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High-temperature Stability of an Iron-rich Smectite: Implications for Smectite Formation on Mars

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Poster

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Abstract:
Iron-rich phyllosilicates on Mars comprise nearly 90% of the H_2O- and OH-bearing phases observed directly by rovers and remotely by orbiters (e.g., Chemtob et al., 2017, JGR). Theories concerning the possible origin of Fe-rich smectite during Mars' earliest history (phyllosian) are hard to test because of limited knowledge of the upper-thermal stability of Fe-rich phyllosilicates. In this study we present data on the upper-thermal stability of a pure-iron smectite to put some minimum constraints on its possible high-temperature origin early in Mars history either from a primordial atmosphere or by hydrothermal activity.

Smectite coexisting with quartz and magnetite was synthesized from the oxides in the system Na_2O-FeO-Fe_2O_3-Al_2O_3-SiO_2-H_2O at 500°C and 2 kbar and f_{O2} near FMQ. Reversal experiments involved mixtures with equal portions of the smectite-synthesis and breakdown products (quartz, fayalite, albite, magnetite (mt) treated in the presence of about 10 wt% H_2O over the range of 1-3 kbar and 530-640°C. The average composition (electron microprobe) of smectite formed both in synthesis and in reversal experiments was $Na_{0.35}(Fe^{2+}_{2.28}Fe^{3+}_{0.31}Al_{0.41})(Al_{1.07}Si_{2.93})O_{10}(OH)_2 \cdot nH_2O$, where ferric iron was calculated by summing the octahedral cations to 3.0. Reversals for the reaction smec+mt1 = fayalite+albite+mt2+quartz+H_2O were obtained at 538±8, 590±10, and 610±10°C at 1, 2, and 3 kbar, respectively, where mt1 and mt2 have the approximate compositions $Fe_{2.8}Si_{0.2}O_4$ and $Fe_{2.8}Al_{0.1}O_4$, respectively, with all other phases being pure. This smectite has up to 2 interlayer H_2O at 25°C (and high humidity), losing 1 H_2O at <50°C, and the second at 125 ± 25°C.

Thermodynamic modeling of this reaction was used to extrapolate the upper-thermal stability of this Fe-smectite down to 10 bars and approximately 239°C.

Applications of these results indicate the maximum temperature for forming Fe-smectite from a dense primordial atmosphere of 100 bars is 390 ± 25°C. Crustal storage of water in Fe-smectite ranges up to a maximum of 10.7 wt% at 0-2 km, 7.4 wt% at 6 km, and 3.8 wt% H_2O at 32 km for a Noachian geotherm of 20°C/km.

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