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Light-toned, layered outcrops of northern Terra Meridiani, Mars: Viking, Phobos 2, and Mars Global Surveyor observations

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Abstract

1. Introduction

Locating outcrops of sedimentary rock on Mars is an important step toward deciphering the planet's geologic and climatologic record. Sedimentary rock representing the earliest martian environments, are of particular interest in this context. This is a report about a vast exposure of material proposed to be martian sedimentary rock (Figure 1, showing a MOC red wide angle view of the outcrop areas and MER ellipse location, from 351°W to 10°W; 5°S to 9°N). The outcrops cover an area (~300,000 km^2) roughly the size of the Colorado Plateau in North America (~260,000 km^2). The materials occur in northern Terra Meridiani, near of one of the four sites being considered for a 2004 NASA Mars Exploration Rover (MER) landing. The landing ellipse, centered at _°S, _°W, lies in a region exhibiting smooth and rough (at meter scale) dark-toned surfaces, with scattered light-toned patches (Figure 2, showing MOC high res. view of MER site surfaces). Stratigraphically, the dark-toned materials at the MER site lie unconformably on top of a previously-eroded, light-toned surface [*Malin and Edgett*, 2000]; the light-toned patches in the landing ellipse are geologic windows down to this lower stratigraphic unit. North of the landing ellipse, the light-toned materials are well-exposed because the darker materials have been removed, stranding outlier remnants in a few locations. The light-toned materials are layered, vertically heterogeneous, and exhibit lateral continuity over hundreds of kilometers [*Malin and Edgett*, 2000]. Eroded layers produce cliffs; some outcrops are expressed as mesas, buttes, and spires; and impact craters ranging in diameter from a few meters to tens of kilometers are interbedded with the layers [*Edgett and Malin*, 2002].

The purpose of this report is to summarize the results of > 6 years of photogeologic investigation into the nature of the light-toned outcrops of northern Terra Meridiani. The work is a "snapshot" of progress made toward eventual geologic mapping and establishment of the stratigraphic sequence for the materials through 30 September 2002, a day prior to the first release of Mars Odyssey Thermal Emission Imaging System (THEMIS) data to the NASA Planetary Data System (PDS). The main body of data examined were Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) images acquired through 30 September 2002. The data also include Viking orbiter images, a Phobos 2 Termoscan image, MGS Mars Orbiter Laser Altimeter (MOLA) topographic observations, and the products of published Viking Infrared Thermal Mapper (IRTM) and Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES) analyses. Through September 2002, over 126,000 MOC images had been acquired, and > 600 of the MOC narrow angle (1.5–12 m/pixel) images occur within the portions of Terra Meridiani and southwestern Arabia Terra shown in Figure 1.

2. Setting

Located between the heavily cratered terrains of western Arabia to the north, Margaritifer Terra to the west/southwest, Deucalionis Regio to the south, and Terra Sabaea and Schiaparelli Crater to the east, Terra Meridiani is dominated by the classical low albedo feature, known for nearly four centuries, Sinus Meridiani (Figure 3, showing regional and global context, location of TES hematite, labeling the divisions of north, central, and south Meridiani). Southern Terra Meridiani is heavily cratered and grossly similar to other heavily cratered regions of Mars. Central and northern Terra Meridiani are less cratered, though craters are in some places buried and in others emergent from beneath the present surface. MGS TES spectra of central Terra Meridiani were interpreted by *Christensen et al.* [2000, 2001] to indicate the presence of abundant (_%), crystalline hematite at the surface (Figure 3). Northern Terra Meridiani is dominated by light-toned, layered outcrops, the materials that are the subject of this report. Valley networks do not occur in northern or central Terra Meridiani; some that do occur in southern Terra Meridiani abruptly end at the contact with the hematite-rich surfaces of central Terra Meridiani (see maps of *Pieri* [1976] and *Carr and Chuang* [1997]).

3. Previous Studies

The earliest views of the geography and geologic configuration of Terra Meridiani came from Mariner 6 image 6N13 and Mariner 7 image 7N7. In these images, the area now known to exhibit light-toned layered outcrops was seen as a sharp-edged, light-toned region amid lower-albedo, cratered surfaces. Mariner 9 and Viking orbiter images provided additional details of the region's geology and geomorphology, and it was from Viking images that most of the pre-MGS observations were documented. In particular, some of the surfaces of north Terra Meridiani were described as "etched" [e.g. Presley, 1986; Murchie et al., 1993], and the terrain of central Terra Meridiani was described as "smooth" [Edgett and Parker, 1997]. Etched materials were best seen in Viking 1 and Viking 2 high resolution images from orbits 709A and 410B, and they were presented in the 1:15,000,000-scale global geologic maps of Scott and Tanka [1986] and Greeley and Guest [1987] as unit "Nple, Noachian etched plains". The etched materials were described by Zimbelman and Craddock [1991] as being "an eroded layer of competent material," and they noted that exhumation of previously-buried impact craters was one of the material's characteristics. The surface described as smooth was best seen in Viking high resolution pictures from orbits 408B and 746A. The smooth surfaces were mapped by Scott and Tanaka [1986] and Greeley and Guest [1987] as a part of "Npl_2, Noachian subdued unit." Schultz and Lutz [1988] referred to these smooth and etched materials as a "deposit," because in some areas the materials cover, fill, and bury pre-existing impact craters.

--more!

4. New Observations

4.1. Regional context

--start with the story that goes from E Arabia, to central Arabia, to W Arabia, to Meridiani, to set the stage that these materials may be a section representative, in general, of cratered highlands geology.

--discuss relation to layered outcrops in W Arabia, Schiaparelli, relation to Hematite

4.2. Material properties

--photogeologic evidence for rock: cliffs, buttes, mesas, spires, impact craters that punched into the material.

--thermal inertia discussion, Termoskan discussion, rock abundance from IRTM?

-- TES thermal inertias from Mellon et al. [2000] map are in the range 410–485 J m-2 K-1 s-0.5. These high thermal inertias may be taken as consistent with effective particle sizes in coarse to very coarse sand range [e.g., Edgett and Christensen 1994, Table 2] or may be considered too high to be an effective measure of particle size [Jakosky 1986, Pelkey et al 2001, Figure 2].---need to explain these things! Need to make reference to Presley and Christensen [1997] and perhaps Presley [2002].

-- IRTM thermal inertias from Christensen and Malin [1989] map are in the range 400–500 J m-2 K-1 s-0.5, which is about the same as the range from the Mellon et al [2000] map.

--IRTM rock abundance from map in Christensen [1986] are in the 15–25% range and, most occurrences are nearer to 25% which is the upper limit shown on his map (ie saturates at 25%)

--IRTM albedos are generally 0.17 – 0.20 (from Christensen [1988] map). TES albedos are also generally in this same range, if you assume the DN to Alb conversion is the same for TES map at http://tes.asu.edu/webdata/sept1_99.html as for IRTM.

-- Bandfield [2002] mineral maps show some plagioclase and some high-Ca pyroxenes may be present in the outcrops. He doesn't show other minerals there, but clearly he's not seeing 100% of the mineral composition, either. Arkosic sediments?

4.3. Outcrop patterns

- layering is evident in VO, MOC WA, MOC NA, and Termoskan images

- bedding and thickness

- stratigraphic sequence (include upper dark units eg hematite)

--include a section on geologic mapping, in which I present the attempts to map like real geology off air photos—the M03-01935 experience. . describe that whole experience, its benefits and problems.

--discuss the "ridge unit"

4.4. Geomorphology

-- this section is about the evidence for processes that have shaped the present landscape—the exposure and erosion of the materials: evidence for wind action, including contemporary dust storms and dust devils and deposition after 2001 storm; discuss mass movement, discuss channels and lack thereof; discuss lack of yardangs

5. Discussion

5.1. Stratigraphic Observations

-- there are unconformities

-- there are multiple layer units that can be recognized throughout the region

-- interbedding of craters

5.2. Origin of the material

-discuss old hypotheses and what their problems are

- Schultz and Lutz (1988) paleopolar hypoth
- Edgett and Parker (1997) "marine" hypoth.
- Christensen's hematite stories
- Hynek et al (2002) story, Chapman and Tanaka (2002) story

- discuss my current ideas on the subject

  - the issue of subaerial vs subaqueous deposition
  - what would we need to find to demonstrate one over the other?
  - Note grand canyon rocks record all types of environments, etc.

- the material could as easily be marine carbonates as tephra from Tharsis, and we wouldn't really be able to know it (explain. ref Kirkland?).

6. Conclusions

1. The materials are sedimentary
2. The materials have properties of rock
3. Outcrops of regional extent, part of larger picture in W Arabia and to the west
4. there are erosional unconformities between beds (exhuming small craters)
5. hematite is in a material above the light-toned stuff
6. Layers have a stratigraphy, there are marker horizons (ridge unit)
7. Thermal properties in part governed by overlying mantles (eg west area in Termoskan image)
8. Termoskan and MOC show layers have differing properties
9. rudimentary stratigraphy in a small region has been worked-out
10. outcrops may be a clue to general nature of cratered highlands

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