Superimposed mineralizing events involved in making giant ore deposits: evolution of the telescoped Chuquicamata porphyry Cu-Mo deposit in Chile

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Emphasis on generalized ore deposit models may result in misleading expectations in the exploration for hidden new deposits. Metal or alteration zoning may not reflect a single event in time and P-T space. Many giant metal deposits are telescoped, meaning early, deep, hot mineralization was overprinted by late, shallower, cooler pulses of notably different chemistry. Furthermore post-ore processes may have modified the original geometry and mineralogy. The giant Chuquicamata porphyry Cu-Mo deposit (Chuqui) in the northern Chilean Andes is a good example of this complexity:

1. Chuqui developed within an active volcanic arc since the late Eocene (40 Ma), within the roots of a stratovolcano undergoing uplift and erosion. The first mineralizing intrusions were emplaced at ca. 36 to 35 Ma and are associated with Cu and potassic alteration. Thermochronology and mineralogical data suggest that the mineralized rock was more than 6 km deep and at ca. 535°C. Ductile and brittle structures indicate an orogenparallel dextral shear regime.
2. Unmineralized porphyries of similar geochemistry were intruded at ca. 33 Ma (Oligocene).
3. Large Mo-rich quartz ("blue") veins followed at ca. 32 Ma, still under a dextral regime and rapid exhumation.
4. At ca. 31 Ma, a new hydrothermal influx invaded the previously mineralized rock, now located at a depth of ca. 2–3 km. This pulse was highly acidic, at a temperature of 335–400°C, and produced sericite and argillic alteration. It was rich in Cu, Au, Ag, but also in (metallurgically) detrimental As, Sb, Zn, and Bi, and anhydrite. The anisotropy of distribution of useful and deleterious elements reflects the evolving permeability in response to changing structural regime.
5. The tectonic system reversed drastically to sinistral brittle shear, now localized along a regional NS fault. This fault truncated one third of the Chuqui orebody and displaced it several km to the south.
6. Exhumation and erosion slowed down and exposed the mineralization to surface weathering and supergene enrichment, during a time of climate desertification. Oxidation of pyrite produced great amounts of sulfuric acid that leached the Cu in the upper portions of the orebody, and deposited it at the level of the paleo groundwater surface. Some of this Cu was carried by groundwater and deposited as "exotic" oxides as far as 10 km downstream within thick Cenozoic gravels that covered the displaced portion of Chuqui (ca. 22 Ma; Miocene). All of these superimposed processes together determined the mining and metallurgical history of the deposit.

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