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New hydrated mineral detections in the ILDs of Valles Marineris: Insights into their aqueous history

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Abstract: This paper presents a survey of the mineralogical diversity of the Interior Layered Deposits (ILDs) of Valles Marineris (VM) and Margaritifer Terra (MT) as determined with the high-resolution hyperspectral imager CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) onboard MRO (Mars Reconnaissance Orbiter). A particular emphasis is made on localized detections of new hydrated phases within the dominantly sulfate-rich deposits. These detections are compared with other recent detections of unindentified minerals across the entire region [e.g. 10-19]. Characterizing the entire mineral assemblages at these sites is designed to provide more information on the chemistry of those complex aqueous deposits and their potential formation mechanism(s).

1. Introduction:

ILDs have been observed in > 10 locations of the VM and MT regions of Mars, where they form kilometer-thick, flat-topped sedimentary mounds [1]. In 2004, the imaging spectrometer OMEGA (Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité, Mars Express) detected sulfates in association with the ILD mounds, which appear to be stratigraphically distributed [2,3]. Mg-rich monohydrated sulfates (MHS) have been observed at low elevations whereas polyhydrated sulfates (PHS) are more commonly detected in the upper deposits. The origin of the ILDs remains uncertain, possibly corresponding to lacustrine deposits [1,4,5], erosion of the canyon walls [5], subice volcanic structure [6,7], non-aqueous aeolian or volcanic deposits [8].

2. Dataset:

Numerous hyperspectral CRISM images were photometrically and atmospherically corrected for this study and projected with the CAT tool using ENVI [9]. The present study makes use of the both the VNIR and IR CRISM image pairs.

3. Results:

In addition to Mg/Fe-rich MHS and PHS previously detected by OMEGA, a wide array of other hydrated minerals appear to be present within the ILDs. Previous CRISM studies show a variety of spectral features in the 2.2-2.4 µm range across the entire VM and MT regions, that are not attributed to Mg-rich sulfates [10-19]. We focused on absorptions near 2.2 µm that are often characteristic of hydrated silicates (such as kaolinite, montmorollonite, opal, allophane, etc…) but are also present in some sulfate species such as gypsum, jarosite, alunite, hydroxylated Fe-sulfates, and in some hydroxides such as gibbsite. Absorptions near 2.2 µm are present in many spectra collected over the ILDs of both VM and MT. As their characteristics vary (band center and width), these spectra were classified in a minimum of 3 spectral groups.

Group 1 includes spectra with a sharp 2.23 µm absorption, as observed in Aureum Chaos (*fig.1, black spectrum*), Ophir Chasma, Aram Chaos, Capri Chasma and Juventae Chasma. The sharp, 2.23 µm absorption is associated with weaker spectral features near 1.43-1.45, 1.94-1.95, and 2.40 µm and could correspond to hydrated silicates or $FeOHSO_4$ species [10-15]. This material is either partially hydrated or is mixed with other hydrated phases because water bands are present in the spectra.

Group 2 includes spectra with a 2.21/2.27 µm doublet absorption as observed in Candor Chasma, Juventae Chasma, Melas Chasma, Ius Chasma, Ophir Chasma (*fig.1, green spectrum)* and Noctis Labyrinthus. Initially reported as an 'unknown hydrated mineral' by Roach et al. [16], this phase is associated with strong water absorptions at 1.9 and 1.4 µm, and a drop in reflectance at 2.4 µm, usually diagnostic of PHS. The relative depths of the 2.21 and 2.27 µm absorptions vary, suggesting that this

doublet signature might be a combination of absorptions from two or more different minerals. As this newly recognized hydrated mineral phase does not correspond to any single mineral within the spectral library, we suggest it corresponds to a mixture of multiple minerals including hydrated silicates (opal, Fe-rich smectites, Al-rich smectites), sulfates, or acid-leached Fe-bearing smectites [16-19].

Group 3 includes spectra with other types of absorptions. Observed spectral features in Valles Marineris include sharp 2.27 µm absorptions sometimes associated with 1.9 and 2.4 µm absorptions but also 1.85 µm or 1.75 µm bands (*fig.1, blue and cyan spectra)* possibly implying a relationship to the materials present in Group 2 (responsible for the 2.27 µm absorption in the doublet) mixed with PHS, jarosite or gypsum. A single spectral type with a wide 2.20 µm absorption was found in Melas Chasma and is consistent with opal silica as previously suggested by [10] (*fig.1, red spectrum).*

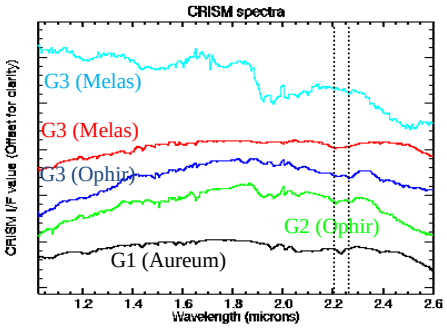

Fig 1: Various spectral types with features around 2.2 µm are observed in the VM and MT areas. Dashed lines are placed at 2.21 and 2.27 µm to assist the reading.

4. Discussion and Conclusion:

Multiple minerals appear to be present together with sulfates with the ILDs of VM and MT, such as: opal silica, Fe and/or Al-rich smectites, gypsum, jarosite, (partially) dehydrated Fe-sulfates. Ongoing work is characterizing the context of these detections and the VNIR spectral character. A particular focus is on the type of material carrying the detections and its relationship to the ILD material. Comparison between different ILDs also is designed to help quantify the regional versus global extent of the processes that formed the ILDs.

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