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Experimental evidence of a new weathering model of the Martian regolith

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Various primary phases have been experimentally weathered in simulated Martian atmosphere, in order to test the influence of the composition of the atmosphere on the weathering process [1]. Indeed, the fundamental difference between Martian and Terrestrial atmospheres is mainly due to the absence of O_2 on Mars, and its replacement by CO_2. Moreover, photochemical activity is responsible for the production of hydrogen peroxide H_2O_2, a strong oxidant [2]. Primary minerals include magnetite and pyrrhotite which account for the main magnetic mineralogy in Martian rocks, as well as iron metal which reflects possible enrichment of the Martian surface in meteoritic matter. This last hypothesis has been recently confirmed by the observation of an iron meteorite in Meridiani Planum (http://marsrovers.jpl.nasa.gov/gallery/press/opportunity/20050119a.html) Sulfides are also more common in meteorites than in basaltic rocks. Weathering was performed during more than 520 days, at room temperature and 0.8 atm, in a pure CO_2 atmosphere, saturated either with water vapor or with hydrogen peroxide. These conditions may also model an eventual primary Martian atmosphere [3]. Neoformed products and primary minerals were investigated using magnetic properties, X-ray diffraction SEM and TEM observations.

The extreme stability of magnetite during the whole experiment indicates that this phase is likely to be inherited in the Martian regolith through weathering process. All the other phases have undergone strong changes in both atmospheres, with goethite as the main neoformed iron (oxy)hydroxide. Lepidocrocite formed occasionally when weathering conditions were slightly less oxidant. Accessory phases included metastable siderite on iron metal, elemental sulfur and sulfates on pyrrhotite. Sulfur bearing assemblages differ according to the atmosphere, and are dominated by

Fe^{3+} sulfates (jarosite and copiapite) in peroxide atmosphere, sulfur and Fe^{2+} sulfates in water atmosphere. Apart from this slight difference, neoformed mineralogy is strongly similar between water and peroxide atmosphere. Nevertheless, water has an important influence on the crystallinity of the neoformed phases.

The ubiquity of goethite in our experiments indicates that this phase is likely to have formed in a potential primary Martian atmosphere, rich in CO_2 and H_2O. The recent observation by MER Spirit of goethite on Clovis rock in Gusev Crater (http://marsrovers.jpl.nasa.gov/gallery/press/spirit/20041213a/Mossbauer_Clovis-B313R1_br.jpg) confirms the possibility for such primary atmosphere. Therefore, the presence of hematite, absent in our experiments, may result from a secondary mechanism, including burial metamorphism [4,5] or long time dehydroxylation processes on the surface. The metastability of siderite in our experiments, and its absence during the weathering process of pyrrhotites indicate that carbonate formation may be prevented by the abundance of sulfur. A correlated result is that sulfides may play an important role in the mineralogical properties of the surface [6], as testifies the presence of jarosite [7] and gypsum.

Using our mineralogical results, we propose a new model of Martian weathering, in which oxidation is conducted by H^+ instead of O_2, according to the following general equation:

$Fe^{2+} + H^+ = Fe^{3+} + \frac{1}{2} H_2$

This reaction is favored toward iron oxidation because of two combined effects: first the volcanism which generates strongly acidic solutions (excess of reactant H^+), and secondly the thermal escape of hydrogen from Mars (defect of product H_2). Such process provides also an efficient trapping mechanism of water in the regolith.

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