

Apatite chemical composition and textures as a probe into magmatic conditions at Galore Creek porphyry copper-gold deposit, British Columbia

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Sulfur is a critical requirement in porphyry Cu deposits. Previous work has shown that apatite is sensitive to the availability of sulfur as sulfate in the magma, and thus can be used to track the magmatic and hydrothermal evolution of a porphyry system. Variable sulfur contents in apatite are known from several alkalic porphyry Cu systems, with Galore Creek having a considerable range of sulfur (up to 1 wt %) in individual crystals. Apatite is present in different intrusions and breccia as a hydrothermal and igneous mineral. Generally, apatite is small, subhedral to euhedral prisms up to 2 mm in diameter as isolated phenocrysts or small inclusions in magnetite and biotite, indicating crystallization throughout magmatic evolution. Hydrothermal apatite is in veinlets, commonly associated with K-feldspar, biotite, anhydrite, magnetite, garnet, epidote and chalcopyrite. During this study over 300 points in 50 apatite grains were analyzed for their chemical constituents (CaO and P₂O₅, MgO, Al₂O₃, Na₂O, SiO₂, FeO, MnO, SrO, SO₃, F and Cl). CaO and P₂O₅ abundances vary negligibly (52.1 to 56.1 wt% CaO and from 36.7 to 43.3 wt% P₂O₅). SiO₂ generally varies from 0.02 to 2.29 wt% and Na₂O <0.25 wt%. Halogen contents vary, and are not considered reliable due to the inherent difficulty in analyzing for these elements. High sulfur (0.27 to 1.75 wt%SO₃) contents suggest the host magma was relatively sulfate-rich, and thus oxidized. Apatite grains typically exhibit growth zones characterized by a subtle decrease in SO₃ content from core to rim. Early stages of apatite preserved within the cores record oxidized, sulfate rich, magmas. The late stages of apatite growth were sulfur-poor, which can either be attributed to the exsolution of a sulfur-bearing hydrothermal fluid or the incorporation of remaining sulphate in minerals such as anhydrite, which formed throughout the mineral paragenesis.

Amphibole controlled Nb/Ta fractionation during subduction

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Niobium and Ta are known as geochemical identical twins, which usually do not fractionate from each other during melting and magma fractionation. Major reservoirs of the silicate Earth, e.g., continental crust, however, have sub-Primitive Mantle (PM) Nb/Ta. Subducted slab stored in the mantle have been proposed as the high Nb/Ta reservoir that can balance the Nb-Ta budget of the silicate earth and explain the formation of the continental crust based on Nb, Ta concentrations of rutile-bearing eclogites from kimberlite [1]. Experimental results however, indicate that rutile favors Ta over Nb [2, 3], indicating that rutile with high Nb/Ta was formed after Nb/Ta fractionation [4]. Here we analysed the HFSEs, such as Nb, Ta, Zr, Hf and Ti, of minerals in ultra-high pressure metamorphic eclogite from drill-hole core samples of the Chinese Continental Scientific Drilling project in Donghai, eastern China, and outcrops nearby, using LA-ICP-MS. The results showed highly variable but overall super-PM Nb/Ta in rutile (Nb/Ta=25.9) and phengite (Nb/Ta=21.5), and much higher Nb/Ta in amphibole (Nb/Ta=48.6). The highly fractionated Nb/Ta in rutile has been interpreted as trace elements fractionation during dehydration at the early stage of subduction, controlled by amphibole [4] and chemical complexing in aqueous fluids [5] because of the different electron configuration of Nb and Ta. These models are strongly supported by the very high Nb/Ta of amphibole in this study. This major fractionation of Nb/Ta induced by amphibole can be transferred to the continental crust through partial melting induced by amphibole dehydration as the slab subducts to deeper depths. Amphibole is more important for Nb/Ta fractionation in the absence of rutile. The behaviors of Nb, Ta are likely to be controlled by rutile at pressure higher than 1.5 GPa.

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