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Redox Controls on Eocene Metallogeny in the Great Basin, U.S.A.: Bridging Porphyry Cu-(Mo-Au) and Reduced Intrusion-Related Au, with Implications for Carlin-Type Deposits

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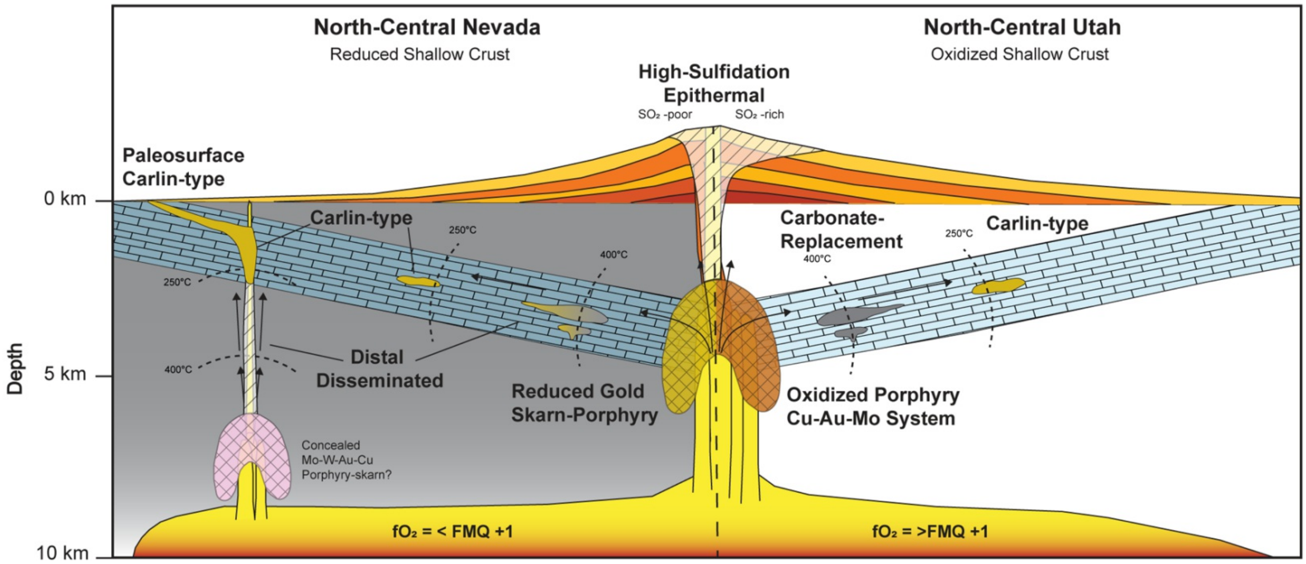
Late Eocene (~42-34 Ma) ore deposits of the Great Basin, U.S.A. have contributed the vast majority of this region's precious and base etals, with the majority of Au production occurring in Nevada and most Cu, Ag, Pb, Zn derived from Utah. Eocene Au deposits in Nevada are almost entirely disseminated in calcareous sedimentary rocks, and here we distinguish four styles: 1) gold skarns, 2) distal disseminated deposits, 3) Carlin-type gold deposits, and 4) shallow-formed, paleosurface Carlin-type deposits. We propose the four styles of SHDG are part of a continuum that spans high-temperature and relatively deeply emplaced to low-temperature and shallow-formed, all during a brief period from ~42-34 Ma, temporally and spatially coincident with Eocene arc magmatism but predating large-magnitude Cenozoic upper-crustal extension. The ubiquitous Au-rich nature of deposits in Nevada is in stark contrast to Utah, which contains world-class porphyry systems dominated by Cu, most notably the 38-39 Ma Bingham Canyon porphyry Cu-Au-Mo system. This progressive change in Eocene deposits from Au-rich in the west to Cu-rich in the east mimics changes in the thickness and composition of the middle and upper crust. Nevada is dominated by a >10-km thickness of reduced, carbonaceous units in the Neoproterozoic through Paleozoic slope, and basin setting in north-central Nevada, while Utah contains a thinner sequence of more oxidized, locally evaporite-bearing, coarse clastic, and carbonate shelf sequences.

Here we present a detailed study of 21 regional mineralization-related intrusions across the Great Basin (Eocene to Oligocene) that shows, through analyses of Ce speciation (Ce^{3+}/Ce^{4+}) and determination of magmatic oxidation state from igneous zircon, initially oxidized mantle-derived arc magmas (~fayalite-magnetite+quartz, FMQ +1-3) were systematically reduced to ~FMQ -1 as they evolved in Nevada, whereas magmas in Utah retained, and in some cases increased, their oxidation state (~FMQ +2-3). Nevada intrusions exhibit a wide range of 0-100% Ce^{4+}/Ce_{Total}, while Utah magmas are dominantly >70%, with substantially more 100% Ce^{4+}/Ce_{Total} measured in zircon. In conjunction, igneous apatite in magmas from Utah is shown to be more enriched in S (dominantly 0.1-1 wt % SO_3) than in Nevada, where apatite is dominantly <0.1 wt % SO_3—likely a function of the elevated magmatic oxidation state in Utah and coupled increase in S solubility due to the transition from S^{2-} to S^{6+} dominance at ~FMQ +0.5. We conclude the assimilation of reduced, carbonaceous sedimentary units in Nevada is a fundamental control on the Au-rich metallogeny of Nevada due to the modification of magmatic redox conditions to optimal levels (~FMQ) for the highest melt solubility and extraction efficiency of Au and reduced S into fluids.

We propose continental arcs emplaced into thick slope and basinal sedimentary sequences are an effective means to form reduced, Au-rich, Cu-poor intrusion-related deposits. Due to the abundance of reduced S in fluids and the buffering capacity of wall rock, these geologic settings are ideal for the transport of Au to low temperatures typical of Carlin-type Au deposits and should be targeted in regional exploration programs for new Carlin-type districts.



North-Central Nevada
Reduced Shallow Crust
North-Central Utah
Oxidized Shallow Crust
High-Sulfidation
Epithermal
SO₂ -poor
SO₂ -rich
Paleosurface
Carlin-type
0 km
Carlin-type
250°C
400°C
Carbonate-
Replacement
400°C
250°C
Carlin-type
250°C
Distal
Disseminated
400°C
5 km
Depth
Reduced Gold
Skarn-Porphyry
Oxidized Porphyry
Cu-Au-Mo System
Concealed
Mo-W-Au-Cu
Porphyry-skarn?
fO₂ = < FMQ +1
fO₂ = >FMQ +1
10 km