Thermophysical Analysis of Debris Aprons in Eastern Hellas using THEMIS. J. L. Piatek[1] (jpiatek@utk.edu) and J. E. Moersch[1], [1]Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN 37996

Introduction: A concentration of lobate debris aprons has been previously identified in the eastern Hellas region. These features are lobate masses extending from massif slopes, and are considered to be analagous to terrestrial rock glaciers or protalus lobes [1-9]. This study focuses on an area of the Reull Vallis region (90-110° E, 30-50° S) that contains 54 identified debris aprons. As a continuation of previous work [8,9], infrared images from the Thermal Emission Imaging System (THEMIS) instrument [10] are used to examine spatial variability in surface thermophysical properties of these features. Variations in thermophysical properties are related to physical properties of the apron materials such as composition, density, and particle size. Analysis of THEMIS data, combined with information from other datasets, may provide insights into the formation processes of these features.

Background: Located in the southern highlands of Mars, the geologic history of the Reull Vallis region has been discussed in detail by [11]. The debris aprons in this area appear to be some of the youngest features, overlying units of Noachian, Hesperian, and Amazonian ages. Similar to concentric crater fill and lineated valley fill, these aprons are commonly thought to be indicators of near-surface volatiles. Potential analogs for apron emplacement include rock glaciers, debris covered glaciers, and mass movements of ice rich material [1-3,7,8,12-13], although it likely that multiple mechanisms are responsible for apron formation. Apron surface expressions should be a record of formation and later modification by volatile loss [e.g. 12].

A preliminary examination of the debris aprons in this area using THEMIS data showed variations in nighttime temperature of these features [9]. At the time this study was undertaken, however, the study region did not have complete THEMIS nighttime IR coverage, and less than half of the 54 aprons identified by [8] were studied. In addition, no daytime images were analyzed. Since then, THEMIS has imaged nearly 100% of this area during the night, as well as acquiring more daytime images. The ability to analyze additional data allows for expansion of the previous work.

Image Analysis: THEMIS infrared images, taken both during daytime and nightime, were identified for the defined study area using JMars [14]. Initial image processing is undertaken via the THMPROC web page interface [15], using the undrift/dewobble, rectify, deplaid, and unrectify options. These processing steps should calibrate the images and remove a significant portion of systematic instrument-induced variations. At this point, radiance values in the image should include only contributions from the surface and atmosphere.

Daytime images are used to examine surface emissivity, which is derived after removal of the atmospheric components via the methods of [16,17]. Surface emissivity can then be compared among areas of interest in one image or across different images to look for similarities or variations in composition between aprons, massifs, and the underlying surface.

Variations in thermophysical properties, specifically thermal inertia values derived from nighttime brightness temperatures, are used to look for variations in material properties. The thermal inertia of a surface is related to the thermal properties of that material (i.e. composition) as well as the physical state (particle size, packing, and induration). THEMIS nighttime infrared images are analyzed without the surface/atmospheric separation process used for day images, as the atmospheric contribution at night should be diminished due to colder atmospheric temperatures.

Brightness temperatures are derived from image radiance values using the normalized emissivity method [18,19]. These temperatures are then used, along with image parameters such as time of day and solar longitude, to predict a value of thermal inertia via a set of lookup tables generated from the model of [20]. Thermal inertia is related to the material properties of the surface via the relationship

$$\text{Thermal Inertia} = \sqrt{\kappa \rho c}$$

where κ is the thermal diffusivity, ρ is the density, and c is the thermal conductivity of the material being examined (in this case, the area covered by a THEMIS pixel). These material properties vary with composition, particle size, and packing state: variations in thermal inertia indicate variations in these physical properties.

Preliminary Results: Previous examination of THEMIS nighttime images [9] suggests that there are a variety of temperature signatures associated with debris aprons in the Reull Vallis region. Further analysis is consistent with the conclusions of this work. Commonly, debris apron material appears darker (cooler) in nighttime temperature images, in contrast to the lighter (warmer) surface over which the apron was emplaced, and the bright (warmest) ridge crests. These temperature variations are typically on the order of 10-20 K. In addition to the general appearance of the studied debris aprons, smaller scale structures are also visible. Linear bands of varying temperature are visible on some apron surfaces, and are often parallel to the inferred direction of flow. These lineations are likely representative of the emplacement mechanism, and the

variations in temperature may be indicative of a particular formation mechanism.

A complication in the estimation of surface thermal inertia values arises when values from different images are compared. Variations in predicted surface temperatures due to changes in season and time of day are included in the lookup tables used (from the model of [20]), but the atmospheric dust opacity is often an unknown quantity with an assumed value. An example of derived thermal inertia values for a debris apron discussed in [9] is shown in Table 1; the apron itself and the regions of interest used in shown in Figure 1. Four regions of interest (ROI) were defined, and values of thermal inertia determined for those regions in three different THEMIS nighttime images, using the same value of dust opacity for each. The average values of brightness temperature in each ROI vary by 10-20K, while the derived thermal inertia values change by a factor of ~1.5 from image ID I07418013 to the other two images. This difference would represent an order of magnitude difference in particle size using the relationship given in [21], while the appearance of the apron does not change significantly between images to indicate additional material had been deposited. The likely culprit is the assumption of similar atmospheric dust opacities, which would affect the determination of both temperature and thermal inertia. To account for this variation, methods of determining the atmospheric absorption for daytime images [16,17] will be applied to night images to attempt to derive values for dust opacity for input into thermal inertia calculations.

Conclusions: The intended outcome of this study is an examination of the identified debris aprons in the study area [8,9] via THEMIS infrared imagery. Daytime infrared images will be used to examine changes in surface emissivity (if any) between apron materials and the massif from which the apron appears to source, and the underlying surface. Nighttime images are used to examine changes in thermophysical properties associated with variations in particle size, packing/ induration, and composition. These physical parameters and observed variations therein should be related to the emplacement and modification history of these features.

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Table 1: Derived values of thermal inertia ($J \cdot m^{-2} \cdot K^{-1} \cdot s^{-0.5}$) and average brightness temperature values from the same ROIs on three nighttime images listed by image ID (ROI colors correspond to Figure 1)

	I07418013	I08554008	I08866007
Red	329 (204 .4K)	219 (194K)	217 (190 K)
Green	325 (204 K)	192.5 (193 K)	182 (188K)
Blue	351.2 (206.2K)	238 (196 K)	211 (191.5 K)
Yellow	226 (200 K)	156 (187 K)	130.8 (182 K)

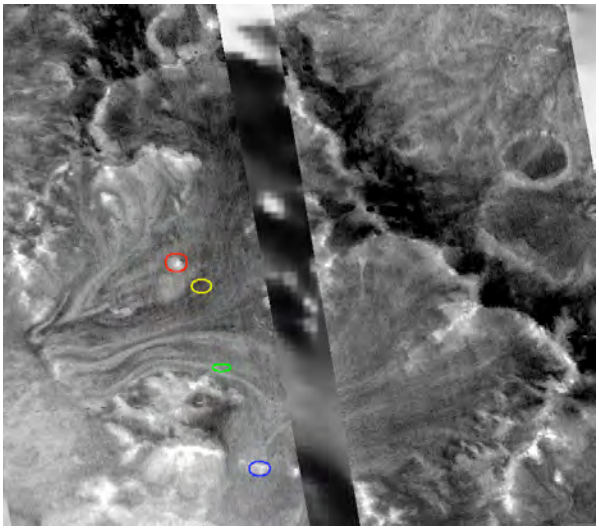

Figure 1: Debris apron complex near 109.5° E, 42°S: subsets of THEMIS nighttime images I08554008 (left) and I08529014 (right) are shown draped over MOLA shaded relief in JMars; each image is 3.2 km across. Colored areas indicate ROIs used in thermal inertia calculations. (Images courtesy NASA/JPL/ASU).