

Valles Marineris ILDs: updated mapping of sulfates from the whole OMEGA dataset

P. Thollot (1,2), N. Mangold (1) and S. Le Mouélic (1)

(1) Laboratoire de Planétologie et Géodynamique de Nantes (LPGN), CNRS/Université Nantes, 44322 Nantes Cedex, France,

(2) Laboratoire de Géologie de Lyon (LGL-TPE), CNRS/Université Lyon 1, 69622 Villeurbanne Cedex, France.

(patrick.thollot@ens-lyon.fr)

Abstract

We present an updated regional mapping of monohydrated and polyhydrated sulfates in Valles Marineris ILDs. Using spectra of actual mixtures of a sulfate with unaltered basalt we infer the amount of sulfur in the ILDs and discuss implications.

1. Introduction

Knowledge of the mineralogy of the Interior Layered Deposits (ILD) of Valles Marineris (VM) can help distinguishing between various hypotheses of their formation (lacustrine, volcanoclastic, etc.). Hyperspectral data acquired by OMEGA (Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité) have provided new insights on the composition of the ILDs, revealing monohydrated and polyhydrated sulfates [1, 2].

2. VM ILDs at various scales

Most studies made since the earliest detections of sulfates in VM ILD have focused on areas of relatively small extent. Notably, high spatial resolution (tens of m scale) data from CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) have revealed a large diversity of minerals in VM, including various sulfates (kieserite, szomolnokite, polyhydrated Fe-sulfates, jarosite), Fe-oxides, Fe/Mg and Al clays [eg. 3], and a hydrated phase which nature is still debated [eg. 4].

While assessing the mineralogical diversity at local scale can give more insight on the chemistry and formation processes of the ILDs, it should be joined with a more synthetic regional scale view, has yet to have been updated since the first detections from OMEGA data.

We therefore used the whole archive of OMEGA data acquired since late 2004 to map monohydrated

and polyhydrated sulfates in VM. We then deployed an original empirical strategy to try and quantify those sulfates in VM ILDs. Our results allow discussing various hypotheses of sulfates formation.

3. Analysis of OMEGA data

OMEGA, operating in the near infrared (NIR), allows distinguishing between two spectral classes of sulfates, based on their absorption bands in the 1.7-2.5 μm range: monohydrated and polyhydrated [5]. After applying routine spectral calibration and atmospheric correction on OMEGA data, we computed respective proxies for monohydrated and polyhydrated sulfates based on absorption band depths at 2.1 μm (BD21) and 1.9 μm (BD19).

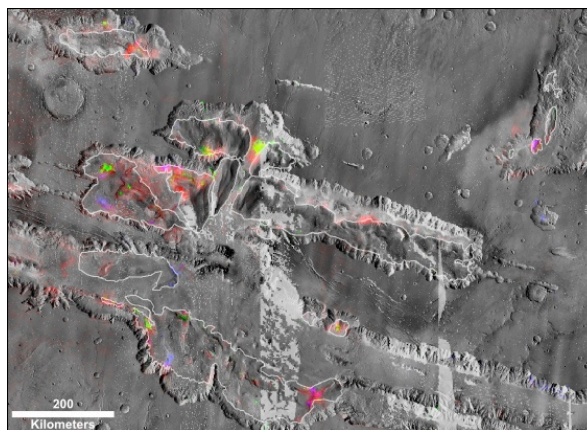


Figure 1: Composite RGB mapping of a Fe-oxide index, BD21 and BD19 in central VM from OMEGA (on Themis day IR).

We mitigated problems arising from variable observation geometry, dust and ice atmospheric opacity, and OMEGA instrument evolution over the course of the mission, through a series of steps. We filtered out observations with unfavorable incidence and emergence angles, high dust or ice opacity as determined from Themis observations [6], and

corrected for the progressive loss of spectral channels. We then built mosaics of OMEGA observations using higher spatial resolution on top. The results are regional scale maps of BD21 and BD19 (Figure 1).

3. Empirical quantification strategy

We decided to tackle the issue of the quantification of sulfates from an original angle, based on preparing, in the laboratory, binary mixtures of a sulfate intimately mixed with an unaltered basalt.

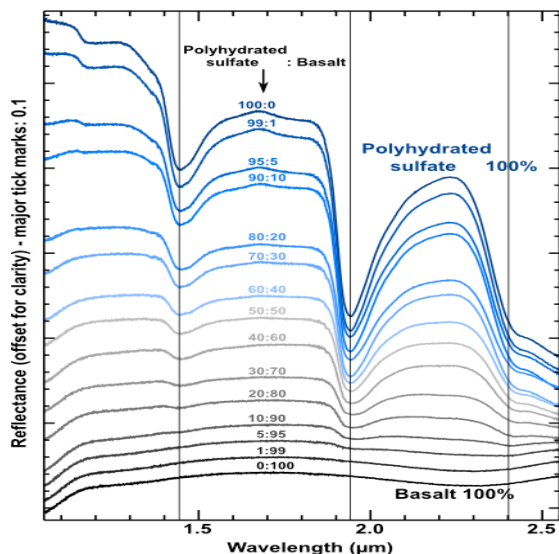


Figure 2: Laboratory spectra of actual mixtures of basalt and polyhydrated sulfate

We manually prepared series of 15 mixtures of two endmember materials from 100%-wt basalt to 100%-wt sulfate. Endmembers were first verified for purity, crushed in a mortar and passed through a 63μm sieve. We then acquired NIR spectra of the whole mixture series. Figure 2 shows the spectral series for polyhydrated sulfate. We found a linear relation between sulfate weight abundance and BD19 or BD21 for polyhydrated and monohydrated sulfates, respectively, for <30%-wt sulfate. We then inverted these relations to produce maps of sulfates weight abundances in VM and MP.

Sulfate abundances retrieved by this method must be interpreted with caution. Indeed, among other assumptions, it assumes that the sulfate-bearing material on the surface of Mars behaves similarly as a 2-endmember mixture of materials with similar fine grain size and that the material is homogeneous,

which may well be untrue. Nonetheless, it allows for tentative first order interpretations.

4. Geological interpretations and discussion

Averaging the abundance of sulfates from OMEGA data over the volume of all ILDs, as mapped using MOLA, Themis, CTX and OMEGA data ($\sim 0.5 \times 10^6$ km³), we propose within the ILDs a total sulfur mass of $\sim 5 \times 10^{16}$ kg, equivalent to a global layer (GEL) of ~ 0.75 m of sulfates (and with a water content of ~ 0.4 m GEL). If all this sulfur were in SO₂ form it would account for ~ 4 times the current Mars atmospheric pressure (~ 25 mbar).

The formation of major sulfate deposits on Mars seems to have been restricted in space and time. Most large sulfate-rich deposits are Hesperian in age while Noachian sulfates are lacking, despite a probable sustained magmatic activity. Our estimates show that Hesperian sulfates in VM ILDs could have resulted from groundwater alteration of sulfide-rich earlier (Noachian) rocks [eg. 7] as well as from uptake of atmospheric sulfur outgassed by volcanism during the Hesperian. In the latter case, our quantitative analysis suggests that VM and other equatorial sulfates could only account for a small fraction of what all of the Hesperian volcanism could have outgassed, questioning either one or both of processes of magmatic outgassing or sulfate precipitation in sediments on Mars.

References

- [1] Gendrin A. et al. (2005) *Science*, 307(5715), 1587-1591.
- [2] Bibring J. P. et al. (2006) *Science*, 312(5772), 400-404.
- [3] Thollot P. et al. (2012) *JGR* 117, E00J06.
- [4] Roach L. H. (2010) *Icarus*, 206(1), 253-268.
- [5] Cloutis E. A. et al. (2006) *Icarus*, 184(1), 121-157.
- [6] Smith M. D. (2009) *Icarus*, 202(2), 444-452.
- [7] Dehouck E. et al. (2012) *GCA*, 90, 47-63.