MAPPING CAPABILITIES USING IMAGES FROM THE THEMIS INSTRUMENT ON THE 2001 MARS ODYSSEY SPACECRAFT

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ABSTRACT

The 2001 Mars Odyssey spacecraft was launched by the United States on April 7, 2001, and entered orbit around the Red Planet on October 24, 2001. Following circularization of the orbit, the primary science mission commenced in February, 2002. The first installment of data obtained from all instruments was released to the world community (via the web) in October, 2002, and a second release occurred in April, 2003. Data releases are planned to take place at three month intervals for the remainder of the mission. The Thermal Emission Imaging System (THEMIS) is providing an incredible wealth of new data about Mars, much of which should be applicable to the production of new maps of Mars. THEMIS obtains images of the planet at both visual and thermal infrared wavelengths. The visual images have a spatial resolution of 19 m/pixel, filling a gap between the global coverage of earlier Viking orbiter images (typically with a spatial resolution >50 m/pixel) and the highly detailed images from the Mars Orbiter Camera on the Mars Global Surveyor spacecraft (typically with a spatial resolution of 2 to 6 m/pixel). Thermal infrared images have a spatial resolution of 100 m/pixel, but they can be obtained during either day or night. The daytime thermal infrared THEMIS images have revealed exquisite sensitivity to shallow slopes, showing subtle slopes by their measurable temperature differences. The nighttime thermal infrared images minimize the effects of both slope and albedo on the surface temperature, revealing the spatial distribution of the dominant particle size of the surface materials. THEMIS images are referenced to the same coordinate system used for the precise topographic measurements made by the Mars Orbiter Laser Altimeter instrument on the Mars Global Surveyor spacecraft, so that both the images and topography can be precisely registered in fixed global reference system. The great potential of THEMIS data for updating and improving maps of Mars at a variety of scales should be of particular interest to all cartographers involved in the mapping of planetary surfaces. Information about the THEMIS instrument and data can be found on the web at themis.la.asu.edu, and information about the Mars Odyssey mission can be found at mars.jpl.nasa.gov/odyssey.

1. INTRODUCTION

The 2001 Mars Odyssey spacecraft was launched by the United States on April 7, 2001, and entered orbit around the Red Planet on October 24, 2001 (1). Following circularization of the orbit, the primary science mission commenced in February, 2002. The first installment of data obtained from all instruments was released to the world community (via the web) in October, 2002, and a second release occurred in April, 2003. Data releases are scheduled to take place at three month intervals for the remainder of the mission. The Thermal Emission Imaging System (THEMIS) is providing an incredible wealth of new data about Mars (2), much of which should be applicable to the production of new maps of Mars. THEMIS obtains images of the planet at both visual and thermal infrared wavelengths. Visual images (VIS) have a spatial resolution of 19 m/pixel, filling a gap between the global coverage of earlier Viking orbiter images (typically with a spatial resolution >50 m/pixel) and the highly detailed images from the Mars Orbiter Camera (MOC; 3) on the Mars Global Surveyor (MGS) spacecraft (typically with a spatial resolution of 2 to 6 m/pixel). Thermal infrared images have a spatial resolution of 100 m/pixel, but they can be obtained during either day or night.

The daytime thermal infrared THEMIS images have revealed exquisite sensitivity to shallow slopes, showing subtle slopes by their measurable temperature differences. The nighttime thermal infrared images minimize the effects of both slope and albedo on the surface temperature, revealing the spatial distribution of the dominant particle sizes of the surface materials. THEMIS images are referenced to the same coordinate system used for the precise topographic measurements made by the Mars Orbiter Laser Altimeter (MOLA) instrument (4) on the MGS spacecraft, so that both the images and topography can be precisely registered in fixed global reference system. The great potential of THEMIS data for updating and improving maps of Mars at a variety of scales should be of particular interest to all cartographers involved in the mapping of planetary surfaces. Information about the THEMIS instrument and data can be found on the web at themis.la.asu.edu, and information about the Mars Odyssey mission can be found at mars.jpl.nasa.gov/odyssey.

2. EXAMPLES OF THE MEDUSAE FOSSAE FORMATION

The Medusae Fossae Formation (MFF) is a regionally extensive deposit located along the equator of Mars between roughly 130° and 240° E longitude, the origin of which has stimulated a host of published hypotheses (5, 6, 7). A volcanic or aeolian origin appear most consistent with Viking (6) and MGS (7) data, but other hypotheses remain viable and new data, as from the Mars Odyssey spacecraft, is likely to stimulate additional hypotheses of origin (e.g. 8). NASA is supporting geologic mapping of portions of the MFF deposits (9) for the area shown in Figure 1, but it is now quite clear that this on-going mapping will need considerable revision as the new data from THEMIS on Mars Odyssey (2, 10) become available.

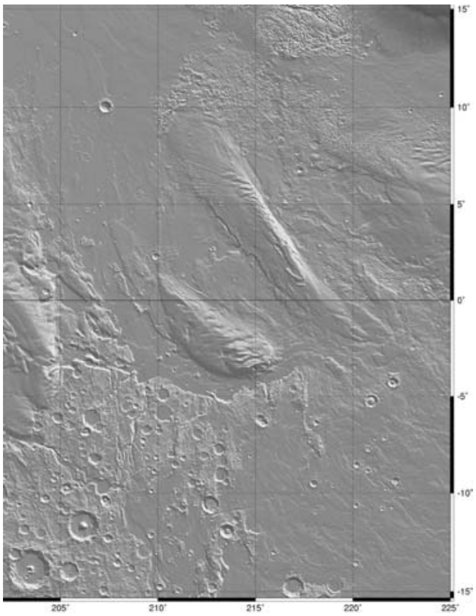

Figure 1. A shaded relief rendition of a gridded topographic data set obtained by the MOLA instrument on the MGS spacecraft. Area shown corresponds to the region for which new geologic maps are being prepared (9). MOLA shaded relief maps are available via the web from (11).

The daytime IR THEMIS images hold particularly strong potential for providing a new basis from which geologic mapping can be carried out. THEMIS data are easily accessible over the web by using a 'clickable' map (Figure 2), where nighttine IR images tilt slightly to the left and daytime IR images tilt slightly to the right (both shown in red) and VIS images (purple) coincide with some daytime IR images.

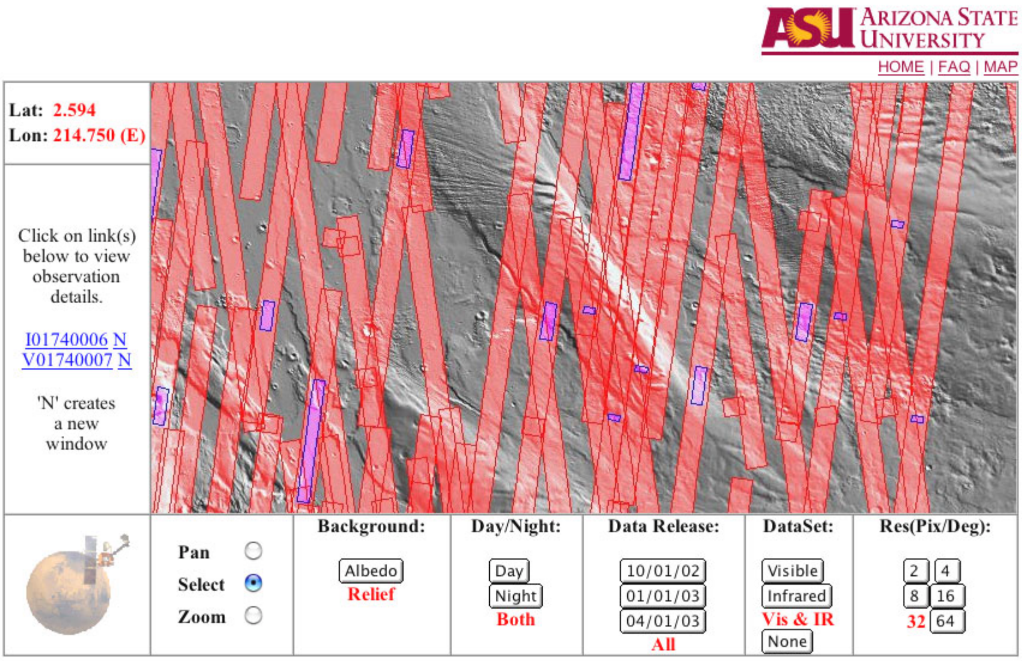

Figure 2. THEMIS home page (themis.la.asu.edu) provides access to a 'clickable' data page, as in this example.

Once a particular image is selected, you are given the option to download the data in different formats. The VIS images are quite remarkable, but here we focus on the information contained within the daytime IR images. Each IR image covers an area on Mars that is ~32 km wide, in strips of variable length as determined by the data rate available for downloads to Earth at the time the image was taken. The daytime images are dominated by temperature differences induced by surface slopes, but THEMIS is sufficiently sensitive at typical daytime temperatures (with a resolution of ~0.2 K) (2) to show subtle features that were not as obvious in Viking images. One example is a fluvial channel being exhumed from beneath the MFF materials, identified in MOLA topography and subsequently related to subtle features in Viking images (12), where the smooth channel floor is distinctly different from the rough MFF materials around it (Figure 3).

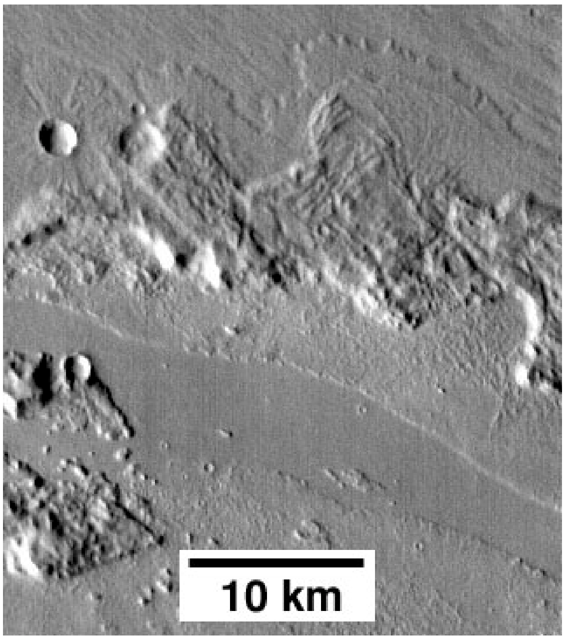

Figure 3. The smooth floor of a river channel (center) is clearly distinguishable from the rough texture of the surrounding MFF material; it is being exhumed from beneath the MFF deposits. Centered on 1.8°N, 223.2° E.

3. LAYERING WITHIN MFF MATERIALS

Multiple layers exposed within MFF have been reported in previous studies (7, 13, 14) at a variety of scales. However, limited coverage of good Viking images for a mapping base (the best Viking images in the area have from 30 to 50 m/pixel resolution) led to considerable portions of the extensive MFF deposits necessarily being mapped with relatively poor (>200 m/pixel) Viking images. The MFF deposits occur within the low thermal inertia region centered on the Tharsis Montes (15), where a thick dust cover gives the surface a uniform thermal emission that allows subtle topographic features to be detected as measurable temperature differences (5, 16). The result is a wonderful new tool for documenting sub-kilometer-scale layering in portions of MFF not imaged well previously (Figure 4, left). The thermal images also document variations in competency of layers within MFF exposures that face the solar insolation (Figure 4, right). Combination of both daytime and nighttime IR images provide additional insight into the competency of the MFF materials. While the thermal sensitivity is poorer at night than during the day, nighttime IR images clearly document warm zones within the cold (low thermal inertia) dusty surface mantling MFF (Figure 5). The warm regions in the night image correlate with some (but not all) of the erosional scarps visible in the day image, which implies that the erosion is not everywhere exposing competent materials; this observation strengthens the likelihood that the majority of MFF deposits are friable and weakly consolidated, except where discreet competent layers (such as in Figure 4) may be exposed. This situation is more consistent with a volcanic (welded and non-welded zones) than aeolian origin for the deposits as a whole.

4. OUTLIERS OF MFF MATERIALS

Isolated patches of MFF occur as outliers beyond the margin of the continuous exposures of MFF. A dramatic example is the nearly complete burial of the central peak of the large impact crater Nicholson by MFF deposits, clearly documented in a mosaic of sections of three daytime IR THEMIS images (Figure 6, left). The asymmetric erosion patterns around the base of the MFF deposit in Nicholson may record variations in the direction of the strongest winds, or perhaps variations in the competency of the materials. The regional view of the THEMIS daytime images can be enhanced by MOC images that can be placed within the THEMIS regional context.

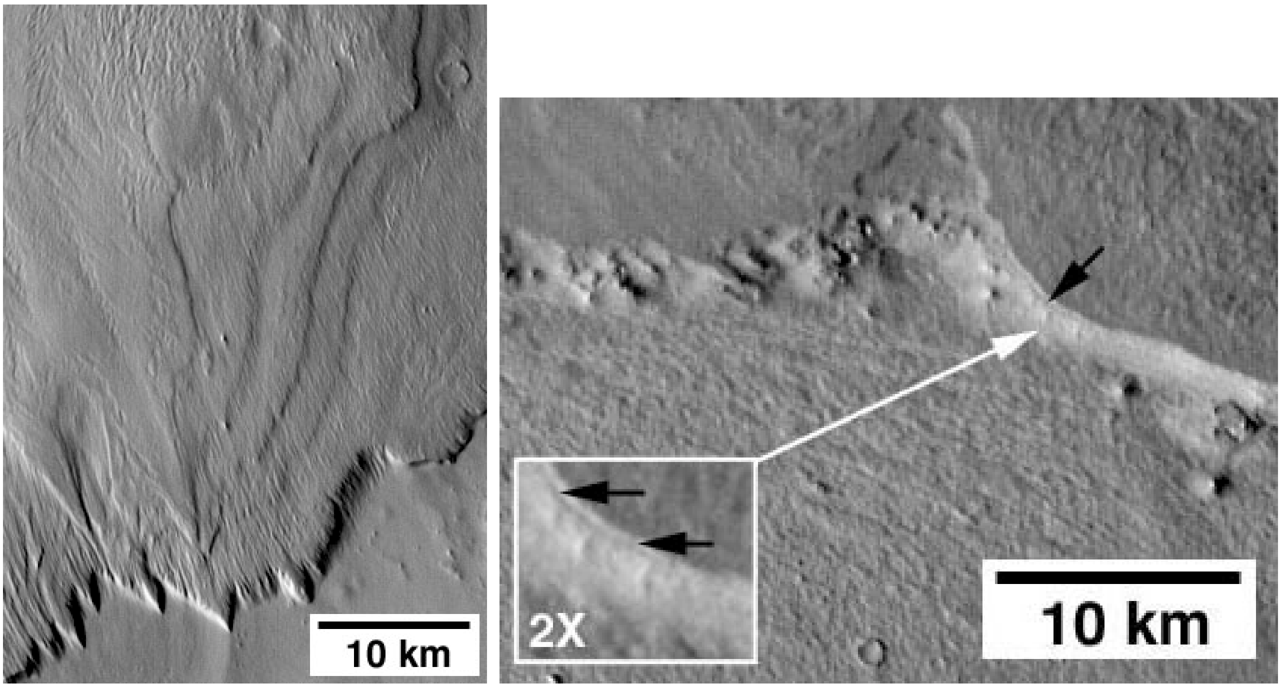

Figure 4. Left: Multiple layers within MFF, exposed by erosion. Portion of THEMIS daytime IR image I01280001, centered on 6.1°S, 191.0°E. Right: A competent (cool during day) layer (black arrow) is exposed on a cliff within MFF (see 2X inset). Portion of THEMIS daytime IR image I01665006, centered on 6.8°N, 218.2°E.

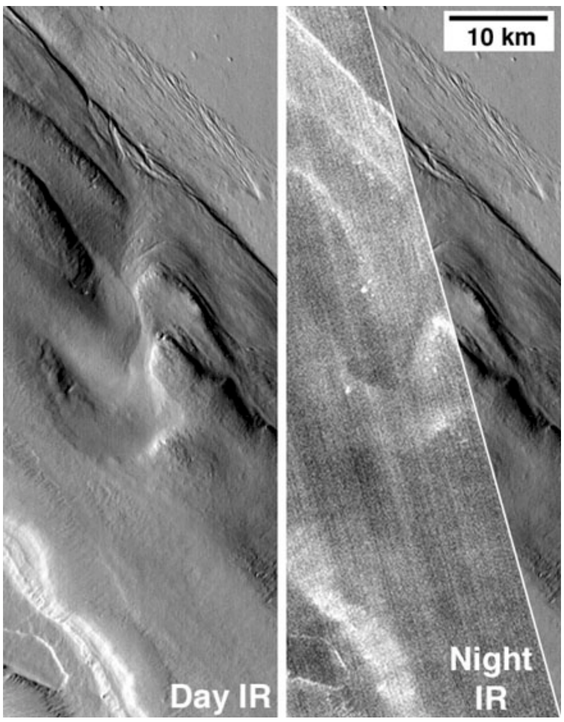

Figure 5. Gordii Dorsum escarpment within MFF materials. Left: Portion of THEMIS daytime IR image I01690010, centered on 3.1°N, 216.6°E. Right: Nighttime image overlaid on daytime image. Note that only some of the erosional scarps are blocky (warm at night). Portion of THEMIS IR image I01859003.

For example, MOC image E02-00308 gives a 4.4 m/pixel view of the southwest margin of the MFF deposit within Nicholson, revealing the presence of decameter-scale layering in the scoured MFF materials (Figure 6, right), similar to fine layering reported from MOC images of other MFF areas (e.g. Figure 5c of reference 7). V-shaped depressions are eroded into the upper surface of both eastern and western margins of the MFF deposits in Nicholson, similar to features described elsewhere within MFF (e.g. Figure 8 of reference 7). The outliers may prove to reveal valuable exposures of MFF that are otherwise buried beneath the extensive regions covered by the MFF deposits.

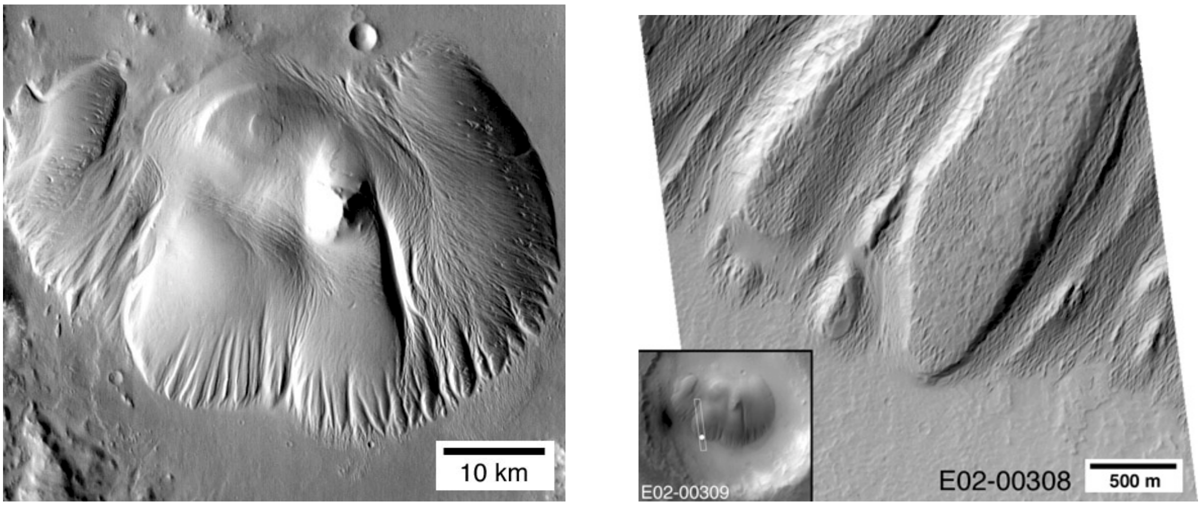

Figure 6. Left: MFF materials on the central peak of Nicholson crater, centered on 0.2°N, 164.7°E. Mosaic of portions of THEMIS daytime IR images (left to right) I01154002, I01853006, and I01491004. Right: MOC image E02-00308, of the southwest margin of the Nicholson MFF deposit. Inset shows the context for detailed view. NASA/JPL/MSSS.

5. SUMMARY

THEMIS images are revealing a wealth of new information about the MFF deposits along the Martian equator. The presence of MFF within the Tharsis low thermal inertia region means that the extensive coating of dust gives the MFF surface a uniform thermal characteristic, which allows daytime IR images to reveal subtle topographic variations. This new information will certainly change ideas about MFF, and likely will result in significant revisions being made to geologic maps based on Viking images. Similar updates to existing maps of Mars can be expected for the rest of Mars as well.

6. REFERENCES

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