

**ANALYSIS OF CANDOR CHASMA INTERIOR LAYERED DEPOSITS FROM OMEGA/MEX SPECTRA.**

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**Background:** Sedimentary deposits are high priority targets for missions to Mars because they recorded the chemical conditions of these past environments. Images interpretation of potential sedimentary layers led to controversial conclusions about their origins. Layered deposits identified by the Mariner 9 and Viking spacecrafts were interpreted as sediments, possibly formed by lacustrine deposition involving stable liquid water<sup>1</sup>, but other origins like volcanic or wind blown material were also proposed<sup>2,3,4,5,6</sup>. The images of the Mars Observer Camera (MOC) of Mars Global Surveyor (MGS) show details of such deposits in the ancient highlands or the Interior Layered Deposits (ILD) of Valles Marineris canyons. They are interpreted as evidence of active sedimentary processes likely involving liquid water in the early Mars<sup>7</sup>. However, no spectral data like TES (Thermal Emission Spectrometer) data have confirmed these interpretations yet<sup>8</sup>. Only the analysis of martian meteorites shown the possibility of evaporite mineral assemblages in fractures of volcanic rocks<sup>9</sup>.

**OMEGA Analysis:** The entire OMEGA dataset consist of about ~100 orbits and ~20 million spectra. Here is detailed the region of Candor Chasma in Valles Marineris. Resolution varies from 600 m to 1.2 km by pixel. We correct the spectra from the atmospheric contribution dividing by a scaled atmospheric spectrum. This technique has been successfully used for the Imaging Spectrometer for Mars (ISM) dataset<sup>10</sup>, and the absence of an atmospheric residual at ~2  $\mu\text{m}$  shows that it is appropriate. Sulfates are identified on many pixels of the Valles Marineris region, especially in the Candor Chasma region (Fig. 1). The match between the spectra and the spectrum of kieserite is excellent between 1.4 and 2.5  $\mu\text{m}$ , with three main absorption bands at 1.6, 2.1 and 2.4  $\mu\text{m}$ . These bands are due, in monohydrated sulfates, to the single, strongly hydrogen bonded, water molecule<sup>11</sup>. A second group of minerals is detected in Candor with absorption bands at 1.4 and 1.9  $\mu\text{m}$  and a drop at 2.4  $\mu\text{m}$ . Such associations are observed in spectra of polyhydrated sulfate minerals. It should not be forgotten that kieserite is one mineral of the sediments but not the only one. For example, 10 or 20 % of kieserite could be visible on spectral data if the rest of the sediment is composed of minerals such as halite salt or quartz that are flat in the wavelength considered.

Additionally, a drop between 1.3 and 1 micron suggests the occurrence of oxides close to the locations

where sulfates are detected (see abstract by Gendrin et al., this LPSC).

**Association of sulfates with layered deposits:** The most striking result of the identification of sulfates is their systematic correlation with bright layered deposits observed at the MOC scale (Fig. 1). On this figure, light toned deposits display the signature of kieserite.

The surface texture of bright deposits displays flutes and yardangs typical of eolian erosion in weakly consolidated material. They are also devoid of small impact craters (< 100 m), which does not mean that the layers formed recently, but that they were exhumed recently. These observations favor the idea that the sulfates are part of the bulk rock rather than being a consequence of surface weathering or duricrust formation. On the other hand, darker parts corresponding to eolian mantling do not show any sulfates.

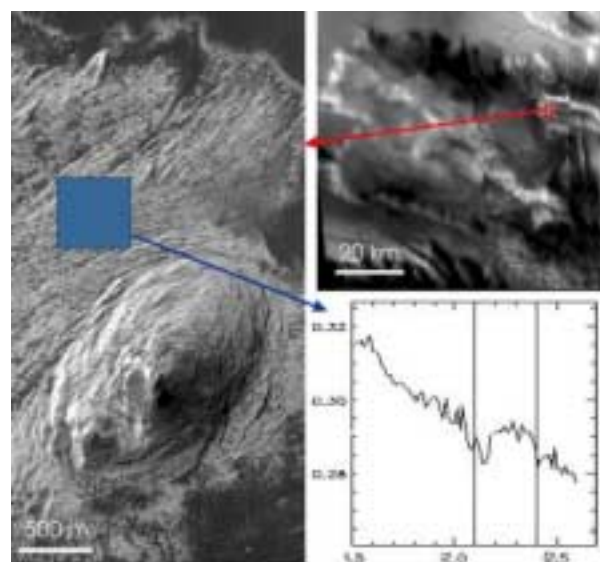
One mesa is affected on the three sides of a 4 km thick hill as we could expect for a geologic unit. Other deposits are affected at elevation that varies from -2 km to 3 km in MOLA scale. This shows that the sulfates are widespread and consist of large volumes in the deposits.

**Discussion:** On Earth sulfates are usually indicators of water related processes either by (1) surface weathering from acidic rains or fog, by (2) evaporation of standing bodies of water or by (3) groundwater circulation at depth. On Mars, acidic rains are unlikely under current climate but this process may have existed on a warm early Mars. However, such process would form a thin crust which is unlikely to have survived to subsequent erosion. By contrast, the occurrence of evaporites at the surface of Mars was already proposed to explained deposits such as those of potential crater lake deposits or Valles Marineris interior<sup>2,4</sup>.

Sulfate minerals can also appear by the crystallization at depth during the burial of sediments in presence of sulphur rich fluids. This case usually occurs when the sediments consist of sulfate layers that are highly soluble in presence of groundwater producing *in situ* dissolution and recrystallization. Kieserite may have formed like this from the dissolution of all types of Mg-sulfates present in sediments because kieserite is a product of dehydration of more hydrated sulfates during the geothermal heating. Alternatively, sulfates may form from the circulation of fluids inside layers formed under other environments such as volcanic tephra or wind blown material. This is especially the case in hy-

drothermal conditions when sulfates may be derived from high contents of magmatic  $\text{SO}_2$ <sup>12</sup>.

**Conclusion:** Layered deposits are usually dated of early period of Mars, Noachian or Hesperian time. The exact origin of the layered deposits will be discussed in more detailed study of the geologic layers. The current association with sulfates shows that liquid water may have played a major role in the formation of sulfate in the surface or subsurface of Mars at that primitive epoch.



**Fig. 1:** Top right: OMEGA albedo map of Candor Chasma. Left: MOC image of layered deposits over a 4 km high mesa (MOC number MOC # E03-01293; 74.5°W, 5.2°S). Bottom right: One OMEGA spectra on layers. Scale: reflectance in Y and wavelength in X. The two bands at 2.1 and 2.4 microns are typical of kieserite. Notice the small peak inside the wide 2.1 micrometer band and high frequency peak at 1.9 micrometers are residuals of atmospheric correction.

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