

SULFATES FORMATION BY WEATHERING OF SILICATES AND SULFIDES ON MARS: EXPERIMENTAL APPROACH. E. Dehouck¹, V. Chevrier², A. Gaudin¹, N. Mangold¹, P.-E. Mathé³, P. Rochette³, ¹LPGN, CNRS/Univ. Nantes, 2 chemin de la Houssinière, 44322 Nantes Cedex 3, France, erwin.dehouck@univ-nantes.fr, ²Arkansas Center for Space and Planetary Science, MUSE 202, University of Arkansas, Fayetteville, AR 72701, USA, ³CEREGE, Europôle Méditerranéen de l'Arbois, BP80, 13545 Aix-en-Provence Cedex 4, France.

Introduction: Meridiani Planum shows a sulfate-dominated paragenesis in sediments that have been reworked by shallow water and eolian activity [1]. Several hypotheses have been proposed to explain the formation of these deposits (playa evaporates, volcanism, etc. [2,3,4,5]), but none of these models has been tested experimentally. In its original theoretical work, R. Burns suggested that sulfides like pyrite or pyrrhotite, abundant in martian shergottites, rather than atmospheric SO₂, were the source of sulfur in the alteration process [6]. In this study, we focused on the weathering of pure silicates and their mixtures with pyrrhotite.

Experimental protocol: We used several primary silicates previously observed on Mars, including olivine forsterite (a dunite, Ol1, and monocrystals from Pakistan, Ol2), orthopyroxene from Ronda, Spain (OPx), and clinopyroxene from Vesuvium, Italy (CPx1). All phases were also weathered as 50/50 wt% mixtures with hexagonal pyrrhotite Fe_{0.9}S (HPy). 10 g of finely powdered phases/mixtures were put in the upper part of a desiccator, the lower part of which was previously filled with 1 L either of DI water (H₂O) or of water containing 33% of hydrogen peroxide (H₂O₂). The desiccators were then equilibrated with gaseous CO₂ at a pressure of 0.8 bar and the temperature was maintained in the range 15-20°C. The final products have been characterized using X-ray diffraction (XRD) and SEM.

Results: Based on preliminary XRD analyses (Table 1), we observe two different weathering assemblages.

Pure silicates. After 4 years, silicates did not show significant alteration. Only olivine showed development of minor nesquehonite MgCO₃·3H₂O in 3 samples.

Mixtures with pyrrhotite. Contrary to pure silicates, mixtures showed extensive weathering, not only of the pyrrhotite but also of the silicates, as testifies the presence of Ca and Mg sulfates (Table 1). All samples showed the formation of elementary sulfur and gypsum. In addition, hexahydrite was observed in 5 out of the 6 samples and jarosite was observed in 3 samples of pyroxene, but not on olivine. Finally, goethite appeared in all samples.

Weathering processes: according to our preliminary results, we can draw the following observations:

1 – Weathering is very different in the presence of sulfides compared to silicates alone. For silicates alone, weathering appears very limited in intensity. Alternatively, in the presence of sulfides, silicates are readily

weathered into Ca and Mg sulfates, depending on the primary silicate composition. This indicates that pyrrhotite alteration promotes silicates weathering probably through acidification of the medium. Alteration of pyrrhotite itself leads to the formation of jarosite and the excess of iron leads to goethite.

2 – Weathering is quite similar between the H₂O-bearing atmosphere and the (H₂O+H₂O₂)-bearing one.

Conclusion: Our experiments showed that the weathering of silicates and sulfides in simulated martian conditions leads to the formation of Ca, Mg and Fe sulfates, in addition to elementary sulfur and goethite. These results demonstrate that the sulfide-induced weathering hypothesis [7] is a plausible process for the formation of the Meridiani Planum paragenesis.

References: [1] Squyres S. W. and Knoll A. H. (2005) *Earth Planet. Sci. Lett.*, 240, 1-10. [2] Squyres S. W. et al. (2004) *Science*, 306, 1709-1714. [3] Knauth L. P. et al. (2005) *Nature*, 438, 1123-1128. [4] McCollom T. M. and Hynek B. M. (2005) *Nature*, 438, 1129-1131. [5] Niles P. B. and Michalski J. (2009) *Nature Geosci.*, 2, 215- 220. [6] Burns R. G. and Fisher D. S. (1990) *JGR*, 95, 14415-14421. [7] Chevrier V. et al. (2006) *Geochim. Cosmochim. Acta*, 70, 4295-4317.

Samples (see text for meaning of the names)	Initial assemblage				Sulfur & sulfates				Goethite	Nesquehonite
	Olivine	Clinopyroxene	Orthopyroxene	Pyrrhotite	Sulfur	Gypsum	Hexahydrite	Jarosite		
Ol1-H ₂ O	X		X							
Ol1-H ₂ O ₂	X		X							X
Ol1-HPy-H ₂ O	X		X	X	X	X	X		X	
Ol1-HPy-H ₂ O ₂	X		X	X	X	X	X		X	
Ol2-H ₂ O	X									X
Ol2-H ₂ O ₂	X									X
CPx1-H ₂ O		X								
CPx1-H ₂ O ₂		X								
CPx1-HPy-H ₂ O		X		X	X	X	X	X	X	
CPx1-HPy-H ₂ O ₂		X		X	X	X		X	X	
OPx-H ₂ O			X							
OPx-H ₂ O ₂			X							
OPx-HPy-H ₂ O			X	X	X	X	X		X	
OPx-HPy-H ₂ O ₂			X	X	X	X	X	X	X	

Table 1. Summary of primary and secondary phases observed after 4 years of weathering, based on XRD analyses.