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Trace element variation in clinopyroxene: a petrogenetic tracer of the evolution of Uralian-Alaskan-type complexes in the Ural Mountains of Russia

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The major and trace element composition of clinopyroxene in igneous mafic and ultramafic rocks, especially cumulates, provides a powerful tool to get information on the evolution and origin of the parental melt. The classical Uralian-Alaskan-type zoned mafic-ultramafic complexes have been described in the Cordillera of Alaska and British Columbia, and the Ural Mountains in Russia. They are often aligned along narrow belts several hundreds of kilometers long and often host ecconomically important Pt mineralizations. A zonal distribution of mafic and ultramafic rocks, with a central dunite body that grades outward into clinopyroxenite and gabbroic lithologies is their distinctive geologic and petrographic feature. In this study we present trace element concentrations in clinopyroxene done by laser ablation analyses (LA-ICPMS). The distribution of the trace elements in clinopyroxene from different lithologies of three Uralian-Alaskan-type complexes in the middle and northern Ural Mountains provides important information on crystallization processes within the cumulate pile. In addition, the calculated concentrations in their parental melts monitor the origin and evolution of the complexes. Clinopyroxene, predominantly of diopsidic composition, is an accessory phase in dunites (<2%) and the main mineral in wehrlites (10-40%), clinopyroxenites (up to 99%) and gabbros (60-80%). The chemical variations in clinopyroxenes are controlled by the host lithology. For example, a negative correlation between Mg/(Mg+Fe) with a continuous decrease from the dunites (0.95) to the gabbros (0.77) and Al_2O_3 that increases from 0.75 to 5.5 wt.% points to a sucessive crystallization of dunite, wehrlite, clinopyroxenite and gabbro. Clinopyroxenes from dunites also have the lowest contents of MnO (0.05 wt.%) and TiO_2 (0.1 wt.%),

but they systematically increase towards clinopyroxenite wehrlite and gabbro (0.25 wt.% MnO, 0.75 wt.% TiO_2), while SiO_2 contents decrease (55-49.5 wt.%). Clinopyroxenes from dunites and clinopyroxenite of all three complexes have similar REE patterns with an enrichment of $LREE_N$ (0.5-20.2; normalized to the primitive mantle value of Hofmann 1988) and other highly incompatible elements (U, Th, Ba, Rb) relative to the $HREE_N$ (0.25-6.0). The large variation of the concentration and the La/Lu ratio (2-45) imply the extensive crystallization of olivine and clinopyroxene together with spinel from a continuously replenished and crystallizing magma chamber. The final crystallization of melt in pore spaces of the cooling cumulates explains the large variation of REE concentrations on a scale of a thin section (e.g. Lu varies by a factor of 10), the REE-enriched rims of zoned clinopyroxene phenocryst (e.g. La_{Rim}/La_{Core}˜2) and the formation of interstitial clinopyroxenes in clinopyroxenite and gabbro with similar REE enrichment. The trace element patterns of the parental melt inferred from clinopyroxene analyses show negative anomalies for Ti, Zr, Hf and a positive for Sr. This implies a subduction related geotectonic setting for the Uralian zoned mafic-ultramafic complexes. This conclusion is supported by high proportions of Al (0.5-15 %) on tetrahedral lattice sites of the diopsides.

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