

MARS: SPECTRAL AND THERMODYNAMIC RESTRICTIONS ON THE GYPSUM EXISTENCE IN THE JUVENTAE CHASMA. R.O.Kuzmin^{1, 2}, M.V. Mironenko¹, N.A. Evdokimova², 1-Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, 19 Kosygin Str., Moscow 119991, Russia, rok@geokhi.ru; 2- Institute for Space Research, RAS, Moscow, 117997, Russia.

Introduction: Majority of the sulfates-rich regions detected on Mars by the OMEGA spectrometer are in association with the interior light layered deposits within the canyon system in the equatorial zone of the planet [1,2,3]. While the all sulfates-rich deposits inside of the canyons are characterized mostly by presence of the kieserite and polyhydrated sulfates, the gypsum's spectrum was detected only in the Juventae Chasma and the Iani Chaos [2]. At that, the gypsum detection in the Juventae Chasma represents more intriguing case. The point is that following to [2], the gypsum's spectrum is associated with the upper part of the layered deposits stacking the erosional remnant on the floor of the Chasma (fig.1), whereas the spectral signature of the kieserite and polyhydrated sulfates was found on the lower flanks of the deposits. However, we suppose that the presence of the gypsum signature within the upper suite of the layered deposits above of the lower suit of the deposits with kieserite and polyhydrated sulfates represents oneself essential contradiction from points of view both geology and thermodynamics.

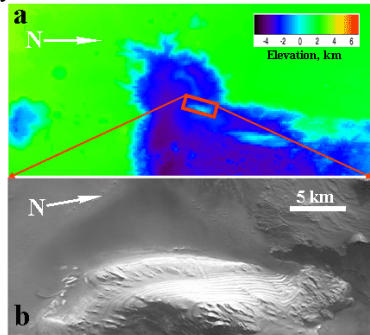


Figure1. OMEGA altimetry of the Juventae Chasma (a) and the THEMIS VIS frame (b) of the southern erosional remnant stacked of the layered deposits.

To clarify the question on presence of the gypsum in the Juventae Chasma, we reanalyzed the OMEGA spectra of the area and conducted chemical thermodynamic modelling of sulfates precipitation sequence at freezing and evaporation of the hypothetical initial solution reservoir which could exist within Juventae Chasma in the past.

Analysis of the OMEGA data: To analyze the surface spectra of the Juventae Chasma we used OMEGA cub ORB0482_2, which was subjected to comprehensive atmospheric corrections to exclude from observing spectra the absorption bands of CO₂, H₂O vapour and CO. For this the atmospheric transmittances have been calculated taking into

account the observation geometry, the atmospheric temperature profiles and the surface pressures from European Mars Climate Database [4] and the water vapor content in the atmospheric column from [5]. The zonally variable scale height of water vapor was simulated using GFDL's, MGCM [6]. Based on corrected OMEGA spectra we mapped the several spectral indexes using the main adsorption bands for the gypsum (1.43, 1.75, 1.93 and 2.2 μm), for the kieserite (1.6, 2.07 and 2.4 μm) and polyhydrated sulfates (1.43 and 1.93 μm). The index mapping results (fig.2) and spectra analysis (fig.3) shown that the spectral signatures of the erosion remnant summit (as well as of its flanks) are consistent well with the spectra of the polyhydrated sulfates and the kieserite (mostly on the remnant's flanks), but not with presence of the gypsum spectrum. Besides, in the place the

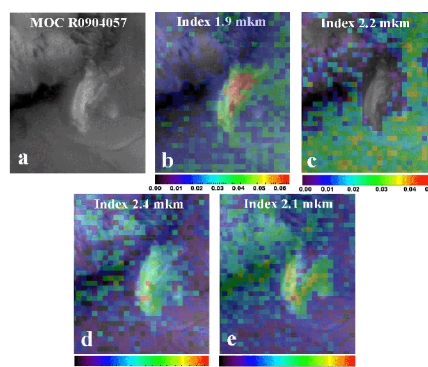


Figure2. The MOC wide-angle image of the erosion remnant in Juventae Chasma (a) and the fragments of the index maps (superimposed on MOC image) for adsorption band 1.93 μm (b), 2.2 μm (c), 2.4 μm (d) and 2.1 μm (e) compiled based on the OMEGA cube ORB0482_2.

index maps for two main absorption bands used for detection of the gypsum (1.93 and 2.2 μm) are not correlated each other (see Fig.2b,c). Besides, the other typical for the gypsum band of 1.75 μm are not detectable generally in the studied area because its depth is lower of the spectral noises level, whereas the kieserite's index (2.07 and 2.4 μm) is well presence mostly on the remnant's flanks (see fig.2d,e).

The thermodynamic modelling results: As far as the Martian soil enriched by such elements as Fe and Mg and notably less by Ca [7], it seems more logical that the original solution on Mars were also enriched mostly in Fe and Mg and less in Ca. By the reason, we used the mole ratios of the main cations and anions similar to ones in the Martian soil: Mg/Ca=10/1,

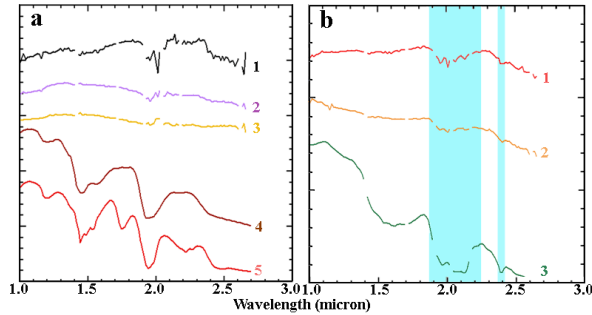


Figure 3. The OMEGA spectra of the erosion remnant in the Juventae Chasma: a- spectral ratio for the summit of the erosion remnant (1), observing (2) and reference spectra (3) and the library spectra of the polyhydrate (4, $MgSO_4 \cdot 5H_2O$) and of the gypsum (5); b- spectral ratio of the erosion remnant flanks (1,2) and the library spectrum of the kiserite (3). Blue bands show the main absorption bands of the kiserite (2.1 and 2.4 μm).

$SO_2/Cl=5$, $Na/Mg=0.5$, $Na/K=4$, $Mg/Fe=5$. To simulate a salt precipitation sequence, we conducted modeling of both freezing and evaporation of the initial mixed electrolyte solutions with various Mg/Ca ratios (from 10/1 to 200/1) at 273.15 K. The calculations were performed for the S- Cl- Mg- Na- Fe- Ca- K system with the FREZCHEM code [8,9], which uses the Pitzer algorithm to calculate activities of water and solutes in concentrated solutions. Both equilibrium and fractional crystallization of salts were simulated. Fractional crystallizations suppress chemical interactions of already deposited salts with each other and with the remaining electrolyte solutions. This scenario is convenient to demonstrate amount of the salt to be deposited step by step during water evaporation. Results of the modelling, presented on the fig.4., show that at all considered processes the gypsum begins precipitate first in a small masses (at different ratio Mg/Ca), whereas the magnesium and the iron sulfates have been precipitated later and in much larger masses. At the equilibrium and fractional freezing of the initial solution (from T ~263K and up to eutectic point of solution) the deposited masses of the magnesium and the iron sulfate is larger than for gypsum ~ in 9 and ~ in 2 times respectively (see fig.4a, c). The similar tendency is observing at the modelling of the equilibrium and fractional evaporation of solution at T=273K (see Fig.4b, d). The modelling results convincingly show that the last stage of the sulfates precipitation from hypothetical solution reservoir is characterized by predominance of the magnesium sulfates over other salts by masses.

Summary: Our results show that spectral signature from the upper suite of the layered deposits of the erosional remnant is consistent rather with presence of the polyhydrated sulfates than with gypsum. Results of

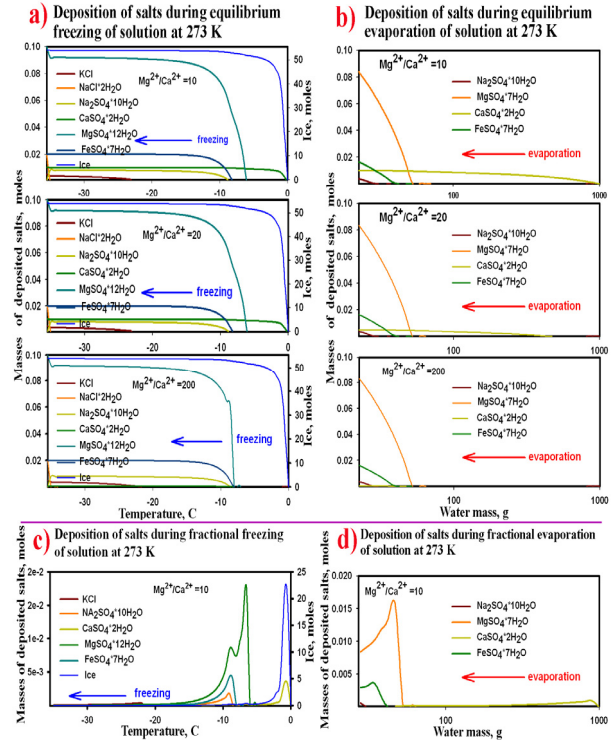


Figure 4. The sequence of the salts precipitation obtained at the thermodynamic modelling of the equilibrium freezing (a) and evaporation (b) of the hypothetical initial solution at different Mg/Ca ratio. c, d – the salts precipitation at the fractional freezing and evaporation respectively.

the thermodynamic modelling of the salt precipitation sequence also exclude the prevailing precipitation of the gypsum in the latest stage of the aqueous sedimentation responsible for formation of the layered deposits suite composing the upper part of the erosional remnant in the Juventae Chasma. It is most likely that the gypsum could to be precipitated in the lower suites of the layered deposits (at smaller amount) and in further the sulfate was re-covered by larger mass of the later deposited magnesium and iron sulfates.

References: [1]-Bibring J-P et al., (2005), Science 307, 1576-1581; [2]-Gendrin A. et al., (2005), Science 307, 1587-1591; [3]- Quantin et al., Workshop on sulfates on Mars, Houston, 2006; [4]-Forget F. et al., (1999), JGR, 104, E10/24155-24176, <http://www.mars.lmd.jussieu.fr/mars/>; [5]- Smith M.D. (2004) Icarus, 167, 148-165; [6]-Rodin A.V. et al. (2006), Kosm. Issled., 44, 4, 344-348; [7]-Wang A. et al., (2006), JGR, 111, E2, E02S17; [8] Marion, G. (2002), Geochim. Cosmochim. Acta, 66, 2499-2516. [9] Marion G.M et al., (2006), EOS Trans.Agu, 87(52), Fall Meet. Suppl.

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