AMPHITRITES AND PENEUS: NEW INSIGHT INTO HIGHLAND PATERAE. R. Greeley[1], D.A. Williams[1], R.L. Fergason[1], G. Neukum[2], D. Baratoux[3], P. Pinet[3] and the HRSC Co-Investigator Team, [1]Arizona State University, School of Earth and Space Exploration, Box 871404, Tempe AZ 85287-1404, greeley@asu.edu, [2]Institute of Geosciences, Freie Universitaet Berlin, [3]DTP/UMR 5562/CNRS/OMP, Toulouse III University, 31400, France.

Introduction: Amphitrites, Peneus, Malea, and Pityusa are four highland paterae that form a volcanic complex draped over the south-southwest rim of the Hellas basin. HRSC images from Mars Express and THEMIS day time thermal images from Mars Odyssey show that Amphitrites and Peneus paterae are geologically equivalent to Tyrrhena and Hadriaca paterae, northeast of Hellas, and (collectively) are the earliest central-vent volcanoes on Mars.

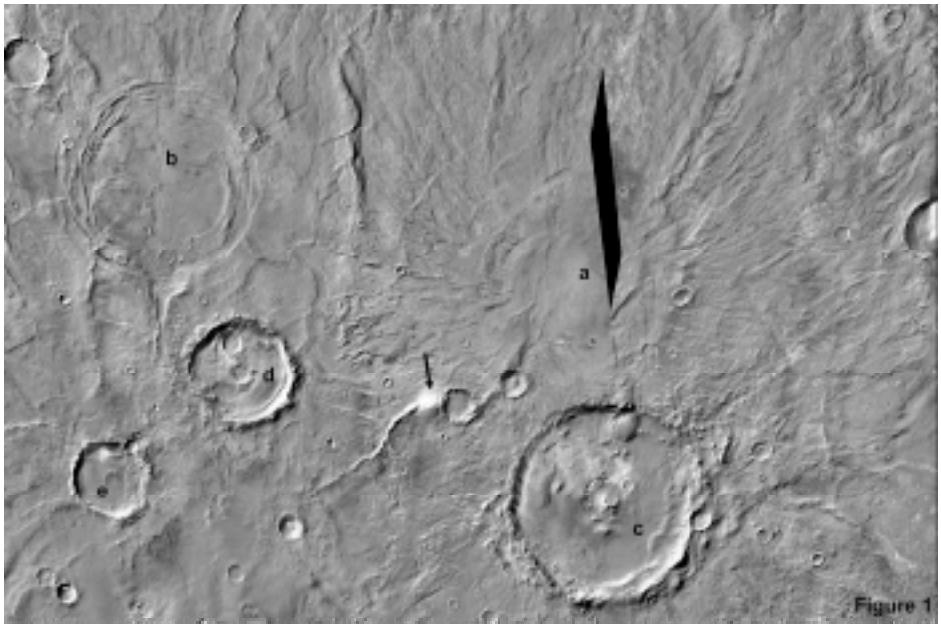


Figure 1. Mosaic of THEMIS day time thermal images (~100 m/pixel) covering Amphitrites (a) and Peneus (b) paterae and the prominent impact craters, such as Barnard (c), Henry Moore (d) and, Chaman (e). The arrow points to a dome that could be a small volcanic construct. Mare-like ridges cut across the floors of both volcanoes, suggesting post-eruption deformation. Black zone is a gap in coverage. Numbers refer to locations for subsequent figures. Image processing by Chris Edwards, Arizona State University.

The term *highland patera* is applied to large, low relief volcanoes on Mars, typified by complex central calderas. *Tyrrhena* and *Hadriaca* paterae on the northeast flanks of the Hellas basin were first imaged by *Mariner 9* and mapped geologically [1,2]. Subsequent imaging by the Viking orbiters enabled more detailed analysis and led to a proposed model of formation in which initial eruptions were explosive (driven by magma rising through impact-generated regolith containing water) to produce broad shields composed of easily-eroded ash [3]. With depletion of water in the regolith, eruptions transitioned to effusive activity, producing lava flows and channels seen on the flanks and filling the caldera floors [4,5]. Viking orbiter images also suggested the presence of four additional structures, subsequently named *Amphitrites* and *Peneus* paterae (both on the southwest flank of the Hellas basin) and *Malea* and *Pityusa* paterae (south and west of Amphitrites and Peneus paterae). However, limits in image resolution, coverage, and quality (the atmosphere is frequently dusty and cloudy in the region) for all four of the features southwest of Hellas has produced their geological analysis. Very high resolution images from the Mars Observer Camera (MOC) have provided tantalizing clues to these features, but isolated coverage without adequate context make study difficult. Now, however, images from the *High Resolution Stereo Camera* (HRSC; [6] and *Thermal Emission Imaging System* (THEMIS; [7] at resolutions of ~ 15 - 25 and 100 m / pixel (Fig. 1), respectively, over wide areas and under relatively clear atmospheric conditions enables Amphitrites and Peneus paterae to be studied for comparisons with Tyrrhena and Hadriaca paterae.

Although Malea and Pityusa paterae await to be imaged satisfactorily for detailed study, reconnaissance mapping [8,9] and *Mars Orbiter Laser Altimeter* (MOLA) data show that Malea, Pityusa, Amphitrites, and Peneus paterae form a broad volcanic province (incorporating part of Malea Planum) draped over the southwest rim of the Hellas basin. Amphitrites Patera is about 280 km across and stands 1-1.3 km above the surrounding plain, while Peneus Patera is about 290 km across and has very little relief. Both contain complex summit calderas about 100 km across and are identified by discontinuous concentric grabens. Flow-like patterns,

segments of channels, and chains of elongate craters following slightly sinuous paths on the flanks of the patera are interpreted as volcanic features, as are the mare-like deposits on the caldera floors. Ejecta from large impacts (Barnard crater on the south flank of Amphitrites and Henry Moore crater on Peneus) is superposed on the volcano flanks. In turn, the ejecta is superposed by caldera floor-flooding material, showing that inferred volcanic activity continued after the impacts occurred.

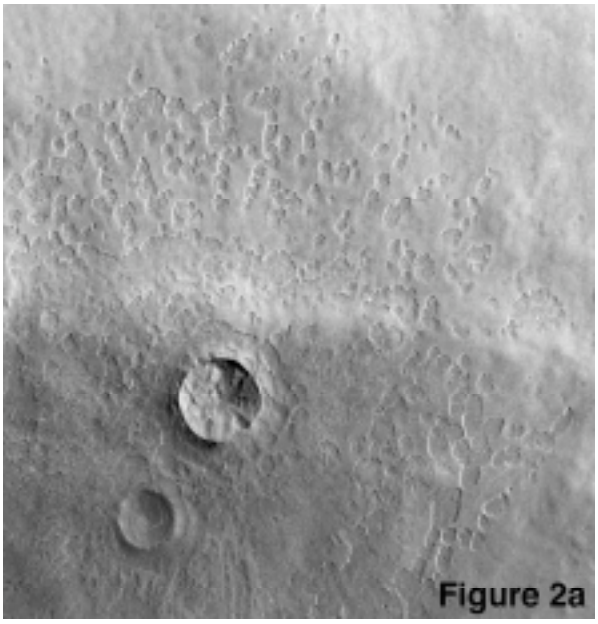
"Softened" terrain of the sort described elsewhere on Mars [10], abundant ejecta-flow impact craters, and mass wasted units all suggest that the region is subject to periglacial and other surface-modifying processes. "Swiss cheese" terrain suggests devolatilization of near-surface materials in many areas, perhaps enhanced by local sub-surface thermal activity. Some of the younger impact craters show distinctive ejecta features (Fig. 2a,b), including irregular pits somewhat similar to the "Swiss cheese" terrain. We suggest that these pits could represent impacts into ice-rich material, in which blocks of ice or ice-rock mixtures were ejected, then "devolatilized," leaving pits. Night time infrared images show these ejecta zones to be anomalously cold, which could represent remnants of surface or near-surface ice.

Table 1. Estimated ages in giga-years of principal paterae and associated units, derived from crater size-frequency distributions.

	Amphitrites	*Peneus*	*Hadriaca*	*Tyrrhena*
Main construct	3.7	3.7	3.9	3.9-4.0
Flank flows	3.45	3.15	3.3	3.1
Caldera floor	3.58	3.60	2.2	1.1/3.3

Impact *crater frequency distributions* (CFDs) for the volcanic constructs, youngest flank materials, and youngest caldera floor units **(Table 1)** show that Amphitrites and Peneus are comparable in age to Tyrrhena and Hadriaca paterae, and collectively represent the earliest eruptions from "central" vents to form volcanic constructs. Volcanic activity continued for a protracted duration, but of lower total volumes, suggested by the limited areal extent of the young flank and caldera floor units. Ages in Table 1 are based on crater counts on HRSC and THEMIS images, using the techniques of [11] and the Mars chronology model of [12].

References: [1] Potter D. B. (1976) *USGS Misc. Inv. Ser. I-941 (MC-28),* 1:5M. [2] Petersen J. E. (1977) *USGS Misc. Inv. Ser. I-910 (MC-27*), 1:5M. [3] Greeley R. and Spudis P. D. (1981) *Geophys. Space Phys., 19,* 13-41. [4] Crown D. A. and Greeley R. (1993) *JGR, 98*, 3431-3451. [5] Gregg T. K. P. et al. (1998) *USGS Misc. Inv. Ser. I-2556*. [6] Neukum G. et al. (2004) *Eur. Space Agency Spec. Publ., ESA-SP 1240*, 17-36. [7] Christensen P. R. et al. (2004) *Space Sci. Rev., 110*, 85-130. [8] Leonard G. J. and Tanaka K. L. (2001) *USGS Misc. Inv. Ser. I-2694*. [9] Kolb E. J. and Tanaka, K. L. (in review), *USGS Misc. Inv. Ser.* [10] Squyres S. W. and Carr M. H. (1986) *Science, 231*, 249-252. [11] Hartmann, W. K. and Neukum G. (2001), *Space Sci. Rev., 96*, 165-194. [12] Ivanov B. (2001), *Space Sci. Rev., 96*, 87-104.



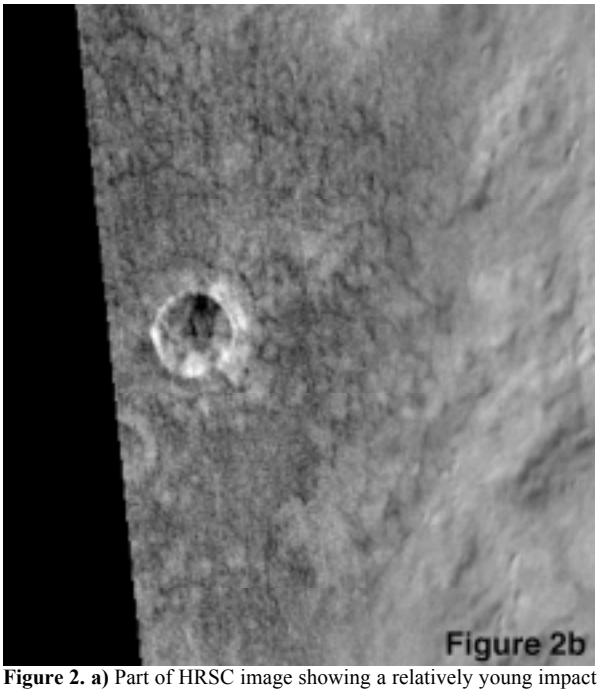


Figure 2. a) Part of HRSC image showing a relatively young impact crater on the northern part of Amphitrites caldera floor, and the unusual irregular pits some 500 m across within the ejecta zone of the crater (HRSC image H2525_0000.nd4; 12.5 m/pixel; **b)** THEMIS night time thermal image showing the low-temperature signature correlated with the ejecta zone of the crater (extracted from THEMIS mosaic).