SISYPHI MONTES AND SOUTHWEST HELLAS PATERAE: POSSIBLE IMPACT, CRYOTECTONIC, VOLCANIC, AND MANTLE TECTONIC PROCESSES ALONG HELLAS BASIN RINGS. J.A.P. Rodriguez[1] and K.L. Tanaka[2]; [1]PSI, Tucson, AZ 85719; [2]Astrogeology Team, U.S. Geological Survey, Flagstaff, AZ 86001.

Introduction. Sisyphi Montes form a chain of prominent circular mountains within Sisyphi Planum (57 to 75ºS, -12 to 34ºE) surrounded by circum-polar and circum-Hellas highlands on Mars [1]. A variety of impact and volcanic origins have been considered for them, as reviewed in [2]. Based on the flat tops, summit craters, and associated channels that many of them possess, Ghatan and Head [2] interpreted them to be subglacial volcanoes. Here, we identify additional geologic controls and various alternative processes that may have led to their formation.

Regional geologic setting. Our regional analysis reveals that nearly all major volcanic and tectonic features within the Hellas region occur within 100 km of possible ring structures at ~1900, 2800, 3800, and 4900 km diameters, whereas the average spacing between rings is ~500 km (Fig. 1). For example, Peneus and Amphitrites Paterae are centered within 50 km of the main ring, Malea and Pityusa Paterae are centered ~100 and 150 km inboard of the 2800 and 3800 km rings, and Sisyphi Montes and related mountains are mostly scattered along the 3800 and 4900 km rings. Pityusa Patera, the farthest from a basin ring, is centered along a particularly prominent wrinkle ridge system of Pityusa Rupes that may represent a lesser, intermediate ring. These observations clearly show an association between zones of crustal weakness and the occurrence of Sisyphi Montes.

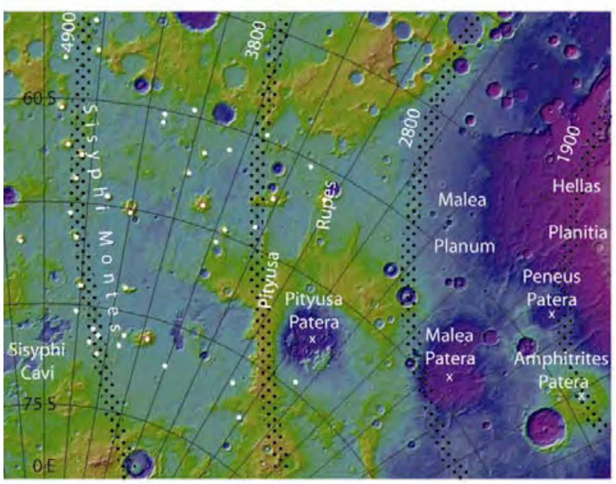

Fig. 1. Sisyphi Montes / Hellas Planitia region of Mars showing feature names and apparent Hellas ring structures (dotted arcs). Centers of paterae shown by x’s; peaks interpreted to be volcanoes shown by white dots. Most of the peaks and patera occur along or near basin rings and perhaps related structure. (MOLA color shaded relief base; 5º lat/long grid; 5º of latitude ~300 km)

A Sisyphi-Malea tectonomagmatic complex? The paterae of Malea Planum have a topographic and geologic form similar to some Venusian coronae [e.g., 3]. They consist of annular topographic highs hundreds of kilometers across surrounding interior depressions and thought to be made up of volcanic flows and deposits deformed by compressional structures manifested by concentric and radiating wrinkle ridges. Although Sisyphi Planum does not include paterae forms, its resurfacing may be related to early, intense magmatic activity. For example, this part of the margin of Hellas basin appears to be deeply eroded, perhaps due to intense intrusive activity during the Early to Middle Noachian [4]. The paterae of Malea Planum may be younger, better preserved parts of this tectonomagmatic complex. While some large volcanic centers on Mars in the Tharsis region have been compared with Venusian coronae previously [5], the Malea Planum features appear to be the oldest and most similar in form to coronae.

Thus, we propose that this region of Mars underwent a period of intense volcanic resurfacing after the formation of Hellas, and possibly was triggered and sustained by the crustal rupturing associated with the impact.

Morphology and morphometry of Sisyphi Montes. Here we consider that all substantial, isolated peaks in and near to Sisyphi Planum may be related in origin. We have identified >40 features thus far, double the number included in the study by [2]. Most form round features. Some have simple forms, whereas others have ridged and knobby flanks and irregular outlines. They range from several to 110 km across, but most a are few tens of kilometers wide. They rise 300 to 2000 m above surrounding plains. Some have slopes exceeding 15º in the MOLA DEM, but slopes >30º are not found. About half of them appear to have partial to complete, circular, shallow (<~200 m deep) surrounding moats that extend for up to a few tens of kilometers beyond peak edges. The better-developed circular moats are about 3 times the diameter of the peaks. (e.g. Fig. 2A-B). One feature outside of SiM on the floor of Hellas basin below Malea Planum has a partly preserved rim (Fig. 2A) Some of the moats have rims. In addition, 10 of the peaks have round summits that contain dish-shaped pits tens to 400 m deep that span most of the summit. Five of the peaks that have conical forms have annular partial to complete, hummocky blankets with rampart margins.

These observations indicate that are either highly degraded impact craters, or the sites of ground subsidence and volcanism controlled by tectonic structures generated by impact craters.

Geomorphic transition from impact craters into Sisyphi Montes. Sisyphi Montes display various degrees of degradation. Fig. 2A shows a flat-floored steep-sided plateau that is surrounded by a moat, partly enclosed by an elevated rim. Fig. 2B shows a similar setting but the peripheral rim is absent (presumably destroyed) and the central plateau appears to be more rounded and have shallower slopes around its margins. Fig. 2C shows a cluster of peaks and a highly degraded central plateau. We propose that these morphologies may represent various degrees, or stages, of impact craters degradation/modification.

The central plateau appears to consist of highly indurated geologic materials that have resisted erosion more effectively than the surrounding plateau materials, which is consistent with their volcanic origin [2].

We propose that volcanism in the central zone of these impact craters may have been initiated and sustained by the existence of a brecciated crustal zone that extends up to 2 crater diameters from the floor of impact craters [6].

The formation of moats, nevertheless, appear to have affected plains materials and thus represents a much younger stage of resurfacing. Moat formation may have involved enhanced loss of volatile materials along systems of concentric faults that extend outwards from impact crater rims [6].

Overview of regional and global significance: Our investigation reveals that possible volcanoes in the proximity of Sisyphi and Malea Plana appear to have emerged from the central zones of impact craters where central peaks usually form. Interestingly, these putative volcanoes occur in the proximities of Hellas basin rings, which strongly suggests that these fault systems formed zones of enhanced volcanic activity. If circum-polar volcanic activity was widespread and extended into the Early Hesperian, then high heat flow anomalies resulting in warmer crustal zones may have significantly influenced regional hydrologic activity, leading to crustal volatile enrichment by cold trapping volatiles into the south polar region and to outflow through the crust.

The formation of moats appears to have involved localized volatile-driven resurfacing of what has been interpreted to be volatile-enriched plains materials [e.g., 7]. Nevertheless, our mapping reveals that other impact craters in the region do not display peripheral moats. We interpret this observation as an indicator of enhanced volatile enrichment of the crustal materials that underlie the putative volcanoes and peripheral remnants of impact structures. Thus, we propose that the formation of impact basin ring structures may have led to magma upwelling, thereby triggering structurally volcanic activity, and that degassing from the upwelling magma led to the volatile enrichment of regional permeable zones within the crust, which in the region of study appear to have been basins ring structures and overlapping impact crater fractures. We suggest that this process may have been important in the hydration of the primordial crust and sustained volatile driven resurfacing over most of the Martian history.

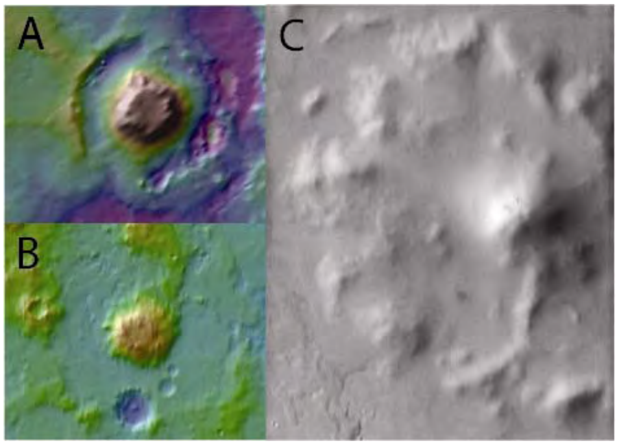

Fig. 2. Examples of Sisyphi Montes and related peak features examined in this study. (A) Peak with partial moat and rim in Hellas basin. (MOLA color shaded relief centered at 45.7ºS, 55.1ºE.) (B) Peak (25 km diameter) with moat (~75 km diameter) (MOLA color shaded relief centered at 60.1ºS, 1.7ºE). (C) THEMIS daytime IR I07615002; image width 30.4 km centered at 66.4ºS, 3.5ºE.

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