Where is The Missing Nb in The Earth?

Jasmin Wilson [1], Vincent Salters[2,3], Rupsa Roy[2,3]

[1] Tallahassee Community College, Tallahassee, FL 32304, USA
[2]National High Magnetic Field Laboratory, Tallahassee, FL 32310, USA
[3] Department of Geological Studies, Florida State University, Tallahassee, FL 32310, USA

ABSTRACT

We analyzed eclogites from subduction zones to test whether Nb is indeed refractory during subduction. Chondritic meteorites are representatives of the makeup of the solar system and the earth when it was formed. In today's terrestrial rocks, the amount Nb compared to Ta is less than what is found in chondrites. One hypothesis is that Nb is more refractory than Ta during subduction [1] which results in a subducted slab with high Nb/Ta. This material creates a reservoir deeper in the mantle that functions as a graveyard for subducted slabs with a high Nb/Ta. All the eclogites show fractionation of Nb/Ta between clinopyroxene and garnet. In addition, we found some eclogites with very high Nb/Ta indicating that subducted slabs could potentially be the "missing reservoir"

INTRODUCTION

The accessible terrestrial reservoirs (continental and oceanic crust, upper mantle), all have subchondritic Nb/Ta ratios, while the Earth as a whole is expected to have chondritic Nb/Ta. This discrepancy has been explained by a) the preference of Nb to go into Earth's core [2]or b) a suprachondritic Nb/Ta "hidden" reservoir near the core-mantle boundary formed by subducted oceanic crust. Learning if a hidden reservoir exists is essential in understanding the evolution of the crust-mantle, the Earth, and the processes that differentiate the mantle and lead to distinct geochemical reservoirs. If such a reservoir exists, we must a) be able to recognize its geochemical footprint in other terrestrial magmas and, b) identify the processes that can create such a reservoir. It has been proposed that eclogite, which represents the subducted oceanic crust, is the hidden reservoir that compliments the terrestrial budget of Nb. Here in our study we have analyzed eclogite samples [Figure 1] from different subduction zones located in Norway, Greenland, Sweden, and Guatemala to test this inference [Figure 2]. These settings were chosen because they represent material that was subducted to different depths.

METHOD

We used Laser Ablation Inductively Coupled Plasma Mass Spectrometry [LA-ICP-MS] to analyze clinopyroxene and garnets mineral phases from the eclogites [Figure 3].

Major and trace element concentrations were determined using UP 193FX ArF (193 nm) excimer laser ablation system coupled to an Element-XR sector field ICP-MS. Individual mineral grains were handpicked under a binocular microscope, mounted in epoxy holes within aluminum disks [Figure 4] and polished to 0.3µm using Buehler alumina slurries. Laser settings for data acquired with the 193nm laser is as follows: repetition rate (rep. rate) 50 Hz, energy level (e.l.) 100%, spot size (pit diameter) of 150µm with dwell time of 10 sec. Internal normalization is accomplished with ^{29}Si. All trace element and major element concentrations were calculated against BHVO-2G, BCR-2G and BIR-1G as glass standard. Blanks (background intensities measured with the laser off) are monitored closely, prior to each sample, to ensure appropriate washout times are used to prevent carryover effects. The precision of the LA-ICP-MS technique can be assessed by examining the reproducibility of multiple analyses of the USGS glass reference materials BHVO- 2G and BCR-2G, and BIR-1G glass. For the five replicate measurements of each of the glasses the precision was <6%.

Figure 1

Analyzed Eclogite Samples

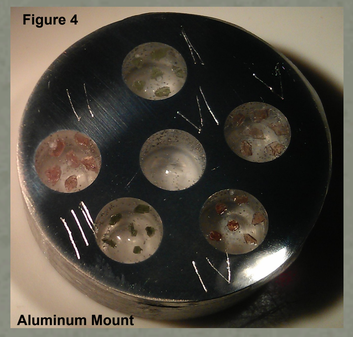
Figure 2

Analyzed Sample Map

Figure 3

Laser Ablation Instrument

Figure 4



Aluminum Mount

Data

Figure 5

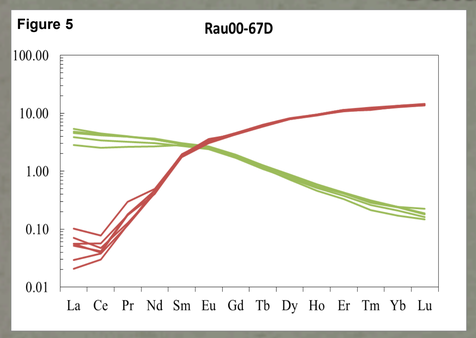
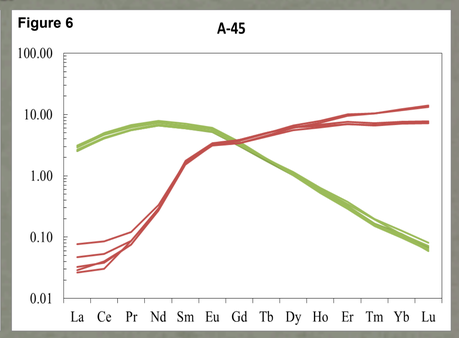


Figure 6



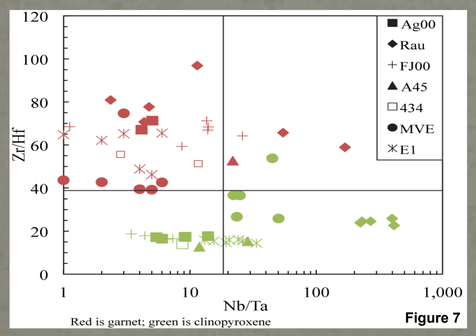
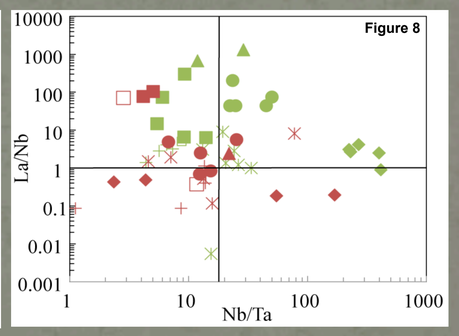


Figure 7



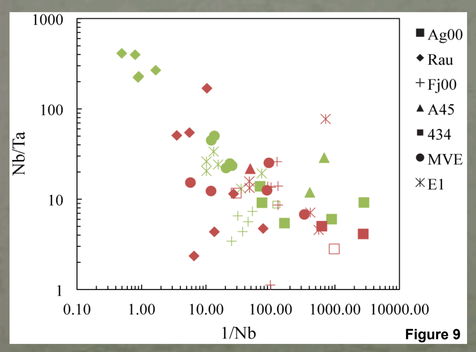
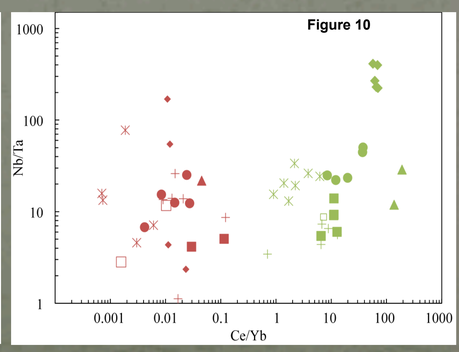


Figure 9



RESULTS and DISCUSSION

Figure 5 and 6 show the Bulk Silicate Earth (BSE) normalized rare earth element (REE) patterns of garnet (red) and clinopyroxene (green) in eclogites. All clinopyroxenes are light REE enriched and garnets are enriched in heavy REE. Clinopyroxene have a consistently lower Zr/Hf ratios than garnet whereas, the Nb/Ta ratios for both the mineral phases display a wide range of values with Nb/Ta being consistently lower in the garnet compared to the clinopyroxene [Figure 7]. Samples Rau [from Norway] and MVE [from Guatemala], display superchondritic (chondrites = 18) Nb/Ta values. The correlation between Nb/Ta and 1/Nb indicates that the Nb/Ta ratio is controlled by the Nb-content. The superchondritic Nb/Ta ratios in Rau samples are thus a Nb-excess [Figure 8]. However, the Nb/Ta vs La/Nb plot [Figure 9] illustrates that Nb is not enriched compared to other elements, like the light REE as in the Rau sample there is no significant fractionation of La from Nb. This is confirmed by positive trend in the clinopyroxene between Nb/Ta and Ce/Yb [Figure 10], again indicating that the Nb-enrichment is associated with light REE enrichment. Rau eclogites came from the deepest subduction zone. This indicates that there was a fractionation event that occurred deep within the subduction zone that enriched the eclogites in Nb compared to Ta. However, their near chondritic La/Nb ratio [~1] denotes that the Nb-enrichment is associated with a general trace element enrichment.

CONCLUSION

Subduction processes can fractionate Nb from Ta and eclogites are the probable candidates to represent high Nb/Ta reservoir.

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REFERENCES

1. Rudnick, R. L., Barth, M., Horn, I. & McDonough, W. F. Rutile-bearing refractory eclogites: missing link between continents and depleted mantle. Science 287, 278±281 (2000).
2. Wade, J., & Wood, J. (2001, January). *The Earth's `missing' niobium may be in the core* , Nature, 409, 75-78.
3. Munker, C., Worner, G., Yogodzinski, G., & Churikova, T. (2004). *Behaviour of high field strength elements in subduction zones: Constraints from Kamchatka–Aleutian arc lavas* Earth Plan. Sci. Lett., 224, 275-293.