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Trace element partitioning in rock forming minerals of co-genetic, subduction-related alkaline and tholeiitic mafic rocks in the Ural Mountains, Russia

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The partitioning of trace elements between rock forming minerals in igneous rocks is largely controlled by physical and chemical parameters e.g. temperature, pressure and chemical composition of the minerals and the coexisting melt. In the present study partition coefficients for REE between hornblende, orthopyroxene, feldspars, apatite and clinopyroxene in a suite of co-genetic alkaline and tholeiitic mafic rocks from the Ural Mountains (Russia) were calculated. The results give insights to the influence of the chemical composition of the parental melt on the partitioning behaviour of the REE.

Nepheline-bearing, alkaline melanogabbros (tilaites) are assumed to represent the most fractionated products of the melt that formed the ultramafic cumulates in zoned mafic-ultramafic complexes in the Ural Mountains. Co-genetic with the latter is a suite of olivine gabbros, gabbronorites and hornblende gabbros formed from a tholeiitic parental melt. Negative anomalies for the HFSE along with low Nb and Ta contents and a positive Sr anomaly indicate a subduction related origin of all parental melts. The nepheline gabbros consist predominantly of coarse-grained clinopyroxene phenocrysts in a matrix of fine grained clinopyroxene, olivine, plagioclase, K-feldspar and nepheline with accessory apatite. The tholeiitic gabbros have equigranular to porphyric textures with phenocrysts of olivine, pyroxene and hornblende in a plagioclase rich matrix with olivine hornblende, pyroxene and accessory apatite. Element concentrations of adjacent matrix grains and rims of phenochrysts were measured with LA-ICPMS.

The distribution of REE between hornblende and clinopyroxene in the tholeiitic rocks is similar for most of the elements ($D_{Hbl/Cpx(La-Tm)}$ = 2.7-2.8, decreasing to 2.6 and 2.4 for Yb and Lu, respectively). These values are about two times higher than published data (e.g. Ionov et al. 1997). Partition coefficients for orthopyroxene/clinopyroxene systematically decrease from the HREE ($D_{Opx/Cpx(Lu)}$ = 0.31) towards the LREE ($D_{Opx/Cpx(Nd)}$ = 0.01). The partition coefficients for plagioclase/clinopyroxene and K-feldspar/clinopyroxene in the alkaline melanogabbros decrease from the LREE ($D_{Plg/Cpx(La)}$ = 0.91, $D_{K-fs/Cpx(La)=0.26)}$ to the MREE ($D_{Plg/Cpx(Sm)}$ = 0.02, $D_{K-fs/Cpx(Sm)}$ = 0.006), but both mineral pairs have similar D_{Eu} ($D_{Plg/Cpx(Eu)}$ = 0.25, $D_{K-fs/Cpx(Eu)}$ = 0.23). Plagioclase/clinopyroxene partition coefficients for all REE in the tholeiitic gabbros are 3-5 times higher, if compared to those of the alkaline gabbros ($D_{Plg/Cpx(La)}$ = 1.7, $D_{Plg/Cpx(Sm)}$ = 0.034). Apatite/clinopyroxene partition coefficients for the REE decrease from the LREE ($D_{Ap/Cpx(La)}$ = 65 in alkaline and 120 in tholeiitic gabbro) to the HREE ($D_{Ap/Cpx(Lu)}$ = 4.5 in alkaline and 5.3 in tholeiitic gabbro). The lower partition coefficients for apatite/clinopyroxene and plagioclase/clinopyroxene in the alkaline melanogabbros can be explained by higher clinopyroxene/melt partition coefficients in this system. The higher Al_2O_3-content in clinopyroxene from the alkali gabbros (Al_2O_3 = 3.5-7 wt.%), if compared to clinopyroxene in the tholeiitic gabbros (Al_2O_3 = 2.0-4.5 wt.%) can account for a stronger partitioning of the REE into clinopyroxene in the alkaline rocks (e.g. Gaetani and Grove 1995). Experimental data by Gaetani (2004) also indicate a systematic increase of the Cpx/melt partition coefficients for the REE with increasing Al_2O_3 and Na_2O contents of the parental melt in mafic systems. This is in agreement with the assumed compositional differences between the alkaline and the tholeiitic parental melts.

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