ORIGIN AND EVOLUTION OF LAYERED DEPOSITS IN MERIDIANI PLANUM. F. P. Seelos IV and R. E. Arvidson, McDonnell Center for the Space Sciences, Department of Earth and Planetary Sciences, Washington University, Box 1169, One Brookings Drive, St. Louis, MO 63130 (seelos@wunder.wustl.edu).

Overview: Multiple remote sensing data sets were used to identify, characterize, map, and understand the origin and evolution of the hematite-bearing deposits [1] and associated units in the Meridiani Planum region of Mars. MOLA and MOC (WA and NA) data were used in combination to identify and map surface units based on planimetric configuration, topography, brightness, and texture and to infer superposition and embayment relationships (Figure 1). The boundary of the hematite-bearing deposits was delineated using the hematite index threshold as defined by *Christensen et al.* [1]. Surface properties of these units were then characterized using MOLA intra-shot pulse width derived RMS roughness [2,3] and TES-based albedo, thermal inertia [4], and spectral emissivity [5]. The data indicate that: (a) the hematite-bearing unit is the remnant of the top stratum of a widespread layered complex that was deposited onto dissected cratered terrain; (b) the complex was covered by a extensive sedimentary mantle; (c) the entire region has been subjected to differential aeolian erosion that has stripped the mantle, exposing underlying materials that in turn have been partially eroded by wind; and (d) the layered complex was emplaced as flows and tephra deposits, and the unusual albedo and spectral properties are consistent with alteration involving aqueous fluids, either during or after emplacement [6].

Surface Unit Characterization: The basal unit in the study area is Noachian cratered terrain that has been extensively dissected by channel systems and is termed the dissected cratered terrain or Unit DCT. The basal unit of the layered complex was termed the etched unit by *Hynek et al.* [7] and we retain that nomenclature here as Unit E. Detailed analysis of WA and NA data shows that the morphology of Unit E is variable and includes extensive exposures of terrain characterized by: (a) relatively flat, dark polygonal blocks separated by bright, fractured ridges; (b) interconnected ridges and stepped plateaus that demarcate underlying plains into polygonal patterns; and (c) land-

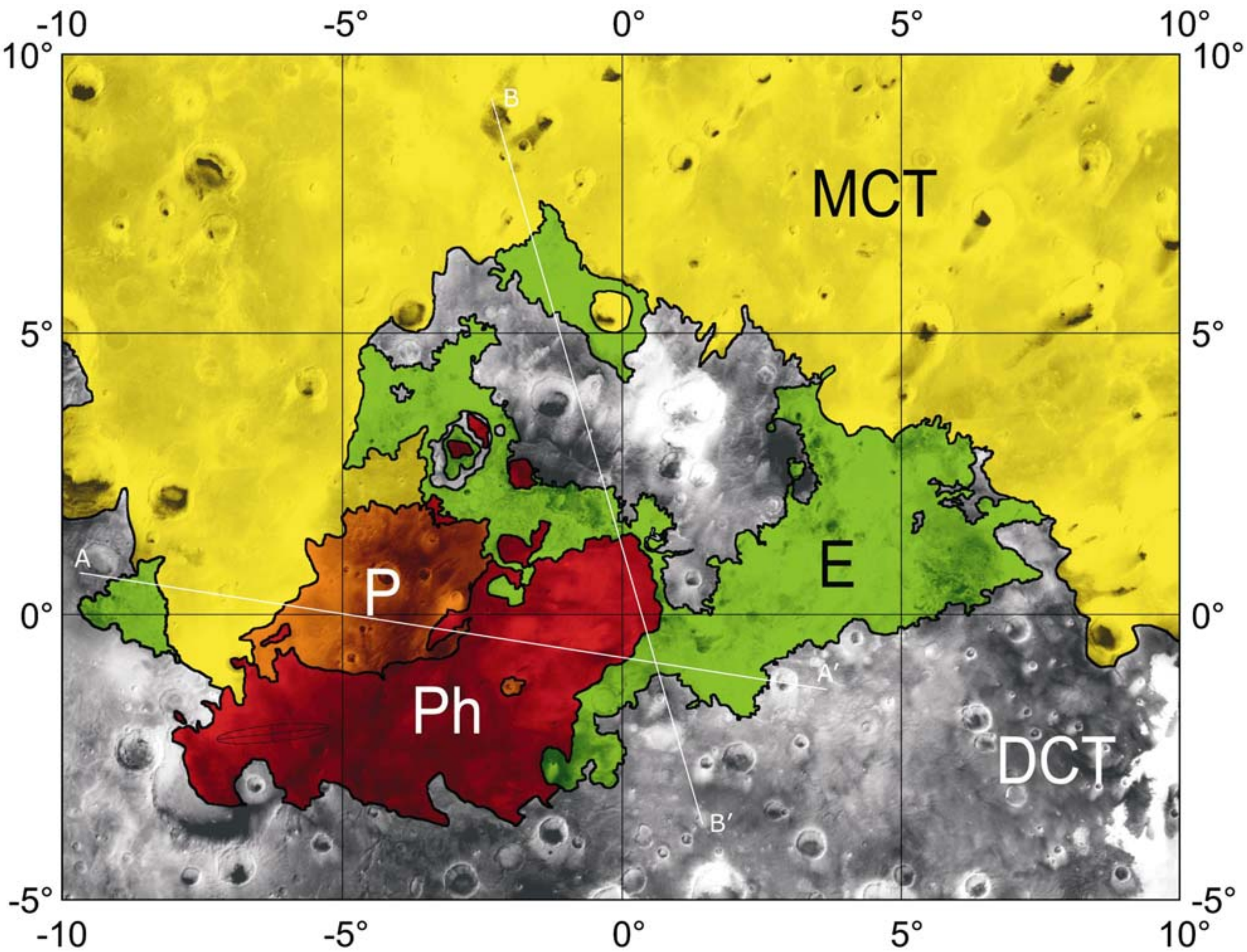

Figure 1. Surface units map for the Meridiani Planum region. The units identified in this study are the Dissected Cratered Terrain (DCT), Etched Terrain (E), Hematite Bearing Plains (Ph), Plains (P) ,and Mantled Cratered Terrain (MCT). The MER landing ellipse is centered on approximately 2° S, -6° E.

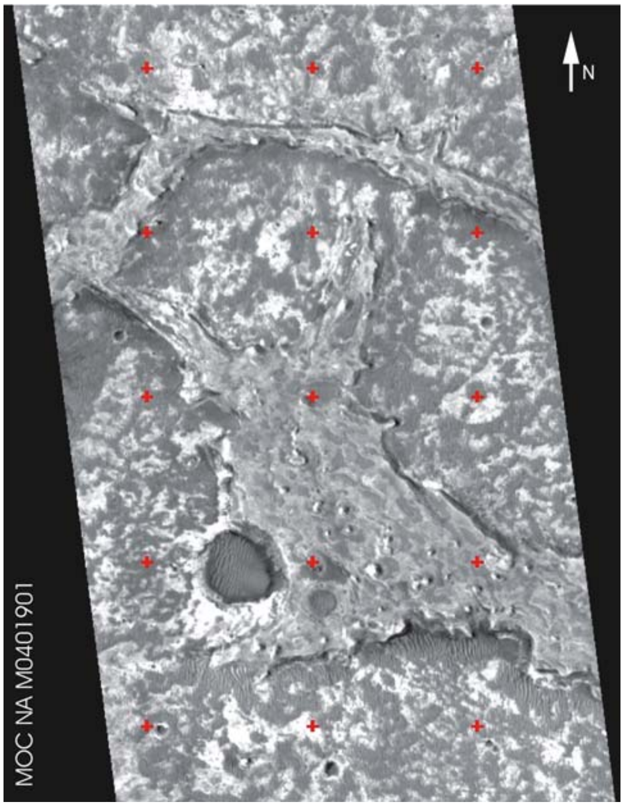

Figure 2. Interconnected ridges forming polygonal terrain patterns characteristic of the Etched Unit.

forms that consist of buttes, mesas, and what appear to be yardangs, often exposing layered deposits on cliff faces and slopes (Figure 2).

The hematite-bearing plains unit (Ph) is stratigraphically above the Unit E. NA data show that Unit Ph consists of smooth, dark plains that are locally reworked into dunes and that in many places only partially cover Unit E (Figure 3). The northwestern edge of the Ph unit transitions to another plains-forming surface, herein termed Unit P. Based on available evidence Unit P is believed to be a lateral facies variation and that both deposits overlie Unit E.

Units DCT, E, P, and Ph are covered by a mantle in the northern portion of the study area that has been partially stripped by aeolian processes to expose underlying materials. The mantled unit largely occurs on Noachian cratered terrain and is mapped as mantled cratered terrain unit or Unit MCT. Examination of WA and NA images covering the boundary between the Units E and MCT shows that the characteristics associated with Unit E landforms become muted and even disappear beneath the mantle that defines Unit MCT. The thickness of the mantle is inferred to be approximately 10 m near the unit boundary, thickening to the north.

Hypothesis Development: The morphology of Unit E includes landforms associated with emplacement, burial, and differential aeolian erosion. A volcaniclastic origin is preferred for Unit E, and the entire layered complex, for several reasons. The deposits are widespread and not confined to a basin as they would be if the material accumulated in a lake or shallow sea. The inferred mineralogy for the complex is dominated by mafic igneous components, with the exception of hematite for the capping Ph unit, whereas minerals such as pyroxene and feldspar would not survive well in a lacustrine or marine environment. The regions within Unit E that exhibit dark polygons separated by bright ridges are interpreted to be exposed resistant materials that retain morphologic evidence for emplacement even after burial and exhumation.

Formation and evolution scenario. The following scenario is a plausible formation and evolution sequence for these landforms. Lava flows were deposited onto Unit DCT and subjected to isotropic extension that fractured the flows into polygons. Fracturing was followed by the emplacement of dikes and flows that were in turn extended to form horst-graben patterns aligned with dike emplacement azimuths. These landforms were then buried by volcaniclastic deposits and subsequently exhumed by wind. In other regions within Unit E the fractures became conduits for eruption of volcaniclastic materials. Widespread tephra blanketed these areas, followed by aeolian erosion to expose the deposits. Regions above the source dikes would have accumulated the thickest deposits and perhaps become the most indurated, thereby leaving behind ridges and stepped plateaus as the region was exhumed. Units Ph and P are interpreted to represent the last stage of the volcaniclastic activity, producing a widespread cap that covered the complex. The hematite bearing material within Ph has been locally reworked into dunes, probably as lag materials due to the high density of this mineral.

Spectral considerations. Analysis of TES-derived emissivity spectra for the mapped units reveals that units DCT, E, and Ph are related mineralogically. The spectral signature for Unit DCT is intermediate to the Type I and Type II surfaces identified by *Bandfied et al.* [8] and is consistent with a basaltic mineralogy. Unit E, despite having a higher albedo and thermal inertia, differs only slightly from the DCT unit in spectral emissivity. This slight variation in spectral character is attributed to an increase in the abundance of volcanic glass. The spectral signature for Unit Ph is also comparable to unit DCT, with the addition of a significant hematite component. In contrast, Unit E is quite distinct from the DCT and Ph units in the visible and reflected infrared wavelengths, appearing to be both brighter and redder. The unusual spectral characteristics associated with Unit E are hypothesized to be due to glassy coatings that have devitrified to cryptocrystalline clays with embedded nanocrystalline hematite crystals, similar to relatively bright, red (in visible and reflected infrared wavelengths) palagonite coatings found on Mauna Kea, Hawaii [9]. It is attractive to ascribe both the formation of the hematite in Unit Ph and the bright, red color of Unit E to the presence of devitrified glasses, although such an explanation is certainly non-unique.

Hypothesis Testing: We are in a fortunate position to be able to test and update the hypotheses presented with the Athena Payload on the Mars Exploration Rover. The rover will be able to investigate both the dark dune material, presumably the source of the hematite spectral signature, and the brighter substrate that is hypothesized to be exposures of the underlying Unit E. The mast-based remote sensing package containing the Pancam imaging system and the Mini-TES emission spectrometer will serve to map the morphology, physical properties, and mineralogy of the sites visited. Key questions that will be addressed over the course of the mission include the identification of the hematite-bearing material, the formation mode of the hematite itself, and the nature of the bright substrate. In addition, all of the acquired data will be used to test the idea that the materials and landforms were emplaced volcanically as flows and tephra deposits, mantled, and then exhumed by wind action. Finally, it is expected that the complete mission data set will provide definitive tests of the nature and extent of interaction of the surface materials with aqueous fluids and thus dramatically increase our understanding of the evidence for habitability on Mars.

[1] Christensen P. R. et al. (2001) *JGR, 106,* 23973-23886. [2] Garvin J. B. et al. (1999) *GRL*, *26*, 381-384. [3] Neumann G. A. et al. (*in press*). [4] Mellon M. T. et al. (2001) *Icarus, 148,* 437-455. [5] Smith M. D. et al. (2000) *JGR, 105*, 9589-9607. [6] Arvidson R. E. et al. (*in press*). [7] Hynek B. M. et al. (2002) *JGR*, *107*, 18. [8] Bandfield J. L. et al. (2000) *Science*, *287*, 1626-1630. [9] Morris R. V. et al. (2000) *JGR*, *105*, 1757-1817.

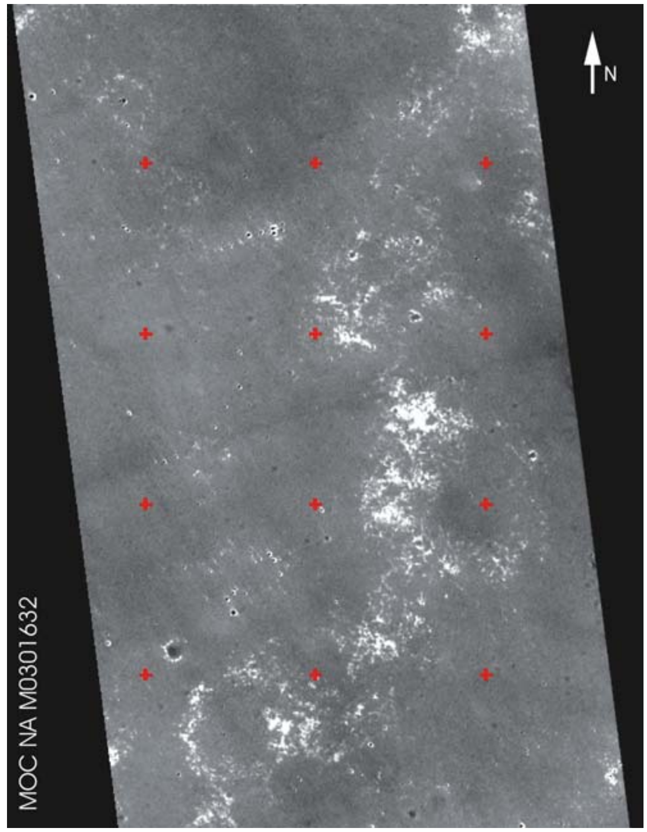

Figure 3. Unit Ph with exposures of the underlying Unit E.