ENHANCED WATER-EQUIVALENT HYDROGEN ON THE WESTERN FLANKS OF THE THARSIS MONTES AND OLYMPUS MONS: REMNANT SUBSURFACE ICE OR HYDRATE MINERALS?.

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Introduction: Mars Odyssey gamma ray and neutron spectrometer (NS) observations have revealed surprisingly high water-equivalent hydrogen abundances at the equatorial and mid-latitudes of Mars [1]. Studies indicate that at these latitudes water ice should not be stable at the depths to which the spectrometers are sensitive (< 1 m) [2,3]. Consequently these 'water' enhancements are a puzzle: do they represent stable, hydrated minerals or regions where special soil and stratigraphic conditions permit remnant shallow water ice deposits? Here we focus on the 'water' enhancements on the west slopes of the Tharsis Montes, Olympus Mons and Alba Patera, where landforms to the west and northwest suggest the possible presence of cold-based mountain glaciers [4,5]. We investigate the possibility that significant snow/ice deposits could have formed in these locations during periods of high obliquity within the last 500 kyr [6], and that present-day remnant water may be locked up in stable hydrate minerals or (less likely) shallowly buried ice in glacial and periglacial landforms.

Neutron Spectrometer Observations: Measurements of the epithermal neutron leakage flux out of the martian surface and atmosphere have been analyzed and a water-equivalent hydrogen (WEH) map (assumed to be homogeneously mixed with dry soil throughout the depth of sensitivity) has been derived [1]. Figure 1 shows this quantity for the Tharsis region, superposed on a MOLA shaded relief map. In this region, WEH ranges between 2 and 8 wt%. Of particular interest is the fact that the western slopes of Olympus Mons, the Tharsis Montes, and Alba Patera have higher WEH abundance than the eastern slopes. Also shown here for interest are the enhanced WEH abundances centered on Noctis Labyrinthus and western Valles Marineris.

The Mars Odyssey NS footprint is ~600 km wide, or about 10° of arc on the surface. This 'point-spread-function' smears out features that are smaller than the footprint, including possible water-bearing deposits associated with particular landforms. So we should not expect to see enhanced WEH localized over geologic features that are too small to resolve. Instead, we may see a smeared-out regional high.

Geology: The Tharsis Montes edifices consist principally of lava flows and ash deposits (as well as eolian mantle) [7], but there are distinctive units to the west and northwest of the three major volcanoes that have an alternative interpretation. In particular, the fan-shaped deposit to the west of Arsia Mons has been interpreted to be of glacial origin in part or in whole [4,8,9]. An outer facies with parallel ridges is linked to drop moraines of episodically retreating cold-based glaciers, while the next innermost facies consisting of knobby terrain is thought to consist of sublimation till from the same glaciers. Finally the innermost facies consists of generally smoother terrain with lobate shapes and ridges that resemble rock glaciers [4,5,7]. Similar landforms can be found on the western and northwestern slopes of Pavonis and Ascraeus Montes [7,9], as well as along the western flank of the Olympus Mons escarpment [11]. Figure 2 highlights in bright green the units that may be associated with glacial processes and subsurface ice. Note that the 'glacial' unit on NW Ascraeus Mons is considerably smaller than those of the other Tharsis Montes, and WEH appears to be lower there as well. This could be a footprint effect in the NS.

Global Climate Modeling: The western slopes of the Tharsis volcanoes have clearly higher WEH than the eastern slopes. Global climate models have shown that at periods of high obliquity, the polar regions lose some of their ground ice due to increased insolation and warming [6]. This water re-accumulates at mid- and low-latitudes, especially at higher elevations on the windward slopes. Here we examine the predictions of the Geophysical Fluid Dynamics Lab Mars GCM, which can vary obliquity, eccentricity, and rock and soil parameters to predict the removal, transport and deposition of volatiles across Mars' surface. Figure 3 shows a map of regolith total ice abundance (in relative values) for 25° obliquity superposed on MOLA shaded relief. In this case the model regolith was previously initialized with a superabundance (60 kg/m^3) of ice which at 25° obliquity is slowly subliming. Here the thermal inertia of the soil is adjusted for the presence of the ice. High residual ice abundances are clearly seen west of the volcanoes, hinting that the Odyssey NS data may be seeing a signature related to this evolution. An important exception is at Ascraeus Mons, where WEH is not elevated as highly as the residual ice in the GCM simulation.

Discussion: Both geologic evidence and GCM calculations point to past epochs of increased water ice deposition on the western flanks of the Tharsis Montes, and Olympus Mons. GCM simulations also suggest these same areas preferentially retain ice longer than other nearby locales. Taken together, these results suggest that enhanced surface and regolith ice accumulations on the windward slopes of the volcanoes during earlier periods of high obliquity led to either remnant ice deposits or stable hydrated minerals in the soils whose hydrogen can still be sensed today.

Enhanced WEH is also found elsewhere in the region, for example, to the west and southwest of Arsia Mons. This is an area of high ice accumulation during very high obliquity (45°), according to the GCM.

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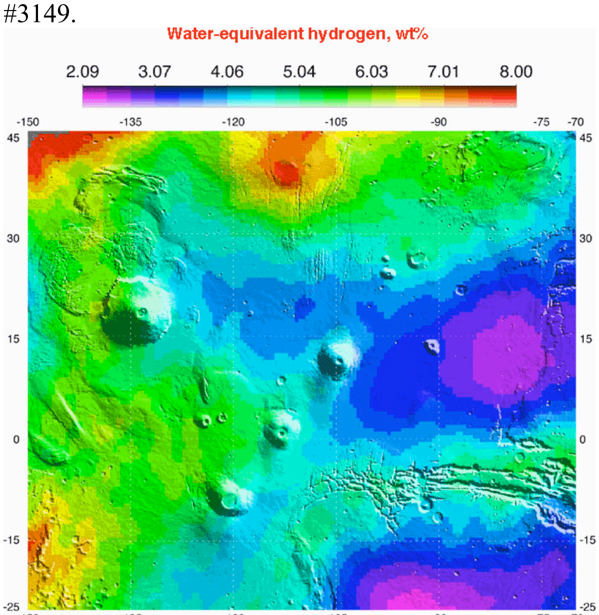

Fig. 1. Mars Odyssey neutron spectrometer derived water-equivalent hydrogen abundance in wt% for the central Tharsis region.

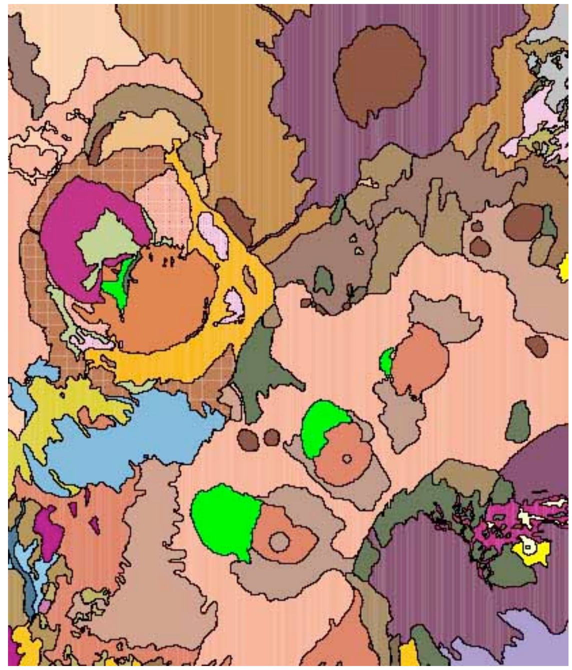

Fig. 2. Geologic units mapped in [7]. Bright green denotes units containing landforms that may be of glacial origin.

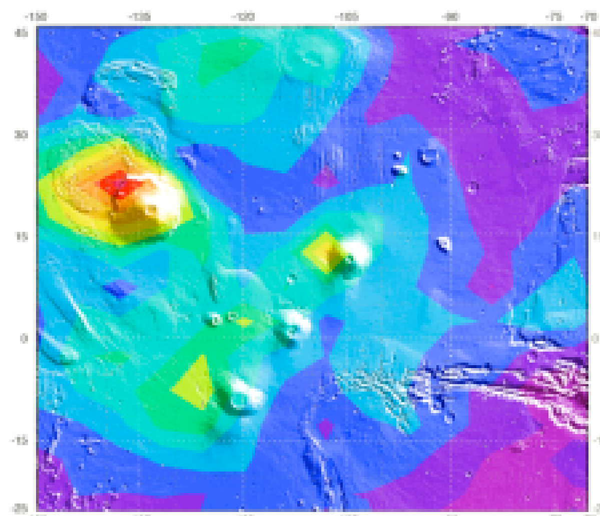

Fig. 3. GFDL Mars GCM regolith total ice abundance (relative) for 25° obliquity. Note the correspondence to WEH.