

Three-phase Carbonic Fluid Inclusions: A Trend Across the Boulder Batholith Region, Southwest Montana

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Southwest Montana hosts numerous magmatic-hydrothermal ore deposits, many of which are related to the late-Cretaceous Boulder batholith. While only some of these deposits are well studied, e.g., the Butte porphyry-lode deposit, recent USGS Earth Mapping Resource Initiative funding, combined with ongoing work at Montana Tech and the Montana Bureau of Mines and Geology, has sparked new investigations of ore deposits across the Boulder batholith. Examination of gangue and ore associated with polymetallic vein, Au-Cu skarn, and porphyry Cu-Au mineralization indicate the widespread presence of liquid CO₂ in three-phase carbonic inclusions. Districts that have been studied to date include Emery, Elkhorn, Winston, and Park. Fluid inclusion homogenization temperatures range from 200 to >300°C, and salinities are typically low to moderate (e.g., 3 to 7 wt.% NaCl_{eq}). Aqueous fluid inclusions lacking CO₂(l) are also present in many samples and may represent de-gassing of a CO₂-H₂O-NaCl fluid. Vein sulfide minerals have δ³⁴S values that typically fall between 0 and +8 ‰. It is hypothesized that these deposits formed at considerable depth (>4 km) from magmatic fluids that, in some cases, interacted with carbonate-bearing wallrock. Despite being hosted by the Boulder batholith, three-phase carbonic inclusions have not been reported from the porphyry-lode deposits of Butte, although CO₂ is present as evidenced by Raman spectroscopy and the uncommon appearance of CO₂-clathrates. Previous workers have concluded that Butte is also a “deep” porphyry-lode deposit. We argue that most, if not all, of the polymetallic mineralization in the Boulder batholith that falls in the age range of 80-65 Ma formed from magmatic fluids released during the emplacement of late-Cretaceous granitoid magmas. A younger generation of gold-rich epithermal deposits in the batholith is hosted by Eocene-Oligocene volcanic rocks. These deposits likely formed at shallower depths from predominantly meteoric waters, although more studies are needed to confirm this hypothesis.