VOLCANOLOGY OF THE ELYSIUM VOLCANOES. J. B. Plescia, Applied Physics Laboratory, Johns Hopkins University, Laurel MD, jeffrey.plescia@jhuapl.edu.

Introduction: Elysium is the second largest volcanic region and includes the youngest volcanic surfaces on Mars [1]. It is characterized by a broad asymmetric topographic rise and three volcanoes: Elysium Mons, Albor Tholus and Hecates Tholus. While the Cerberus Plains have been the subject of considerable work [2], the volcanoes themselves have been little studied beyond a general overview of the region, comparing them to Tibesti, and studies of specific volcanic features and deposits [3]. The morphology and geology of the three volcanoes are discussed here and interpreted in terms of volcanic style and geologic history. Basic data for each volcano are listed in Table I [4].

Table I. Elysium Region Volcanoes

Volcano	Alt. km	Relief km	Slope	Volume m^3
Elysium Mons	14.1	12.6	7°	20×10^{13}
Albor Tholus	4.1	4.2	5°	2.9×10^{13}
Hecates Tholus	4.8	6.6	6°	6.7×10^{13}

Elysium Mons: Elysium Mons is the largest volcano with a summit elevation of >14 km. It has a well-defined construct; however, it's margins are poorly defined as lavas and other deposits extend a considerable distance down the regional topographic high. The caldera is 14.6 km in diameter; its western margin is marked by a scarp 400-500 m high whereas the eastern margin is defined by a slope break. The western margin is a normal fault. On the eastern side, lavas that filled the caldera overtopped its edge and flowed downslope. Several rille systems radiate from the caldera to the north, west and southwest. Most rilles are perched suggesting activity when the caldera floor was higher.

The flanks have lava flows of variable morphology and size as well as pits and rilles. Tube-fed flows are extensive, forming linear ridges with extrusive build-ups and pits. Surface flows with lobate margins are typical of the lower elevations but are rare near the summit. Rilles are more extensive on the western than the eastern flank, forming long, complex distribution systems. The present caldera geometry indicates that lavas on the western flank were erupted from a higher, possibly smaller, caldera. Lavas filling the present caldera would simply flow down the eastern and southeastern flank.

Tectonic deformation is limited. Graben are typically simple and concentric about the summit. An arcuate, somewhat sinuous, wrinkle ridge occurs on the eastern flank ~70-90 km from the caldera center; its morphology suggests a thrust dipping toward the summit. The flanks exhibit terraces as observed on Olympus Mons and suggested to be due to radial thrust faulting. The flank is mantled by aeolian material as evidenced by the subdued morphology, partly-filled craters, the absence of ejecta and the presence of dunes.

Albor Tholus: Albor's flank has a radial, hummocky morphology. Lava flows (500-1000 m wide where observed) have lobate margins, some with channels. The summit complex (32-35 km wide) consists of a large caldera and a smaller one on the north margin. Relative to the rim, the large one is ~5.9-7.5 km deep; the northern one is ~6-6.5 km deep. The uppermost caldera wall has spurs and gullies indicating exposed bedrock; the lower slope is smoother debris.

The flank is cut by graben, rilles, and, pits primarily on the eastern and southern sides. A pair of wrinkle ridges extend from the caldera's east side. These thrust faults, ~25 km long, arc to the NE and SE with the faults dipping back toward the caldera. Albor Fossae, on the SE flank, is two structures composed of troughs, graben and pits chains. The northern fossae is ~75 km long; the southern one >140 km. The fossae have radii of curvature too large to be associated with Albor but may be concentric about Elysium Mons. A series of narrow (250-750 m) graben cut the lower eastern flank; their orientation is concentric about the summit. A mantling deposit, presumably of aeolian origin, covers the entire flank. Craters are partly filled and fresh craters (having diameters of hundreds of meters to a few km) with recognizable ejecta blankets are absent.

Bordering the northern and northwestern margin of Albor is a moat-like trough ~26 km wide filled with lavas. The structure is in part bounded by faults along it's north side; the scarps are locally covered by lavas.

Hecates Tholus: Hecates lies on northeast margin of the Elysium high. It is has a summit caldera complex (~12 x 9.5 km) and its flanks are etched with rilles of varying size and morphology. The summit complex consists of 4 calderas that becoming younger to the south; the caldera margins appear scalloped as if each caldera was formed by the coalescence of a number of smaller structures. A large reentrant cuts into the western flank. The floor is covered with material having a morphology indicative of westward flow, away from the edifice toward the plains. Several deep rilles cut the flank above the reentrant and material is observed flowing down those rilles and onto the floor.

Lava flows are not commonly exposed on the flanks, but they are observed. In addition, linear ridges, some with pits chains, suggest the presence of tube-fed flows extending down the flank. In several locations U-shaped depressions occur with the open-end facing downslope; these are interpreted to be volcanic vents.

The flank rilles can be classified into two types: deep rilles that generally lack tributaries and begin full width and shallow rilles that typically have tributaries and develop downslope into more prominent features. Locally, rilles are deflected by the topography, diverge into a braided-stream-like patterns, and then remerge. Rilles are shallower and less frequent toward the summit, which might be the result of burial; but as some small rilles are observed it suggests a real absence. At the base of the flank along the contact with the plains, several rilles have deposited fans of material. These deposits are both older and younger than the surrounding plains. In a few cases the rilles and their associated deposits can be traced onto the plains.

Hecates' summit was suggested to be covered with pyroclastic material [5] because of the relatively low frequency of impact craters and the subdued morphology. The summit region is indeed mantled, but the mantling is interpreted to be aeolian rather than volcanic based on the extensive dune forms, the detailed morphology of the deposit, and the presence of mantling material across the entire volcano. The entire flank is mantled to some degree. The northwest flank is heavily mantled largely obscuring any volcanic morphologic. In this area, the surface has a morphology clearly indicative of downslope material flow.

Discussion: The widespread flow-like morphology of material on the flanks clearly indicates that surficial material has been laterally transported downslope. The morphology observed in Elysium is similar to that observed at other locations on Mars where it has been interpreted as flow of ice-rich, ice-cored, or ice-transported material [6]. The material being transported on the volcanoes is suggested to be a combination of locally eroded debris and aeolian materials, presumably with ice facilitating the mobility. Recent climate modeling suggests that snow/ice could have accumulated in the Elysium area [7] providing the ice necessary for such flow.

The rilles, particularly on Hecates, could be of either volcanic or fluvial origin. There is insufficient data from which to draw a firm conclusion. Some rilles are simple, relatively deep, meandering troughs that begin at a pit; others exhibit the confluence of a dendritic group of rilles; and some have a braided morphology along their course. Volcanic channels [8] and fluvial systems [9] can produce the observed morphologies. Some martian rilles have been attributed to sapping processes [10], and while this may be true, it is difficult to reconcile with rilles extending up to the crest of impact crater rims where a source is lacking. To first order, it is suggest that the deep isolated rilles are volcanic whereas the dendritic rilles are fluvial.

The overall morphology of these volcanoes indicates they are shield volcanoes formed by the eruption of low viscosity lavas. Variation in morphology with age on some volcanoes indicates changes in the physical properties of the lavas or the eruption rates. Volcano volumes are of the order 10^{13}-10^{14} m^3. Assuming the eruption rates for the Hawaiian chain [11] are typical of eruption rates for martian shield volcanoes, these edifices could have been built in a few tens of thousands of years to perhaps a few million years. Pyroclastic materials are apparently absent on these volcanoes. A few small hills are noted which might be cinder cones, but they are rare. Low shields do occur in association with faults on the flank margins and surrounding plains.

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