

Immiscible sulfide melts in primitive oceanic magmas: Evidence and implications from picrite lavas (Eastern Kamchatka, Russia)

**DMITRY P. SAVELYEV¹, VADIM S. KAMENETSKY^{2,3,*,*†}, LEONID V. DANYUSHEVSKY²,
ROMAN E. BOTCHARNIKOV⁴, MAYA B. KAMENETSKY², JUNG-WOO PARK⁵, MAXIM V. PORTNYAGIN^{6,7},
PAUL OLIN², STEPAN P. KRASHENINNIKOV⁷, FOLKMAR HAUFF⁶, AND MICHAEL E. ZELENSKI³**

¹Institute of Volcanology and Seismology FEB RAS, Petropavlovsk-Kamchatsky 683006, Russia

²Earth Sciences and CODES, University of Tasmania, Hobart, Tasmania 7001, Australia

³Institute of Experimental Mineralogy RAS, Chernogolovka 142432, Russia

⁴Institut für Mineralogie, Leibniz Universität, Hannover 30167, Germany

⁵School of Earth and Environmental Sciences & Research Institute of Oceanography, Seoul National University, Seoul 08826, South Korea

⁶GEOMAR Helmholtz Center for Ocean Research, Kiel 24148, Germany

⁷V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow 119991, Russia

ABSTRACT

Silicate-sulfide liquid immiscibility in mantle-derived magmas has important control on the budget of siderophile and chalcophile metals, and is considered to be instrumental in the origin orthomagmatic sulfide deposits. Data on primitive sulfide melts in natural samples, even those representing most voluminous magmatism in oceanic rifts, are very scarce due to the small size and poor preservation of incipient sulfide melt globules. Here we present the first detailed report of the crystallized sulfides melts in the oceanic picrites of the (presumably) Cretaceous age Kamchatsky Mys ophiolite complex in Eastern Kamchatka (Far East Russia). Sulfide melts are present in three forms; (1) as inclusions in olivine (87.1–89.6 mol% Fo), (2) interstitial to the groundmass minerals (clinopyroxene, plagioclase, and Ti-magnetite) of studied picrites, and (3) as daughter phases in silicate melt inclusions hosted by olivine and Cr-spinel phenocrysts. The sulfide melt inclusions in olivine and the groundmass of studied rocks are composed of several sulfide phases that correspond to the monosulfide (Fe–Ni; *Mss*) and intermediate (Fe–Cu–Ni; *Iss*) solid solutions. Several <0.5 μm Pd–Sn, Pt–Ag, and Au–Ag phases are recorded within the matrix sulfides, commonly along phase boundaries and fractures. Major elements (S, Fe, Cu, Ni, Co), platinum group elements (PGE), and gold analyzed in the homogenized olivine-hosted sulfide melt inclusions, and phases identified in the matrix sulfides record the range of magmatic sulfide compositions. The most primitive sulfide liquids are notably enriched in Ni and Cu [(Ni+Cu)/Fe, at% > 0.5], continuously evolve with crystallization of (e.g., increasing Cu/Ni and Au/PGE) and demonstrate metal fractionation between *Mss* and *Iss*. Although the compositional systematics found in this study are consistent with those previously recorded, the compositions of individual sulfide phases are strongly affected by the noble metal (PGE, Au) “nuggets” that exsolve at subsolidus temperatures and form during serpentinization of the rocks. We conclude that the budget of noble metals in the studied picrites is controlled by sulfides, but the abundances of Pt and Au are influenced by mobility in post-magmatic alteration. Our data can be also used for modeling sulfide saturation at crustal pressures and understanding behavior of the noble metals in primitive oceanic magmas.

Keywords: Silicate-sulfide immiscibility, mid-ocean ridge magmatism, picrite, olivine, sulfide melt, platinum-group elements; Planetary Processes as Revealed by Sulfides and Chalcophile Elements