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Heterogeneous distribution of Al-hematite regulated by hydrologic regime in a basaltic laterite of Hainan Island, South China: Implications for the aqueous history of Mars

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Abstract

Al-hematite occurs in a wide range of terrestrial soils, but the impact of hydrologic factors on the formation and preservation of Al-hematite remains uncertain. Experimental studies indicate that the ratio of the intensity (I) of the (110) reflection to the intensity of the (104) reflection [(I(110)/I(104)] increases with increasing Al content in a series of synthetic Al-hematite analyzed by X-ray diffraction (XRD), whereas the ratio of the full-width at half maximum (W) of the (110) reflection to the full-width at half maximum of the (104) reflection [W(110)/W(104)] decreases. Quantitative constraints were applied to determine the various levels of Al-substituted hematite in a basaltic laterite (a 48-m-long drill hole) from Hainan Island in South China. The spatial correlation between the distribution of hematite with varying Al content and the location of the groundwater table in the basaltic laterite indicates that hydrologic conditions play a crucial role in regulating the formation and preservation of Al-hematite. The weathering of basalt in a stable water-saturated environment with a relatively slower flow rate promotes the formation of Al-poor hematite. Conversely, the formation of Al-rich hematite was favored by a relatively high flow rate and alternating wet and dry conditions above the groundwater table. Additionally, capillary water in the surficial soil facilitates the expulsion of Al during the recrystallization of Al-rich hematite, resulting in the formation of Al-poor hematite in the surficial soil. Observations from landed instruments and ground-based telescopes have led to the longstanding suspicion that Al-hematite exists on the surface of Mars. The potential presence of Al-hematite in certain martian outcrops may suggest the existence of transient liquid water with slightly higher flow rates, such as episodic floods, emphasizing the dynamic hydrologic conditions on Mars. Moreover, this study suggests that visible and near-infrared (VNIR) spectroscopy can be employed to identify and characterize Al-rich hematite. This approach could be employed to assess the potential presence of Al-rich hematite on Mars, aiding in the study of the planet's hydrologic environment.

Keywords: Al-hematite, basaltic laterite, hydrologic environments, visible and near-infrared spectroscopy, Mars