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The Influence of Lithospheric Flexure Upon the Structure of Olympus Mons

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Olympus Mons is the biggest volcano on Mars, towering 22 km above the NW flank of the Tharsis-Syria upland. Olympus has a characteristic morphology featuring a flat summit, convex upper flanks, concave lower flanks, and a basal escarpment. The summit hosts a six-caldera collapse complex. The upper flanks are terraced in a circumferential, imbricate pattern, whilst the lower flanks are covered in leveed lava channels and lava fans. The basal scarp surrounds much of the shield and reaches heights of 6 km in places. Beyond the escarpment lie aureole deposits, particularly prominent to the NW, downslope from the Tharsis Rise.

Although the caldera complex probably developed due to multi-cyclic recharge and evacuation of magma chambers within the edifice, the origin of the remaining features is contentious. Flank terraces have been ascribed to lithospheric flexure, magma chamber tumescence, or volcano spreading. The basal scarp has been linked to tectonic, eruptive, and mass movement processes. The aureole deposits are generally regarded as causally related to the escarpment, but they too have been attributed to a range of formation mechanisms. Previous attempts to explain the genesis of this suite of structures have primarily invoked lithospheric flexure or volcano spreading, but no holistic model yet exists.

Here we show that lithospheric flexure, with coeval slip along a basal décollement, is the leading candidate mechanism for the formation of the terraces, scarp, and aureole deposits of Olympus Mons. In a set of scaled analogue experiments, we loaded a ductile silicone putty "lithosphere" with a brittle sand cone "edifice"; a thin layer of putty below the cone served as a detachment surface. Flexure of the underlying silicone produced imbricate, outward-verging convexities on the cone's upper- and mid flanks, a concave-upward annular trough on its lower flanks, and a prominent scarp at its base. The convexities closely resembled the geometry of terraces on Olympus, and the scarp bore a structural similarity to the basal escarpment encircling the volcano.

We therefore propose that the distinctive features of Olympus Mons were generated as follows. Flexure-induced constriction of the volcano was accommodated on its mid- to upper flanks by distributed terracing, and at its base by flexural slip along a décollement; movement along this slip surface produced the basal scarp. Oversteepening of the escarpment led it to fail along localised listric normal faults, forming landslide deposits in an aureole about the volcano. These deposits probably helped fill the attendant flexural trough and obscure associated surface fractures. A detachment has long been suspected beneath Olympus, and may consist of incompetent material entrained within the edifice, e.g. (ice-rich) volcanoclastics, aeolian deposits, and argillaceous sediments. Beyond shaping this volcano, flexural slip might also have influenced the structure of other volcanoes, accounting for the smaller scarps at the NW bases of the nearby Arsia and Ascraeus Montes. This work complements our larger study of gravitational deformation of volcanic edifices on the terrestrial planets, also presented in this volume (Abstract EGU2011-658).