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Platinum-Group Minerals in ophiolitic chromitites from Kop Mountain, NE-Turkey

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Different types of chromitites including massive, disseminated and banded textures are present in the Kop ultramafic rocks which extend from Erzincan to Erzurum in NE-Turkey and consist mainly of highly serpentinized harzburgite and limited dunite and lherzolite. The chemical composition of unaltered chromite from the deposits investigated varies in the range 48.53-61.93 wt% Cr_2O_3, 9.44-18.92 wt% Al_2O_3, 2.00-4.96 wt% Fe_2O_3, 11.21-16.18 FeO, 11.46-14.63 wt% MgO, and 0.04-0.40 wt% TiO_2. Cr# (Cr/Cr+Al) varies from 0.64 to 0.81 and Mg# (Mg/Mg+Fe^{2+}) from 0.56 to 0.70. Some samples are highly altered and composition of chromite differs from those of fresh samples. For example the Fe_2O_3 content increase up to 15.07 wt% and, Al_2O_3 and MgO content decrease down to 2.70 and 0.77 wt%, respectively. Calculated parental compositions of melts (10.1-13.5 wt% Al_2O_3 and FeO/MgO ratio of 0.71-1.12) from which the Kop chromitites precipitated are very similar to picritic basalt and boninite in distinct contrast to MORB type magma. Temperature and $\Delta \log^{FMQ} f(O_2)$ estimations on the basis of olivine-spinel composition for chromitites give 900-1150 ^{o}C and -0.86 - +0.81, respectively.

Total contents of platinum-group elements (PGE) in different deposits range from 87 to 520 ppb, with an average of 183 ppb. Chondrite (CI)-normalized values show negatively sloped PGE patterns with slight positive Ru and Pd anomaly. IPGE (Os, Ir, Ru) and PPGE (Rh, Pt, Pd) abundances range between 0.027 - 0.319 x Cl and, 0.003 – 0.138 x Cl, respectively. Although there is no correlation between chromite composition (Cr#) and bulk rock total PGE concentration, positive and negative correlations were observed between Cr# and, whole rock Ru# (0.591), and whole rock Os# (-0.647) of chromitites.

Primary solid inclusions of silicates and platinum-group minerals (PGM) in chromite have been studied. Silicate inclusions, up to 150 μm, consist of olivine, amphibole, phlogopite, chlorite and rare clinopyroxene randomly distributed within the Kop chromitites. A few grains of garnet were also identified. Mostly IPGE dominated euhedral to subhedral single and composite PGM inclusions (up to 20 μm) of sulphides and alloys are the main component of PGE phases in chromite. Some PPGE phases were also found as inclusions in unaltered chromite which is uncommon for the ophiolitic chromitites.

Euhedral to subhedral laurite, (Ru>Os>Ir)S_2, in the size of 2-20 μm are the most abundant PGM detected in the Kop chromitites. They formed as single or polyphase inclusions with silicate (amphibole and chlorite), Cu-sulphide, Ni-Fe alloy, unidentified Rh-Ir-S, Os-Ir alloy and native Pt. Their compositions range between $Ru_{0.92}Os_{0.06}Ir_{0.02}$ and $Ru_{0.62}Os_{0.20}Ir_{0.18}$. One grain of euhedral hollingworthite, (Rh>Ir>Ru)SAs, was observed as main component of polyphase inclusion of unidentified Rh-Ni-S, Pd-Sb-Te and native Pt in fresh chromite. An unidentified Rh-Ir-S phase and native Pt intergrown with Os and As-rich laurite were found within unaltered chromite. Very small grains of Os-Ir alloys intergrown with laurite as well as other single alloys give the composition of $Os_{0.63}Ir_{0.35}Ru_{0.02}$. Stabilization of PGE alloys and Ru-rich laurite during the early stage of PGM crystallization in Kop chromitites should be explained by relatively low fS_2 conditions of the melt during the chromite precipitation.

Calculated composition of parental melts, high-Cr content (Cr#>0.60) and low Ti values of chromites with presence of primary hydrosilicates inclusions in chromite suggest that chromite crystallized from the hydrous melt, enriched in incompatible elements, formed as a result of high degree partial melting of upper mantle, probably in supra-subduction setting.

Recent studies by other authors show clear evidence for the low temperature in situ alteration and modification of PGM by loss of S and addition of base metals leading to the transformation of laurites to alloys or S depleted laurites. Similar alteration of laurite grains were observed in some chromitite samples from Kop. Laurites from the altered chromitites are affected by low temperature alteration by loosing their sulphur completely or partly along the rim of the grains. Consequently, Ru-Os alloys and S depleted, Ni-Fe-bearing laurites were formed.

As a conclusion, the presence of PPGE dominated PGMs in addition to the refractory IPGE minerals in Kop chromitites reflects that Rh, Pt and Pd were also crystallized together or after IPGE bearing PGMs and were not completely fractionated before and during the chromite crystallization.