Nb/Ta - Zr/Hf Fractionations during Subduction: Implications for the “Missing” Nb


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 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. It has been suggested that during subduction Nb is more refractory than Ta resulting in low Nb/Ta in the subducted slab, which then serves as a reservoir for the high Nb/Ta. 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), oceanic island arc basalts and supra subduction zone peridotites.

Results and Discussion
While the Zr/Hf ratios in subduction-related volcanics and ocean island basalts vary by less than a factor of two, the Nb/Ta ratio varies by a factor of four. Most of the Nb/Ta variation is observed in subduction related rocks. Samples with the highest Nb/Ta ratio (up to 19.5) are adakites from the Austral Volcanic Zone (Andes) which are thought to represent eclogitic melts from subducted oceanic crust which was most likely dehydrated. The lowest Nb/Ta (5) was found in boninites from Chichi-Jima, Bonin Island. Samples from Chichi-Jima and from the Marianas show good correlations between Nb/Ta and indicators of fluid addition such as Ba/Th, (238U/230Th), Ta/Th and 143Nd/144Nd, whereby the low Nb/Ta samples are always related to the fluid rich endmember of the trend. Further evidence for the fluid mobility of Ta comes from high precision analyses of Nb/Ta on serpentinites from the Marianas forearc. These serpentinites show evidence for alteration by fluids derived from the subducted slab [1] and have extremely low Nb/Ta ratios (0.1-5, average Nb/Ta =1.2), at near chondritic average Zr/Hf (37.1), again pointing at Ta being fluid mobile. However, the concentrations in the serpentinites are too low for this process to have any leverage on the bulk subducted oceanic crust (see figure).

Mineral phase data on eclogites from the Caledonides, Guatemala and Moses Rock who represent subducted and processed oceanic crust also show no evidence for high Nb/Ta. Cpx has consistently lower Nb/Ta and Zr/Hf than garnet. Except for Koidu eclogites all eclogites have sub-chondritic Nb/Ta values. Common minerals in eclogites like zoisite and kyanite have no influence on the trace element budget. Experimental partition coefficients for rutile are higher for Ta than for Nb, which fits the Roberts Victor rutile data. Thus it is unlikely that rutile will harbour Nb and Ta to compensate for the low Nb/Ta in garnet and cpx

Conclusions
Subduction processes can FRACTIONATE Nb/Ta ratios relative to the terrestrial differentiation array (OIB-MORB peridotites): slab fluids have low Nb/Ta; slab melts have high Nb/Ta. Ta-rich fluids from the subducted slab still have low concentrations and have little effect on the bulk Nb/Ta of the subducted slab. Eclogites and pyroxenites are unlikely candidates to represent the high Nb/Ta reservoir.

Acknowledgements
This research was funded by the NSF Earth Sciences Division award# 0635864.

References