Tyrrhena Patera and Hesperia Planum, Mars: New insights (and old interpretations) from high-resolution imagery. Tracy K.P. Gregg[1] and Shan de Silva[2], [1]Department of Geology, 411 Cooke Hall, University at Buffalo, Buffalo, NY 14260-3050, tgregg@buffalo.edu; [2]Department of Geosciences, Oregon State University, Corvallis, OR 97331, desilvas@geo.oregonstate.edu.

Introduction: Tyrrhena Patera (~22°S, 104°E), Mars is located within Hesperia Planum, northeast of the Hellas impact structure [1]. The low-lying (<2° slope), heavily dissected central-vent volcano has been interpreted to be composed primarily of pyroclastic deposits [2-4], and probably pyroclastic flows [5, 6]. Hesperia Planum is most commonly interpreted to be composed of fluid lavas [1] although results of recent work [7,8] cannot confidently rule out layered sediments (volcaniclastic or lacustrine). Here, we examine available high-resolution (<19 m/pixel) imagery of Tyrrhena Patera and Hesperia Planum deposits to help constrain their origins.

Background: Mandt and others [9] examined Mars Orbiter Camera (MOC) Narrow-Angle images of the Medusae Fosse Formation (MFF) in an attempt to diagnose the lithologies of the MFF. After studying >700 Mars Obiter Camera (MOC) images (resolutions <3.5 m/pixel) of the MFF, a set of deposit-wide characteristics were identified. These, along with the morphologies of yardangs and mesas, pointed to variably indurated lithology. By comparisons to terrestrial satellite, air photo and field images of Andean ignimbrites, Mandt and others [9] concluded that the MFF displays characteristics that are most analogous to terrestrial ignimbrite deposits.

We seek evidence for or against the origins of Hesperia Planum and Tyrrhena Patera flank materials. Mandt and others [9] suggest that the following features are consistent with ignimbrite deposits: 1) evidence of a vertical induration profile with a resistant capping layer; 2) *yardangs* (including nascent yardang-like features and serrated planforms of eroding cliffs), particularly if associated with block collapse; and 3) *layering*, particularly if *jointing* can be observed within the layers.

A strong, dominant wind direction is important for yardang formation; however, yardangs may be initiated by fluvial incision, dessication cracking and mass movement [10]. The material in which yardangs form needs to be sufficiently consolidated to hold its shape (and sometimes steep cliffs [9]) but sufficiently friable to be abraded by wind-borne sand/crystals. On Earth, although yardangs are known in basaltic lava flows [11], they are poorly defined, and do not display the mega-yardang forms with high length-to-width ratios found in ignimbrites and indurated sediments on Earth. Martian yardangs have been identified on the Medusae Fosse Formation, and can be resolved with available image data [cf. 9].

Layering and jointing (caused primarily by thermal contraction during cooling) requires higher resolution imagery to identify on the Martian surface than do yardangs. Milazzo and others [12] identified columnar jointing in a Martian outcrop using images collected by the High Resolution Imaging Science Experiment (HiRISE) aboard Mars Reconnaissance Orbiter. These images typically have a resolution of ~1 m/pixel. Using available HiRISE and MOC narrow-angle images, combined with comprehensive Thermal Emission Imaging System (THEMIS) visible images (~19 m/pixel), we examine the geologic units within Hesperia Planum to constrain their origin(s).

Methods: We examined available THEMIS visible, MOC narrow-angle, and HiRISE images of the volcano Tyrrhena Patera, surrounding Hesperia Planum, and the contact between Hesperia Planum deposits and the surrounding cratered highlands. We searched the images for: 1) layering; 2) evidence of a resistant capping layer; 3) yardangs; 4) surface textures; 5) jointing; and 6) relations between adjacent materials.

Results: Regrettably, all images examined reveal a surface dust or fine-grained surficial deposit that makes unequivocal identification of layering within the Hesperia Planum materials difficult and rare (Fig. 1). Gross layering (layers on the order of hundreds of meters thick, based on shadow measurements and Mars Orbiter Laser Altimeter (MOLA) data [4, 6], can be readily observed within the Tyrrhena Patera flank materials, but no details (such as jointing) are resolved because of the surface mantle. Neither the Tyrrhena Patera flank materials nor the Hesperia Planum deposits display serrated margins, as seen in the MFF and in some terrestrial ignimbrites [9]; instead, margins of these materials are linear to arcuate. Within the freshest impact crater walls, some layering, and possibly rough jointing, can be observed in all deposits.

There are clear differences in surface textures for materials identified as having been erupted from Tyrrhena Patera as compared to both Hesperia Planum ridged plains and surrounding Noachian highlands [1-4]. Materials associated with Tyrrhena Patera flank materials are rough on the scale of tens of meters, and boulders ~1 m across are observed scattered across the surface (Fig. 2). In contrast, the Hesperia Planum materials contain few boulders, and abundant, shallow craters with scalloped edges that are commonly filled with a smooth, flat-lying deposit. No volcanic vents or constructs have yet been unequivocally identified within the Hesperia Planum materials, although small (<10s meters wide) channels have been observed [5]. The channels are linear with few (if any) branches (one such feature is described as a "channel or crack" on the HiRISE website [http://hirise.lpl.arizona.edu/PSP_007700_1630]); they maintain a constant width along their lengths and display topographic levees. Although these morphologies could be created by either fluvial or volcanic processes, the channels appear to be most consistent with a volcanic origin.

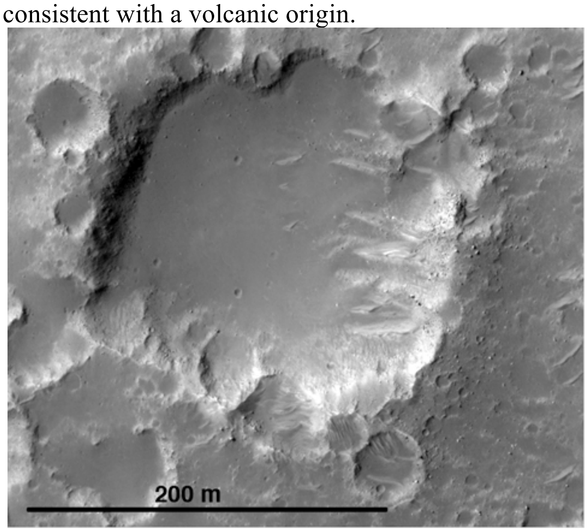

Figure 1. Portion of the ridged plains of Hesperia Planum, located near 15°S, 103°E. Impact crater, filled with smooth deposit, is ~225 m across. Boulders ~1m across are observed scattered around the remains of the crater rim. From HiRISE image PSP_010337_1650.

Discussion and Conclusions: Interestingly, among the earliest published interpretations of Tyrrhena Patera [1, 13], based primarily on Viking Orbiter data, were that the volcano's extremely low flank slopes (<2°) were the result of low-viscosity lavas. More recent investigations, based on MOLA, THEMIS, and High Resolution Stereo Camera (HRSC) data consistently point to pyroclastic flows as generating the Tyrrhena Patera edifice [14].

Hesperia Planum remains enigmatic, lacking convincing primary volcanic morphologies. We will continue to examine high-resolution images of the Hesperia Planum region as they become available. To date, however, the morphologies of Hesperia Planum deposits and the Tyrrhena Patera flank materials as revealed in HiRISE images are more consistent with deeply eroded fluid lavas than with ignimbrites [14].

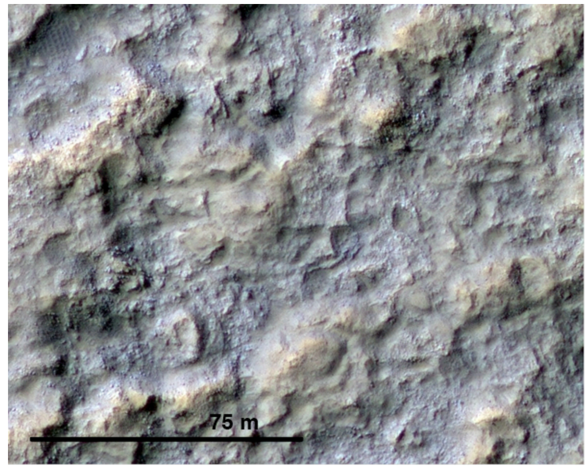

Figure 2. Surface of a plateau located north of the Tyrrhena Patera summit (19.2°S, 106°E) and mapped as Tyrrhena Patera shield materials, interpreted to be pyroclastic deposits [Gregg et al., 1998]. Possible layering is observed near the center of the image. Boulders as small as ~1 m across can be seen throughout the image. Portion of HiRISE image TRA_00869_1605.

References: [1] Greeley, R. and J.E. Guest, 1987, USGS Misc. Invest. Series Geologic Map I-1802B, 1:15M. [2] Greeley, R. and D.A. Crown, 1990, *J. Geophys. Res. 95(B5)*:7133-7149. [3] Crown, D.A. and R. Greeley, 1993, *J. Geophys. Res. 98(E2)*:3431-3451. [4] Gregg, T.K.P., D.A. Crown and R. Greeley, 1998, USGS Misc. Invest. Series Geologic Map I-2556, 1:500K. [5] Farley, M.A. and T.K.P. Gregg, 2004, Abstracts of the Annual Meeting of Planetary Mappers, Flagstaff, AZ, 2004, *USGS Open-File Report 2004-1289*. [6] Gregg, T.K.P. and M.A. Farley, 2006, *J. Volcanol. Geotherm. Res. 155(1-2)*:81-89. [7] Gregg, T.K.P. and D.A. Crown, 2007, *Lun. Planet. Sci. Conf. 38*, Abstract # 1190. [8] Crown, D.A., D.C. Berman and T.K.P. Gregg, 2007, *Lun. Planet. Sci. Conf. 38*, Abstract #1169. [9] Mandt, K.E., S.L. de Silva, J.R. Zimbelman and D.A. Crown, 2008, *J. Geophys. Res. 113, E12011*, doi:10.1029/2008JE003076. [10] Goudie, A.S., 2007, *Geography Compass 1(1):*65-81, 10.1111/j.1749-8198.2006.00003.x. [11] Inbar, M. and C. Risso, 2001, *Earth Surf. Process. Landforms 26*:657-666. [12] Milazzo, M.P., W.L. Jaeger, L.P. Keszthelyi, A.S. McEwen and R.A. Beyer, 2008, *Lun. Planet. Sci. Conf. 39*, Abstract #1391. [13] King, E.A., 1978, USGS Misc. Invest. Series Geologic Map I-1073, 1:5M. [14] Williams, D.A., R. Greeley, S.C. Werner, G. Michael, D.A. Crown, G. Neukum and J. Raitala, 2008, *J. Geophys. Res. 113, E11005*, doi:10.1029/2008JE003104.