EXTENSIVE BEDROCK THROUGHOUT TERRA MERIDIANI, MARS: IMPLICATIONS FOR REGIONAL HYDROLOGIC PROCESSES. B. M. Hynek, B. M. Jakosky, N. T. Putzig, and M. T. Mellon, Laboratory for Atmospheric and Space Sciences, University of Colorado, 392 UCB, Boulder, CO 80309. brian.hynek@lasp.colorado.edu

Introduction: The mineral gray hematite was discovered in the Terra Meridiani region of Mars by the TES aboard the Mars Global Surveyor spacecraft [1]. The hematite occurs on a broad plain that rests unconformably on the underlying Noachian cratered terrain and covers an area of ~1 x 10^5 km^2. Formation of this mineral often requires the presence of water for extended periods of time, making the site of high astrobiological importance and the destination of the 2003 Mars Exploration Rover (MER) named Opportunity [2]. The Opportunity Rover has since found light-toned bedrock outcrops in the walls of craters where it landed and *in situ* analysis strongly suggests that they have been altered, and perhaps formed, by long-term interaction with water [3]. In this paper, we use remote sensing data to argue that these outcrops are seen across the entire hematite-bearing plain and well beyond it. Thus, whatever water-driven process acted to alter these materials did so on a regional, not local, basis.

Light-Toned Outcrops Occur Throughout the Hematite Plain: Previous geomorphic mapping of the Meridiani region indicated that the hematite-rich plains unit (herein referred to as unit Ph, for "plains, hematite") is an upper stratum in a thick (100s m) stack of layered deposits [4]. A major stratigraphic component of these layered deposits are high albedo, high thermal inertia bedforms [4-6]. Thermal inertia, determined from remotely-sensed observations, is used to infer near-surface particle size, degree of induration, rock abundance, and bedrock exposure [7]. The high inertia and albedo layers were called "etched" terrain (herein termed unit E) because of their rough appearance resulting from eons of differential erosion [4].

The properties of unit Ph are markedly different than the subjacent unit E, making the two readily distinguishable. Unit Ph is characterized by laterally extensive plains that are smooth at all scales. The unit is quite dark relative to surrounding terrains, with a mean bolometric albedo of ~0.15, and also has a low thermal inertia as derived from TES [*5*,8]. Conversely, unit E has both a high albedo and high thermal inertia [5,8] and consequently appears very bright in MOC WA and MOC NA images

The underlying bright terrain is exposed throughout unit Ph as seen within MOC WA, MOC NA, and THEMIS images [8]. Nearly every fresh crater on unit Ph (*i.e.* those that impacted the pre-existing dark plain and underlying stratigraphy) has light-toned layered materials comprising its walls (Figs. 1a and 1b). In THEMIS data, the layers have relatively high thermal inertias, often several hundred SI units above the adjacent hematite-bearing plains. These layers begin just below the rim of the impact craters, usually within a few to 10s of meters. Light-toned layering extends down hundreds of meters in the larger impacts. For example, this characteristic layering is seen spanning 500 vertical meters in the walls of a 20-km-diameter superposed impact crater just south of the landing ellipse (centered at 3.0ºS, 6.3ºW). This impact postdates the deposition of the layered sequence and was large enough to form strings of smaller secondary impacts, several of which cut through the Opportunity landing ellipse and are visible in MOC NA images. Even these small impacts, with diameters <<1 km and implied depths of a few to tens of meters have pierced the underlying bright terrain (such as those seen in Fig. 1b).

The Opportunity Rover landed in a ~20-m-diameter impact crater where light-toned layered outcrops are exposed in the walls [2]. The bedrock is covered with a thin, dark, hematite-rich soil [9]. We hypothesize that the Rover is observing the uppermost layers of unit E. The occurrence of light-toned bedrock in a crater that is only a few meters deep reveals that in this region of the hematite-bearing plains, the dark Ph unit is a few-meter-thick deposit sitting atop unit E. Unit E has a much greater thickness inferred from its exposure in deeper nearby craters that are visible in MOC and THEMIS data. In fact, the dark soil is probably a lag deposit made of dense, coarse, hematite-rich grains derived from the erosion of previously-existing overlying layers, and this is the source of the hematite signature detected by the TES instrument. Conversely, unit E consists of in-place underlying bedrock as is evident from its high thermal inertia and its layered exposures seen in images. Exposure of unit E in the walls of impact craters across the entire hematite plain suggests that a thin, mobile unit Ph resting atop a much thicker unit E bedrock is the norm.

Full Exposure of the Etched Terrain: Prior to the MER mission, unit E was known to outcrop around much of the margin to the east, north, and west [4-5]. We have been using MOC and THEMIS data to expand and revise previous mapping efforts as well as characterize the thermophysical properties of the unit beyond the hematite plain. Our new results show that unit E has a surface exposure covering 2.3 × 10^5 km^2 in the Meridiani region that spans 20º of longitude and 14º of longitude [8]. Large, contiguous outcrops are exposed vertically as well as laterally. For example, a deep trough just north of unit Ph cuts through ~500 m of stratigraphy and unit E is exposed across the entire section. Layering is evident throughout the unit and in places individual layers can be continuously mapped for >250 km, particularly to the east of unit Ph. These layers are often extremely flat lying and maintain a nearly constant elevation over great distances.

Details of the Etched Terrain: While the etched deposits have been previously recognized [4-6], their stratigraphy and composition were not known. We have begun to characterize the many individual layers that are observable in the topographic, visible, and thermal infrared data sets from MGS and MO. Although the light-toned units are ubiquitously high in thermal inertia, there is substantial variation between facies within the layered complex, implying compositional differences (Fig. 2). In many places, tens of layers are identifiable within the thermal inertia maps covering stratigraphic sections of the light-toned outcrops. Further, large craters and troughs in the region have exposed an equally large number of layers. Thermal inertia differences from one layer to the next can be large, on the order of 80 J m^{-2} K^{-1} $s^{-1/2}$. This suggests very different conditions during emplacement of individual facies. The many alternating laminar facies with differing thermophysical and erosional properties suggest periodic deposition of different sedimentary compositions possibly related to clast size, grain orientation and packing, or mineralogy. Alternatively, the parent rock could have had the same initial lithology with discrete sections having undergone different degrees of subsequent alteration.

Summary: Light-toned bedrock has been observed at the Opportunity landing site. These outcrops are rich in a slew of mineral and textural signatures that require long-term interaction of, and possibly formation from, water [2]. Remote sensing data suggest that these outcrops are not a local phenomenon, rather, they are exposed across the entire hematite-bearing plain and well beyond. These units have a complex, thick, and extensive stratigraphy that covers an area $>3 \times 10^5$ km^2, an area greater than that of all the Great Lakes combined [8]. Thus, the water-driven process altered, and possibly formed, the rocks at the Opportunity landing site acted over a vast region of Mars.

References: [1] Christensen P.R. *et al*. (2000) *JGR, 105,* 9623-9642. [2] Golombek, M. P., *et al*., (2003) *J. Geophys. Res., 108,* doi:10.1029/2003JE002074. [3] Squyres, S. W., *et al*., (2004) *Lunar Planet. Sci. Conf.,* XXXV, abstract 2187.pdf. [4] Hynek B.M. *et al*. (2002) *JGR, 107, E10*, doi:10.1029/2002JE001891 [5] Arvidson R.E. *et a*l. (2003) *JGR, 108, E12,* doi:10.1029/2002JE001982. [6] Edgett, K.S., and M.C. Malin (2002) *Geophys. Res. Lett.*, *29,* doi:10.1029/2002GL016515. [7] Mellon M.T. *et al*. (2000) *Icarus*, *148,* 437-455 [8] Hynek, B. M. (2004), *Nature*, in the press. [9] Christensen, P.R. *et al*. (2004) *Lunar Planet. Sci. Conf.*, XXXV, abstract 2186.

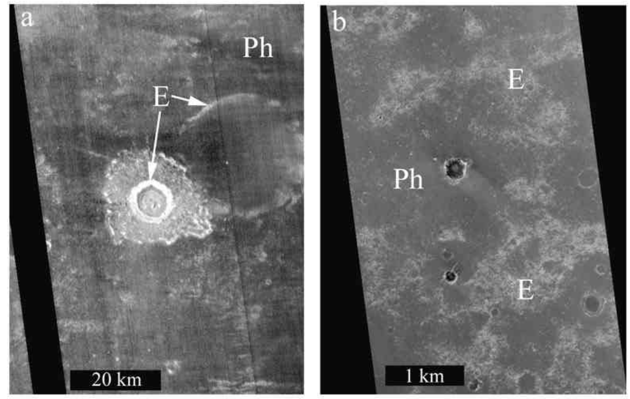

Figure 1. (a) THEMIS thermal inertia data showing exposures of etched terrain within crater rims across the hematite-bearing plain (bright = high inertia). (b) MOC NA image showing similar exposures.

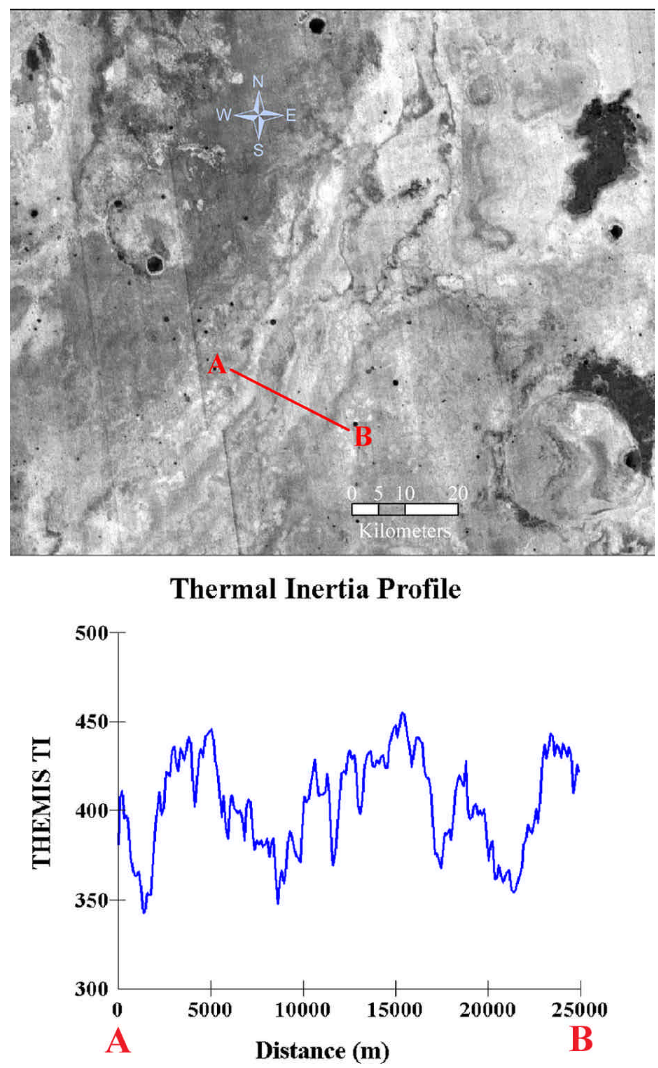

Figure 2. THEMIS-derived thermal inertia map of a portion of etched terrain east of the hematite plain. Substantial differences in thermal inertia occur within the unit, implying compositional heterogeneity.