THE EPIREGOLITH. W. W. Mendell[1] and S. K. Noble[2], [1]NASA/JSC/KA, Houston TX 77058 (wendell.mendell@nasa.gov), [2]University of Alabama at Huntsville, 320 Sparkman Dr. Huntsville, AL 35805.

Introduction: The physical properties of the lunar regolith were originally inferred from remotely sensed data, first from the Earth and later from orbiting spacecraft. The Surveyor landings and the Apollo surface explorations produced a more concrete characterization of the macroscopic properties.

In general, the upper regolith consists of a loosely consolidated layer centimeters thick underlain by a particulate but extremely compacted layer to depths of meters or tens of meters. The median particle size as determined by mechanical sieving in terrestrial laboratories is several tens of micrometers. However, the comminuting processes that form the layer produce particles in all sizes down to nanometers. The smallest particles, having a high surface to volume ratio, tend to be electrostatically bound to larger particles and are quite difficult to separate mechanically in the laboratory. Particle size distributions determined from lunar soil samples often group particles smaller than 10 µm.

Photometric Function: One of the earliest enigmas was the nature of the surface structure that produced the highly retroreflective photometric function and the zero-phase opposition effect. Hapke successfully modeled the phenomenon using ideas from the Lommel-Seeliger function and assuming a complex latticework structure wherein surface elements mutually shadowed each other. [1] Photons reflected into any direction other than back along the incoming path had a low probability of escape, a condition that led to the surge at zero phase. The latticework was about 95% emptiness, leading Hapke to use the term *fairycastle*. The scale of the structure was unknown although its elements must be much larger than the wavelength of light but much smaller than the resolution of any surface photograph.

Directionality of Thermal Emissivity: Pettit and Nicholson scanned the disk of the full Moon and noted that the surface did not radiate in a Lambertian manner, implying some sort of surface roughness. [2] Saari and Shorthill produced much higher resolution scans of the illuminated Moon over a lunation at a wavelength of 11 µm. [3] Montgomery, et al, derived the directivity function of the surface emissivity from the data. [4] Buhl attempted to model the directivity using a surface with hemispherical craters but could not quite reproduce the degree of deviation from Lambertian behavior. [5] Bastin succeeded with a model that invoked an artificial surface with rectangular corrugations. [6] The key to the success of the corrugated model was that the depths of the "valleys" between the "ridges" equaled the spacing of the ridges. A hemispherical crater can never a have a depth-to-diameter ratio greater than 0.5. Each of the modelers assumed that the conductivity between adjacent surface elements was negligible, allowing each surface element to independently equilibrate with its radiative environment.

Once again, the scale of this hypothetical structure was unknown except that the radiating surface elements needed to be conductively isolated. Conceivably, it might have something to do with macroscopic roughness seen in surface photographs.

Thermophysical Structure: In the basic one-dimensional model of heat conduction, the surface temperature is determined by the thermal inertia, defined as the square root of the product of the thermal conductivity, the bulk density, and the specific heat of the material. The first attempts to monitor the fall of surface temperature during an eclipse and to measure the temperature of the antisolar point (at new Moon) yielded different values of thermal inertia, possibly implying a thin upper layer of lower thermal inertia. Radio astronomy measurements in Australia appeared to support this conclusion. [7]

The two-layer model was soon abandoned; but Winter and Saari constructed a particulate model of the lunar surface, attempting to reproduce the measurements. [8] The heat transfer model was based on a construct consisting of an array of cubes, touching only at their edges, creating a material with 50% porosity. Heat is transferred between layers both by radiation and by conduction. Conduction is modeled by a series of thermal resistors connecting each cube with its neighbors above and below. The resulting set of coupled equations contains parameters quantifying the roles of radiation and conduction. Initially, they chose the size of the cubes and the value of the thermal resistance to agree with the experiments of Watson [9] on radiative transfer in simulated lunar material.

Although the equations were derived for a specific physical configuration, they could be manipulated to explore the sensitivity of the calculated surface temperature to variations in the thermal parameters. The authors concluded that the conductive component must increase with depth, as suggested by the soil measurements from the Surveyor spacecraft. Their final functional characterization is consistent with that of Carrier [10] in his later model of lunar surface pentrometer measurements. Winter and Saari were successful in reproducing with a single model the behavior of the eclipse observations and also the lunation temperature behavior.

Interestingly, this model shows that cubes (i.e., particles) in the second layer are significantly warmer than those sitting at the 'surface'. The difference stems from the hemispherical view of 'cold' space by the top layer while the solid angle view of the second layer is quite restricted. Coincidentally, the depth-to-width ratio of unity of the vacancies in the surface layer is consistent with the condition derived by Bastin for his model of the thermal emission directivity.

The Epiregolith: Based on these disparate lines of evidence, we propose the existence of a ubiquitous surficial layer on the Moon, at least 250 µm thick and having a porosity on the order of 90% in a structurally complex fairycastle arrangement. A layer about 5-10 particles deep (i.e., <1 mm) would be sufficient to produce all the photometric and directional emissivity phenomena outlined above. Of course, the unusual porous structure could be somewhat thicker.

This epiregolith would be difficult to image directly and would be mechanically fragile. Any type of surface disturbance such as micrometeorite impact would destroy it, implying it must reconstitute itself somehow. We suggest that it is dynamic, arising anew every lunation through the action of electrostatic repulsion among similarly charged grains.

Surface Charging: Manka [11] proposed that the surface of the Moon would become positively charged from the photoelectric ejection of electrons by solar illumination. The degree of charging would be greatest at the subsolar point and fall off toward the terminators. He further predicted that the night side of the Moon would be negatively charged, as the more mobile electrons from the plasma sheath would preferentially repopulate the Moon's wake in the solar wind. Lunar Prospector data confirmed the general aspects of the model. [12] Here, we are concerned only with the dayside charge because no evidence exists for directionality of reflection or emission from unilluminated lunar regions.

Dust levitated by surface charging is seen as a potential operational hazard. The dayside potential from photoemission is deemed too small to levitate even a particle of 10 µm. However, fields between individual particles at the surface may be significant during stochastic charging processes. Surface particles, being like-charged, should try to separate, conceivably building small linear structures jutting from the surface plane. As mutual shadowing occurs or as the Sun moves, changes in the illumination environment could alter local charge distributions, possibly creating a locally dynamic microstructure. Halekas [13] notes measurements of transient large negative potentials on the lunar night side associated with solar energetic particle events. We conclude that significant repulsive interparticle fields will be commonplace and that smaller mobile particles will experience the most displacement.

Surface Layer Detection: The Ap16 Clam Shell Sampling Devices (CSSDs) were designed to sample the uppermost surface of lunar soil. [14] The two devices used beta cloth (69003) and velvet (69004) to collect soil from the top 100 and 500 µm of the soil, respectively. Due to the difficulty of the sampling method, little material was collected and little research has been done on these samples. Recently, samples were obtained directly from the beta cloth using carbon tape. A size distribution was determined and compared to the scoop sample taken at the same location (69941). Preliminary results suggest that the uppermost layer of soil is enriched in submicron particles. [15]

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