LATE-STAGE INTRUSIVE ACTIVITY AT OLYMPUS AND ASCRAEUS MONTES, MARS.
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Introduction: We have mapped the distribution of lava flows at the summit of Olympus Mons (OM), using Context Camera (CTX) [1] and High Resolution Imaging Science Experiment [2] images. 351 flows are located at the volcano summit (Fig. 1), of which 28 are truncated by the caldera rim. All flows are >10 km in length, and are recognized either by the lobate edges of individual flow lobes or by a continuous central lava channel. Surprisingly, many flows south of the caldera rim appear to have moved uphill (Fig. 2)!

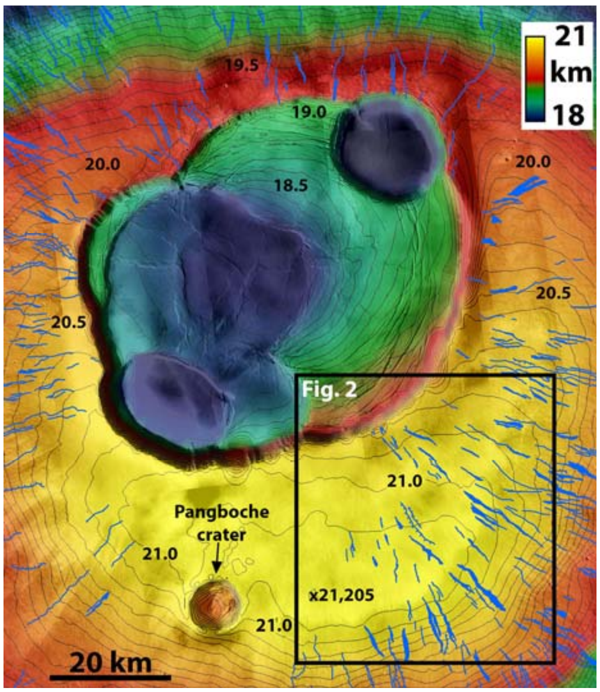

Fig. 1: Summit topography of Olympus Mons. Contours are in kilometers and the interval is 100 meters. Lava channels and lava flow lobes are blue lines, and are hachured where only the flow edge can be identified. The highest elevation (21,205 m) lies to the south of the rim. Note that the relative absence of flows south of the caldera rim may be due to partial burial by ejecta from young Pangboche crater, which post-dates caldera collapse [3]. Box denotes area shown in Fig. 2. Mosaic of multiple CTX frames.

Results comparable to those for OM have been found at the summit of Ascraeus Mons (AM), where 126 individual lava flows have been mapped (Fig. 3). No clear examples of vents can be identified for any of these flows, which supports the idea that the flows originated within a summit area since destroyed by caldera collapse [3-5]. Some flows at AM also appear to have flowed uphill.

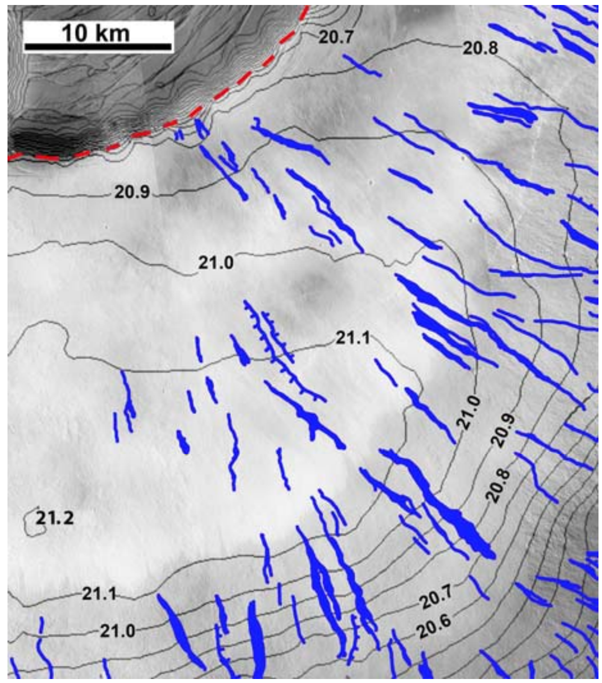

Fig. 2: Lava flows (solid blue, except where only margins can be identified and shown as hachured lines) on SE flank of Olympus Mons. Caldera rim is the dashed-red line. Contour interval is 100 m, heights are in km. See Fig. 1 for location.

Summit Deformation: The mismatch between flow direction and present day topography is greatest on the northern rim of the AM caldera, where truncated flows are evident [6, 7]. At AM, there appears to have been tilting of at least one of the paterae (not named) on the northern side of the caldera. This patera is proximal to the highest point on the volcano, and is >400 m higher on its northern floor than on its southern floor (Fig. 4). This appears to have been true tilting of the floor, rather than subsidence of the center of the patera, as the slope extends across the entire floor and is radial to the high-point.

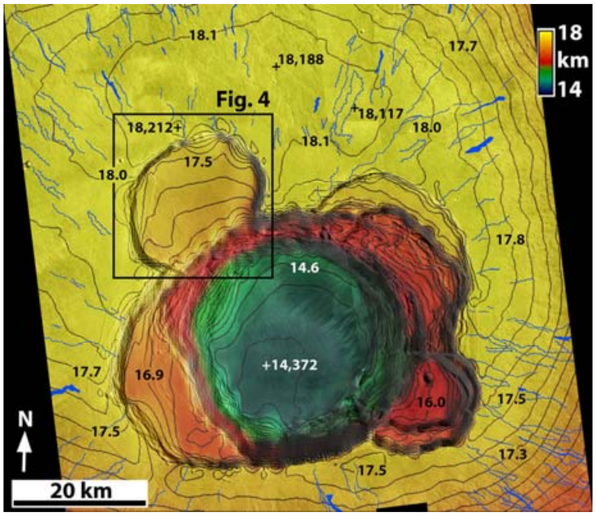

Fig. 3: Topography and distribution of mapped lava flows at the summit area of Ascraeus Mons. Note that the flows (hachured where only the flow edge can be identified) on the southern rim are perpendicular to the contours and go downhill, indicating no late-stage inflation here. The highest points are identified on the north rim. Box marks location of Fig. 4. Contour interval is 100 m. Base image is a mosaic of multiple CTX frames.

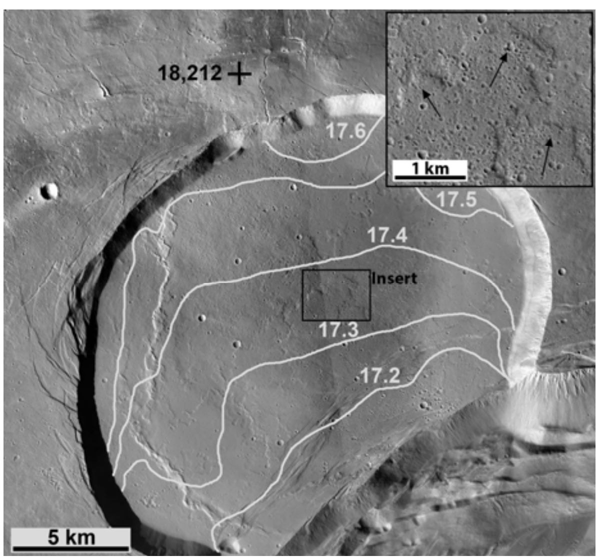

Fig. 4: Topography of the floor of the northwest patera at Ascraeus Mons, presumed to have formed as a flat surface which has subsequently been tilted downward towards the south by more than 400 m. Contours in km, see Fig. 3 for location. The highest point on the rim (18,212 m) is identified. Insert shows lava flow lobes which appear to have traveled up-slope (arrows show flow direction). Mosaic of CTX frames B06_012006_1912 and B07_012362_1912.

Our observations of OM and AM imply that sometimes igneous activity on Mars, in the form of summit inflation of some of the Tharsis volcanoes due to late-stage intrusions, continued closer to the present day than previously inferred from crater counting of the geological units on the caldera floors [8, 9]. One cause may be continued magma intrusion into a shallow magma chamber beneath the summit. Caldera formation would then have been initiated by the partial emptying of the chamber by radial dikes with volumes of a few 10^3 km^3. Such a conclusion is consistent with the idea that a giant dike from Arsia Mons initiated the outflow of water which formed Mangala Vallis [10], and that large dikes from Elysium Mons could have been responsible for the formation of Hrad Vallis [11].

Conclusions: It is proposed that the magma chambers within Olympus and Ascraeus Montes were fed with new magma from the mantle after the floors of the summit calderas were created, causing each chamber to inflate and up-dome parts of the volcano summit. The duration and/or the absolute timing of these inflation events cannot be resolved, but potentially collecting relative age dates (through detailed crater counting using high-resolution images) on the surface expressions of the radial dikes (specifically those interpreted to be associated with these volcanoes) might provide such information. Such analyses would be important for estimating the timing of this last phase of igneous activity, but await a future investigation.

References: [1] Malin, M. C. et al. (2007). *JGR* 112 (E5), doi: 10.1029/2006JE002808. [2] McEwen, A. S. et al. (2007). *JGR* 112 (E5), doi: 10.1029 /2005JE002605; [3] Mouginis-Mark, P. J. (2018). *Chemie der Erde*, 78, 397 - 431. [4] Mouginis-Mark, P. J. (1981). *PLPC. 12th*, 1431-1447. [5] Mouginis-Mark, P. J., Robinson, M. (1992). *Bull. Volcanol*. 54, 347 – 360. [6] Mouginis-Mark, P. J., Christensen, P. R. (2005). *JGR* 110 (E08), doi:10.1029 /2005JE002421. [7] Mouginis-Mark, P. J., Rowland, S. K. (2001). *Geomorphology* 37, 201–223. [8] Neukum, G. et al. (2004). *Nature* 432, 971 – 979. [9] Robbins, S. J. et al. (2011). *Icarus* 211, 1179 – 1203. [10] Wilson, L., Head, J. W. (2004). *GRL* 31 (15), doi:10.1029/2004GL020322. [11] Wilson, L., Mouginis-Mark, P. J., *JGR* 97 (E11), 18295 – 18307.