SEARCH FOR DIKES IN THE HADRIACA PATERA REGION, MARS: PRELIMINARY FINDINGS.
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Introduction: The Hadriaca Patera volcano (HP, 29°S, 93°E) is located at the junction of three regional provinces: it is on the NE rim of Hellas basin, S of cratered Tyrrhena Terra highlands and E of the Hesperia Planum lava plains (Fig. 1). This area has been modified by cratering, glaciation, volcanism and fluvial activity [e.g. 1-8]. Previously the causal relationships of these have largely been only hypothesized.

We study a circular region (D ~1200 km) around HP in search of dike-indicative formations. So far, we have identified and documented a large number of straight /curvilinear ridges, fractures and grabens (Fig. 2) on the volcano itself as well as in its vicinity. Here we describe the ongoing mapping process, categorize the found features and propose formation scenarios.

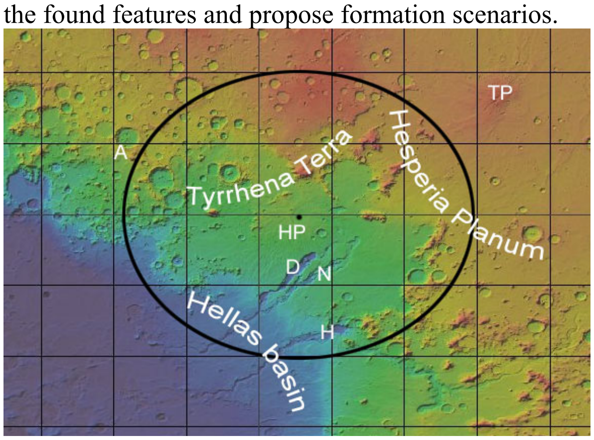

Figure 1. Location of the 1200 km diameter study region (black ellipse) around Hardiaca (HP). The outflow channels Dao (D) and Niger (N) are at the foot of the volcano, and Harmakhis (H) at ~300 km distance. A location in which dikes have been identified (A, from [11]) lies at ~600-700 km from the HP flank, as does the closest other known volcanic centre, Tyrrhena Patera (TP).

1. Study rationale: Radial and/or concentric giant dike swarms are known to extend for 100s of km from their sources on volcanic provinces on Mars, Earth and Venus [9]. Dike systems have also been identified on the N side of the Hellas basin [10,11]; see A in Fig. 1.

The origin and distribution of the dikes in the greater Hellas region is of importance when discussing the regional geology, especially when attempting to synthesize a chronology and causal relationships between events. The dike patterns and sizes are related to the whereabouts and characteristics of the feeding magma bodies. Thus, the dike distribution around HP gives a hint about the heat flux in the region. This reflects on the possible formation scenarios of e.g. the outflow channels near HP and the formation of several floor-fractured craters in the NE Hellas region [12]. Additionally, mapping out the dike patterns around HP helps to determine whether the volcano is the only magmatic center in the region, or if other, previously unknown sources, have existed.

2.1 Volcanic environment: *Hadriaca Patera* is a low-relief volcano (height 1.2 km, D >350 km) [13]. It has a simple caldera (d ~700 m, D ~90 km). Its flanks extend ~120-350 km from the caldera center. They are characterized by downslope-running troughs (d ~100-200 m, W ~5 km), which appear to have a complex evolution of both fluvial and lava origins [14,15].

Applied terrestrial models show that HP deposits are consistent with gravity-driven ash flows generated by hydromagmatic or magmatic explosive eruptions [16-20]. HP has also been interpreted to be of ignimbritic composition [20]. It may also be above tension zones resulting from the formation/evolution of Hellas basin, and, thus, may in fact be directly analogous to terrestrial mafic explosive volcanoes [21].

2.2. Hesperia Planum is a saddle-shaped volcanic lava plain province, characterized by a prominent wrinkle ridge population. It is connected to Hellas by a 300 km wide smooth valley, indicative of ancient volatile outbursts from Hesperia, caused by heat transport from volcanic activity [22]. Later, similar but smaller, outbursts formed the Dao, Niger and Harmakhis Vallis channels south of HP [e.g. 1,5,6]. These originate from obvious, several km deep chaotic regions.

3. Methods, used data: HRSC images were chosen for this study due to their high resolution and large areal coverage. To pick out the properties of the dike-related features, we use the desktop HRSCview [23].

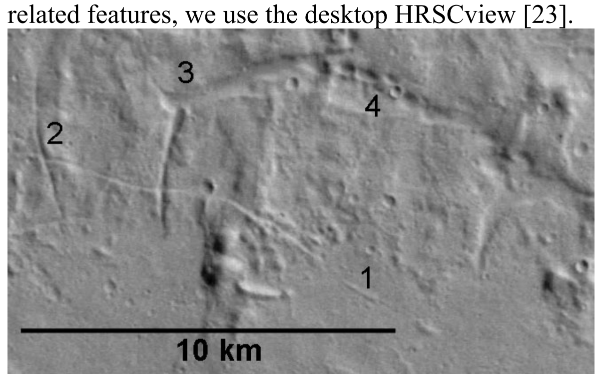

Figure 2. Examples of the mapped features found on the HP caldera rim: linear ridges (1), linear fractures (2), grabens (3) and pit chains (4), all possible indicators of dikes. Note how they transform from one type to the next. North is up, image cut from HRSC-nd 528.

4. Preliminary findings: Four feature categories are recognized (cf. Figs. 2 and 3). Each type is found transforming into others. The identified features are concentrated mainly on the HP volcano and in various isolated locales throughout the study region (Fig. 3).

4.1. Linear ridges are tens to hundreds of m wide, have reliefs of only few m, extending for tens of km. They are distinct from the wrinkle ridges found widely throughout the study region. We interpret these ridges to be mostly dikes, exhumed by later erosion processes. Thus, they are expected to occur especially in local lows. Their abundance is highest on the HP summit and flanks, and in some cases on graben floors. Most of the dikes on HP are concentric to the summit and the caldera; here the transitions between ridges and fractures are very common, indicating almost a certain dike.

5.2. Linear fractures are identical to the ridges, except for their inverted vertical topography. They occur all over the region, but concentrate near the canyons. The ones located at the channel banks and walls we interpret to be manifestations of 'regular' gravity-controlled tectonic fracturing or canyon wall failing.

In places (see 36.7°S and 34.2°S in Fig. 3) the fractures cut the otherwise flat surface in a chaotic manner, breaking it into blocks separated by a complex fracture system. This is also always connected to fluvial activity. The chaotic fractures may be caused by collapses and surface material volume diminution due to volatile removal from the materials. However, in places the fracture patterns resemble those of the floor-fractured craters [11,12]; see also crater at 31.5°S, 94.3°E. These have been shown to be caused by dikes propagating through pre-existing fracture patterns in the subsurface [24], which are abundant on Mars [25].

5.3. Grabens are depressed land blocks bordered by parallel faults. In the study region they are 0.1-1 km across and occur often close to the smaller linear fractures and canyon systems. Such shallow grabens are probably be purely tectonic extensional features. Grabens may also be suggestive of deep dike injections [9]. This is supported by the identification of some graben floors exhibiting single or double linear ridges, parallel to the strike of the graben. This suggests that these grabens were initially caused by dike injections, with later erosion exhuming the dike bodies.

5.4. Pits and pit chains are elliptical depressions, comparable in width to grabens. They occur in marginal areas close to fractures or grabens, indicating similar but only partial collapse.

6. Summary: We have identified several, possibly dike-related features. The best candidates for actual dike manifestations include 1) the transitions from linear fractures or grabens to linear ridges, and 2) the ridge-harbouring grabens. Some dikes are radial / concentric to HP, while others appear not to be controlled directly by obvious magma reservoirs. Many of the latter may be explained through cracking, mass movements or other tectonic phenomena, especially near the steep cliffs of the large canyons.

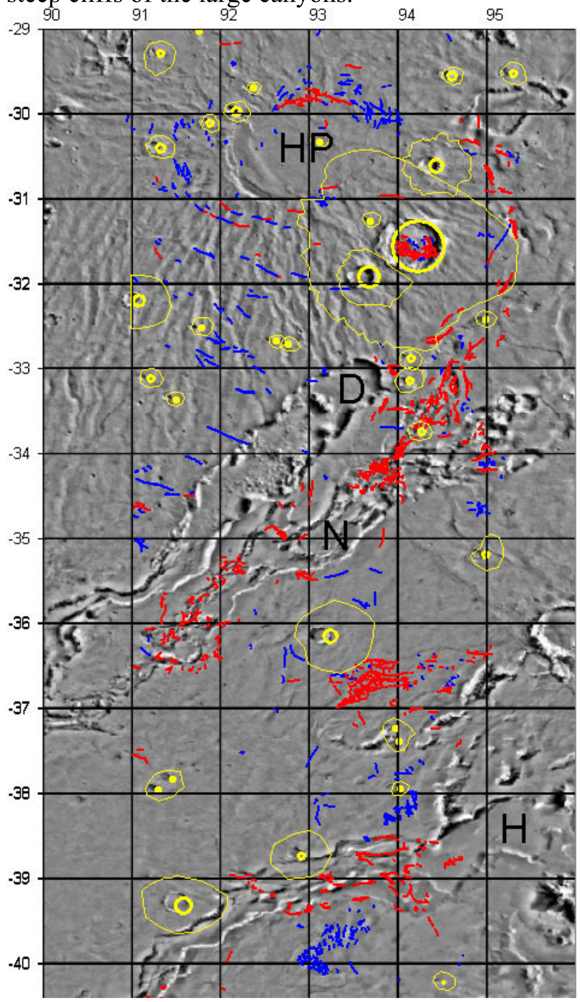

Figure 3. Structure distribution S of Hadriaca (HP). Ridges (blue) occur concentrically on the summit and at the flanks, and as radial / irregular patterns further away. Fractures / grabens (red) occur near the canyon walls and chaotic terrains. Craters (yellow) marked for reference; background image Viking MDIM2.

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