STRUCTURE AND EVOLUTION OF THE OLYMPUS MONS VOLCANIC EDIFICE AND BASAL ESCARPMENT, MARS. P. J. McGovern[1], J. K. Morgan[2], and M. A. Higbie[1]; [1]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston TX 77058, USA (mcgovern@lpi.usra.edu, higbie@lpi.usra.edu), [2]Department of Earth Science, Rice University, Houston, TX 77005, USA (morganj@rice.edu).

Introduction: The immense edifice of the Olympus Mons volcano on Mars is bounded by a basal escarpment with relief of up to 8 km. Based on recent topography and image data, we propose that the topography and structure of the edifice and scarp are the products of sustained volcanic spreading [1,2], causing the offscraping of debris that sloughs from the edifice over time. However, this process appears to have different manifestations in different sectors of the edifice. Here, topographic profiles of Olympus Mons [3] are compared to profiles generated by Distinct Element Method (DEM) models of volcanic spreading [4]. Our goal is to evaluate the relative contributions of spreading to the volcano's structure and to infer the spatially varying boundary conditions (i.e., high- or low-friction) at the base of the edifice.

Data: It has long been known that the Olympus Mons edifice is asymmetric with respect to the central caldera complex [5,6] that presumably indicates the location of the underlying mantle magma source. The asymmetry and other characteristics of the edifice can be quantified by plotting cross-sections of MOLA gridded topography [7] that radiate from this common magmatic center (Fig. 1). For example, the southeast (SE) azimuth profile (Fig. 1a, left) has steeper slopes and a shorter distance to the basal escarpment than the northwest (NW) part of the profile (Fig. 1a, right). However, both the SE and NW profiles are concave-upward between the caldera and the scarp (i.e., they show continually decreasing slope with increasing radius). The SE and NW profiles are also similar in that both contain a strongly expressed basal scarp signature. In contrast, the expression of the scarp in the northeast (NE) and southwest (SW) profiles is subdued (Fig. 1b) or even absent (Fig. 1c); thus, flank slopes generally don't exceed 10 degrees (Fig. 1b-c). Furthermore, the SW profile exhibits nearly constant mean slopes (4-6 degrees) out to the intersection of the flank with the surrounding plains.

THEMIS VIS images [e.g., 8] reveal structural details of the flanks of Olympus Mons. Much of the edifice is covered by long and narrow (presumably basaltic) lava flow units (e.g., Fig. 2). In the NE and SW quadrants of the Olympus Mons edifice, numerous long and thin lava flows drape and smooth over the remnants of old scarps in some areas; in others, the coalesced flows form a continuous low-slope flank all the way to the plains surrounding the edifice (see also Fig. 1c). In the NW and SE quadrants, steep rock faces are exposed in the scarp; over-scarp draping of lava flows tends to be restricted to narrow breakouts and ramps of moderate size (e.g., Fig. 2). In addition, the lower SW flank exhibits blocky protuberances that divert lava flows around them.

Models: Comparisons of Olympus Mons edifice and scarp topographic profiles to the shapes of DEM models of volcanic growth and spreading [4] can yield insights into the deep structure and frictional environment present at various sectors of the edifice. For example, NW flank profiles (e.g., Fig. 1a, right) exhibit a consistently concave-upward shape, as seen in two types of DEM models of volcanic piles: one with low friction across the entire base, and another with a cohesive central base but low-friction distal base [4]. In the latter case, high central friction keeps the central slopes high while distal flank slip reduces slope with increasing distance from the center. The greater lateral extent of the NW edifice with respect to those of the other quadrants is also consistent with a low-friction base. In contrast, moderate-to-high flank slopes are seen throughout the SE flank profiles (e.g., Fig. 1a, left), resembling models with moderate-to-high basal friction [4]. In particular, the presence of entrained blocks and back-tilting of layers seen at the SE flank (Fig. 2) suggest a strong reverse faulting environment at the SE scarp, consistent with the predictions of several DEM models with elevated friction at the basal margins [4]. Topographic profiles for the NE and SW quadrants show a near-constant moderate mid-flank slope and lower flank slopes that gently decline to near-zero values at the distal margin (Figs. 1b, 1c). DEM models with intermediate basal friction values and those with inner high-friction and distal low friction [4] are consistent with such profiles.

Discussion: The basal boundary condition of a volcanic edifice is a critical determinant of its structural evolution [4,9,10]. We have suggested [1] that a detachment beneath Olympus Mons is rooted in water-saturated sediments emplaced atop ancient lowlands basement. In this setting, sediment thickness will tend to decrease with increasing elevation above the plains, i.e., with increasing proximity to the proto-Tharsis Rise. Two effects from such a gradient in sediment thickness are predicted. First, a thinning sediment horizon will increase the strength of the detachment, such that the overlying flank sector (SE) will slip less effectively. Second, the roughness of the pre-sediment basement (induced by ancient heavy impact bombardment plus tectonism) will inhibit flank slip [11, 4]. For a given basement roughness, the effect will increase with decreasing sediment thickness (i.e., with increasing proximity to Tharsis). The combination of effects yields a NW-SE gradient in detachment strength.

The northwest-southeast gradient in basal friction at Olympus Mons proposed above yields successful predictions of the topography and slope characteristics for each quadrant of the volcano. We expect the flank quadrant closest to Tharsis (SE) to exhibit the highest friction on its detachment and the one farthest from Tharsis (NW) the lowest. This prediction is consistent with the absence of a flat (zero-slope) bench, the shorter lateral extent of the flank, and the presence of steeper slopes (Fig. 1a), as well as the greater incidence of entrained blocks in the southeast flank (Fig. 2). The high basal friction in the SE quadrant will also allow transmission of horizontally compressive flexural stress from the lithosphere into the edifice [9,10], accounting for the higher incidence of presumably compressive terraces southeast of summit. In contrast, the flat bench, shallow slopes, and long lateral extent of the northwest flank indicate a low-friction basal boundary condition, also concordant with the reduced friction predicted by the proposed gradient. Furthermore, topographic profiles of the intermediate flanks (northeast and southwest) are consistent with basal slip at moderate friction conditions (i.e., intermediate between those of the NW and SE flanks).

Azimuthal variations in basal sliding and the basal friction gradient will also have consequences for the stress state and tectonics of the Olympus Mons edifice. Circumferentially oriented principal extension from outward flank movement [9] is taken up by radial tear faults in the NW and SE quadrants [2]. Major tear faults are absent in the NE and SW quadrants; instead, mid-to-lower flank vents fed by radial dikes [8] produce numerous lava flows there. We suggest that the extension induced by preferential NW-oriented edifice spreading enhances NE-SW-oriented dike emplacement and surface eruptions in these quadrants.

The frequency and long radial extent of lava flows in the NE and SW quadrants [e.g., 12], and the concomitant absence of pristine sections of basal scarp, suggests that emplacement of lava flows has been the primary mechanism of edifice growth in these quadrants, at least in the most recent history of the volcano. Nonetheless, the buried paleoscarps indicate that volcanic spreading of the type seen in the NW and SE quadrants was active in the NE and SW ones at an earlier time, and the overall shape of topographic profiles is consistent with several scenarios of volcanic spreading, as described above. Furthermore, the presence of fresh graben (that cut the most recent lava flows) on the east flank (see the map of [12]) indicates an extensional stress state consistent with relatively recent edifice spreading.

References: [1] P. J. McGovern et al., *JGR, 107*, doi10.1029/ 2004JE002258, 2004; [2] A. Borgia et al., *JGR, 95*, 14,357, 1990; [3] P. J. McGovern and J. K. Morgan, LPS XXXVI, abstract 2258, 2005; [4] J. K. Morgan and P. J. McGovern, JGR, doi10.1029/2004JB003252, 2005; [5] R. M. Lopes et al., *JGR, 87*, 9917, 1982; [6] P. W. Francis and G. Wadge *JGR, 88*, 9333, 1983; [7] D. E. Smith et al., *JGR, 106*, 23,689, 2001; [8] P. J. Mouginis-Mark and P. R. Christensen, *JGR, 110*, doi:10.1029/2005JE002421, 2005; [9] P. J. McGovern and S. C. Solomon, *JGR, 98*, 23,553, 1993; [10] P. J. McGovern and S. C. Solomon, *JGR, 103*, 11,071, 1998; [11] P. J. McGovern, Ph.D. thesis, M.I.T., 339 pp., 1996; [12] E. C Morris and K. L. Tanaka, USGS map I-2327, 1994.

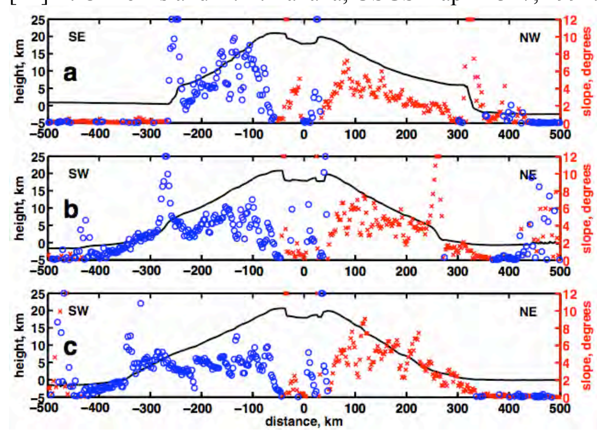

Figure 1. Topography [7] cross-sections and slopes for three profiles through the caldera of Olympus Mons. Half-profiles are defined by azimuth from the caldera center (the zero coordinate on the x-axis.) Left y-axis: black line denotes topography in km. V.E. approx. 7:1. Right y-axis: symbols denote magnitudes of rightward- (red 'x') and leftward-facing (blue circle) along-track slopes, averaged in 2.5-km-wide bins. Slopes with magnitudes greater than 12° are plotted at the 12° value. (a) SE-NW profile (azimuths 135° and 315°). (b) SW-NE profile (azimuths 240 and 60). (c) SW-NE profile (azimuths 225° and 45°).

Figure 2. A three-dimensional rendering of THEMIS VIS image mosaics of the Southeast flank and basal escarpment of Olympus Mons, overlain on MOLA topography. V.E. approx 50:1.