High Field Strength Element Fractionation During Subduction Processes

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Introduction

Key differences between the chemical composition of terrestrial materials and those of meteorites have led to the suggestion that a `hidden' high Nb/Ta reservoir exists in the Earth's mantle. In order to test this hypothesis we must identify the processes that can create such a reservoir. By identifying the geochemical fingerprint of such processes we can then use it as a tracer of recycling in the earth's mantle. Niobium and Ta are "geochemical twins" and terrestrial processes impose only limited fractionation on the Nb/Ta ratio. Therefore high precision Nb/Ta analyses are needed in order to accurately quantify the magnitude and direction of the Nb/Ta fractionations. Here we report high precision HFSE data on products of the subduction processes thought to fractionate Nb from Ta: boninites (hydrous melting), adakites (slab melting), OIBs (Koolau, Walvis: plume with recycled oceanic crust), as well as kimberlites and lamproites.

Results and Discussion

We developed a new method for the high precision determination of Nb, Ta, Zr, Hf concentrations based on a modification of the standard addition technique. We used the ELEMENT -1 ICP-MS at the Geochemistry Division, NHMFL. We used internal standardization for drift correction, simultaneous Nb, Ta, Zr, Hf spiking and a York-type regression for fitting the data. Further analytical details are presented in an accompanying report.

The Koolau and Walvis Ridge lavas have subchondritic Nb/Ta for a given Zr/Hf, overlapping other OIB suites. The Koolau lavas show a negative correlation between Nb/Ta and Hf-isotopes, showing for the first time that Nb/Ta variations in OIBs may be related to source heterogeneity. The negative correlation between Nb/Ta and Ti/Zr in the Koolau lavas argues against the involvement of recycled basaltic oceanic crust in their source. When considered as a group, OIB have relatively constant Nb/Ta (15-16) but more variable Zr/Hf (35-50). In contrast, boninites (Chichi Jima) have significantly subchondritic Nb/Ta (4-12; Fig. 1) at near constant Zr/Hf (35), while adakites (South Andes) extend to near chondritic Nb/Ta (13-19) at more variable Zr/Hf (30-40). The adakites showing the least evidence for crustal contamination have the highest Nb/Ta. The arc lavas cross the OIB trend at near right angle on a Nb/Ta vs. Zr/Hf plot having larger Nb/Ta fractionations at a given Zr/Hf than OIB. Our data suggests that during fluid flux melting of the mantle wedge (i.e. boninites), Ta is preferentially mobilized from the slab to the wedge, creating (by inference) a high Nb/Ta subducting slab. In contrast, during slab melting (i.e. adakites) the residual slab should develop subchondritic Nb/Ta. Our data suggests that only slab dehydration and not melting may increase the Nb/Ta of a subducting slab. In turn, the adakite data suggests that melting of the oceanic crust may generate high Nb/Ta melts. Our HFSE data from kimberlites and lamproites extends to highly superchondritic Nb/Ta (15-27) for a low Zr/Hf (35-40), essentially overlapping the adakites. These kimberlites and lamproites require a long-term melt-enriched source in the subcontinental mantle. It is conceivable that the subcontinental mantle has high Nb/Ta ratios (and high Nb-Ta concentrations; Fig. 1) produced by melts from subducting slabs, over multiple subduction events over the earth's history and may represent a non-convecting (thereby `hidden' from our sampling ability) high Nb/Ta reservoir.

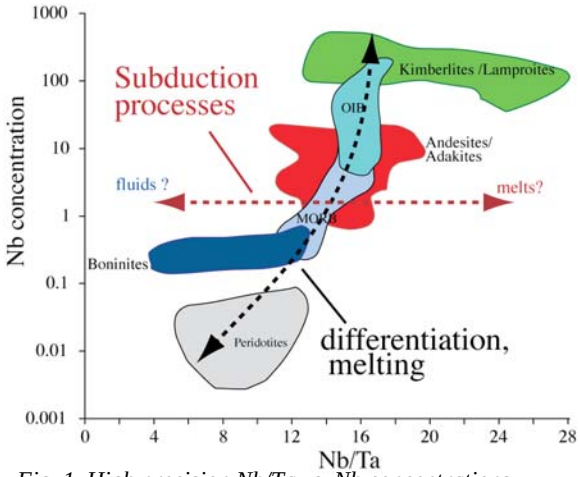

Fig. 1. High precision Nb/Ta vs. Nb concentrations determined in this study.

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