HADRIACA PATERA: VOLCANIC HISTORY DERIVED FROM HRSC-BASED CRATER COUNTS.
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Introduction: The High Resolution Stereo Camera (HRSC) on the European Space Agency's *Mars Express* orbiter [1] obtained color and stereo images of the Martian highland volcano *Hadriaca Patera* in June 2004. These data provide insights into the volcanic history of Hadriaca Patera in the context of previous *Viking* orbiter-based geologic mapping, and enable use of crater counts to assign model ages to various map units.

Previous Work: Hadriaca Patera is one of four 'highland paterae' identified near the Hellas basin rim [2] in Mars' southern cratered highlands. These volcanoes are thought to be among the oldest central vent volcanoes on Mars [3]. They are noted for shallow, central calderas on low-relief, deeply dissected flanks with radial channels and ridges [4,5]. The lack of primary lava flow features and the nature of their eroded flanks suggested that these paterae are composed mostly of friable pyroclastic deposits [5,6]. Early and recent modeling [6-8] supports the construction of the paterae by gravity-driven pyroclastic flows. A geologic map of MTM quadrangles -30262 and -30267 [9] was completed using *Viking* orbiter images, in an attempt to define the volcanic history of Hadriaca Patera.

HRSC Imaging: The HRSC imaged Hadriaca Patera on orbits 528 (19 June 2004) and 550 (25 June 2004). The orbit 528 coverage included nadir imaging at 44 m/pixel, with corresponding stereo imaging at 88 m/pixel and 4-color imaging at 176 m/pixel. The orbit 550 coverage included nadir and stereo imaging at 48 m/pixel. Super Resolution Camera (SRC) mosaics were also obtained on each orbit, covering different parts of the caldera rim at ~10 m/pixel.

Crater Counts: Using *Crown and Greeley's* [9] geologic map as a guide, we mapped discrete units on the HRSC orbit 550 nadir image for age assessment. Crater counts were performed following the guidelines established in *Hartmann and Neukum* [10]. The typical uncertainty on counts using these guidelines is ±50 Ma.

Caldera floor: The caldera floor of Hadriaca Patera is the smoothest, least cratered part of the volcano, which was mapped by *Crown and Greeley* [6] as Hesperian Caldera-filling materials (Hcf), and interpreted as either lava flows and/or pyroclastic flows representing late-stage activity. High-resolution HRSC images show at least three discrete units on the caldera floor (**Figure 1**). The oldest part of the floor is in the center and east (cf-1 and cf-2), with a cratering model age of 3.5 Ga and later resurfacing at ~2.3-2.5 Ga. The southwest unit (cf-4) has a cratering model age of 2.2 Ga, and the north-northeast unit (cf-3) has an age of 1.1 Ga. These cratering model results suggest that activity within the caldera was pervasive throughout much of martian history, with the most recent activity extending into the Amazonian (<2-2.9 Ga). This is consistent with similar results obtained for other Martian volcanoes [11].

Smooth flank materials: We mapped two units on the north (vf-1) and west (vf-4) sides of the caldera that correspond to part of the Smooth flank material (Hvfs) mapped by *Crown and Greeley* [6]. They interpreted this unit as likely pyroclastic flow deposits dissected by later fluvial activity, although to a lesser degree than the Channeled flank materials south of the caldera. This difference was attributed to variations in topography and resulting degrees of erosion. Our crater counts result in a cratering model age for vf-1 of 3.9 Ga, with a possible resurfacing event at 3.3 Ga. The latter age may be related to the event which produced the 3.3 Ga crater-filling unit NW of the caldera. For unit vf-4 we obtained a model age of 3.7 Ga. These dates (3.7-3.9 Ga) confirm the extreme age of the Hadriaca edifice, dating back to the Noachian.

Channeled flank materials: We mapped two units of Hesperian Channeled flank materials (Hvfc) on the heavily dissected southern (vf-5) and eastern (vf-6) flanks of the volcano. This material is described by *Crown and Greeley* [9] as layered, radially-dissected materials containing numerous scarps, channels, and ridges, and is interpreted as probable pyroclastic flow deposits dissected by fluvial activity on a steeper slope than smooth flank materials. We obtained cratering model ages of 3.3 Ga for vf-5 and 3.9 Ga for vf-6. The 3.3 Ga date may place a constraint on the time of primary fluvial activity that eroded the southern flank. We will be able to use the HRSC-derived DTM to assess the slopes on various parts of Hadriaca Patera.

Plateau materials: We mapped a unit of plains material NNE of the caldera on the HRSC image, which corresponds to Hesperian Smooth plateau material (Hpl_3) and Smooth volcanic flank material (separated by a dashed contact) in the *Crown and Greeley* map. These units were combined for counting because no clear boundary was visible in the HRSC image. Hesperian Smooth plateau material is interpreted as sedimentary deposits of fluvial and aeolian origin, possibly including volcanic materials, which fill low-lying regions. Our cratering model age date of 3.4 Ga confirms a Hesperian age for this unit.

Results: Our new crater counts using HRSC data show that Hadriaca Patera was active through a long period of martian history, and that the earliest shield-building events ocurred ~3.7-3.9 Ga, prior to the end of the Noachian period (3.5-3.7 Ga: [10]).

References: [1] *Neukum et al*., 2004, *ESA SP-1240*, ESA Pub. Div., Noordwijk, The Netherlands, 17-36; [2] *Peterson*, 1978, *Proc. 9th LPSC*, 3411-3432; *Schultz*, 1984, *LPSC XV*, 728-9; [3] *Scott and Carr*, 1978, *USGS Misc Inv Ser Map I-1083*, 1:25M; [4] *Plescia and Saunders*, 1979, *Proc 10th LPSC*, 2841-2859; [5] *Greeley and Spudis*, 1981, *Rev Geophys Space Phys 19*, 13-41; [6] *Crown and Greeley*, 1993, *JGR 98*, 3431-3451; [7] *Greeley and Crown*, 1990, *JGR 95*, 7133-7149; [8] *Gregg and Crown*, 2004, *IAVCEI Gen Assem, Pucon, Chile Abst*; [9] *Crown and Greeley*, USGS in review; [10] *Hartmann and Neukum*, 2001, *Sp Sci Rev 96*, 165-194; [11] *Neukum et al*., 2004, *Nature 432*, 971-979.

Figure 1. Summary of crater count areas and ages obtained thus far for Hadriaca Patera using HRSC data. Crater counts performed by Wilhelm Zuschneid, FU-Berlin.