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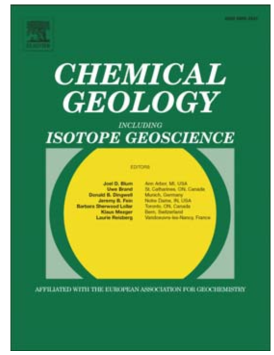

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Reprint of Silicate-sulfide liquid immiscibility in modern arc basalt (Tolbachik volcano, Kamchatka): Part II. Composition, liquidus assemblage and fractionation of the silicate melt☆

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ABSTRACT

Olivine-hosted inclusions of silicate and sulfide melts, Cr-spinel and pyroxene were studied to estimate magma composition, temperature, pressure, and fO_2 at the onset and during the silicate-sulfide immiscibility in modern arc basalt from Tolbachik volcano, Kamchatka arc. We demonstrate that the olivine phenocrysts hosting sulfide and silicate melt inclusions belong to the same population. The compositions of the silicate melt inclusions in most primitive olivine (88–91 mol% Fo) represent moderately oxidized (~QFM + 1.1) high-MgO (up to 12–12.6 wt%) and high CaO/Al_2O_3 (0.8–1.2) melt that has abundances and ratios of the lithophile trace elements typical of island arc magmas. The initial volatile contents in parental Tolbachik magma are estimated from the melt inclusions and mass-balance considerations to be at least 4.9 wt% H_2O, 2600 ppm S, 1100 ppm Cl, 550 ppm F, and 1200 ppm CO_2. These data are used to calculate the temperature (~1220 °C) and minimum pressure (3 kbar) at which the beginning of crystallization and exsolution of sulfide melt took place. The presence of anhydrite, especially ubiquitous in the crystallized silicate melt associated with sulfide globules, suggest that much higher sulfur abundances prior to degassing and sulfate immiscibility and/or crystallization should be expected. We tentatively considered hydrothermal accumulations of sulfur (elemental, sulfate and sulfide) in the volcanic conduit responsible for local contamination and oversaturation of the Tolbachik magma in sulfur and related sulfide immiscibility. Coexisting sulfide and sulfate can be also interpreted in favor of the magmatic sulfide oxidation and related generation of S-rich fluids. Such fluids are expected to accumulate metals released from decomposed sulfide melts and supply significant epithermal mineralization, including native gold.

1. Introduction

The evolution of most mantle and crustal silicate magmas inevitably results in the separation of another phase of essentially non-silicate composition (e.g. Kamenetsky and Kamenetsky, 2010; Roedder, 1992). Such unmixing or immiscibility of two or more liquid and vapor phases occurs during continuously changing conditions associated with magma decompression, cooling, crystallization, mixing etc. The phenomenon of magmatic immiscibility in continental mafic magmas is most conspicuous for sulfide liquids that are commonly accepted as parental to Cu-Ni-PGE deposits, associated with komatiites, flood basalts and some layered intrusions (e.g. Naldrett, 2004). On the other hand, the origin of sulfide mineralization in subduction-related settings is still considerably debated. One possible explanation involves contribution of magmatic sulfides formed by unmixing of basaltic melts from earlier volcanic cycles. Several models imply genetic links between mineralizing fluids forming Cu-Au porphyry deposits to the silicate-sulfide liquid immiscibility in mafic magmas followed by breakdown of early-formed magmatic sulfides (e.g. Keith et al., 1997; Larocque et al., 2000; Wilkinson, 2013). Numerous experimental and theoretical

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