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Nb and Ta intracrustal differentiation during granulite-facies metamorphism: Evidence from geochemical data of natural rocks and thermodynamic modeling

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Abstract

Both continental crust and depleted mantle are characterized by subchondritic Nb/Ta, leading to a mass imbalance when compared to the bulk Earth. Even though several potential high-Nb/Ta reservoirs in Earth's core and undepleted mantle have been proposed, little attention has been given to those in the crust. Here we present bulk-rock and rutile geochemical data for samples from a lower crustal pelitic granulite, North China Craton, which exhibit systematic variation in their Nb and Ta contents. High-temperature (HT) and ultrahigh-temperature (UHT) granulite residues exhibit Nb/Ta ratios that are close to chondritic and subchondritic, respectively, whereas leucosomes from UHT granulite mostly have suprachondritic Nb/Ta. These variations are best explained via competition for Nb and Ta between biotite and rutile during metamorphism, although initial bulk-rock Nb/Ta values also have an effect. As biotite preferentially incorporates Nb over Ta, the early stages of biotite dehydration melting produce a high-Nb/Ta residue and a low-Nb/Ta melt; however, geochemical modeling suggests that once biotite is depleted, the Nb/Ta ratio of the system is instead controlled by rutile growth, which promotes the formation of a lower Nb/Ta residue and a higher Nb/Ta melt, even though the volume of melt produced at this stage may be small. We propose that in situ and in-source leucosomes and leucocractic veins in UHT terranes may retain a high-Nb/Ta geochemical signature. However, residual crustal-derived A2-type granites that experience significant fractionation of Nb- or Ta-bearing minerals during crystallization or contamination from other low-Nb/Ta sources cannot retain this high-Nb/Ta ratio, even though these ratios are generally higher than that of S-type granites. Anhydrous partial melting of metapelite can generate Nb-rich melts, such that high-temperature leucosomes, in addition to related A2-type granites, may represent significant Nb deposits.

Keywords: Nb/Ta, granulite, partial melting, forward modeling, ultrahigh temperature, rutile; High-Grade Metamorphism, Crustal Melting, and Granite Magmas