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Chromian Spinels: Petrogenic Indicator of the Evolution of Uralian-Alaskan-Type zoned mafic-ultramafic Complexes

J. Krause (1,2), G.E. Brügmann (2), E.V. Pushkarev (3)

(1) Inst. für Geowissenschaften, Universität Mainz, Becherweg 21, D-55099 Mainz, Germany, (2) Max-Planck-Institut für Chemie, Becherweg 27, D-55020 Mainz, Germany, (3) Inst. of Geology and Geochemistry, Russ. Acad. Sciences, 620151 Ekaterinburg, Russia (krause@mpch-mainz.mpg.de)

The chemical composition of chromian spinel has been used to monitor partial melting processes und the evolution of mantle melts from different tectonic settings. The classical zoned mafic-ultramafic complexes have been described in the Cordillera of Alaska and British Columbia and the Ural Mountains where they are distributed along narrow belts several hundreds of kilometers long. Their distinctive geologic and petrographic feature is the zonal distribution of mafic and ultramafic rocks, where a central dunite body grades outward into clinopyroxenite and gabbroic lithologies. The dunite consists of 98-99% olivine, up to 2% of Cr- spinel and traces of interstitial clinopyroxene and amphibole. In places cm to meter size chromitite bodies, hosting important Pt mineralization, intrude or replace the dunite. This study compares new and published data of spinel compositions from a variety of occurrences in Alaska, British Columbia and the Ural Mountains in order to constrain the origin and evolution of the parental melts.

Even if one ignores the magnetite–rich compositions (Cr/(Cr+Fe^{3+}) $<$0.4), the spinel from zoned complexes indicate considerable chemical variations. Thus, the Cr_2O_3 content varies from about 60 to 35 wt%, FeO from 20 to 50 wt% and Al_2O_3 from 2 to 10 wt.%. These major components are very well correlated with each other, however, they define trends which are clearly distinctive from those observed in tholeiitic, komatiitic, boninitic melts, alpine and oceanic mantel peridotites and ophiolite rocks. In the ternary diagram of the trivalent ions Fe, Al, Cr, zoned complexes world wide define a clear Fe enrichment trend ($Fe^{2+}/(Fe^{2+}+Mg)$= 0.5-0.8). The spinel compositions change from about $Fe^{3+}_{20}Cr_{65}Al_{15}$ towards $Fe^{3+}_{53}Cr_{43}Al_{4}$. This large variation is even displayed by analyses of spinel grains from individual samples. It reflects the combination of several fractionation processes, such as fractional crystallization, reaction with interstitial liquid and possibly oxidation.

Analyses of spinel-olivine pairs from zoned complexes in Alaska and the Ural mountains also indicate such fractionation processes. The most primitive olivine (Fo 93) are in equilibrium with Cr-rich spinels (Cr/(Cr+Al)=0.8) but during crystallization of Olivine and Chromite the Fo content in olivine and the Cr/(Cr+Al) in spinel systemically decreases.

The Fe increase is accompanied by an increase of Ti, however, the Ti enrichment is significantly less than that observed in tholeiitic volcanic and intrusive rocks from continental and oceanic tectonic settings. TiO_2 and Al_2O_3 contents are relatively low, less than 2 and 15 wt.%, respectively, and typical for arc-related magmas. The Cr/(Cr+Al) in the most primitive spinels ($>$0.7) is high and similar to those observed in spinels of boninites suggesting a refractory source for the parental magma.

The composition of the parental melt is not well constraint. Primitive volcanic rocks which share many chemical and mineralogical features and the tectonic setting are ankaramites. Such olivine-clinopyroxene-rich melts also form in island arc settings and would explain the crystallization sequence of the zoned dunite-clinopyroxenite complexes. The spinels in such melts are Cr-rich (Cr/(Cr+Al)$>$0.7) and follow fractionation trends as observed in the dunite of the zoned complexes.