Fluid evolution in porphyry copper deposits

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The porphyry copper deposits provide some of the best examples of the effects of fluid-assisted mass and energy transport in the earth's crust. Much of our understanding of the physical and chemical conditions attending magmatic-hydrothermal fluid flow in the porphyry environment has come from studies of fluid inclusions (Beane and Bodnar, 1995; Bodnar, 1992, 1995; Cline and Bodnar, 1994; Roedder and Bodnar, 1997). These studies have shown that fluid inclusions that trap the earliest magmatic fluids may have a broad range of room temperature phase ratios depending on a variety of factors including (1) the degree of crystallization of the intrusion, (2) the depth of emplacement and (3) the composition of the magmatic fluid.

Using the Burnham model (Burnham, 1979) for crystallization of a granodioritic magma emplaced at shallow levels in the earth's crust, the time-space
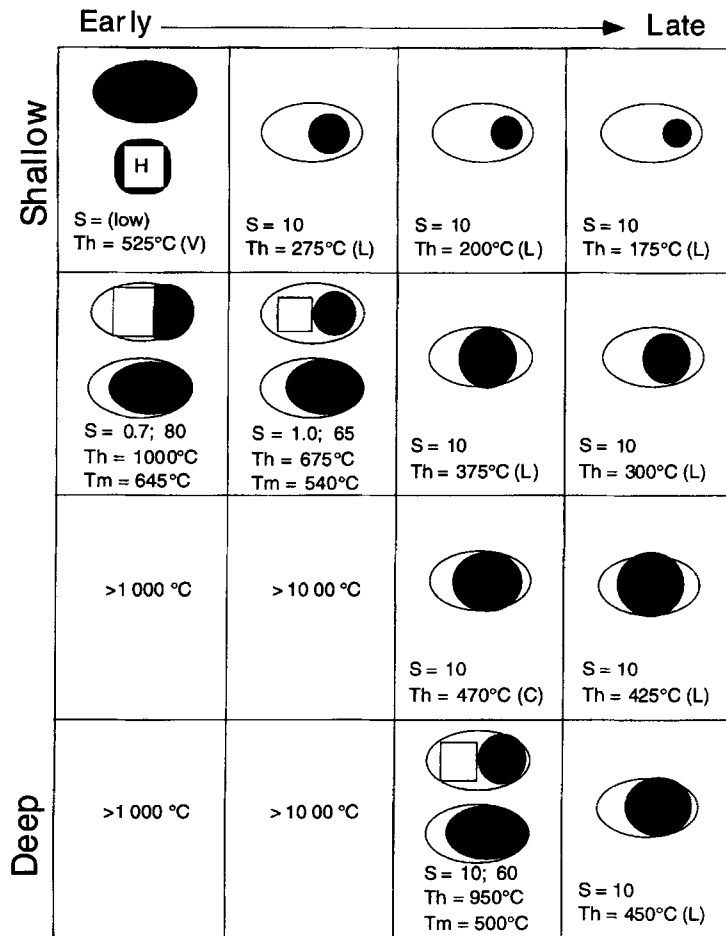

FIG. 1 Distribution of fluid inclusion types as a function of depth and time in the porphyry copper environment.

evolution of fluid inclusions in a typical porphyry copper deposit have been calculated using the PVTX properties of H_2O-NaCl. In this model, the pressure regime at temperatures less than 400°C is assumed to be hydrostatic, and lithostatic at greater temperatures (depths), thus approximating the brittle-ductile transition in this environment. During the earliest stages of crystallization, a liquid + vapour zone exists immediately above the pluton - inclusions trapped here would produce coexisting halite-bearing and vapour-rich inclusions that would both homogenize at the same temperature, and this temperature in turn would equal the trapping temperature (Fig. 1). Copper transported in the original magmatic fluid would be partitioned into the high salinity liquid phase. This higher density phase would flow downward along the sides of the pluton, whereas the copper-poor vapour would move upwards into the shallower volcanic system. Above the liquid + vapour zone, a small vapour + halite zone exists - inclusions trapped here would be vapour-rich with occasional 'halite' inclusions surrounded by variable amounts of vapour (Fig. 1). This zone would show relatively low copper grades (in the early veins), but may contain significant amounts of precious metals. Above the vapour + halite zone is a zone of moderate temperature, moderate salinity fluids.

As crystallization proceeds, the halite + vapour zone gradually migrates downwards and eventually is replaced by a vapour-only zone directly above the crystallizing pluton. Inclusions trapped at this point in time-space would be vapour-rich and homogenize at temperatures well below the trapping temperature (Fig. 1). This zone evolves into a liquid-only zone at shallower depths without crossing a phase boundary or entering a field of immiscibility. These fluids are capable of transporting copper and gold from the pluton into overlying volcanic rocks and may account for the common occurrence of enargite-gold mineralization in volcanic rocks associated with deeper porphyry copper type mineralization. This empirical model for the time-space distribution of fluid inclusion types in porphyry copper deposits provides a basis for interpretation of fluid inclusions from porphyry systems, and may be used in exploration for other mineralized systems.

References

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