MARS EXPRESS HRSC VIEW OF WESTERN OLYMPUS MONS: EVIDENCE FOR ICE-BEARING DEPOSIT AND HIGH-ALTITUDE GLACIATION.

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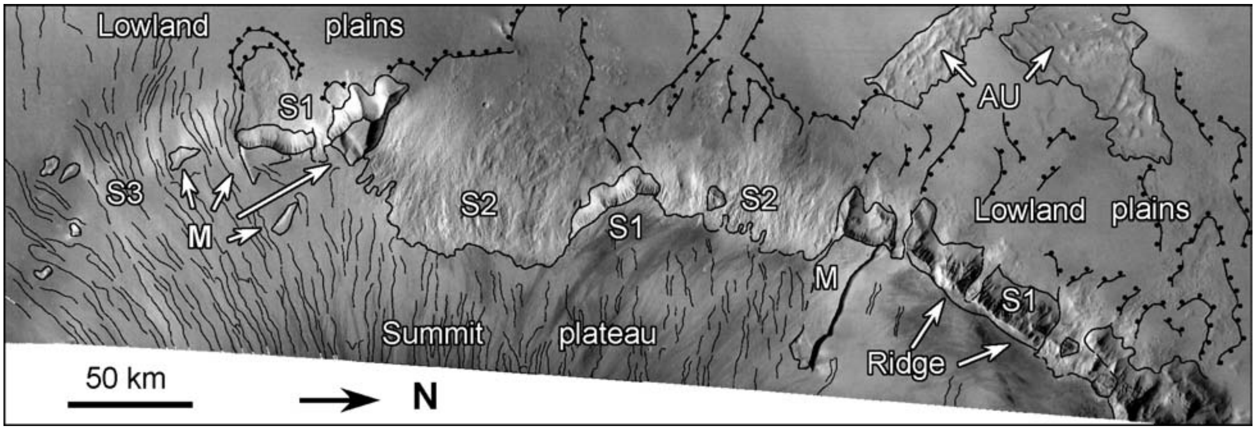

Figure 1. The study area. Black thin lines designate prominent lava flows. Thicker dotted lines designate glacial-type flows. M - mesas.

Introduction: This study is based on the geological analysis of the HRSC images taken on the orbit 0143 (12 m/px in nadir channel). The study area includes the western segment of Olympus Mons and the adjacent lowland plains (Fig. 1). Part of the volcano above the scarp is rather flat and is called "summit plateau" below. What is often called the volcano scarp is a slope classified into three morphologic types: Type 1 (S1 in Fig.1) is the steepest and dominated by ravines in its upper part and by talus beneath; Type 2 (S2) is intermediate in steepness and dominated by downslope trending linear depressions, part of which have channel-like morphology; and Type 3 (S3), is the most gentle and covered by lava flows, continuing from the summit plateau down to the lowland plains (Fig. 1).

Observations. In this paper we emphasize our new findings for the western Olympus Mons and only briefly mention those things, which are well known from the earlier works: the volcanic nature of the construct [3, 5] and the presence of the glacier-type flows at the foot of the western slope [10, 13]. In the area studied, prominent lava flows dominate in the southern and central parts of the summit plateau, on the Type 3 slope and at the adjacent part of the plains. Crater counts show ages of the lava flow fields varying from 100-200 m.y. at the summit plateau to 25 m.y. at the Type 3 slope and even to 2 m.y. at the Type 3 slope foot [15]. The glacier-type flows are seen at the foot of slopes of Type 1 and Type 2. Their HRSC-based analysis is given in [7]. Crater ages of different flows vary from 280 to ~50 m.y. with one flow being as young as 4 m.y. Our new findings deal with features, which we interpret as evidence of the presence of ice-bearing deposit composing part of the Olympus Mons construct and evidence of the high-altitude glaciations in the geologic past.

The ice-bearing deposits are seen along the western edge of the summit plateau composing several mesas standing above the adjacent lava fields (M's in Fig. 1). In their steep slopes, numerous thin (a few meters from the MOC image analysis) horizontal layers are seen. The layered sequence is traced downslope to the altitude level by 100's m to 1 km below the mesa summit. On the summit surface of one of the mesas there is a 1.4 x 1.8 km steep-sloped pit whose morphology favors its collapse origin (Fig. 2). In the center of the eastern boundary of this mesa, where the adjacent lava field stands above the mesa surface, lavas flowing upon the mesa summit and surface there came to be hummocky as in the cases described by [8, 16] when lavas flowed upon the material rich in water ice. Crater counts show that the age of mesas is close to 3 b.y. [15].

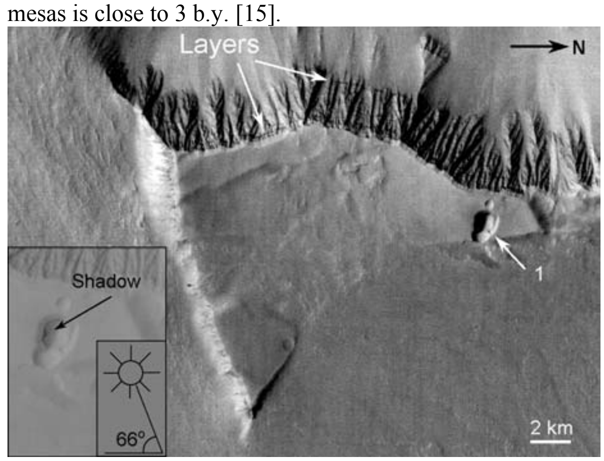

Figure 2. Mesa with steep-slope (>66°) collapse pit (1) and hummocky terrain where lavas flowed on the mesa.

Neighboring to mesas there are segments of Type 2 slopes with numerous downslope trending linear depressions on them (Fig. 3). In the upper parts of these slopes, are seen outcrops of layered material. These outcrops are at the same altitude level as the layered material seen in the upper parts of the mesa slopes so they obviously represent the same material unit. In association with these layered outcrops are seen irregular depressions morphologically very similar (although smaller in size) to chaos which are thought to be sources for typical catastrophic flood valleys of Mars [1, 2]. Here are also seen downslope trending channel-like depressions and chains of rimless pits.

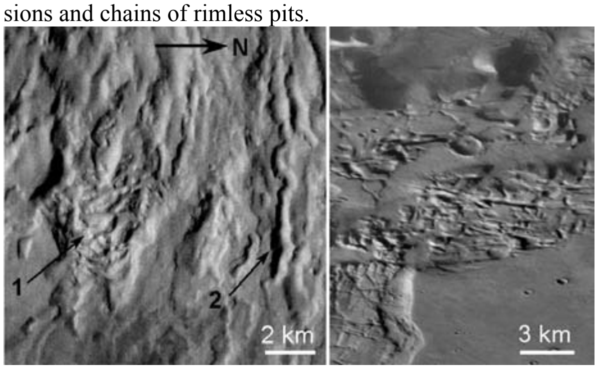

Figure 3. Left: chaos (1) and channels (2) at rhe Olympus Type 2 slope; right: chaos of the source area of Dao Vallis, NE of Hellas.

These observations suggest that the layered material seen in the mesa walls and in the upper parts of the Type 2 slopes is an airborne deposit consisting of debris (dust and or ash) and water ice. Melting of the latter, for example, at the places of dike intrusions and surface lava flows, could result in local collapses (pit on mesa and chaoses) and fluvial erosion (channels) [17].

In the northern part of the study area, the summit plateau is rimmed at its west boundary by a ridge standing several hundred meters above the adjacent surface of the plateau. It is seen on the HRSC and MOC images that the ridge is also composed of the fine-layered deposits described above. The HRSC-based color anaglyph shows that the western slope of the ridge is dissected with downslope-trending valleys going down to the lowland plains (Fig. 4). In a few cases, the valleys even cut back into the summit plateau. The valleys have roughly U-shaped cross profile and end up at the scarp foot with hummocky piles. We interpret the valleys as being ploughed by glaciers and the downslope hummocky piles as debris-covered remnants of piedmont glaciers. If so, the source areas of the valley-cutting glaciers should be high on the summit plateau (above +7-8 km of today's topography).

The suggestion that ice deposit was present at such a high altitude is supported by observation that on the summit plateau, in the potential source area of one of these valleys, a lobate landform resembling a glacier is seen (Fig. 4, inset). Its orientation suggests glacier movement to the east, towards the volcano center. The age of this landform now covered by dust, as almost all other landforms of its vicinity, is estimated to be 200-300 m.y. [15]. We see evidence of sublimation or eolian degradation noticeably erasing the cratering record, thus implying that the lobate landform was not active in the geologically recent time.

On the top surfaces of mesas and the ridge, the bright material unit of a few tens meter thick is seen. The HRSC and MOC images show that when this unit is observed at the scarp edge, the slope within it is significantly less steep then the slope beneath (Fig. 2), giving an impression that this material is relatively “soft”. It was suggested by [15], that this layer may contain significant amounts of H_2O ice. This suggestion is supported by the MGS Neutron Spectrometer

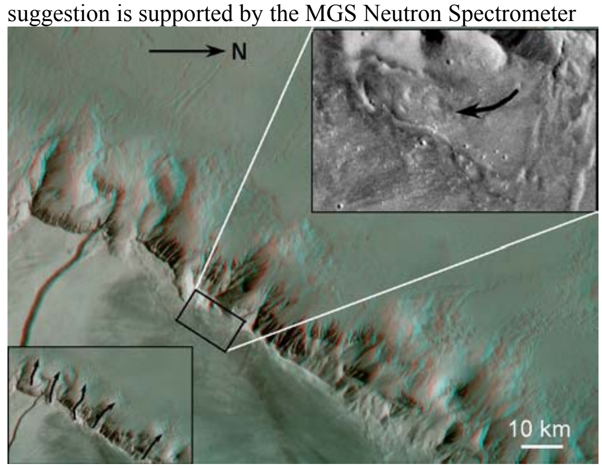

Figure 3. Color anaglyph: Type 3 slope in the study area north with glacier-type valleys (arrows) and the glacier-type flow (inset).

data which show that the surface layer within the western Olympus contains hydrogen in amounts equivalent to 5-6 mass % of water [4] that corresponds to 15-18 volume % of water ice. If one considers that a significant part of the area is covered with lava flows probably not rich in water ice, then this suggests that the NS signature of H_2O is due to the “soft” unit; it is then logical to conclude that the latter may contain much more ice than the estimated 15-18 volume %.

Discussion and conclusions. The analysis of the HRSC images and other data for the western Olympus Mons provides evidence of the presence of an ice-bearing deposit composing part of the Olympus Mons construct as well as evidence of the high-altitude (above the scarp) glaciations in the geologic past. The possibility of deposition of water ice from the atmosphere high on Olympus Mons in current Mars surface conditions is demonstrated by modelling of [12]. Effective deposition of water ice on the western Olympus Mons at epochs of high (45^o) obliquity is demonstrated by modelling of [14]. So our conclusions on the presence of water ice both in the surface "soft" layer and in the layered deposits of the western Olympus appear theoretically plausible. The presence of water ice in the body of the volcano is important for the origin of the Olympus aureole by the mechanism of gravitational sliding (see e.g., 9, 11, 18].

References: [1] Baker V.R. (1982) *The channels of Mars*. Austin Univ. of Texas. [2] Baker V.R. et al. (1992) In: *Mars*, Kiefer H.H. et al., eds. Univ. Arizona Press,. 493. [3] Carr M.H. (1973) *JGR*. 78. 4049. [4] Feldman W.C. et al. (2004) *LPSC XXXV*, #2035. [5] Greeley R., Spudis P.D. (1981) *Rev. Geophys. Space Phys*. 19. 13. [6] Harris S.A. (1977) *JGR*. 82. 3099. [7] Head J.W. et al. (2004) *Nature*. [8] Ivanov M.A., Head J.W. *JGR* (2003) 108. doi 10.1029/2002JE001994. [9] Lopes R., et al. (1982) *JGR*. 87. 9917. [10] Lucchitta B.K. (1981) *Icarus*. 45. 264. [11] McGovern P. et al. (2004) *JGR*. 109. E8. Doi 1029/2004JE002259. [12] Michaels T. et al. (2004) *36th DPS meeting*. Abs 37.16. [13] Milkovich S.M., Head J.W. (2003) *6th Internat. Mars Conference*. #3149. [14] Mishna M. et al. (2004) *LPSC XXXV*. #1861. [15] Neukum G. et al. (2004) *Nature*. 432.. [16] Squyres S.W., et al. (1987) *Icarus*. 70. [17] Head, J. and Wilson, L. (2002) *Geol. Soc. SP 202*, 27. [18] Tanaka K. (1985) *Icarus*. 62. 191.

Acknowledgements: Authors acknowledge support of German DFG and DLR agencies and the US NASA as well.