The Formation of the Continental Crust, a Nb/Ta Perspective

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The formation of the continental crust has been debated for decades and attracted much attention. Niobium and Ta provide one of the most important constraints on the formation of the continental crust because of “Nb/Ta paradox” and Nb-Ta depletions. It was plausibly explained by the presence of rutile in the subducting slab or melting in the presence of amphibole. One of the most important arguments supporting the rutile hypothesis is the superchrondritic Nb/Ta of rutile in kimberlitic eclogites, making the subducted oceanic slab an important reservoir that is complementary to the continental crust. This argument, however, has been criticized for two reasons. First, the Nb/Ta of rutile from kimberlites ranges dramatically from ~5 to >100, with suprachondritic geometric mean value of 24, such that the geologic significance of the mean value is not well defined. Second, high pressure experiments showed that rutile favors Ta over Nb, therefore, partial melting of basaltic rocks in the presence of rutile at eclogitic conditions forms melts with higher Nb/Ta than the source rock. It was then argued that the continental crust was formed through partial melting of garnet amphibolite in the absence of rutile. However, such models cannot explain the obvious Nb, Ta depletions. Major fractionations between Nb and Ta occur in hydrothermal processes. Given that amphibole favors Nb over Ta, the fluids in equilibrium with amphibole should have low Nb/Ta. Therefore, fluids released during the blueschist to amphibolite transition have low Nb/Ta. Consequently, the wet portions of the subducting slab have lower Nb/Ta, whereas the dry portions have higher Nb/Ta. During further plate subduciton, the wet parts are easier to get partially melted, forming building blocks with low Nb/Ta for the continental crust. Meanwhile, the residual eclogites have even more varied and overall suprachondritic Nb/Ta. It has also been well demonstrated that Nb and Ta can significantly fractionate in hydrous andesitic and basaltic magmas from each other under a thermal gradient. From this point of view, major fractionation between Nb and Ta may also occur within thick mafic Archean crust, as long as the crust is wet enough.