GEOLOGIC MAPPING OF ATHABASCA VALLES, MARS: NOW AND AGAIN. L. P. Keszthelyi, J. Laura A. E. Huff, and W. L. Jaeger, USGS Astrogeology Science Center, 2255 N. Gemini Dr., Flagstaff, AZ. 86001 (laz@usgs.gov).

Introduction: The geologic mapping of the Athabasca Valles region of Mars (MTM quads 05202, 05207, 10202, 10207) was submitted for review in mid-2018 and, as of this writing, we are addressing recently received comments from the reviewers. While originally proposed in 2006 as four separate USGS SIM products at 1:500,000 scale, it was decided it is more helpful to publish this as a single map at 1:1,000,000 scale.

We are also proposing to use this area in FY20 to test the hypothesis that controlled CTX mosaics would significantly aid high-resolution geologic mapping at certain scales. Okubo [1,2] finds that controlled CTX was not essential for mapping at 1:150,000 scale but mapping done at 1:18,000 scale on overlapping HiRISE images did not extend past the coverage of those images. It is plausible that detailed mapping at ~1:50,000 scale over areas larger than HiRISE images, but smaller than an entire MTM quadrangle, would significantly benefit from a base of controlled CTX images.

Mapping Methodology: The scientific focus of this mapping effort is on the extremely recent (i.e., Late Amazonian) volcanism in and around Athabasca Valles. Mapping on the controlled THEMIS daytime IR basemap was augmented with MOLA, CTX, and HiRISE data. Many of the key lava flow contacts are not readily apparent in the THEMIS data and are ambiguous even at CTX resolution. Therefore, we used HiRISE data to determine the nature of flow contacts and CTX data to map them.

Given the extremely young and pristine lavas that dominate this map region, an attempt was made to strictly map lithochronostratigraphic units – i.e., units delineated on the basis of (1) lithology, (2) age, and (3) stratigraphic position (Table 1). While this is the norm in terrestrial geologic mapping, it is often not practical in planetary geologic mapping. Even in this area the lithologic and age constraints become progressively poorer with age. This mapping methodology does violate some cherished traditions in planetary geologic mapping. Perhaps most jarring is that impact craters are considered to be a form of modification of map units as opposed to being a distinct map unit. The extreme level of detail in the presented stratigraphic relationships between the young volcanic units was also disconcerting to the reviewers.

We considered displaying facies variations within lava units but found this impractical at the 1:1,000,000 scale. Instead, we chose to set the coloring of map units transparent enough to allow surface textures visible in the THEMIS basemap to show through. Arrows indicating the flow directions help the reader discern the kinematic interpretation of rafted crustal plates and other features that are prominent in the THEMIS data. The downside of this decision is that it highlights the fact that the contact relationships that are visible only in HiRISE/CTX data do not follow the features visible in the THEMIS basemap.

Geologic Summary: *Noachian Period.* Remains of the highly cratered ancient surface of Mars are present in the map area in the form of patches of cratered terrain and isolated massifs at the southern end of the Tartarus Montes (eNtm). This rugged terrain was extensively degraded into colluvium that is interpreted to be part of the widely mapped Nepenthes Planum Formation (lNnp) [2-5].

Hesperian-Amazonian Transition. The region seems to have been quiet through much of the Hesperian but geologic activity picked up in the Late Hesperian and Early Amazonian. Lavas from the Elysium Rise (AHer) covered the northern part of the map area and a prominent set of NW-SE trending wrinkle ridges formed. At about the same time, the Medusae Fossae Formation (AHmf) began to be laid down in the southern part of the map area. There is strong evidence that this formation has temporally distinct members in the map area but we have not been able to confidently map their extents. However, as described below, the youngest portion of the AHmf must be broken out in our stratigraphy. Our observations support previous interpretations that the AHmf is reworked and subsequently cemented pyroclastic material [6-8].

Late Amazonian. Atypically for Mars, the most vigorous geologic activity has taken place in the last epoch. The lavas of the Cerberus Tholi (lAct) form a textbook example of plains volcanism [9] with intercalated low shields and flood lavas. We are able to discern thirteen separate eruptive episodes that are classified as members of this formation. The volcanism in the region was capped with the cataclysmic emplacement of the Athabasca Valles Basalt (lAav) as a turbulent flood. Curiously, there is a significant deposit of AHmf atop this most recent lava which may be reworking of older AHmf [8] or deposits of pyroclastics from the fountains that fed the lAav .

Future Work: The unanswered geologic questions in this region range from the Noachian to latest Amazonian. We are specifically interested in investigating (1) the possible role of aqueous fluids in the degradation of the Noachian terrains (conversion of eNtm into lNnp); (2) detailing the time evolution of eruption style and vigor of the recent volcanic activity in this region; and (3) the relationship between the Medusae Fossae Formation and the Athabasca Valles flood lava.

We expect that these questions can be addressed with high-resolution geologic mapping. We observed interesting features and relationships in the CTX and HiRISE images that could not be represented at the 1:1,000,000 map scale. The misalignment of the CTX data was sufficient to frustrate mapping at the more appropriate 1:50,000 scale. Controlled CTX data should enable such mapping of key regions within this map area.

We are currently working to control >500 CTX images from this area. For FY19, the goal is the develop methods and procedures that could be used to create a global controlled CTX data product. However, creation of such a product would take years of effort at considerable cost to NASA. An uncontrolled global CTX mosaic is already available [8] and we need to establish if the cost of controlling CTX adds sufficient value to justify the cost. Our proposal for FY20 is to conduct 1:50,000 scale mapping of selected areas using the uncontrolled and controlled CTX data to ascertain if there is a substantial difference in the geologic interpretations. The Athabasca Valles region seems especially well-suited for this investigation. We hope to present those results at next year's mappers' conference.

References: [1] Okubo, C. (2019) *PGM Meeting*, Abstract #TBD. [2] Okubo, C. (2014) *USGS SIM* 3309. [3] Tanaka, T., et al. (2005) *USGS SIM* 2888. [4] Skinner, J., and K. Tanaka (2018) *USGS SIM* 3389. [5] Huff, A. E., and J. Skinner (2018) *PGM Meeting* Abstract #7033. [6] Scott, D. H., and K. Tanaka (1982) *JGR, 87*, 1179-1190. [7] Ohja, L., and K. Lewis (2018) *JGR*, *123*, JE005565. [8] Kerber, L., and J. W. Head (2010) *Icarus*, *206*, 669-684. [9] Greeley, R. (1982) JGR, 87, 2705-2712. [10] Dickson, J. et al. (2018) *LPSC 49*, Abstract #2480. [11] Werner, S. C., and K. Tanaka (2011) *Icarus*, *215*, 603-607.

Unit name	Unit symbol	Lithology	N(1)	N(5)	N(16)	Crater-density age[1]	Superposition relations[2]
Medusae Fossae Formation	AHmf	Volcaniclastics	830.7 ± 214.5	166.1 ± 95.9	0	eH – eA	<eNtm, lNnp, lAav; >lAct, lAav
Athabasca Valles basalt	lAav	Basalt	8.7 ± 8.7	0	0	lA	<eNtm, lNnp, AHer, lAct; >AHmf
Cerberus Tholi basalt	lAct	Basalt	94.8 ± 39.7	0	0	lA	<eNtm, lNnp, AHer, AHmf; >lAav
Elysium rise basalt	AHer	Basalt	1901.82 ± 139.1	61.0 ± 24.9	0	lH – eA	<eNtm, lNnp; >lAct, lAav
Nepenthes Planum Formation	lNnp	Various	6285.01 ± 430.6	354.1 ± 102.2	29.5 ± 29.5	lN – lH	<eNtm; >AHer, lAct, lAav, AHmf
Tartarus Montes Formation	eNtm	Various	2846.14 ± 383.8	1138.5 ± 242.7	465.7 ± 155.2	eN – lH	>lNnp, AHer, lAct, lAav, AHmf

Table 1. Characteristics of geologic units in the map region: areas, crater densities, and superposition relations. [1]Based on crater-density boundaries as determined by Werner and Tanaka [11]. A, Amazonian; H, Hesperian; N, Noachian; e, Early; m, Middle; l, Late. [2]"<" indicates "younger than", "~" indicates "overlaps in time with", and ">" indicates "older than". Only adjacent units listed.