MARS GLOBAL GEOLOGIC MAPPING: AMAZONIAN RESULTS. K.L. Tanaka[1], J.M. Dohm[2], R. Irwin[3], E.J. Kolb[4], J.A. Skinner, Jr.[1], and T.M. Hare[1], [1]U.S. Geological Survey, Flagstaff, AZ, ktanaka@usgs.gov, [2]U. Arizona, Tucson, AZ, [3]Smithsonian Inst., Washington, DC, [4]Google, Inc., CA.

Introduction: We are in the second year of a five-year effort to map the geology of Mars using mainly Mars Global Surveyor, Mars Express, and Mars Odyssey imaging and altimetry datasets. Previously, we have reported on details of project management, mapping datasets (local and regional), initial and anticipated mapping approaches, and tactics of map unit delineation and description [1-2]. For example, we have seen how the multiple types and huge quantity of image data as well as more accurate and detailed altimetry data now available allow for broader and deeper geologic perspectives, based largely on improved landform perception, characterization, and analysis. Here, we describe early mapping results, which include updating of previous northern plains mapping [3], including delineation of mainly Amazonian units and regional fault mapping, as well as other advances.

Northern plains: One of the first steps in re-drawing Amazonian contacts within and around the Martian lowlands includes the adaptation of the recent geologic map of the northern plains [3], which ranges from 1:7.5M scale at the equator to 1:15M scale at the north pole due to its polar stereographic projection. Our new map will be compiled at 1:20M scale in either Lambert Equal-area Azimuthal (as proposed) or another planet-wide projection, such as Mollweide (as used in [4]). This reduction in scale has led us to (1) eliminate units whose outcrop extents are not readily viewable at 1:20M scale and (2) merge units having broadly correlative ages and similar regional occurrences (e.g., several Amazonis Planitia units). For contact types, we have eliminated “inferred” and “inferred, approximate” and added “time-transgressive.” We also expect some contacts to shift in significant ways. In particular, the outer margins of the Vastitas Borealis interior and marginal units were based on only a handful of released Thermal Emission Imaging System (THEMIS) infrared (IR) images available at the time; we now have ~100% coverage of the planet with this data set, including global mosaics of day time and night time images. The thermal characteristics of the marginal unit are commonly distinctive, especially when coupled with kilometer-scale surface textures (e.g., as observed in Mars Orbiter Laser Altimeter (MOLA) digital elevation models (DEMs) and THEMIS visible (VIS) images).

Highlands: Several changes to previous mapping efforts [e.g., 5-7] are being made in the cratered highlands, although some consistency with older mapping is not uncommon. Where tenable, we are defining units on the basis of primary morphologic characteristics, relative age, and composition at 1:20M scale rather than post-depositional features, such as faults and valley networks; the latter are being mapped as secondary (superposing) geologic features. To substantiate this approach, we have begun assessing methods of dividing highland terrains into discrete geologic units. This includes analysis of overlapping impact crater materials of variable age. These assessments are improved by simple qualitative application of THEMIS and Mars Reconnaissance Orbiter (MRO) Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) spectral data sets. The combination of spectral and morphologic information may be a critical method to differentiating impact units within the highlands. This tactic is still being explored.

Amazonian highland features and rock materials thus far include the ice-rich debris aprons that are commonly seen on hill slopes along the eastern Hellas rim and much of the upper part of Reull Vallis. In addition, the western floor sections of Hellas basin contain mapped Amazonian mantles; these mantles are also assumed to be ice-rich based on THEMIS VIS images showing mild flow deformation features in mantle sections that overlie locally steep terrain. The relative-age assignments for the Argyre basin floor materials (mostly Noachian and Hesperian in Viking-era mapping [5]) is being re-evaluated to see whether Amazonian resurfacing also occurred in this Noachian highland impact basin [8].

Wind-eroded layered deposits and alluvial fans are also noted. A few large dune fields occur inside impact basins. Smooth plains material in a broad trough SE of Isidis basin may also be Amazonian [5]. Finally, Amazonian layered materials comprise the south polar plateau, Planum Australe.

Tharsis: For Tharsis, we include an expanded number of tentative geologic contact types mapped, as well as specification of where they are used, including: (1) certain (e.g., older outcrops that are deformed by tectonic structures are clearly onlapped by younger flow materials); (2) approximate (e.g., individual outcrops at mappable scale that are embayed by flow materials such as the margins of the aureole deposits of the large shield volcanoes, Tharsis Montes and Olympus Mons); (3) gradational (e.g., flows that lack lobate flow margins which transition into plains-forming materials such as in the case of flows that drape parts of the eastern basal scarp of Olympus Mons); and (4) buried (e.g., parts of shield-forming basal scarp materials of Olympus Mons that are draped by lavas). Other improvements of previous, Viking-based mapping [5, 7] consist of: (1) enhanced stratigraphic and cross-cutting relations among rock materials and structures [9]; (2) an increase in the types and number of mapped structures, including improved differentiation of fault segments, fault scarps of complex rift systems, and ridge types [9, 10].

Summary: We have completed preliminary mapping of most Amazonian materials as defined in previous mapping. Yet to be explored in detail, however, is Amazonian mantling. For example, a meters-thick mantle ~<150,000 years old covers mid-latitude parts of Mars [12], but is difficult to recognize in global-scale datasets. Also, there may be vestiges of earlier mantling such as the Astapus Colles unit mapped in NW Utopia Planitia [3]. Where highland mantles are thin, the highland materials will be mapped based on the materials that define the surface topography at mapping resolution. The character and relative age of the local mantling and its affect on surface appearance will be discussed in the map-unit descriptions. Extensive yet thin mantles such as described in [12] can be portrayed in digital-only map layers and in figures in the printed map. On the other hand, where the mantles are thicker and more extensive, they will be mapped and attributed as Amazonian units.

Notable improvements in technique over previous work include (1) improved delineation and differentiation of rock materials, (2) more sophisticated use of digital tools to portray in more detail various types of geologic contacts, structural landforms, and stratigraphic and cross-cutting relations among rock materials and structures, and (3) significant refinement in how the stratigraphic correlations among map units are depicted (adapting some of the techniques shown in [11]). Additional questions will need to be addressed as we deal with crater units, secondary crater fields, units resulting from extensive reworking of older materials (e.g., as in chaotic terrains), and other issues.

References: [1] Tanaka K.L. et al. (2007) *7th Intl. Conf. Mars* Abs. #3143. [2] Tanaka K.L. et al. (2008) *LPSC XXXIX*, Abs. #2130. [3] Tanaka K.L. et al. (2005) *USGS Map SIM-2888*. [4] Nimmo F. and Tanaka K. (2006) Ann. Rev. Earth Planet. Sci. 33, 133-161. [5] Scott D.H. et al. (1986-87) *USGS Maps I-1802-A, B, C.* [6] Leonard G.J. and Tanaka K.L. (2001) *USGS Map I-2694*. [7] Dohm J.M. et al. (2001) *USGS Map I-2650.* [8] Dohm J.M. et al., this meeting. [9] Dohm, J.M., and T.M. Hare (2007) *LPSC 38*, Abstract #1403. [10] Dohm, J.M., and T.M. Hare (2008) *LPSC 39*, Abstract #1935. [11] Geological Survey of Queensland (1975) *Mines Dept. State Series: Map 2*. [12] Mustard J.F. et al. (2001) Nature 412, 411-414.

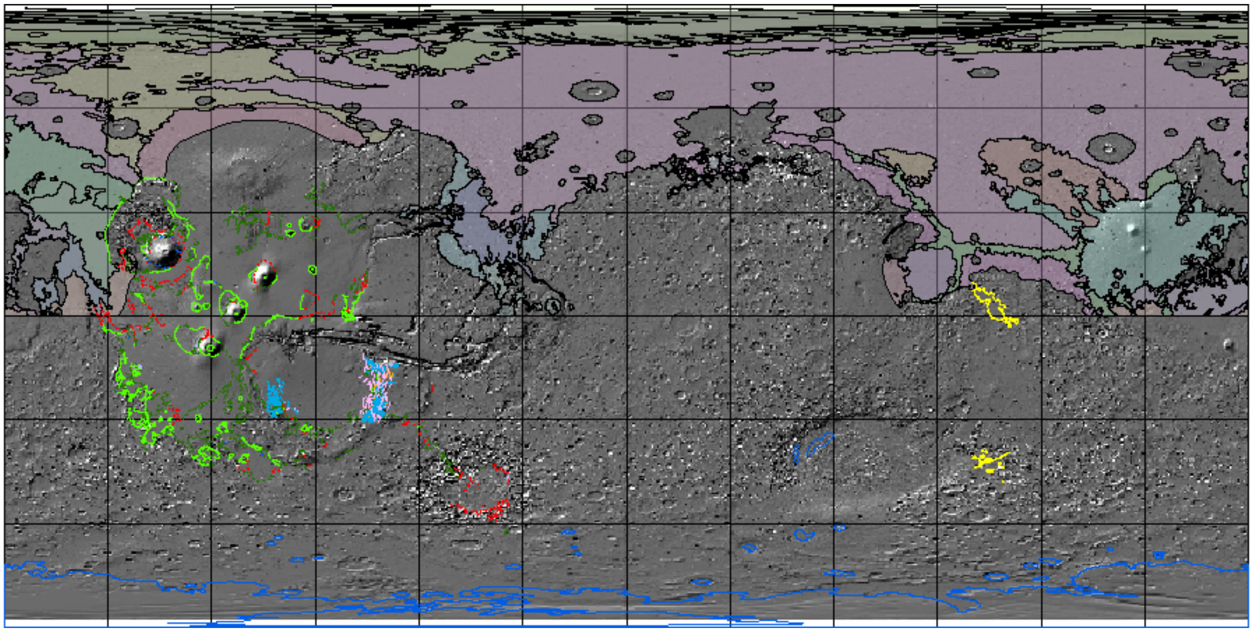

Figure 1. Current status of the global geologic map of Mars (in progress). The colored outcrops of Amazonian and Hesperian materials in the northern hemisphere are adapted from [3] by mapper JAS (see text for details). Tharsis and Argyre region mapping by JMD includes contacts of most Amazonian units (certain, bright green solid lines; approximate, dark green dashed lines; gradational, red dashed lines; buried, blue dashed lines) and some of the SE Tharsis tectonic structures (fault, medium blue lines; narrow ridge, orange lines; wrinkle ridge, pink lines). Southern highland Amazonian unit contacts are shown as mapped by EJK (dark blue lines) and RI (yellow lines). MOLA shaded relief base, Simple Cylindrical projection, 30° grid.