THEMIS OBSERVATIONS OF PITTED CONES IN ACIDALIA PLANITIA AND CYDONIA MENSAE.

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Introduction: Analysis of Viking imagery revealed the presence of large numbers of pitted or cratered cones in the northern plains of Mars with the highest concentrations occurring in eastern Acidalia Planitia and Cydonia Mensae [1-3]. Based largely on crater/cone diameter ratio comparisons, these features were hypothesized as being analogous to terrestrial pseudocraters (rootless cones) [1-2] such as occur in the Lake Myvatn region of Iceland [4]. Doubts remained about this connection given the disparity in mean diameters between these Martian features (mean diameter of ~600 m [2]) and the Icelandic rootless cones (mean diameter of ~ 50 m [5]). Recent analysis of MOC Narrow Angle camera images of Elysium Planitia, Amazonis Planitia and elsewhere have revealed another class of features with diameters commensurate with the Icelandic rootless cones [5, 6]. If the features in Acidalia and Cydonia are not rootless cones, what are they? Recent information on the thermophysical properties of these features as provided by the Mars Odyssey THEMIS instrument may help to answer this question.

Geologic Setting: Much of Acidalia has been mapped as being covered by the Vastitas Borealis Formation (VBF); the mottled member and knobby member of which were tentatively interpreted as being volcanic in origin [7]. Features in Acidalia have been interpreted as being analogous to features formed by the interaction of volcanoes and ice sheets: tuyas and moberg hills [8,9]. Recently, the VBF has been reinterpreted as the sedimentary residue left from the deposition of sediments and sublimation of water deposited from outflow channels to the south [10]. While there are numerous pitted cones within the VBF, they also occur beyond its boundaries. For example, the present investigation examines numerous pitted cones within Cydonia Mensae which lies outside the mapped boundaries of the VBF. The VBF is Hesperian in age and is overlain in central Acidalia by a member of the Amazonian-aged Arcadia formation. Acidalia also hosts numerous mesas which have been alternatively interpreted as tuyas [8,9] or as erosional remnants of younger overburden sediments. There are instances where these mesas partially overlie pitted cones. An example of such an occurrence is provided in **Figure 1**.

Observations: The spectral emittance characteristics of the regional deposits that serve as substrates for these pitted cones in Acidalia have been examined with TES data [11]. Earlier analyses with TES have identified Acidalia as the type locale for the “Surface Type 2” (ST2) dark region cover type [12]. The ST2 spectral signature was originally interpreted as being produced by volcanic products of basaltic andesite to andesite in composition [12]. It has since been suggested to also be explainable as being caused by weathered basalt [13], a higher glass component [14], and palagonite coatings [15]. Analyses by [11] and [16] have indicated that Acidalia has higher fractions of basaltic glass than does the Surface Type 1 type region of Syrtis Major. Higher basaltic glass fractions would be consistent with extensive ice-magma interactions in Acidalia.

THEMIS multispectral infrared and single band visible information was analyzed in this investigation. THEMIS provides 10 Mid-Wave Infrared (MWIR) bands, one of which is in an atmospheric absorption. THEMIS also has a 5 band visible to very near infrared imaging system. Some residual problems remain with some of the THEMIS bands; however, gross spectral differences can be determined. The system is very effective at determining thermophysical properties of the surface. Nighttime brightness temperature images can be used as a proxy for thermal inertia [17]. The locations of the THEMIS scenes discussed here are indicated in **Figure 2**.

Using THEMIS to help determine thermophysical properties of the pitted cones in Acidalia is demonstrated in **Figure 3**, a daytime THEMIS image, and **Figure 4**, a nighttime brightness temperature THEMIS image over approximately the same region in eastern Acidalia very near the border with Cydonia. In the image acquired in the day, the pitted cones appear bright. Because they have positive relief the slopes facing the solar illumination are especially bright (indicating warmest temperatures). In the night image, the pitted cones are very dark. Dark signatures in the brightness temperature image suggests that the cones have a low thermal inertia, and that they are composed of, or mantled by, fine-grained materials.

The east-central Acidalia nighttime brightness temperature image I03390003 (which, at the time of the writing of this abstract, does not have an overlapping daytime THEMIS image) shows remarkable temperature differences both between dark spots (likely pitted cones) and the background and among very bright, irregularly shaped, flow-like features on the surface (**Figure 5**). Irregularly shaped flow-like features are also apparent in daytime THEMIS images (**Figure 6**) in which they appear dark. The nature of these flow-like surface units remains to be determined. However, the fact that they are bright in nighttime brightness temperature images and dark in daytime images indicates that they consist of materials which have higher thermal inertia than the surroundings. Also, their apparent proximity to units with pitted cones suggests that their presence may have bearing on the origin of the pitted cones.

Interpretation: The inferred low thermal inertia of the pitted cones is an important clue to their nature. Their apparent low thermal inertia values provide evidence against their possible origin as rootless cones. Rootless cones consist mainly of coarse scoria, are often capped by spatter, and have finer material admixed with scoria blocks on the outer apron [5]. Such spatter and scoria blocks are materials with high thermal inertias. Cinder cones are also formed from coarse scoria which would be higher in thermal inertia than the observed pitted cones. Tuff cones consist of cemented palagonite tuffs which also should produce a relatively high thermal inertia signature. Neither origin as rootless cones nor as cinder cones explains the inferred low thermal values of the pitted cones in Acidalia. These pitted cones have also been hypothesized as being pingoes or mud volcanoes [18]. Both of these landforms are commonly composed of fine grained, poorly to semi-indurated materials which would be consistent with the thermal inertia observations. The presence of the flow-like surface units may be supportive of the mud volcano origin; however, the flow-like units have not been observed to emanate from any pitted cones. Alternatively, the conundrum of mesas partially overlying some cones (**Figure 1**) might be evidence that the features are pingos. Pingos are ice cored domes. Domes of ice have the internal integrity to withstand burial and exhumation. Sublimation of the ice after exhumation would leave a crater and a mantle of the low thermal inertia sediments (which had been admixed with the ice).

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Figure 1. Subsection of MOC narrow angle camera image m1500479. The rightmost of three pitted cones at the bottom of this image is partially overlain by a mesa. Resolution is 4.63 m/pixel.

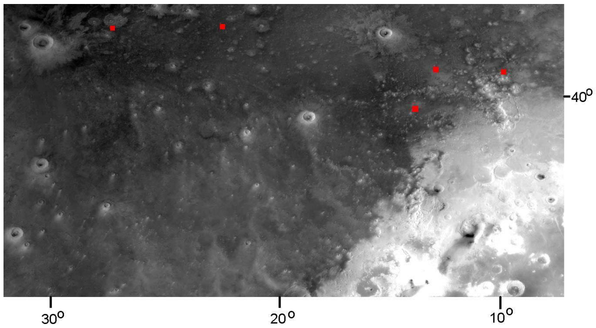

Figure 2. MOC wide angle camera mosaic of central to east Acidalia and Cydonia. Red dots indicate nominal centers of THEMIS scenes shown in **Figures 3 –6**.

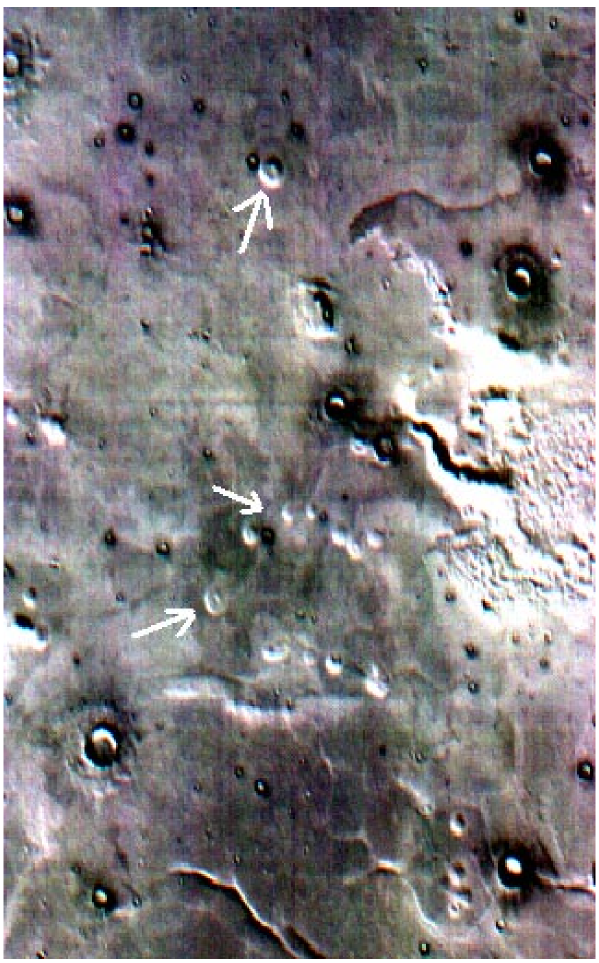

Figure 3. Subsection of THEMIS daytime scene I01461009 band 8, 5, 3 composite. Arrows point to pitted cones. Fresh impact craters with blocky ejecta have dark halos in this image. Solar illumination is from the lower left. North is towards the top. Resolution of the MWIR THEMIS images shown here is 100 m/pixel. THEMIS images show here are 304 to 320 pixels (30.4 to 32 km) in width.

Figure 4. Subsection of nighttime THEMIS brightness temperature image for scene I01692010 covering approximately the same area as in Figure 1. Arrows point to pitted cones which are very dark indicating low thermal inertia. In contrast blocky ejecta near fresh impact craters are bright in this image.


Figure 5. Subsection of nighttime THEMIS image I03390003 showing marked contrast in temperature between dark spots in lower portion of image (assumed pitted cones) and background and among irregularly shaped surface units in upper portion of image.


Figure 6. Dark flow-like surface unit in central Acidalia. The unit is bounded in its upper center portion by grooves and is overlain on the lower left by a field of pitted cones. Image is a subsection of a band 8, 5, 3 composite of THEMIS scene I03284002.