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## SUB-SURFACE DEPOSITS OF HYDROUS SILICATES OR HYDRATED MAGNESIUM SULFATES AS HYDROGEN RESERVOIRS NEAR THE MARTIAN EQUATOR: PLAUSIBLE OR NOT?

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**Introduction:** Neutron maps obtained using the neutron spectrometer (NS) and the high-energy neutron detector aboard the Mars Odyssey spacecraft reveal variations in the concentration of hydrogen over the martian low to middle latitudes, with up to ~10 wt% water-equivalent hydrogen in some equatorial regions [1,2]. Infrared spectroscopic data provide evidence of chemically and/or physically bound H<sub>2</sub>O and/or OH [3]. Likewise, the decrease in flux of epithermal neutrons in Arabia Terra and southwest of Olympus Mons has been attributed to enhanced concentration of water-bearing minerals in the subsurface [2].

The near-surface martian regolith is expected to contain both unweathered and weathered materials. It may contain significant and heterogeneously distributed amounts of hydrous minerals, such as clays, zeolites, and/or salt hydrates, such as MgSO<sub>4</sub>·nH<sub>2</sub>O. Experimental studies suggest that if such water-bearing minerals formed in the past on the martian surface, they may retain significant amounts of water under present martian surface conditions. Hydrous minerals could thus account for some or all of the water observed in the martian regolith by Odyssey [4,5,6].

Our study uses surface P-T data to predict regions of stability and the hydration state of selected water-bearing minerals from low to middle latitudes and to identify the nature and amount of hydrous minerals that could possibly account for the water observed by NS.

**Methods and Results:** A 2x2-degree grid of yearly mean temperatures and H<sub>2</sub>O pressures at the martian surface was obtained by a standard thermal model of the martian surface using albedo and thermal inertia data [7,8]. Thermodynamic data were used to calculate the hydration states of four zeolites (Ca-chabazite, Ca-, Na- and K-clinoptilolite) [5,9] and two smectites (Na- and Ca-montmorillonite) [4] and the stability of epsomite (MgSO<sub>4</sub>·7H<sub>2</sub>O) and kieserite (MgSO<sub>4</sub>·1H<sub>2</sub>O) [10] at each 2x2 degree cell.

For each surface P-T datum, bounding calculations of the water-bearing mineral abundances were performed by estimating the abundance necessary to account for the subsurface water observed by [1] (Figure 1a), if each mineral alone were the sole contributor. Results in Figure 1b were obtained by dividing the observed water content (Figure 1a) by the calculated amount of water in the mineral. Figure 1b indicates that to be the sole contributor of observed subsurface wa-

ter, Ca-smectite would have to be unrealistically abundant in the martian soil, in some places as much as 70 wt%. However, more realistic abundances of Ca-smectite (e.g. 5 wt%) could still provide a significant contribution to overall water content.

Figure 2 shows the same calculation, in a longitudinal slice through Figure 1b, in which Ca-smectite is compared with Na-smectite and with zeolites. At this longitude H<sub>2</sub>O reaches a maximum of ~10 wt% at ~10° latitude (Figures 1a, 2). Figure 2 indicates that required abundances of each hydrous silicate differ greatly depending on mineralogy. At the peak H<sub>2</sub>O abundance along this longitude, a martian soil containing 45 wt% chabazite would explain the H<sub>2</sub>O while more than 80 wt% Na-smectite or K-clinoptilolite would be required.

Figure 3 shows a similar calculation for seven- and one-hydrate Mg-sulfates at the same longitude. The large increase in required wt% of MgSO<sub>4</sub>·nH<sub>2</sub>O near the equator corresponds to a calculated change in stability between epsomite and kieserite [10]. Figure 3 shows poor correlation between the stability fields of epsomite and kieserite compared with variations in H<sub>2</sub>O wt%. Radical changes in the Mg-sulfate abundance across narrow geographic regions would be needed to account for the NS observations. This is doubtful and suggests that Mg-sulfates are unlikely to be the sole contributors to the observed subsurface water distribution if kieserite is indeed the only stable Mg-sulfate in equatorial regions [10].

Our analysis indicates that large surface deposits of a single hydrous mineral are unlikely to account for the most H<sub>2</sub>O rich martian equatorial regolith. However, martian soils containing a mixture of different hydrous minerals may account for the observed H<sub>2</sub>O abundances within most of the low to middle latitudes.

**References:** [1] Feldman W.C. et al. (in press) *JGR*. [2] Basilevsky A.T. (2003) *Sol. Syst. Res.* 37, 387-396. [3] Soderblom L.A. (1992) in Kieffer H.H. et al., Eds, *Univ of Arizona Press, Tucson*, pp 557-593. [4] Bish D.L. et al. (2003) *Icarus* 164, 96-103. [5] Fialips C.I. et al. (2003) *Eos Trans. AGU*, 84(46), Fall Meet. Suppl., Abst. P22A-0059. [6] Vaniman D.T. et al. (2003) *Eos Trans. AGU*, 84(46), Fall Meet. Suppl., Abst. P22A-0060. [7] Mellon M.T. et al. (2000) *Icarus* 148, 437-455. [8] Mellon M.T. et al. (in press) *Icarus*. [9] Carey J.W. and Bish D.L. (1996) *Amer. Miner.* 81, 952-962. [10] Chou I.M. and Seal R.R., II (2003) *Astrobio* 3, 619-630.

Figure 1: a) Map of estimated water-equivalent hydrogen distribution on the surface of Mars published by [1]. Polygons delimit areas with  $H_2O > 6$  wt%. b) Distribution of Ca-smectite abundance (in wt%) required in the martian regolith to account for the observed subsurface water. Regions in black have more  $H_2O$  than can be explained by Ca-smectite but coincide with regions of water-ice stability.

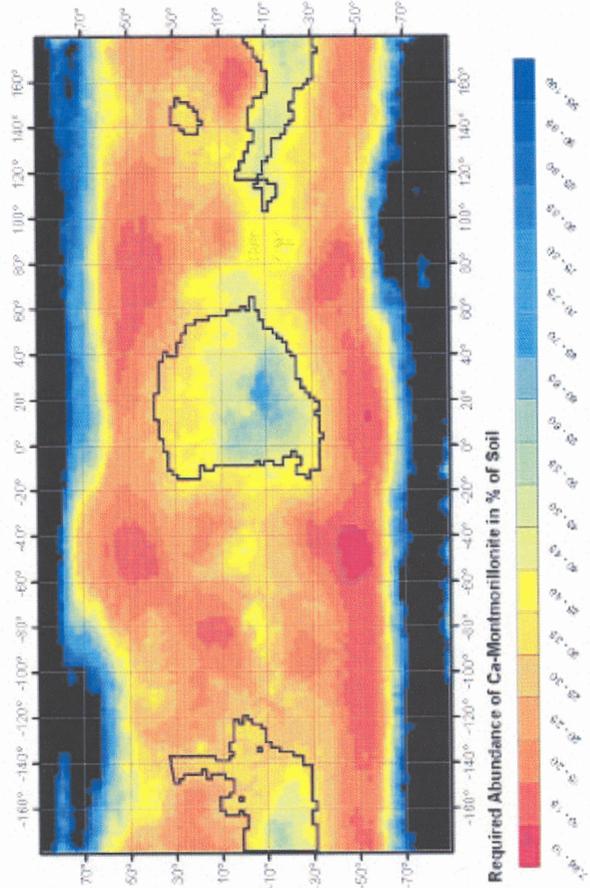
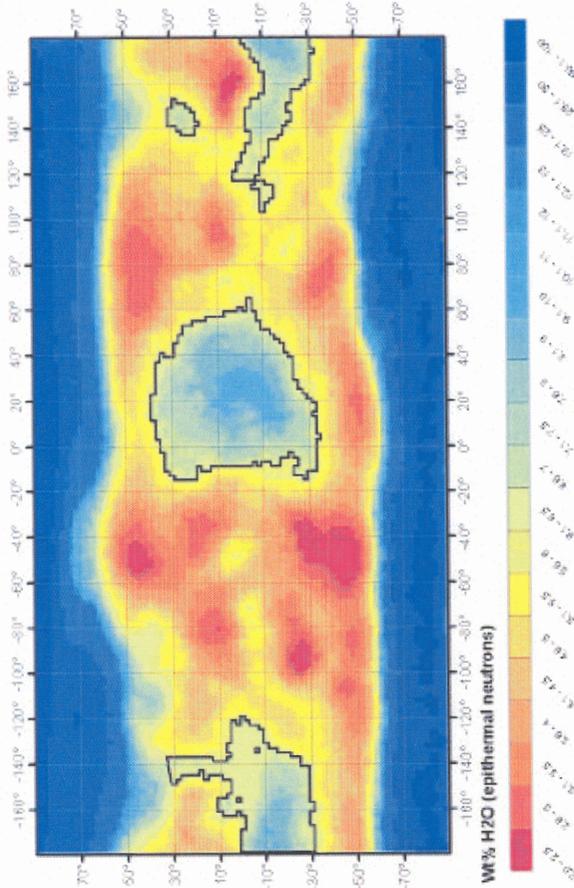


Figure 2: Abundance of individual hydrous silicates required in the martian regolith to account for all of the  $H_2O$  observed at 21-23° longitude and -50 to +50° latitude.

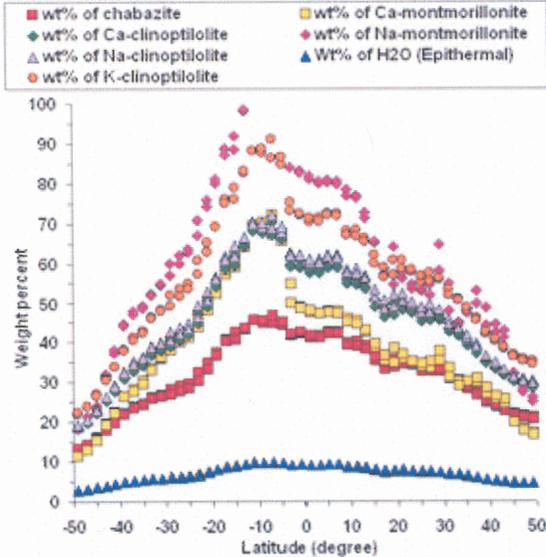


Figure 3: Abundance of epsomite (7-hydrate, 51 wt%  $H_2O$ ) and kieserite (1-hydrate, 13 wt%  $H_2O$ ) required in the martian regolith to account for all  $H_2O$  observed at 21-23° longitude and -50 to +50° latitude. Hexahydrate (47 wt%  $H_2O$ ) is assumed to be unstable [10].

