BASIN-FILLING STRATA EXPOSED IN HADRIACUS CAVI, MARS RECORD COMPLEX TRANSITIONAL ENVIRONMENTS DURING THE MIDDLE NOACHIAN. J. A. Skinner, Jr.[1], C. M. Fortezzo[1], and M. L. Barton[1,2], [1]Astrogeology Science Center, U. S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ 86001 (jskinner@usgs.gov), [2]School of Earth Sciences and Environmental Sustainability, Northern Arizona University, Flagstaff, AZ 86011.

Introduction: We are completing a 1:24,000-scale geologic map of strata exposed along the northeastern margin of Hellas Planitia in the Martian cratered highlands. This map-based investigation was designed to identify and temporally and spatially constrain the basin-filling processes for a principally non-crater basin within a typical sequence of cratered highland materials. We previously reported details about the regional geologic setting and mapping rationale [1], relative and model absolute ages of these units and their bounding terrains [2], key unit-bounded textures and bedforms [3-5], and the potential of these types of basin-related strata for future robotic and human exploration [6]. Here, we summarize unit details and a geologic map-based history as the project nears completion.

Geologic Setting: The map region is defined by a HiRISE stereo-derived digital terrain model (DTM) that transects central Hadriacus Cavi, located in the cratered highland of southwest Tyrrhena Terra, along the northeastern rim of the Hellas basin. The cavi are a 65 km long, 15 km wide set of irregularly-shaped, east-west oriented depressions bound on the south by topographic promontories and eroded cratered terrains and on the north by Hadriacus Palus, a nearly horizontal plain (**Fig. 1**). The map region contains light- and dark-toned stratified and massive rocks that outcrop between -2506 and -2844 m elevation. It is dominated by a broad surface with an average 1° northward slope that is locally disrupted by up to 200 m tall mesas and hills and up to 350 meter deep depressions and canyons. The northern part of the study area is located ~530 m below the southern part and contains the southern, scarp-forming margin of Hadriacus Palus. The map region does not contain, but is located adjacent to, bounding topographic promontories.

Results: We identify, describe, and subdivide local strata based on dominant grayscale tone and texture and lateral continuity as observed in a stereo-derived HiRISE orthoimage (0.5 m/px) and DTM (1.5 m/post), supplemented by HiRISE grayscale images. CTX, HRSC, and THEMIS daytime and nighttime IR mosaics helped link local observations to surrounding terrains. Three unit groups form the volumetric bulk of Hadriacus Cavi and one group that constitutes the strata at the southern margin of Hadriacus Palus. Throughout, light-toned strata form steep (40°) slopes and scarps, implying increased erosional resistance compared to intervening dark-toned strata, which form shallower slopes and which source pervasively-occurring surficial cover. We identify no widespread angular unconformities within or between any of the mapped units, though disconformities may exist. Lineaments, interpreted as near-vertical joints and faults with minor offset, are mapped throughout the map area and parallel E-W and NE-SW regional trends. Stratal orientations were determined via three-point solutions.

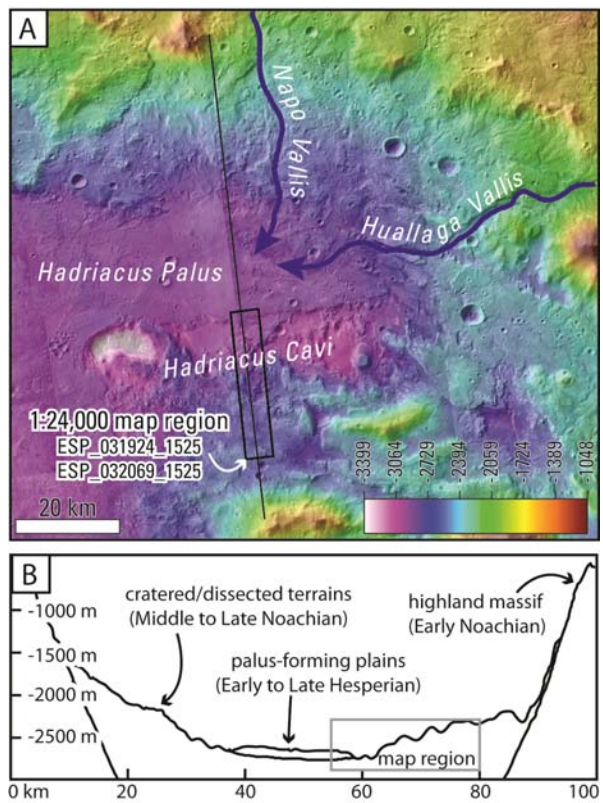

Figure 1. Context for Hadriacus Cavi map region. (A) HRSC DTM over CTX image mosaic shows 1500 m tall massifs bounding the rugged cratered and dissected plains and smooth basin plains of Hadriacus Palus. Napo and Huallaga Valles drain highland terrains and terminate in palus. (B) N-S cross-section depicts basic framework of the massif, highland, and palus units.

The basal group is topographically and stratigraphically the lowest group in the study region, covers 8.1 km^2 (6%) of the map area, and crops out between -2492 and -2838 m elevation. It consists of mostly massive, dark-toned material that is bounded (and subdi-

vided) by three cavi-wide light-toned layers that form low-relief (<10 m) scarps, which shed meter-scale blocks. Other than these scarps, the bulk of the basal group is slope-forming, heavily obscured by dark-toned colluvium and dunes, and displays few internal textures or features at orthoimage resolution. Basal group strata show an average dip of 4° to the west.

The cavi group superposes the basal group and forms the upper walls of the cavi located in the study area. The uppermost unit of this group represents a reference surface (informally termed "level zero") that occurs throughout Hadriacus Cavi. The cavi group covers 62 km^2 (47%) of the map area and crops out between -2185 and -2812 m elevation. It consists of light- and dark-toned strata that form scarps and slopes. The cavi group contains a lowermost unit of non-interlocking, meter-scale angular blocks capped by ~10 meter tall columnar joints (which appear as hexagonal polygons on horizontal surfaces), a light-toned, mostly massive unit containing asymmetrical lenses with flat tops and parabolic bottoms [6], and an uppermost unit characterized by rhythmic sequences of light- and dark-toned strata. Cavi group strata show an average dip of 4° to the northwest.

The mons group forms and crops out at the margins of irregularly-shaped hills located above the "level zero" reference surface. It covers 14 km^2 (10%) of the map area and crops out between -2117 and -2505 m elevation. The mons group consists of mostly massive, light-toned units that often contain meter-scale angular blocks. This group forms continuous steep slopes with intermittent scarps and infrequent meters-thick dark-toned strata. Though discrete meter-scale layers are locally apparent in this group, they are not as consistently traceable as other unit groups. Mons group strata show an average dip of 3° to the northwest, though dip direction of mons group strata significanlty vary.

The palus group crops out in the northern part of the map area along the topographic scarp separating Hadriacus Palus from Hadriacus Cavi. The group covers 14 km^2 (11%) of the map area and crops out between -2640 and -2802 m elevation. It consists of a lowermost, light-toned stratified to massive unit, a light-toned unit composed of meter- to decameter-scale angular blocks, and an uppermost light- and dark-toned stratified unit. The palus group superposes the cavi group and exhumed palus group strata are locally overlain by ejecta from a 2 km-diameter crater located outside of the map area to the east. Palus group strata show an average dip of 3° to the south, though some layers – particularly lower sections – show slight northward dip.

Discussion: We interpret the geologic units mapped in central Hadriacus Cavi as a nearly continuous record of Middle Noachian deposition within annular topographic basins formed by the Early Noachian-aged Hellas multi-ring impact. Though massif-related units do not occur in the map region, lateral extension of mapped units into immediately adjacent areas of Hadriacus Cavi demonstrates these units superpose bounding topographic promontories. The accommodation space for these units was either provided by uplifted crustal massifs related to the Hellas impact or large-scale impact basins that superpose these crustal massifs. A slight northward dip of the basal, cavi, and mons groups implies deposition from south to north. Several sets of E-W trending near vertical fractures and joints transect all of these unit groups, indicating that post-depositional faulting deformed all accumulated strata into broad, monocline like structures. Faulting was perhaps related to reactivation of Hellas-related crustal faults. The palus group has tonal and textural characteristics and stratal orientations that are generally distinct from other mapped groups. This group superposes – and possibly interfingers with – all other units in the map region. All mapped groups were deposited prior to exhumation and exposure of strata to form the existing depressions and canyons.

The occurrence of breccia-like units, columnar joints, broadly traceable light- and dark-tones, and sheer thickness and vertical continuity of local units lead us to postulate that the basal, cavi, and mons groups are predominantly volcanic in origin. The dominant dark-toned, slope-forming character of the lowermost basal group markedly contrasts the dominant light-toned, scarp-forming character of the uppermost mons group. Between these, the cavi group contains tonal and textural characteristics of both subjacent and suprajacent unit groups, which we interpret as recording a transitional depositional environment. If the bulk of these units are indeed volcanic in origin, the cavi group may represent a transitional phase of local volcanic eruptions. Volcanic activity was followed by fluvial activity from Napo and Huallaga Valles, forming Hadriacus Palus as accumulated clastic debris sourced from highland terrains located east and north.

References: [1] Fortezzo C. M. and Skinner J. A., Jr. (2012), *LPS XLIII*, Abstract #2681. [2] Fortezzo C. M. and Skinner J. A., Jr. (2013), *LPS XLIV*, Abstract #2104. [3] Skinner J. A., Jr. and Fortezzo C. M. (2016) *Ann. PGM Meet*, Abstract #7041. [4] Skinner J. A., Jr. et al. (2016), *LPS XLVII*, Abstract #2806. [5] Barton M. L. et al. (2016), *LPS XLVII*, Abstract #2833. [6] Skinner J. A., Jr. et al. (2015) *1st Human EZ Workshop*, Abstract #1052.

Acknowledgements: This work was supported by NASA's Planetary Geology and Geophysics Program under award No. NNH1AU831.