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Compositional modification of accessory chromites from the serpentinized-dunite of the Archean Madawara ultramafic-mafic complex, Bundelkhand Craton (central India): imprints of metamorphism and hydrothermal alterations

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The late Archean Madawara ultramafic-mafic complex in the Bundelkhand Craton is constituted by sporadic and intermittent outcrops of serpentinized dunite and gabbro that are surrounded by tremolite-talc-chlorite schists. Chromites (~ 6-8%) in the serpentinized-dunite are modified and show a range of textures and compositions, based on which they have been categorized into: (i) Type I - dark chromite core enclosed by high reflectance rims of ferritchromite, followed by magnetite; (ii) Type II - ferritchromite mantled by magnetite rim; (iii) Type III - similar zoning feature like Type II, except that grain boundaries are characteristically irregular with tunnel and fish-hook features; (iv) Type IV - disseminated and smaller grained chrome magnetite/magnetite.

The chromites show a range of different compositional ratios like Mg# ([Mg/(Mg+Fe^{2+})] = <0.20), Cr# ([Cr/(Cr+Al)] = 0.6-1), and Fe^{3+}# ([Fe^{3+}/(Fe^{3+}+Cr^{3+}+Al^{3+})] = 0.1-1) across different categories, suggesting that the grains are significantly modified. The dark chromite core in Type I grains shows a relatively higher Mg# (0.001-0.2) relative to the ferritchromite (0.01-0.06) and magnetite rims (< 0.007), while the Cr# (core 0.6-1; rim ~1) and Fe^{3+}# (core 0.06-0.67; rim 0.37-1) show a contrasting trend. Diffusion and elemental exchange during metamorphism results in the decrease of Al^{3+}, Cr^{3+}, and Ti^{4+} from the core to the rim. Complementary distributions are observed for Mn^{2+} and Zn^{2+} that are enriched in the core, while Fe^{3+} and Ni^{2+} show an increase in the rim.

Modification in chromite compositions is primarily due to metamorphism, which perhaps was at the greenschist-amphibolite facies transition, supported by the predominance of antigorite over lizardite (confirmed from Raman spectroscopy) and the presence of tremolite-talc-chlorite. The Cr-Al-Fe^{3+} composition of chromites corresponds to modification occurring between 450-500 ^{o}C, which is also supported by thermometry of adjacent ilmenite-magnetite pairs (449-497 ^{o}C). Metamorphism was followed by hydrothermal events, which is defined by phases like chrysotile, dolomite, magnesite (identified from Raman spectroscopy), and sulfides like millerite, violarite, and vaesite (stable below 379 ^{o}C). Increased fluid activity, higher fO_2, and extensive dissolution-reprecipitation processes during hydrothermal alteration resulted in irregular grain boundaries and anhedral forms in chromites (Type III & IV) and greater magnetite stability.