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# Petrology and Crystallization History of Multiphase Sulfide Droplets in a Mafic Dike from Uruguay: Implications for the Origin of Cu-Ni-PGE Sulfide Deposits

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## Abstract

Sulfide blebs in a mafic dike belonging to the Uruguayan dike swarm replicate, at a small scale, many features observed in larger platinum-group element–enriched nickel-copper sulfide deposits, such as in Sudbury and Noril'sk. These blebs, formed by the crystallization of droplets of immiscible sulfide liquid, form ~1-cm-sized ovoid geopetal structures with pyrrhotite and pentlandite at the base, chalcopyrite and cubanite at the top, and titaniferous magnetite at the margins. Magnetite crystallized first followed by nickel- and iron-rich monosulfide solid solution, which sank to the bottom of the droplets and from which pyrrhotite and pentlandite subsequently exsolved. The remaining copper-rich liquid in the upper part of the droplets crystallized to form an intermediate solid solution from which chalcopyrite and cubanite subsequently exsolved. The final extremely evolved Cu-, Fe-, S-rich, Pd-, Sn-, Pb-, Mo-,Ag-, Bi-, Te, and Sb-bearing liquid crystallized as 10- to 20-$\mu$m-sized veinlets filling fractures in the magnetite and adjacent silicate minerals. The veinlets crossing the magnetite often terminate in 100-$\mu$m-sized subrounded globules at the contact of the magnetite and the surrounding silicate minerals, indicating a direction of veinlet filling away from the center of the blebs. Textural evidence in the blebs illustrates that as crystallization proceeded and the immiscible sulfide liquid droplets within the dike sank (a distance of less than 1 mm relative to the adjacent silicate) onto already partially crystallized silicate minerals, the sulfide liquid surrounded and resorbed the already-solid magnetite grains. At the top of the blebs magnetite grains were isolated above the sulfide liquid and partially surrounded by quartz, plagioclase, and amphibole, an assemblage representing a late-stage magma that had been drawn into the space created above the droplets as they sank and which is more evolved than that of the surrounding host dike. The location of the blebs within the dike, isolated from influences external to the dike, indicates both that the fracture filling by evolved immiscible Cu-rich sulfide liquid is related to crystallization processes rather than later tectonic events and that the bismuth, tellurium, and antimony have a late magmatic origin associated with crystallization of the immiscible sulfide liquid.

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