WHAT CAN THERMAL INERTIA DO FOR YOU? *M.A. Presley*, (Dept. of Geological Sciences, Box 871404, Arizona State University, Tempe, AZ 85287-1404; mpresley@asu.edu

Introduction: Thermal inertia is the tendency of a material to resist changes in temperature. $I = (\kappa\rho c)^{1/2}$, where I is thermal inertia, κ is thermal conductivity, ρ is the bulk density of the material, and c is the specific heat capacity per unit mass. Units of thermal inertia are given in $J/m^2s^{1/2}K$, which will be referred to as IU (for inertia units) in this abstract.

A global map of thermal inertia was derived from the Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES) surface temperature data [1]. The resolution of this global map is 1/4°/pixel resolution. Higher resolution is possible, down to 3 km/pixel. Mars Odyssey's Thermal Emission Imaging System (THEMIS) will improve this resolution even further, with limits down to 100 m/pixel.

The variation in bulk density and specific heat is small enough, that their product can be treated as a constant [2,3,4]. So most of the variation in thermal inertia is due to the variation in thermal conductivity. Under martian atmospheric pressures, the thermal conductivity is strongly dependent on particle size [5,6]. Important clues about the history of erosion, transport, and depositional processes may be found in the particle size of the deposit or landform.

The mean particle diameters of surficial units on Mars had been estimated from early conductivity measurements of particulate materials and thermal inertia determinations from the Mariner 9 Infrared Radiometer and the Viking Infrared Thermal Mapper [4,7]. Several studies [*e.g.*, 7,8,9] have used these estimates to characterize the surficial units and infer their depositional histories.

Particle size from thermal inertia: A comprehensive set of measurements of the dependence of thermal conductivity on particle size for particulate materials under martian atmospheric pressures has been previously presented [6,10]. The thermal model used to derive the thermal inertia from Viking Infrared Thermal Mapper (IRTM) assumed that the product of ρc was equal to 1.0×10^6 J/m^3K [2]. Thus, the thermal conductivity may be derived from the thermal inertia value, and compared to the dependence of thermal conductivity on particle size [6]. The thermal model used to derive thermal inertia from MGS TES data [1,10] is more complicated than that used for Viking [11]. To a first order, the product of ρc can still be assumed to equal 1.0×10^6 J/m^3K for the estimate of thermal conductivity.

While this assumption is not exact, a particle size may be derived from thermal inertia by using the following relation derived from laboratory studies [6,12]:

$$\kappa = (CP^{2/3})\, d^{\,(0.52 - K \cdot P)}$$

where κ is the thermal conductivity, P is atmospheric pressure, d is the particle diameter, and C and K are constants. $C \approx 0.0014$, and $K \approx 0.01$, when units of W/m K are used for thermal conductivity and torr is used for pressure.

This abstract is presented in order to make this derivation a little easier. Fig. 1 is a plot of thermal inertia (and thermal conductivity) vs. particle size, assuming that $\rho c = 1.0 \times 10^6$ J/m3K, for a "typical" martian atmospheric pressure of 5 torr.

Results. Particle sizes derived in this manner appear to be consistent with estimates derived from other methods. The low thermal inertia values correspond with high albedo surficial units, commonly thought to be dust deposits from global dust storms [*e.g.*, 13]. Early estimates of the size distribution for atmospheric dust is 1-10 µm [14]. Later estimates indicate an even smaller size distribution [15]. These values are consistent with values of 10 µm for 2.5 IU and 1 µm for 1.5 IU observed in the high albedo units. The high thermal inertias correspond with low albedo units, commonly thought to be sand-sized deposits [*e.g.*, 16]. Edgett and Christensen [9] argue that eolian physics indicates the average particle size on martian dunes is probably larger than 430 µm. This is consistent with a particle size of 450 µm for 6.5 IU, which is a "typical" thermal inertia for the low albedo units.

Caveats: Particle size and atmospheric pressure are not the only parameters that can determine the thermal conductivity of martian surficial deposits. As previously discussed [5,6], the transfer of thermal energy due to collisions of gas molecules that exist between the particles is the predominant mechanism of thermal conduction in porous sediments not under vacuum. The mean free path of gas molecules at the martian surface will vary between 3 and 42 µm [6], and is approximately the same order of magnitude as the effective distance over which conduction takes place between the particles. Conduction occurs primarily near the points of contact between the particles [17], and the effective conduction distance is approximately one-sixth the particle diameter or less [18]. Gas molecules are thus as likely to collide with the solid particles as they are with each other, and the average heat transfer distance between particles, which is related to pore size and shape, will determine how fast heat will flow through a particulate material [19]. Particle shape, bulk density of the material, and particle size sorting, as well as particle size, will affect the average heat transfer distance between particles, and therefore, the thermal conductivity of the deposit.

The effects of these parameters are the subject of ongoing laboratory studies. For instance, an increase of 85% in bulk density of a particulate material results in an approximate increase of thermal conductivity of 18%, for 25-30 µm particles at 5 torr.

Thus, the investigator must use other clues such as morphology to get a sense of the particle size. For instance, the steep cliff faces on "White Rock", a name given to a landform on the floor of Pollack crater (8°S, 335°W), may lead investigators to assume that the landform must be bedrock. However, the thermal inertia of the landform (230 I.U.), corresponds to fine sand. Since fine sand would not form cliff faces, the assumption is that the particle size of the deposit is actually a little smaller, and lightly cemented [20]. This interpretation is quite reasonable considering very steep cliffs form in sand along shore lines, with relatively little cementation. For comparison, even porous rock would have a thermal inertia close to 650 I.U., based on thermal conductivity measurements [5].

Conclusion: A first order estimate of particle size may be derived from thermal inertia and the plot in Fig. 1. Further interpretation of the deposits or landforms must take into consideration the morphology and geological setting.

References: [1] Mellon M.T. et al. (2000) *Icarus*, *148*, 437-455. [2] Neugebauer G. et al. (1971) *Astron. J..*, *76*, 719-728. [3] Kieffer,H.H. et al. (1972) *Icarus*, *16*. 46-56. [4] Kieffer H.H. et al. (1973) *JGR 78*, 4291-4312. [5] Wechsler and Glaser (1965) *Icarus 4*, 335-352. [6] Presley and Christensen (1997) *JGR 102*, 6551-6566. [7] Kieffer H.H. et al. (1981) *Proc. LPSC 12B*, 1395-1417. [8] Presley and Arvidson (1988) *Icarus 75*, 499-517. [9] Edgett and Christensen (1991) *JGR 96*, 22765-22776. [10] Jakosky B.M. et al. *JGR 105*, 9643-9652. [11] Kieffer H.H. (1977) *JGR 82*, 4249-4291. [12] Presley M.A. (1995) PhD Dissertation, ASU. [13] Christensen P.R. (1982). *JGR. 87*, 9985-9998. [14] Toon O.B. et al. (1977) *Icarus 30*, 663-696. [15] Haberle and Jakosky (1991). *Icarus 90*, 187-204. [16] Thomas P. (1981). *Icarus 48*, 76-90. [17] Deissler and Boegli (1958). *Trans. ASME 80*, 1417-1425. [18] Woodside and Messmer (1961) *J. Appl. Phys. 32*, 1688-1699 [19] Schotte W. (1960) *AIChE J. 16*, 63-67. [20] Ruff, S.W. et al. (2001) *JGR 106*, 23921-23928.

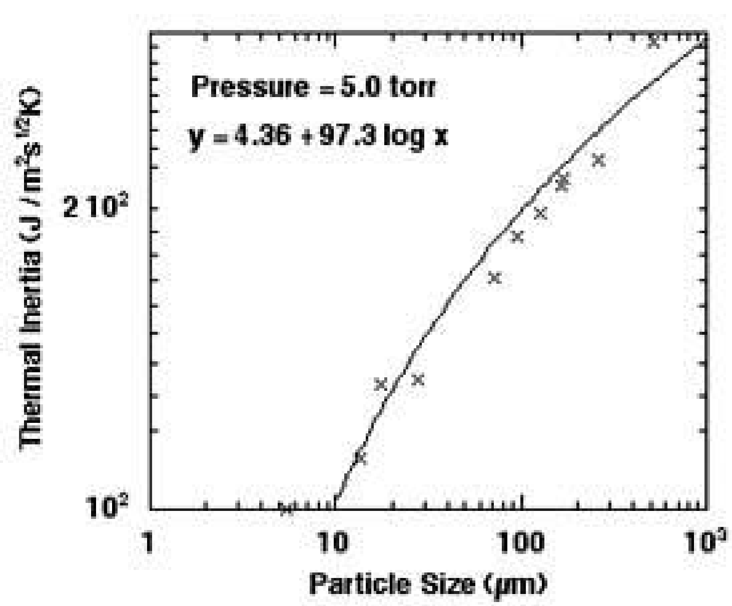

Fig. 1: Plot of Thermal Inertia vs. Particle Size under an atmospheric pressure of 5 torr.