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Titanite geochemistry and textures: Implications for magmatic and post-magmatic processes in the Notch Peak and Little Cottonwood granitic intrusions, Utah

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Abstract

Textural and compositional variations in titanite constrain the roles of magma mixing and hydrothermal alteration in two plutons in central Utah: the Jurassic Notch Peak and the Oligocene Little Cottonwood stocks. In the Notch Peak intrusion, magmatic titanite grains usually have oscillatory zones combined with BSE-bright sector zones, in some cases surrounding simple unzoned cores. These grains are frequently overprinted by hydrothermal titanite with low concentrations of high field strength elements (HFSE). Magmatic titanite has an average $\delta^{18}O$ of 6.0‰ and post-magmatic titanite is 6.2‰, as analyzed by SIMS. Average Zr-in-titanite temperatures are also similar, with 718 °C for magmatic and 711 °C for hydrothermal titanite. These observations indicate simple magmatic growth, followed by hydrothermal alteration by magmatic fluids. Titanite in aplite dikes and sills has lower concentrations of all trace elements except F. Many titanite grains in the aplites have late overgrowths of high-Fe titanite. This high-Fe titanite has $\delta^{18}O$ of 6‰ and an average Zr-in-titanite temperature of 718 °C and likely precipitated from a last flush of exsolved magmatic water enriched in Cl and Fe.

Titanite in the Little Cottonwood stock typically has distinct patchy cores with rounded and embayed ilmenite inclusions. Mafic enclaves have abundant titanite that is similar in texture and $\delta^{18}O$ (5.1‰) to titanite in the host ($\delta^{18}O$ = 4.9‰), but it has a slightly higher average Zr-in-titanite temperature (731 vs. 717 °C). The patchy cores in the enclaves have the highest average Zr-in-titanite temperature (759 °C) and distinctive REE patterns. The textural and compositional data indicate that a hotter, more reduced, ilmenite-bearing mafic magma mixed into an oxidized felsic magma, destabilizing existing ilmenite and allowing crystallization of titanite. In the granodiorite and in the enclaves, hydrothermal growth of titanite is evidenced by distinct narrow rims as well as anhedral titanite that grew between sheets of chloritized biotite. Secondary hydrothermal titanite typically has lower concentrations of most HFSE, but is relatively enriched in F, Mg, Mo, and U, and it has higher Nb/Ta and lower Th/U ratios. Post-magmatic titanite also has strikingly different REE patterns than magmatic titanite, including the absence of pronounced Eu anomalies and lower REE abundances. These chemical features are controlled by element solubilities in aqueous fluids. In most cases, hydrothermal titanite has $\delta^{18}O$ values similar to magmatic titanite, indicating alteration and recrystallization from exsolved magmatic fluids. The involvement of meteoric water with low $\delta^{18}O$ is evident locally; individual spots have $\delta^{18}O$ as low as 1.7‰ in the Little Cottonwood stock.

Titanite compositions and textures provide important insights into the origins of granitic rocks and can be used to distinguish separate batches of magma, gauge the evolution of magmatic rocks, assess mixing processes, and infer compositions of mixing components. Because titanite also forms hydrothermally, it retains hints about the composition, temperature, and oxygen fugacity of the hydrothermal fluids and reveals details about titanite-forming reactions. However, the Al-in-titanite geobarometer does not yield realistic pressures of crystallization and the use of titanite as a geochronometer is compromised by the development of U-rich hydrothermal titanite.

Keywords: Titanite, Notch Peak granite, Little Cottonwood stock, granite, mafic enclave, $\delta^{18}O$, magma mixing, hydrothermal alteration; Isotopes, Minerals, and Petrology: Honoring John Valley