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Chromatite and its Cr^{3+}- and Cr^{6+}-bearing precursor minerals from the Nabi Musa Mottled Zone complex, Judean Desert

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Abstract

Chromatite ($CaCrO_4$, tetragonal) is mainly known from Cr^{6+}-contaminated soils associated with chromium ore processing residue. This extremely rare mineral was found at the Nabi Musa locality (Judean Desert, Israel), in a peculiar rock complex of the Mottled Zone. We have explored the possible mechanisms responsible for leaching Cr^{6+} from natural rocks, by means of field observations, batch experiments, thermodynamic modeling, and mineralogical analyses of the Nabi Musa rocks (XRPD, EMPA, SEM, FTIR, and optical microscopy). A remarkable feature of the Mottled Zone rocks is a broad occurrence of high- and ultrahigh-temperature combustion metamorphic rocks, with Cr^{3+} accumulated mainly in opaque minerals such as Fe-spinel, brownmillerite, and perovskite. Another feature of the Mottled Zone sequence is abundant Cr^{3+} (bentorite and volkonskoite) and Cr^{6+} mineralization (Cr^{6+}-bearing ettringite and baryte-hashemite solid solution) in low-temperature hydrothermal veins. Field, mineralogical, and thermodynamic modeling data suggest that Cr was leached from Cr^{3+}-bearing opaque minerals during late hydrothermal alteration of combustion metamorphic rocks by unusual hyperalkaline waters (pH up to 12). The Cr^{3+} was then oxidized to Cr^{6+}, and subsequently partially immobilized in Cr^{6+}-bearing ettringite. As a consequence of the highway construction across Nabi Musa hill in 2006, the buried veins filled by Cr^{6+}-substituted ettringite were exhumed and exposed to supergene alteration. The ensuing decomposition of Cr^{6+}-bearing ettringite was followed by Cr^{6+} release into pore waters in rainy seasons, and then by precipitation of chromatite on the evaporation barrier under the hard desert insolation in dry seasons. The chromatite formation has been due to both unique rock and water chemistry of the Mottled Zone sequence and to the arid climate of the Judean Desert.

Keywords: Chromatite, calcium chromate dehydrate, hexavalent chromium mineralization, Cr^{6+}-bearing ettringite, bentorite, hyperalkaline waters, Mottled Zone, Judean Desert