THERMAL CONDUCTIVITY MEASUREMENTS OF PARTICULATE MATERIALS UNDER MARTIAN CONDITIONS *M.A. Presley and P.R. Christensen, Dept. of Geology, Arizona State University, Tempe AZ 85287*

The mean particle diameter of surficial units on Mars has been approximated by applying thermal inertia determinations from the Mariner 9 Infrared Radiometer and the Viking Infrared Thermal Mapper data together with thermal conductivity measurements [1,2]. Several studies [e.g. 2,3,4] have used this approximation to characterize surficial units and infer their nature and possible origin. Such interpretations are possible because previous measurements of the thermal conductivity of particulate materials have shown that particle size significantly affects thermal conductivity under martian atmospheric pressures [e.g. 5,6,7]. The transfer of thermal energy due to collisions of gas molecules is the predominant mechanism of thermal conductivity in porous systems for gas pressures above about 0.01 torr [6]. At martian atmospheric pressures the mean free path of the gas molecules becomes greater than the effective distance over which conduction takes place between the particles. Gas particles are then more likely to collide with the solid particles than they are with each other. The average heat transfer distance between particles, which is related to particle size [8], shape and packing, thus determines how fast heat will flow through a particulate material.

The derived one-to-one correspondence of thermal inertia to mean particle diameter implies a certain homogeneity in the materials analyzed. Yet the samples used [5] were often characterized by fairly wide ranges of particle sizes with little information about the possible distribution of sizes within those ranges. Interpretation of thermal inertia data is further limited by the lack of data on other effects on the interparticle spacing relative to particle size, such as particle shape, bimodal or polymodal mixtures of grain sizes and formation of salt cements between grains. Furthermore, the thermal conductivities used in the derived correspondence were measured in a nitrogen-oxygen atmosphere (air) at room temperature. Temperature effects are expected to be minimal [11]. Thermal conductivities measured in a carbon-dioxide atmosphere are, however, consistently smaller than those measured in air by a small but significant amount (~7%) [9,10].

To address these limitations and to provide a more comprehensive set of thermal conductivities vs. particle size a linear heat source apparatus, similar to that of Cremers [12,13], was assembled to provide a means of measuring the thermal conductivity of particulate samples. In order to concentrate on the dependence of the thermal conductivity on particle size, initial runs will use spherical glass beads that are precision sieved into relatively small size ranges and thoroughly washed. All size ranges to be used have less than a 10 μm spread, except for the two largest samples (500-520 μm and 250-275 μm), and several samples have a spread of 5 μm or less. The total range of sizes to be examined is 10 μm to 500 μm.

Some of the preliminary data collected so far in the particle size analysis are plotted as thermal conductivity vs. pressure in Figure 1. The data fit a smooth curve with a deviation of less than 6%. Individual measurements appear to have a repeatability to within 7%, based on three duplicate measurements. These measures of inaccuracy are consistent with error analyses of the technique [14,15,16].

The thermal conductivity of 500-520 μm glass beads in carbon dioxide atmosphere are compared to previous data collected for similar grain sizes (Fig. 1): 470 μm glass beads [7] and 590-840 μm quartz sand [17]. The thermal conductivity vs. pressure trend measured in this study parallels that of the 470 μm glass beads, but with significantly lower values. This is expected in part because the 470 μm glass beads were examined under a nitrogen-oxygen atmosphere (air) and in part because the comparative method that was used to determine their thermal conductivity yields higher thermal conductivity values than any other method [6]. The trend for the quartz sand, however, has a much steeper slope than that of the glass beads for

pressures greater than around 0.5 torr. This deviation could simply be a peculiarity of the probe technique, which is known to be less accurate than the linear heat source method at low pressures [5,6]. Another possibility is that the steeper trend is caused by differences in the interparticle spacing of the samples, due either to a difference in grain shape (angular sand vs. spherical glass bead) or to a heterogeneity in sample particle size due to the rather wide range of grain sizes used in [17].

Some initial data from particle size mixing in this study should be ready for discussion at conference time and may help to shed some light on this question. The affects of the heterogeneity of samples will be examined by considering two component systems, varying the abundance of the fine component from 0 to 100% by 10%. In these experiments the 250 µm material will be the coarse fraction and the 75 µm material will be the fine fraction. Later runs will also be made on real eolian and fluvial sediments to determine the effects of natural distributions of particle sizes and to determine how these compare to the controlled set of experiments. This project will also examine the affect of particle shape by using angular grains (ground quartz), sieved and washed to the same size ranges as the glass beads, and platy clays. Salt encrusted samples will also be prepared in the lab in order to measure the effect of cements on the thermal conductivity of granular materials.

When complete this study will provide a refined correspondence of particle size to thermal conductivity at various pressures of carbon dioxide expected on the martian surface. The additional measurements on grain shape, heterogeneous mixtures and salts will provide additional information that would be necessary in the interpretation of the nature of surficial deposits using thermal data.

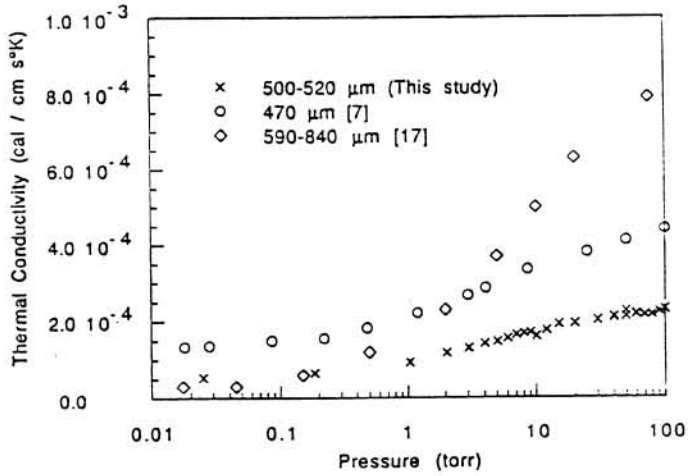

Fig.1: A comparison of effective thermal conductivity vs. pressure for glass beads analyzed in this study with that for glass beads [7] and quartz sand [17] analyzed in previous studies.

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