Preliminary notes on the geochemical characteristics of mantle during 1.93–1.79 Ga beneath the Svecofennian Domain, Finland

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Introduction

The Svecofennian domain is characterized by the occurrence of the extensive Central Finland Granitoid Complex (GFGC), surrounded by the Bothnian Schist Belt (BSB) in the west, the Tampere Schist Belt (TSB) in the south, and the Savo Schist Belt (SSB) in the east. The granitoids in the CFGC range in age from 1.89 Ga to 1.88 Ga and similar ages have been obtained for granitoids intruding the 1.93-1.91 Ga volcano-plutonic formation in the SSB. South of the TSB is the Hämeenlinna Schist Belt (HSB) with the Mica gneiss-migmatite Belt (MB) between them. Post-orogenic (1.80 Ga) granitoids trend roughly parallel to the northern margin of the zone characterized by 1.84–1.83 Ga late Svecofennian granites. The origin of the Svecofennian domain has been attributed to mixing of depleted mantle melts with variable amounts of Archean crustal component via subduction (Patchett and Kouvo, 1986; Huhma, 1986). Although this is valid for some parts of the Svecofennian domain (SSB and BSB), the interpretation of Nd and Pb isotope data combined with geochemical evidence indicate the occurrence of 2.0–2.1 Ga aged crust beneath the CFGC and TSB (Lahtinen and Huhma in prep.). The abundant occurrence of mafic plutonics and dykes, and granitoids of within plate affinity in the Svecofennian domain indicate the occurrence of heterogenous mantle. Incompatible trace element ratios involving the elements Rb, Ba, Th, Nb, Zr and La are used to study selected samples and are compared with the data given by Weaver (1991) for HIMU, EMI and EMII end-members. Gabbros and diorites have intruded through thick crust and are often associated with granitoids showing e.g. comingling features. Only non-cumulate samples with the least possible evidence for interaction with felsic melt have been included in the study. The results are briefly correlated with the available isotope data and the plate tectonic model proposed by Lahtinen (submitted).

Results and discussion

The HSB is characterized by linear rifting with abundant tholeiitic basalts and the group showing a more evident WPB-affinity is included in this study. The HSB samples show variable enrichment of Th, Rb and Ba due to crustal contamination but the occurrence of a slab contribution is also possible. The Zr/Nb and La/Nb ratios of most primitive samples are comparable with an EMI dominated source as also high Ba/Nb and Ba/La ratios but the effect of possible contamination hampers the interpretation of Ba related ratios. The Haveri volcanics in the TSB are considered to represent a rift stage ($\geqslant$1.91 Ga) preceding arc volcanism. There is only one sample from the Haveri formation which show Th enrichment probably due to contamination. Zr/Nb ratio is comparable with MORB but the additional occurrence of more enriched source component is proposed. Hornblende gabbros and diorites ($\leqslant$1.88 Ga) from the GFGC are divided to alkalic and sub-alkalic groups. Sub-alkalic group plutonics from the CFGC show highly variable Ba/La, Ba/Nb, and Rb/Nb ratios which is interpreted as due to an increase in Ba and Rb due to stabilization of biotite during interaction with felsic melts. The most primitive gabbro has Zr/Nb, Ba/La and Th/La ratios comparable with the HSB samples. Alkalic diorites from the CFGC are enriched in incompatible elements and also contain high P_2O_5, up to 1.2%. The Th/La ratios are very low (0.03–0.05) and lowest ratios are from samples having highest Nb/Th ratio. The increasing La/Nb ratio reflects hornblendemagnetitesphene fractionation which is consistent with the mineralogical data. The interpreted source had an Zr/Nb ratio < 10 and Th/La about 0.04 but the high level of Ba can be attributed to interaction with felsic melt and/or source characteristics. Alkalic dykes from the MB and HSB also show minor assimilation effects and evidence of Nb depletion during fractionation. The interpreted source characteristics are Th/Nb $\leqslant$

10, La/Nb $\geqslant$ 0.7, Th/La $\leqslant$ 0.1, Ba/La $\leqslant$ 12, Zr/Nb $\leqslant$ 6 and Ba/Nb ~ 10 which indicate the occurrence of HIMU and/or an EMI component.

Two gabbros and an associated quartz diorite from Varparanta and two alkalic dykes from Rautalampi are representative samples of mafic 1.88 Ga magmatism in the SSB related to post-collision mafic underplating. The Varparanta gabbros are primitive rocks (MgO 10%) with low Rb/Nb ratios (0.5–0.8) indicating a lack of crustal contamination. The Zr/Nb (6.0), La/Nb (1.0), Ba/Nb (12), Rb/Nb (0.7) and Ba/La (9) ratios are comparable with a HIMU-EMI mixture or EMII but the low Th/La (0.03) and Th/Nb (0.03) and high Ba/Th (240) ratios indicate relative depletion of Th in the source. The two alkalic dykes from the SSB are more evolved rocks with high Rb/Nb (3.1), Th/Nb (0.2) and SiO_2 (52–56%), hence favouring an EM origin associated with crustal contamination. Two tonalites from Luonteri stock and one quartz monzodiorite from Renko have slightly elevated SiO_2 (53 %) but are the most primitive samples available from the post-orogenic 1.80 Ga rocks. They show incompatible element enriched characteristics with high La/Nb and Th/Nb ratios. They contain biotite, magnetite, apatite, sphene and zircon, with additional hornblende in the Renko quartz monzodiorite and allanite in the Luonteri tonalites. These features indicate strong depletion of Nb (Ta) and possibly also Th due to fractionation. The presence of zircon is one possible factor that can explain decrease in the Th/La ratio but the high level of Zr (700–800 ppm) in Luonteri samples does not favour significant zircon removal. The Zr-Nb and Th-La relations define a trend where the Varparanta, GFGC alkalic diorites and 1.80 Ga samples show strong increases in Zr/Nb and slight increases in Th/La ratios with increasing Zr and Th values, possibly representing a similar source for these rocks combined with variable Nb depletion during fractionation.

Conclusions

The DMM beneath the SSB and BSB during 1.93–1.91 Ga stage is well constrained by isotopic and geochemical data. Preliminary data indicate the occurrence of 2.0–2.1 Ga aged crust and associated lithospheric mantle beneath the GFGC and TSB at the same time. In the SSB there was a change from DMM to EM during collision and proposed lithosphere stacking. Simple binary crustal assimilation or assimilation coupled with fractional crystallization interacting with DMM melts can not be solely responsible for observed characteristics and a lithospheric or deeper source is predicted. The preliminary data indicate the occurrence of an EMI-HIMU component, seen especially in the alkalic diorites in the GFGC, alkalic dykes in the MB-HSB, primitive gabbros in the SSB and possibly also in the alkalic 1.80 Ga post-orogenic intrusions. Depletion in Th seem to characterize this end-member but the origin of this depletion is uncertain. Available isotopic data indicate ε_{Nd} (1.9) +0 – +1.5 for associated rocks, but if the lithospheric mantle is considered to be heterogenous on a small scale the above considered rocks could be mixtures of different mantle compositions. The more positive ε_{Nd} (1.9) values from +2.5 to +4 in some gabbros and mafic volcanics point to a DMM component as the other end-member. This indicates a more negative epsilon value for the EM component. More detailed isotopical and geochemical data are needed to verify the end-member compositions and especially to demonstrate the Th depletion.

References

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