# GEOLOGICAL HISTORY OF ARAM CHAOS (MARS) BASED ON JOINT MINERALOGICAL AND MORPHOLOGICAL ANALYSIS.

M. Massé[1], S. Le Mouélic[1], O. Bourgeois[1], J.-Ph. Combe[2], L. Le Deit[1], C. Sotin[1,3], J.-P. Bibring[4], B. Gondet[4],Y. Langevin[4] and the OMEGA Team. [1]Laboratoire de Planétologie et Géodynamique, UMR 6112, CNRS, Université de Nantes, Faculté des Sciences et Techniques, 2 chemin de la Houssinière BP 92208, 44322 Nantes Cedex 3, France (marion.masse@univ-nantes.fr), [2] Bear Fight Center, a Columbus Technologies and Services Inc. affiliate, Box 667, Winthrop WA 98862, USA, [3]Jet Propulsion Laboratory, M/S 183-303, 4800 Oak Grove Drive, Pasadena, CA 91109, [4]Institut d'Astrophysique Spatiale, Université Paris 11, Bâtiment 121, 91405 Orsay Campus, France.

**Introduction:** Aram Chaos is a 280 km wide Martian crater centered at 2.5°N, 338.5°E. This depression is connected to the Ares Vallis outflow channel by a gorge 15 km wide and 2.5 km deep, which cuts across the eastern wall of the crater (*Figure 1*). Previous studies have shown that this crater is filled by chaotic terrains, overlain by a dome-shaped, layered, 900 m thick formation (*Figure 1*) displaying strong spectral signatures of ferric oxides on TES and OMEGA data at medium spatial resolution [1, 2, 3, 4]. We describe in details the mineralogical composition, the structure and the morphology of Aram Chaos, using high-resolution data, in order to constrain the geological processes and the history of its formation.

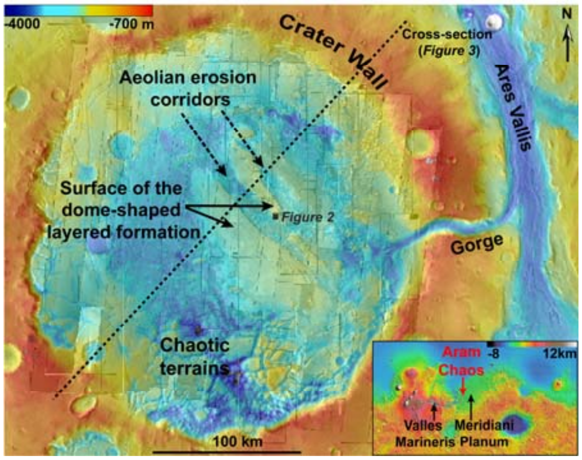

*Figure 1: Morphological map of Aram Chaos (superimposition of a MOLA DTM on a mosaic of visible THEMIS images). The box indicates the location of Aram Chaos on a MOLA topographic map of Mars.*

**Methodology:** We investigate in details the mineralogical composition of Aram Chaos using data acquired by the OMEGA imaging spectrometer [5] onboard Mars Express. This instrument has completed a global coverage of Mars in 352 spectral channels from 0.38 to 5.2 µm at a spatial resolution ranging from 300 m to 4 km. We compute maps of various spectral parameters and maps of spectral contributions of several minerals derived from a spectral linear unmixing algorithm [6]. These OMEGA processed products are integrated into a Geographic Information System (GIS).

Morphological, textural and sedimentological information is provided by available high resolution images: MOLA for topographic information, MOC and HiRISE for visible images, and THEMIS for visible and infrared images. These images are integrated into the same GIS in order to investigate the correlations between the mineralogical and morphological characteristics.

**Results:** Four spectral units (SU) are identified (*Figure 2*), which display distinct spectral characteristics. The first three ones are located on the dome-shaped layered formation whereas the last one is located on the chaotic terrains (*Figure 1*).

SU1 contains a strong signature of ferric oxides, with a deep absorption band at 0.9 µm, and a significant increase of the reflectance between 0.9 and 1.3 µm. Absorption bands at 1.4 and 1.9 µm also indicate the presence of hydrated minerals. These spectral features are consistent with a mixture of goethite and/or hematite and ferrihydrite and/or schwertmannite. SU1 is located on different areas corresponding, on high-resolution images, to large sheets of dark dunes covering outcrops, too small to be resolved by OMEGA, of a layered, cohesive, bright material.

SU2 presents the same characteristics as SU1 but with an additional broad band at 2.1 µm, which is typical of sulfates (kieserite and szomolnokite being good candidates). SU2 is correlated with discrete, scattered and dark dunes similar to those of SU1, alternating with wide outcrops of the bright, layered material. These outcrops are large enough to be resolved by OMEGA and the 2.1 µm absorption band is particularly deep on this material.

SU3 displays the same absorption bands as SU2 but the bands are always shallower and these spectra display a negative slope characteristic of dust. On high-resolution images, this unit is composed of the same bright material as SU2, partially covered by dust and extensively sculpted into hectometric ridges and furrows striking E-W.

The spectral characteristics of SU4 are typical of dusty areas. SU4 appears as chaotic terrains which are stratigraphically below, and which crop out around the dome-shaped formation (*Figure 1*).

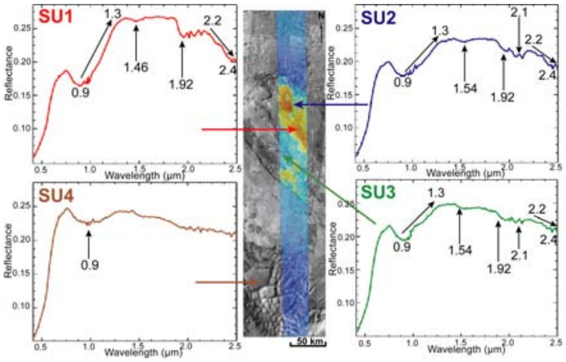

*Figure 2: Typical spectra of each spectral unit. These spectra are located on a map of a spectral criterion, corresponding to the 1.92 µm band depth, superimposed on a mosaic of visible THEMIS images.*

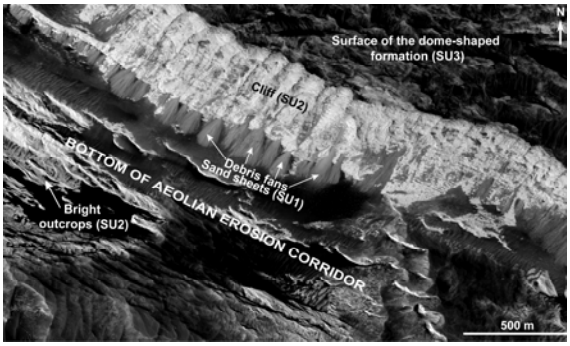

*Figure 3: HiRISE image showing the three spectral units SU1, SU2 and SU3.*

**Interpretation:** Wide aeolian erosion corridors striking NW-SE (*Figures 1, 3 and 4*) have grooved the dome-shaped formation down to various depths. The borders of these corridors are steep linear cliffs where the bright, layered, sulfate-rich material crops out (*Figure 3*). These cliffs are also partially covered by dark debris fans, which originate from the bright formation itself, and feed the dark sand sheets (*Figure 3*). We therefore conclude that the dark ferric oxide sand sheets and debris fans are erosional products of the bright formation. This hypothesis is consistent with observations by the rover Opportunity, in Meridiani Planum, of (1) stratified outcrops containing both sulfates and ferric oxides and (2) accumulations in topographic lows of ferric oxide spherules derived from the stratified outcrops [7, 8].

**Conclusion:** We propose the following history for Aram Chaos, which accounts for the observed mineralogical and geomorphological constraints. 1- The crater floor was covered by a first geological formation. 2- Chaotic terrains were formed at the expense of this formation, possibly in response to sudden withdrawal of water stored in this same formation [3]. 3- A second, dome-shaped, layered formation was emplaced unconformably on the chaotic terrains. This unit is composed of a bright material that contains both sulfates and ferric oxides. Ridges and furrows at the surface of this formation indicate that the bright material has been mobilized by E-W blowing winds during or after its deposition. It has been subsequently covered by dust. 4- After its emplacement, the dome-shaped formation has been grooved down to various depths by large aeolian erosion corridors striking NW-SE. In these corridors, aeolian removal of the sulfate-rich matrix of the bright material has left local accumulations (in the form of debris fans on cliffs and of dark sand sheets and dunes on topographic flats and depressions), of residual grains enriched in iron oxides (*Figure 4*).

**References:** [1] Christensen P. R. et al. (2001) *JGR*, *106*, 873-885. [2] Catling D. C. and Moore J. M. (2003) *Icarus*, *144*, 21-26. [3] Glotch T. D. and Christensen P. R. (2005) *JGR*, *110*, E09006. [4] Oosthoek et al. (2007) *LPS XXXVIII*, Abstract #1577. [5] Bibring J.-P. et al. (2004) *Eur. Space Agency Spec. Publ. 1240*, *37*. [6] Combe J.-Ph. et al. (in press) *Planetary and Space Science*. [7] Bell J.F. et al. (2004), *Science*, *vol.305*, p. 800-806. [8] Soderblom et al. (2004), *Science*, *vol.306*, p. 1723-1726.

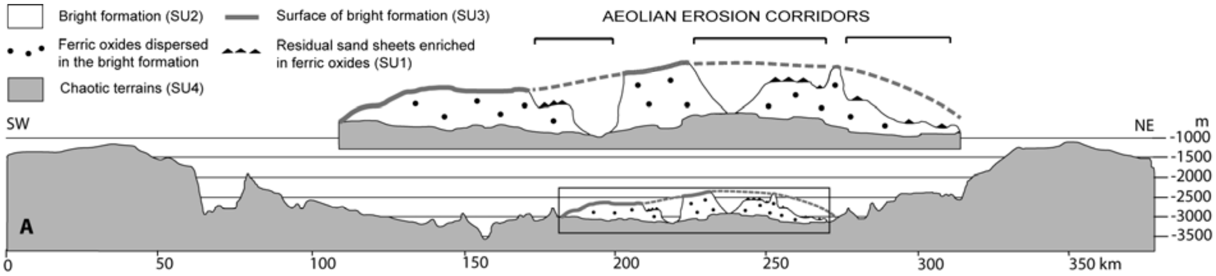

*Figure 4: Interpretative cross-section of Aram Chaos (location on Figure 1), vertical exaggeration: x12.5.*