Ascent and cooling of a magmatic-hydrothermal fluid and the traces of its passage recorded in the rock in Butte, Montana

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Abstract:

Computer modeling of magmatic hydrothermal fluid reaction with granite shows that a magmatic-hydrothermal fluid of a single composition is capable of producing all of the many alteration types in the Butte, Montana porphyry copper system. The Butte system is defined by two internally zoned domes with alteration assemblages containing biotite, K-feldspar, sericite and chlorite. Each of the domes has concentric zones of centimeter-scale stockwork veinlets. The deepest and innermost zone consists of quartz veinlets that grade upward and cut quartz-sulfide veinlets with biotite-K-feldspar-sericite-andalusite alteration envelopes. The biotite-dominant alteration grades upward to alteration on quartz-magnetite veins consisting of sericite-K-feldspar-chlorite bordered by biotite-bearing outer envelopes. Further upward, the outer envelopes change from biotitic to chloritic, and quartz-pyrite-chalcopyrite veins with chlorite-sericite-K-feldspar envelopes become abundant, intermixed with pyrite-rich veins with gray sericite. In the outermost zone, millimeter-scale veinlets containing sphalerite and galena are bordered by alteration consisting of K-feldspar, chlorite and epidote. Between the two domes, a zone of intense pervasive sericitic alteration formed around a stockwork of pyrite-quartz veinlets bordered by gray sericite-pyrite-quarz alteration.

Geochemical modeling of reaction of a magmatic fluid with Butte granite between 600ºC and 200ºC at 1 kbar shows that the full array of alteration types– from high-temperature biotite-feldspar-andalusite to low-temperature sericite-pyrite-quartz and the late advanced argillic alteration– could all have formed from a single initial fluid composition as it cooled and reacted with wall rock. The high temperature model fluid is pH-neutral and in equilibrium with biotite, feldspar and andalusite. It is transformed upon cooling as disproportionation of aqueous SO2 makes the fluid increasingly acidic. As the acidic fluid is neutralized by rock reaction, it yields all of the observed alteration assemblages in the observed spatial order at the scale of vein envelopes and the scale of the hydrothermal system as a whole. The key implication of this finding is that one single initial magmatic fluid composition is chemically capable of producing all of the alteration and mineralization features observed in the system. Thus, a single fluid composition may form porphyry copper deposits in some settings and shallow epithermal veins in others, or both ore types superimposed in single districts. The universally observed sequence of vein cutting relations in porphyry copper systems is likely to be an inevitable consequence of cooling of a single fluid type, not a consequence of successive distinct fluid compositions expelled from an igneous source.