposit in north-central Nevada is hosted in the upper 175 m of the Siluro-Devonian Roberts Mountains Formation. Pre-, syn- and post-gold episodes at Carlin are distinguished by 1) hydrocarbon (HC) maturation, 2) Au mineralization and associated alteration and 3) subsequent oxidation. Alteration related to Au mineralization is younger than Early Cretaceous dike emplacement, which in turn is younger than the thermal maturation of petroleum residues to solid pyrobitumen. Coexisting saline aqueous and high-density CH_4 -rich fluid inclusions in pre-ore HC-stage veinlets define early P-T conditions at Carlin of $155 \pm 20^\circ\text{C}$ and 0.6 to 1.4 kb. These P-T-X conditions are similar to contemporary dry-gas reservoirs and reflect depths of 2.4 to 5.6 km under near-lithostatic pressure gradients.

Main Gold Ore Stage alteration is characterized by extensive carbonate removal and silicification in unoxidized pyrite- and carbon- bearing rocks. Alteration is zoned from unaltered calcareous argillaceous siltstones, through K-feldspar silt and calcite destruction, then dolomite dissolution, and finally conversion of illite to dickite+kaolinite and quartz in the most intensely altered zones near feeder structures and high permeability interbeds. Au is generally associated with intermediate alteration zones of carbonate removal. Volume loss due to compaction following the removal of carbonate creates apparent enrichments in Al, Fe, K and other elements, but ratios to relatively immobile Al and Ti show little change except for the loss of Ca, Mg, CO_2 and minor K, as well as gain of SiO_2 . Cooling associated with decompressional boiling, or the mixing of two fluids of different temperatures, is necessary in order to deposit silica in a geometry that is spatially associated with Au.

The high acidity is due to elevated CO_2 contents in the Main Gold Ore Stage (MGOS) fluids, which, in addition to between 5-10 mole % CO_2 , contain appreciable H_2S , have salinities of 3 ± 1 wt% NaCl equivalent, and are isotopically evolved with $\delta^{18}\text{O}_{\text{H}_2\text{O}}$ values $\geq +5$ to $+9\%$. Two-phase, or "boiling" conditions at about $215 \pm 30^\circ\text{C}$ and 800 ± 400 bars occur during portions of MGOS time. In contrast, Late Gold Ore Stage (LGOS) fluids are gas-poor with ≤ 1.5 wt% NaCl equivalent, record only non-boiling conditions, and isotopically resemble unevolved meteoric water with $\delta^{18}\text{O}_{\text{H}_2\text{O}}$ values ≤ -4 to -3% .

From MGOS to LGOS time, calcite $\delta^{18}\text{O}$ values shift from near whole-rock values of $+12 \pm 3\%$ to around $0 \pm 1\%$ as LGOS fluids flood the system. This $\delta^{18}\text{O}$ shift occurs in unoxidized veinlet types containing LGOS As+Sb phases associated with Au. Two separate fluid reservoirs are required to account for the large range in $\delta^{18}\text{O}$ values recorded both in MGOS and LGOS vein calcite and jasperoids with associated quartz veins. One fluid is gas-rich, moderately saline, contains Au and SiO_2 etc., and is isotopically evolved, whereas the second fluid is gas-poor, of low-salinity and is isotopically unevolved.

Gas-rich MGOS fluids may result directly from buried intrusions or their contact aureoles, or from low-grade metamorphism at depth. Minimum depths of 4.4 ± 2.2 km are required to accommodate the 800 ± 400 bars of pressure recorded during MGOS. Ore deposition may occur in zones of throttling, where fluids experience a change from lithostatic to hydrostatic conditions; however, pressure gradients in excess of hydrostatic are required in order to deliver IGOS fluids to the site of ore deposition at depths less than 8 ± 4 km. Dilational zones along active structures may provide a mechanism to trigger decompressional boiling of gas-rich MGOS-type fluids and actively draw IGOS-type fluids similar to those at Carlin into deep zones of probable fluid-mixing.



Schematic geologic setting of a structural-related deep fluid-mixing model for the formation of the Carlin gold deposit. Figure is modified from Sibson et al. (1988) for the tectonic setting during the mid-Tertiary onset of crustal extension in the Great Basin. Insets "a" through "e" outline critical aspects of the earthquake-rupturing, or structural-related hydrothermal transport models developed by Sibson. Fluid pressure regimes during extension are quantified in "f" from Reynolds and Lister (1987) where T = tensile strength, ρ = density, μ = coefficient of friction and λ_v is the ratio of pore-fluid pressure (p_f) to vertical compressive stress (σ_v).

GREAT BASIN SYMPOSIUM

Time is running short for registering for the GSN-USGS symposium "Geology and Ore Deposits of the Great Basin". For those of you who have not yet registered please note-advance registration is \$150.00, on-site registration (if there are any spaces left!) will be \$200.00.

The symposium committee has done an outstanding job of putting together an excellent technical program, field trips, and social activities. Not only will there be updates on many of the existing mines in the Great Basin, But there will be a significant amount of new data presented on deposits and geologic features of the region. Field trips are scheduled to all parts of the Great Basin region, but spaces are limited and some of the trips are sold out. (trips 2, 7, 12) Due to logistical constraints the last day for registration for most field trips will be March 20.

Please note the following changes in field trip itineraries, which have arisen since printing of the Third Announcement:

Trip Number 4: Southern Extension of the Carlin Trend: Influence of Structure and Stratigraphy on Gold Deposition. This trip is oriented toward examining evidence for a southern extension of the Carlin Trend. Primary emphasis will be placed on structural and stratigraphic controls. The trip will include stops at both operating mines and properties in the advanced exploration or pre-development stages. Properties that will be visited that were not listed in the registration booklet are: Bald Mountain, Winrock , Casino, and Emigrant Springs.

Trip Number 5: Geology and Ore Deposits of the Eastern Great Basin. The trip will depart from Salt Lake City on March 28, 1990, (not March 29) and will return on March 31, 1990, (not April 1). The trip will include stops to Tecoma, Tintic and Victoria properties (none of which were listed in the registration booklet).

Trip Number 11: Rawhide, Tonopah and Round Mountain Districts, West-Central Nevada: Relation of Gold and Silver Mineralization to Volcanic Geology, Structural History and Hydrothermal Alteration. The trip will depart Reno the afternoon of March 28 (not March 29 as noted in the registration booklet). The return to Reno remains the same as outlines in the booklet.

Trip Number 15: Structure & Stratigraphy of the Battle Mountain Gold Belts their relation to Active & Prospective Mines & Exploration for Gold. This trip will now include visits to Atlas' GOLD BAR Mines and Tonkin Springs Mines. No change in dates.

Trip Number 17: Volcanic-Hosted Gold Deposits and Structural Setting of the Mojave Region: A four day (not three day) leaving Reno on March 29 (not March 30) and ending in Reno on April 1 (no change from the registration booklet). Cost includes three nights' lodging (not two), three dinners (not two) and four lunches (not three).

The Keynote Luncheon speaker will be Dr. Ralph Roberts who will speak on "Exploration Philosophy based on 50 years of Experience in the Great Basin Region". This should prove to be a most interesting talk. Bill DuBois will present an aerial photo tour of a number of Nevada's gold mines at the Wednesday symposium luncheon.

John Cleary and the symposium social committee have planned a variety of activities for attendees and their guests. John and his side-kicks know a good time (so does Bo) when they see it, so you can plan on enjoying yourself.

Are you interested in geophysics and what they can do for you? The Society of Exploration Geophysicists Mining and Geothermal Committee is sponsoring a one-day seminar on geophysics in gold, which will be held in conjunction with the Great Basin Symposium on Friday April 6, 1990. This seminar will be directed toward the exploration geologist and will discuss basic geophysical techniques and their application in an exploration program. In addition, a dozen posters on case histories of applied geophysics in the Great Basin will be presented on Wednesday and Thursday of the symposium.

Information on any aspect of the symposium can be obtained by contacting:

Great Basin Symposium

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