FLANK TERRACE ARCHITECTURE OF MARTIAN SHIELD VOLCANOES. P. K. Byrne[1], J. B. Murray[2], B. van Wyk de Vries[3], and V. R. Troll[1], [1]Department. of Geology, Trinity College Dublin, Ireland, (byrnepk@tcd.ie), [2]Department of Earth Sciences, The Open University, Walton Hall, Milton Keynes, England, MK7 6AA, [3]Laboratoire Magmas et Volcans, Université Blaise Pascal, Clermont-Ferrand, France.

Introduction: Olympus Mons and the Tharsis Montes volcanoes display a variety of tectonic features. These include large bulge-like structures on their flanks, previously referred to as "terraces", e.g. [1, 2]. Terraces are regarded as compressive structures (based on their profiles), formed by either a.) compressional failure of the volcano [2]; b.) flexure of the underlying lithosphere in response to the load [3]; c.) (cyclic) magma chamber inflation and deflation [3]; or d.) shallow gravitational collapse slumps [4, 5]. No consensus as to their mechanism(s) of formation exists, however. We use MOLA data to comprehensively describe terrace architecture, in an attempt to aid in the determination of terrace formation mechanism(s).

Observations: Terraces are visible on Olympus Mons and all three Tharsis Montes, and can be seen at all elevations, from the summit to the volcanic plains (e.g. Ascraeus Mons), or to the top of the basal scarp on Olympus Mons; they are not limited to the upper flanks as previously reported [2, 6]. Terraces are more prominent on volcanoes with nested caldera complexes (Olympus and Ascraeus), than those without (Arsia and Pavonis). Additionally, we suggest that faint terraces are also visible on the flanks of Elysium Mons, and the NE flank of Hecates Tholus.

MOLA profiles show that terrace morphology on all volcanoes is characterized by a broad, convex form, with a flat upper surface whose slope increases towards the terrace base. In plan, terraces are arcuate structures, and are generally not laterally continuous. They are configured in an overlapping manner, wherein the anterior portion of a terrace is superposed upon the posterior area of the topographically lower, adjoining terrace. This arrangement produces an imbricate pattern around the volcano. Terraces can be up to 100 km in circumferential length, 30 km in radial length, and 3km in height, depending on the edifice.

Terrace distribution on the volcanoes can be summarized as follows:

Olympus Mons: 1) broadly circumferential distribution; 2) no predominate elongation or size; 3) slightly greater concentration of terraces on the E and SE flanks; 4) terrace basal slopes greatest on the SE flank; 5) terraces quite prominent on this volcano.

Ascraeus Mons: 1) greatest circumferential lengths for the NW and SE terraces; 2) longer terraces preferentially elongated along a SW-NE trend; 3) terrace slopes steepest on the NW and SE flanks; 4) most prominent terraces of all studied volcanoes (**Fig. 1**).

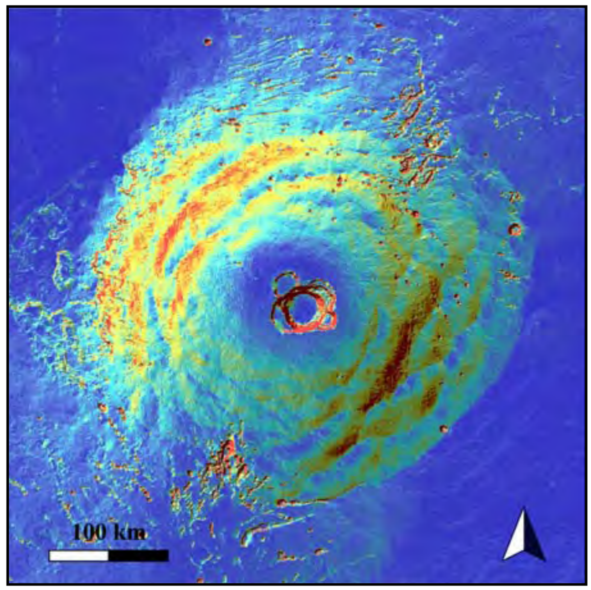

Fig. 1 Composite slope and hillshade map of Ascraeus Mons (based on the 128 ppd USGS gridded dataset). NW and SE flank terraces are elongated and orientated SW-NE. Terraces are visible at all elevations on the flanks. Slope increases from blue to red. Centre of image: 11°09' N, 104°23' E.

Pavonis Mons: 1) most uniform terrace distribution, slope, and size of the Tharsis Montes; 2) no obvious preferential terrace elongation; 3) average terrace size, relative to edifice surface area, is smaller than the other Tharsis volcanoes.

Arsia Mons: 1) terraces generally smaller than those on Olympus or Ascraeus Montes; 2) single, very large terrace on the SE flank of the edifice, trending SW-NE; 3) terraces obscured on the W and NW flanks by mass wasting [1].

Elysium Mons: 1) similar to Pavonis Mons; 2) no pronounced terrace elongation in any orientation; 3) terrace sizes generally consistent across the edifice; 4) basal slopes slightly steeper towards the base (**Fig. 2**).

Hecates Tholus: 1) only has terraces between middle flanks and the base; 2) distribution is similar to that of Pavonis and Elysium Montes.

Discussion: Since terraces are generally expressed at all elevations on the volcanoes, the stresses responsible for their formation are likely to be present throughout the edifice. Their presence on volcanoes other than giant Tharsis shields has implications for the tectonic development of all volcanoes above a certain scale on Mars. Moreover, whatever the mechanism(s) of formation, it must occur at a relatively late stage in the volcano's life, or occur repeatedly, to account for the terraces not being totally obscured by later volcanism.

The SE flank of Olympus is its steepest flank, possibly due to high basal friction or buttressing by the Tharsis Rise [7]. The NW and SE flanks of Ascraeus Mons are also steeper than the SW and NE flanks. The best-expressed terraces – those with the steepest basal slopes – lie on these same flanks, suggesting a link between flank slope and terrace expression.

Olympus and Ascraeus Montes are also the only volcanoes to have nested caldera complexes – eight for Ascraeus [8], and six for Olympus [9]. Cyclic magma chamber inflation and relaxation may therefore reactivate terrace-bounding faults, preventing terraces from being totally obscured by successive lava flows. If terraces are related to cyclic chamber tumescence, they may not be late stage, since the calderas have likely been active for much of the volcanoes' lifetimes [8]. It is therefore possible that these features began to form early on in the volcanoes' histories.

As there are no apparent crustal structures beneath Olympus Mons, its circumferential terrace architecture may be due solely to stresses within the edifice. Inherent volcanic stresses may also account for the circumferential distribution of the Elysium Mons and Hecates Tholus terraces. The elongated terraces on the NW and SE flanks of Arsia and Ascraeus Montes imply a tectonic influence beyond that of intrinsic stresses, however. The SW-NE terrace orientations suggest an effect of the possible rift underlying the Tharsis Montes, whose orientation is also SW-NE [1]. Pavonis Mons lacks any pronounced elongation of terraces on its flanks, and so may not be susceptible to regional stresses in the same manner as Arsia and Ascraeus Montes.

Conclusions: This is an ongoing study, but our preliminary conclusions can be summarized as follows:

1) the mechanism of terrace formation is not limited to the Tharsis shield volcanoes on Mars; **2**) the formation process must continue into a late stage in the volcanoes' development, to account for the terraces being visible today; **3**) the slope of volcanic flanks may influence terrace expression; **4**) the most prominent terraces are found on volcanoes with nested caldera complexes; **5**) in the absence of stress fields extrinsic to the edifice, terraces may be manifested in a generally circumferential pattern; and **6**) terrace elongation may be the result of the superposition of edifice- and regional-scale stresses, changing a near-circumferential terrace distribution to an ellipsoidal one.

References: [1] Carr, M. H. et al. (1977) JGR, 82, 3,985-4,015. [2] Thomas, P. J. et al. (1990) JGR, 95, 14,345-14,355. [3] McGovern, P. J. & Solomon, S. C. (1993) JGR, 98, 23,553-23,579. [4] Cipa, A. et al. (1996) l'Acad. Sci. Paris, II, 322, 369-376. [5] Morgan, J. K. & McGovern, P. J. (2005) JGR, 110, doi10.1029/2004JB003252. [6] Montési, L. G. (2001) Geol. Soc. Spec. Pap., 352, 165-182. [7] McGovern, P. J. & Morgan, J. K. (2005) LPS XXXVI, Abstract #2258. [8] Scott, E. D. & Wilson, L. (2000) J. Geol. Soc. Lond., 157, 1101-1106. [9] Zuber, M. T. & Mouginis-Mark, P. J. (1992) JGR, 97, 18,295-18,307.

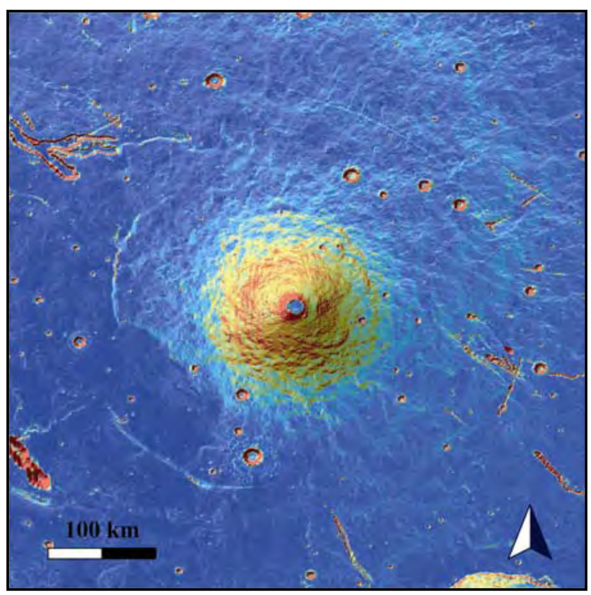

Fig. 2 Composite slope and hillshade map of Elysium Mons (based on the 128 ppd USGS gridded dataset). Whilst less prominent than those on Ascraeus, the Elysium terraces are still visible in a circumferential distribution around the cone. Slope increases from blue to red. Centre of image: 24°40' N, 146°44' E.