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WHAT LURKS IN THE MARTIAN ROCKS AND SOIL? INVESTIGATIONS OF SULFATES, PHOSPHATES, AND PERCHLORATES

Ferrian saponite from the Santa Monica Mountains (California, U.S.A., Earth): Characterization as an analog for clay minerals on Mars with application to Yellowknife Bay in Gale Crater†

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Abstract

Ferrian saponite from the eastern Santa Monica Mountain, near Griffith Park (Los Angeles, California), was investigated as a mineralogical analog to smectites discovered on Mars by the CheMin X-ray diffraction instrument onboard the Mars Science Laboratory (MSL) rover. The martian clay minerals occur in sediment of basaltic composition and have 02*l* diffraction bands peaking at 4.59 Å, consistent with tri-octahedral smectites. The Griffith saponite occurs in basalts as pseudomorphs after olivine and mesostasis glass and as fillings of vesicles and cracks and has 02*l* diffraction bands at that same position. We obtained chemical compositions (by electron microprobe), X-ray diffraction patterns with a lab version of the CheMin instrument, Mössbauer spectra, and visible and near-IR reflectance (VNIR) spectra on several samples from that locality. The Griffith saponite is magnesian, $Mg/(Mg+\Sigma Fe) = 65–70\%$, lacks tetrahedral Fe^{3+} and octahedral Al^{3+}, and has $Fe^{3+}/\Sigma Fe$ from 64 to 93%. Its chemical composition is consistent with a fully tri-octahedral smectite, but the abundance of Fe^{3+} gives a nominal excess charge of +1 to +2 per formula unit. The excess charge is likely compensated by substitution of O^{2-} for OH^-, causing distortion of octahedral sites as inferred from Mössbauer spectra. We hypothesize that the Griffith saponite was initially deposited with all its iron as Fe^{2+} and was oxidized later. X-ray diffraction shows a sharp 001 peak at 15 Å, 00*l* peaks, and a 02*l* diffraction band at the same position (4.59 Å) and shape as those of the martian samples, indicating that the martian saponite is not fully oxidized. VNIR spectra of the Griffith saponite show distinct absorptions at 1.40, 1.90, 2.30–2.32, and 2.40 μm, arising from H_2O and hydroxyl groups in various settings. The position of the ~2.31 μm spectral feature varies systematically with the redox state of the octahedrally coordinated Fe. This correlation may permit surface oxidation state to be inferred (in some cases) from VNIR spectra of Mars obtained from orbit, and, in any case, ferrian saponite is a viable assignment for spectral detections in the range 2.30–2.32 μm.

Keywords: Saponite, smectite, X-ray diffraction, MSL, Mars, Griffith Park