

The role of high temperature fluids and melts in the Grasberg porphyry Cu-Au deposit

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The Grasberg Cu-Au deposit is located in the Late Pliocene Ertsberg-Grasberg porphyry-skarn Cu-Au-(Mo) district, which occupies an area of about 50 km within the central highlands of Papua Indonesia. Grasberg is a pipelike body approximately 950 m in diameter, which widens above 3,400 m, reaching approximately 2.4 by 1.7 km at surface. A quartz-magnetite-anhydrite with Au-bearing, chalcopyrite +bornite stockwork vein system, ~1,500 m in vertical extent, is centred on the axis of the Main Grasberg Intrusion. These chalcopyrite-bornite veins account for the bulk of the copper and gold in the Grasberg deposit.

Previous fluid inclusion studies of the Grasberg deposit reported homogenization temperatures up to 700 °C (the limit of the heating stage). This study focused on quartz-hosted salt melt and hypersaline fluid inclusions from deep in the Grasberg System that partially homogenize by vapor disappearance at temperatures (up to 1300°C), well above the hottest measured fumaroles on Earth. The hypersaline inclusions contain 20 – 40 vol.% vapour, halite, sylvite, anhydrite, an unidentified salt, hematite, chalcopyrite ± pyrite ± silicates.

Upon heating the hypersaline inclusions, sylvite is the first crystal to dissolve between 147 °C and 292 °C. An unidentified crystal is the next to dissolve between 318 °C and 439 °C. As heating progresses the halite crystal dissolves between 538 °C and 605 °C. Anhydrite dissolves next at temperatures between 600 °C and 648 °C, typically leaving chalcopyrite and hematite as the only remaining solids. Hematite is the last solid to dissolve between 976 °C and 990 °C, leaving a vapour bubble, salt melt and a very small rim of a second, clear, immiscible phase, thought to be silicate melt. At this point the bubble may also disappear leaving only two immiscible liquids which do not homogenise below 1400 °C (the limit of the heating stage).

We propose that these inclusions form by heterogeneous entrapment of silicate and salt melts. This is supported by the formation of two immiscible fluids, an inner hypersaline brine, and an outer clear fluid (silicate liquid?) at temperatures above 900 °C. Homogenisation temperatures may also be increased due to post-entrapment modification of inclusions. The coexistence of both sulfide and anhydrite suggests the inclusions were partially oxidised after entrapment by hydrogen loss.

The quartz veins also contain a significant number of inclusions that have been trapped at pressures below 400 bar and these lie within the vapour + halite field. Under these conditions salt melt had formed as evidenced by the coexistence of water-absent, salt melt inclusions and vapor-rich inclusions containing small amounts of salt melt. A comparison with the more complex NaCl-KCl-FeCl₂ system shows that salt melts exist down to temperatures as low as 309 °C. LA-ICPMS analyses shows that these salt melts have a high metal extraction capacity, and hence, may play a critical, and previously unrecognised role in the metal enrichment of porphyry systems.