THERMOPHYSICAL PROPERTIES OF FOUR TERRESTRIAL INDURATED MATERIALS AND THEIR IMPLICATIONS FOR MARTIAN DURICRUSTS. N. W. Murphy[1], B. M. Jakosky[2], M. T. Mellon[3], D. A. Budd[2]. [1]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK 99775-7320, [2]Department of Geological Sciences, University of Colorado, Boulder, CO 80309-0392. [3]Southwest Research Institute, 1050 Walnut St, Suite 300, Boulder, CO 80302.

Introduction: Indurated surface materials have been directly observed at multiple locations on Mars by landers and rovers and inferred from thermal remote sensing data from multiple Mars orbital spacecraft. It is well documented that the properties of indurated surfaces on Earth are highly dependent on current and past climate conditions, their geologic setting, and the mineralogy of parent materials [e.g., 1]. Indurated surfaces on Mars should show a similar dependence on past climate and geologic conditions of Mars, which suggests that the occurrence and physical character of indurated Martian materials can provide insights into the climate history of Mars. In addition, indurated surfaces provide stable platforms for lander missions on Mars as well as hardpan surfaces that can be readily traversed by rovers.

Only a small fraction of the Martian surface has been directly observed despite the multiple observations of Martian duricrusts. This requires that much of the Mars surface be inferred from remote sensing data and Mars analogs on Earth. In this study, we seek to better characterize the thermophysical properties of indurated terrestrial materials in order to better understand the properties and potential variety of Martian duricrusts.

Sites and samples: We collected four samples of indurated materials from three field sites located within the southwest United States. Samples were chosen to both provide a reasonable sampling of the materials at the site and These sites included (1) an exposed gypsum duricrust (gypcrete) deposite located just north of Las Cruces in southern New Mexico within the Upham Hills quadrangle, (2) Lunar Lake Playa in central Nevada, and (3) exposed Bandelier volcanic tuff near the Bandelier National Monument and Santa Fe in northern New Mexico.

Of the four samples, we collected two visually distinct gypsum duricrusts from the Upham Hills gypcrete site that are hereafter referred to as UH1 and UH2. UH1 was more prevalent in the deposit and has a disctinctive pink hue. UH2 was whiter without any notable coloration and was typically concentrated around thin (<1 cm wide, <0.5 m long) cracks observed throughout the surface of the deposit. From Lunar Lake Playa, we collected dessicated playa clays, which are referred to as sample LL. Lastly, we collected samples from the Bandelier volcanic tuff exposure, which is hereafter called sample BT. For each site we collected environmental data and subsurface temperatures to support the subsequent laboratory measurements on each of the samples.

Laboratory Measurements: We conducted a variety of laboratory analyses to characterize the granular structure and the thermal properties of the samples. These included: (1) measuring the intrinsic and bulk densities, (2) microscopic imaging of thin sections, (3) X-ray diffraction, (4) mercury porosimetry analysis, and (5) measurements of the thermal conductivity and volumetric heat capacity using a single needle probe (Decagon Devices *KS-1*) under gas pressures ranging from <1 mbar to ambient atmospheric pressure.

Results: Selected results for these measurements are summarized below. For this abstract, we do not discuss all of the results of the laboratory measurements and instead concentrate on the thin section imaging, bulk density measurements, and thermal properties.

Thermophysical Properties: Table 1 summarizes the results of the thermophysical properties as measured under a representative Mars atmospheric pressure of 7 mbar. In general, the thermal inertia values (TI) are typical for surfaces inferred to be duricrusts from remote sensing data [2]. As evident in Figure 1, there do not appear to be any strong trends between the trends in thermal inertia and either the bulk density or porosity.

	k **@ P_{Mars} [$Wm^{-1}K^{-1}$]**	**ρc [$MJm^{-3}K^{-1}$]**	***TI*** **@ P_{Mars} [tiu]**	**ρ_{bulk} [$kg\ m^{-3}$]**	**Porosity**
UH1	0.069 ± 0.004	1.30 ± 0.07	300 ± 20	1420 ± 50	0.39 ± 0.03
UH2	0.132 ± 0.006	1.66 ± 0.10	470 ± 30	1500 ± 50	0.35 ± 0.02
LL	0.073 ± 0.004	1.40 ± 0.07	330 ± 25	1700 ± 50	0.31 ± 0.02
BT	0.073 ± .0.004	1.01 ± 0.05	270 ± 20	1270 ± 50	0.47 ± 0.03

Table 1: Summary of selected laboratory results. Shown are the thermal conductivity (k @P_{Mars}) at 7 mbar gas pressure, thermal mass (ρc), thermal inertia at 7 mbar gas pressure (TI @P_{Mars}), the bulk density (ρ_{bulk}), and porosity.

Previous models of indurated materials on Mars [3] suggest that the bulk thermal conductivity should increase with increasing bulk density and decreasing porosity. These models assume a regularly spaced grain structure with increasing induration represented by filling the pore spaces at the interstices between the grains. Despite the differences in composition between the samples, based on past models it would still be reasonable to expect the thermal inertia and bulk thermal conductivity to show some dependence on bulk density. However, as shown in Fig. 1, there is no correlation between these quantities.

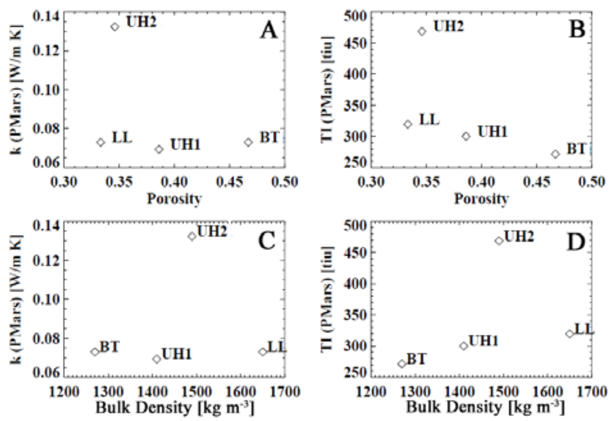

Figure 1: Plots showing the lack of correlation between either the thermal conductivity (A and C) or thermal inertia (B and D) and the porosity (A and B) or bulk density (C and D).

Thin section images: To prepare a sample for thin sectioning, we inject epoxy into the samples under vacuum conditions to fully evacuate the gas from the pore spaces. Once the epoxy is hardened, the samples can then be sliced into thin sections in a manner similar to hard rock samples.

Figure 2 shows the thin section image from the UH1 and UH2 samples and Figure 3 shows selected images of the thin sections from the LL and BT samples.

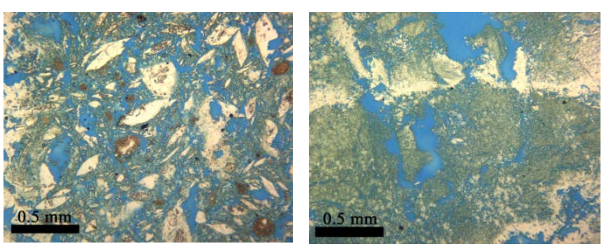

Figure 2: Thin section images of the UH1 (left) and UH2 (right) samples. The pore spaces appear blue due to the injected epoxy. The black scale bar is 0.5 mm in both images.

The UH1 and UH2 samples are both gypsum duricrusts, with no significant compositional difference beyond the presense of oxidized iron granules in the UH1 sample. However, the granular sizes and configuration, or fabric, of these two duricrusts are substantially different with the UH1 sample showing a variety of sizes in crystal sizes and orientations and the UH2 showing overall smaller, but more uniformly sized crystals.

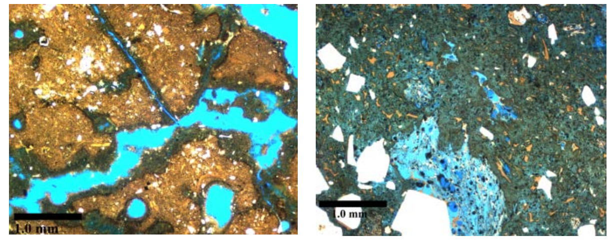

Figure 3: Thin section images of the LL (left) and BT (right) samples. The pore spaces appear blue due to the injected epoxy. The white areas are typically transparent grains and not pore spaces. The black scale bar is 1.0 mm in both images.

The LL sample (playa clay) shows very large particle sizes separated by long, linear cracks that likely result from the expansion and contraction of the clay as it is wetted and dried on the playa. Converseley, the BT sample shows generally well-connected grains despite its much lower bulk density compared to the other samples.

Discussion and Conclusions: Previous thermal modeling of indurated materials under Mars conditions suggest that the bulk thermal conductivity and thermal inertia are strongly tied to the bulk density of the material. While this likely remains true for certain types of duricrusts, it does not hold true for these samples. While these four samples differ in their composition, the thermal properties of the solid material under Mars atmospheric conditions are not significant enough to explain the complete lack of correlation between the thermal and physical properties for these four samples.

Based on the differences in the fabric observed in the thin section images, it appears that these variations in the fabric can signicantly alter the bulk thermal properties of the material with little to no corresponding change in the bulk density or porosity of the material. The results from the UH1 and UH2 samples further suggests that differences in the fabric can cause compositionally identical duricrusts to have significantly different bulk thermal properties.

Our data suggest that Mars duricrusts are likely much more complex than previous theoretical work has assumed. Additional analog studies and modeling are necessary to better understand the potential range of duricrusts present on Mars and the geologic history recorded in the Martian duricrusts.

References: [1] Watson, A. and D. J. Nash D.J. (1997) in Desert crusts and varnishes, in Arid Zone Geomorphology—Processes, Form and Change in Drylands, 69-107. [2] Putzig, N.E. et al (2005) Icarus, 173(2), 325 – 341. [3] Mellon, M. T. et al (1997) JGR, 102(E8), 19,357 – 19,369.