Biotite is an important host for Nb in the lower crust

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The trace element-enriched continental crust is a result of partial melting of the mantle, which displays a complementary depleted composition. Nb and Ta are elements regarded as geochemical twins showing very similar properties and they display a strong affinity to Ti minerals. Therefore it is surprising that significant fractionation of Nb and Ta are observed at global scale. The subchondritic Nb/Ta ratio of both the continental crust and the depleted mantle is known as the "missing Nb paradox".

We present partitioning data between biotite and granitic melt for experimental and natural samples that provide evidence that Nb is compatible in biotite. Nb can thus be enriched in the residue during partial melting of crustal rocks. Additionally, biotite preferentially incorporates Nb over Ta (Stepanov and Hermann, 2013). Hence, incipient partial melting in the lower crust with biotite as residual mineral can result in restites with high Nb contents and super chondritic Nb/Ta.

Data from two key localities of crustal anatexis provide additional evidence for intracrustal Nb and Ta fractionation during partial melting of biotite-bearing rocks. Crustal, granulite facies metapelite encalves from the El Hoyazo (EH) dacite, Spain, contain melt inclusions that have significantly lower Nb and Nb/Ta than the bulk rock composition. In contrast, residual biotite is an abundant phase in the enclaves and has high Nb contents and Nb/Ta significantly higher than the bulk rock. In the classic lower crustal section in the Ivrea Verbano zone, northern Italy, metasedimentary amphibolite grade rocks have typical crustal Nb/Ta ratios, whereas granulite grade restites have higher and partial melts lower ratios. Therefore we suggest that intra-crustal differentiation might be an important process to produce Nb-rich rocks with superchondritic Nb/Ta that represent one of the missing reservoirs to balance the subchondritic Nb/Ta of the upper crust and the depleted mantle.

[1] Stepanov, A.S., Hermann, J., 2013. Fractionation of Nb and Ta by biotite and phengite: Implications for the "missing Nb paradox". *Geology 41, 303–306*.

The Paleoproterozoic MORB-type tholeiitic dykes as indicators of early continents breakup

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The time and circumstances of the Precambrian continents fragmentation is usually highly controversial issue because of deep erosion and absence of clear evidences of breakup events. Relics of various igneous provinces occur in Precambrian Shields, but it is difficult to decide which of them is indicator of final continent breakup.

In the Karelian Craton, Eastern Fennoscandian Shield there are a lot of Paleoproterozoic (2.5 -1.97 Ga) mafic dykes that vary in composition from high-Mg to high-Fe-Ti tholeiites [1]. Among them we recognize very specific dykes of age 2.13-2.14 Ga. In spite of intracontinental tectonic setting these dykes are MORB-type tholeiites with flat REE patterns, HFSE enrichment, Nb/Nb*=0.7-1.6 and εNd_t range from +3.0 to +1.4. Geochemical modelling indicates that chemical and isotopic compositions of the dykes are best explained by derivation of their parental magmas from partial melting of depleted mantle sources in the spinel peridotite stability field, followed by fractional crystallization and low (< 6%) extent assimilation of continental crustal material. The latter suggests a rapid rise of mafic melts, accompanied by rapid crust extension, which follows from the morphology of the dykes.

Widespread MORB-type tholeiitic dykes on the Karelian Craton suggest substantial lithosphere thinning accompanied by asthenosphere rising. This allows us to consider MORB-type tholeiitic dykes as indicators of final breakup of the Achaean continent and Lapland-Kola and Svecofennian oceans opening. This statement is supported by strong compositional similarity between studied dykes and syn-breakup basalts in North Atlantic Igneous Province [2], [3] and Afar [4], [5].

[1] Vuollo & Huhma (2005) *Prec. Geol. of Finland,* 195–236. [2] Søager & Holm (2011), *Chem. Geol.*, 297–313. [3] Waight & Baker (2012), *JP*, 1569–1596. [4] Barrat *et al*. (2003) *Lithos*, 1–13. [5] Daoud *et al*. (2010) *Lithos*, 327–336.

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