Origin of dunite of the Sapat Complex, Himalaya, North Pakistan

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The geotectonic framework of northern part of Pakistan involves intra-oceanic Kohistan arc formation in early Cretaceous time, its accretion to the Karakoram plate along the Shyok suture some 85-102 Ma ago and subsequent obduction onto the higher Himalayas of the Indian plate along the Indus suture about 55 Ma ago. The investigated area lies in the upper Kaghan valley of the North West Frontier Province of Pakistan, which is traversed by Indus suture or Main Mantle Thrust (MMT). The Indus suture comprises ophiolite and ophiolitic mélange, exposed at several places in northwestern Himalayas that includes Shangla, Mingora and Malakand ophiolite and ophiolitic melange, and further towards south the Waziristan, Muslim Bagh-Bela ophiolites and towards east Nidar ophiolite in Ladakh, India.

The Sapat area is characterized by rocks of the Indian plate, which has tectonic contact with mafic-ultramafic rocks of the Sapat complex. Our main interest is in the Sapat complex where high quality peridot (gem olivine) occurs. The Sapat complex is distinguished by peridot-bearing dunite and serpentinite at the base, followed by the ultramafic cumulates and layered to isotropic gabbros and metavolcanics of basaltic composition. Talc carbonate lenses and greenschist are incorporated as tectonic mélange within the phyllitic schists of the underlying Indian continental plate. The peridot-bearing dunite is homogeneous and sheared and traversed by numerous joints and fractures, along which gem-quality peridot mineralization has taken place. Other minerals associated with peridot are clinochrysotile, antigorite, talc and magnetite. The dunite contains mainly olivine, and serpentine along fractures. It also contains well-developed chrome spinel grains as accessory mineral. Besides, altered chrome spinel grains are also noticed in the rock. Olivine and chrome spinel of dunite were analyzed with EPMA, showing the forsterite content of olivine ranging between Fo_{91-94}, and Mg# (0.41), Cr# (0.72) and Fe^{3+}# (0.05) at average, Cr_2O_3 (51.62-53.99 wt.%) and Al_2O_3 (7.89-14.83 wt.%) in chrome spinel.

In Cr_2O_3- Al_2O_3 diagram, the chrome spinel data plots in mantle array field, which indicates that the dunite has mantle origin (**Figure 1**). Plotting on TiO_2-Cr# of chrome spinel, this dunite seems to be the end member for fore-arc peridotite with Cr# (>0.7), which in turn lies close and/or overlaps the fields of Izu-Bonin-Mariana boninite and the Lau Basin depleted arc basalt, some transitional to boninites (**Figure 2**). This infers that the dunite of the Sapat complex might have formed in a supra-subduction zone tectonic setting of fore-arc affinity. As evident from field and mineral chemistry data, it is further inferred that the Sapat mafic-ultramafic complex does not represent base of the Kohistan island arc as described previously but typifies an ophiolite sequence along the Indus suture between the Kohistan island arc and the Indian continental plate, and marks same zone along which other ophiolite sequences are exposed in Pakistan and India.

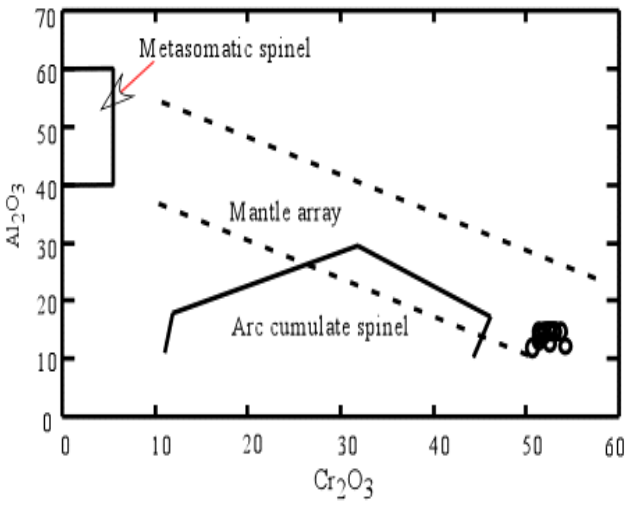

FIGURE 1. Al_2O_3-Cr_2O_3 diagram for chrome spinel and chromite samples from Sapat dunite and serpentinized dunite

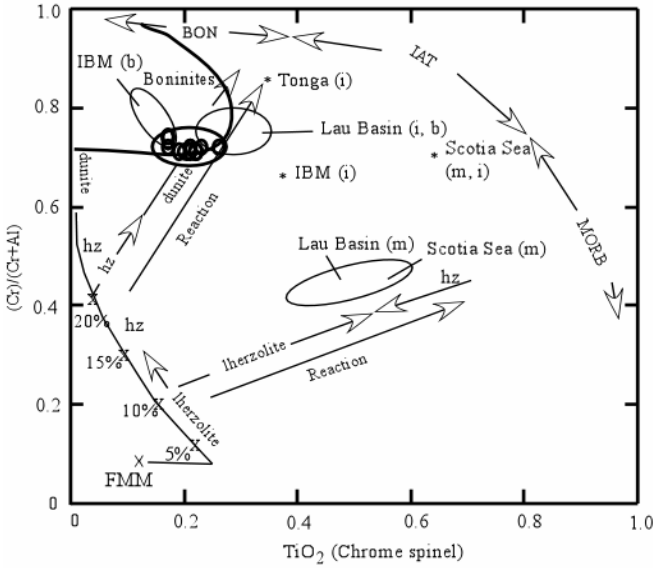

FIGURE 2. Plot of Cr# (Cr/Cr+Al) against TiO_2 in chrome spinel for the dunite of Sapat mafic-ultramafic complex. Symbols: IBM, Izu-Bonin Mariana System; BON, boninites; IAT, island arc tholeiites; MORB, mid ocean ridge basalts; hz, harzbergite; i, island arc; m, MORB; b, boninites; FMM, fertile MORB mantle.