THERMAL INERTIA AND RADAR REFLECTIVITY OF THE MARTIAN NORTH POLAR ERG: LOW-DENSITY AGGREGATES;

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The north polar layered deposits on Mars appear to be the source of the dark material that comprises the north polar erg [1]. The physical properties and chemical composition of the erg material therefore have important implications for the origin and evolution of the Martian layered deposits. Viking bistatic radar and infrared thermal mapping (IRTM) data indicate that the bulk density of the erg material is lower than that of the average Martian surface [2,3]. These data are consistent with hypotheses involving formation of filamentary sublimation residue (FSR) particles from erosion of the layered deposits [4,5]. The color and albedo of the erg and of the layered deposits, and the presence of magnetic material on Mars, suggest that the dark material is composed of low-density aggregates of magnetic dust grains, perhaps similar to FSR particles created in laboratory experiments.

Magnetic FSR Particles

Sublimation of dust/ice mixtures has been shown to result in the formation of FSR particles of various sizes [6]. Such particles can saltate along the Martian surface, and may therefore create dunes [4,7]. In order to form saltating material that is at least 3 times darker (in red light) than the bright dust that mantles much of Mars, dark dust grains must preferentially form FSR particles. Magnetic dust grains would be expected to form FSR more easily than non-magnetic dust, and are probably much darker. Experimental formation of FSR with magnetic material has not been attempted, and should be the subject of future research.

There is direct evidence for 1-7% magnetic material (magnetite or maghemite) in the surface fines at the Viking lander sites [8]. In addition, analysis of Viking lander sky brightness data indicates that suspended dust over the landing sites contains about 1% opaque phase, perhaps of the same composition as the magnetic material on the surface [8,9]. Within the uncertainties in these measurements, the percentages of magnetic material given above are identical to the volume of dark dune deposits in the polar regions expressed as a percentage of the estimated volume of eroded layered deposits [10-12]. This comparison indicates that the presence of magnetic dust in the layered deposits is likely, and that formation of dunes from dark FSR particles is plausible. Eventual destruction of the particles could allow recycling of the dark dust into the layered deposits via atmospheric suspension. Under the assumption that FSR can be formed by sublimation of mixtures of water ice and magnetic dust, the thermal properties of this material have been estimated and compared with observational data, as detailed below.

Thermal Inertias

A recent study using Viking IRTM observations of an area completely covered by dunes within the north polar erg [11] shows that the dunes have thermal inertias of less than 100 J m^{-2} sec$^{-1/2}$ K^{-1} [2]. Previous interpretations of Martian thermal inertia data in terms of particle sizes have utilized the relationship between these quantities presented by Kieffer et al. [13], which is based primarily upon measurements of the thermal properties of quartz sands [14]. The low albedos of Martian dunes are inconsistent with a siliceous composition, so basalt grains and magnetite FSR are considered here. The thermal conductivities of the materials considered here are only weakly dependent on temperature between 200 and 300 K, so values measured near 300 K have been used in all cases.

The thermal conductivity of basaltic sands is about 1.2×10^{-2} W m^{-1} K^{-1} (~40%) less than that of pure quartz sands of the same size (~100 microns). If the polar dunes are composed purely of basaltic grains, their effective particle size is no greater than about 50 microns (40% porosity). Particles in this size range will be transported by atmospheric

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suspension [15], and are therefore not likely to form dunes. Hence, low-inertia materials that are capable of saltation must be examined as possible dune-forming materials on Mars. The thermal properties of FSR particles are therefore estimated below.

The density of magnetite is 5200 kg m^{-3}, almost twice that of quartz (2650 kg m^{-3}) or basalt (2680-2830 kg m^{-3}). The specific heat of magnetite is 544 J kg^{-1} K^{-1} at 220 K [16], only slightly less than the specific heat of various silicates [17]. The porosity of clay FSR formed in laboratory experiments is 99% [6]. Magnetite FSR would therefore have a bulk density of only 52 kg m^{-3}. The thermal conductivity of porous clay at 313 K, 740 torr ranges from 0.477 to 2.05 W m^{-1} K^{-1}, depending on water content [16]. The lowest value is identical to that of clay FSR [6]. When this dry clay was placed in a high vacuum, its thermal conductivity decreased only 7%. Therefore, the conductivity of clay FSR at 6 mbar is probably no greater than 0.47 W m^{-1} K^{-1}. The thermal conductivity of clay *minerals* is probably similar to that of most silicates, about 2.8 times less than the conductivity of magnetite. Hence, magnetite FSR should have a thermal conductivity of 1.2 W m^{-1} K^{-1} or less, implying a thermal inertia of no more than 187 J m^{-2} sec$^{-1/2}$ K^{-1}. The thermal inertia of ensembles of FSR particles may be lower still, and is compatible with the north polar erg thermal inertias derived from Viking data.

Radar Reflectivity

Viking bistatic radar data show that the north polar erg is rougher and less reflective (and therefore less dense) than surrounding terrains [3]. Increased radar roughness is expected for dune fields, and their low apparent density is consistent with the presence of FSR particles. Although magnetite is a conductor, experiments involving low-density suspensions of conductors in dielectrics [18,19] suggest that the index of refraction (and therefore reflectivity) of magnetite FSR might be very low. The results of further analysis of theoretical and experimental work on loaded dielectrics will be discussed at the conference.

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