Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.26065

Alteration and zoning in chromite from Ghutrigaon and Sukinda in the Singhbhum Craton (India): Unravelling the enigma of metasedimentary vs. orthomagmatic origins

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Chromite, an economically significant mineral and a crucial marker of geological processes, displays unique compositional variations (from rim to core) and zoning patterns influenced by its formation environment. This study examines the alteration and zoning characteristics of chromite grains from Ghutrigaon (metasedimentary) and Sukinda (orthomagmatic), both located in the Singhbhum Craton, exploring their genetic evolution and the physio-chemical transformations during post-protolithic processes. Petrographic and mineral chemistry analyses reveal two distinct features: Ghutrigaon chromite exhibits a zoned structure with a brighter core, whereas Sukinda chromite shows increased marginal reflectivity due to alteration. In Ghutrigaon chromite, zoning follows an aluminium trend, with the core enriched in Cr and Fe while the rim is dominated by Al and Mg. Conversely, Sukinda chromite displays an iron trend, where Mg, Al and Ni dominate the core, whereas Cr, Fe, Ti, and Mn are enriched in the outer periphery. Within the Ghutrigaon chromite, Mg ions preferentially migrate from the core to the altered rim, while trace elements like Sc, Nb and U shift inward from the rim to the core. Additionally, Sr, Hf, and Zr exhibit an increasing trend from the core to the rim. In contrast, Sukinda chromite undergoes leaching of Cr and Fe from the core, with subsequent precipitation in the rim. The trace elements in Sukinda chromite, including Cu, Sr, Zr, Hf, and La, shows a decreasing trend with increasing Mg#, suggesting that Mg variations influence these trace elements (including rare earth elements) during alteration. It is likely that Ghutrigaon chromite is formed in a supra-subduction zone environment, with its Cr-spinel zoning attributed to solid-state diffusion during metamorphism. Conversely, Sukinda chromite is associated with boninitic magma in a back-arc rifting environment, where it's zoning results from secondary changes during serpentinization. These findings highlight the distinct nature of metasedimentary and orthomagmatic chromite deposits in the Singhbhum Craton, distinguished by variations in their formation, mineral composition, geochemistry, and tectonic settings. Understanding these variations provides valuable insights into the processes of chromite mineralization and their broader geological implications.