EVALUATION OF GEOPHYSICAL PROPERTIES OF THE LUNAR REGOLITH FOR THE DESIGN OF PRECURSOR SCIENTIFIC MISSIONS FOR THE SPACE EXPLORATION INITIATIVE; Paul Morgan, Department of Geology, Northern Arizona University, Flagstaff, AZ 86011-6030, and Wendell W. Mendell, SN-14, NASA Johnson Space Center, Houston, TX 77058.

A working knowledge of the physical parameters of the upper ten meters of the lunar regolith is crucial to the planning of experimentation, mining, resource utilization, and construction associated with future lunar bases. Scientific research literature pertaining to studies of the lunar surface, including results of Apollo experiments and exploration, have been reviewed to produce a summary of our present knowledge of the physical properties of the lunar regolith. Particular emphasis was placed on gaps in our understanding. The primary data source for this review has been Carrier *et al. (1)*.

The purpose of this review is to address the following questions: 1) With what frequency may boulders be encountered that represent hazards to lunar operations?; 2) How easy may lunar soil be excavated?; 3) How may explosives be used in excavation operations?; 4) What is the trafficability of the regolith?; 5) What problems may be encountered in mining (probably strip mining) of the regolith?; 6) What angle(s) of repose will be stable in excavation of the regolith?; 7) What layering may be encountered in the subsurface?; 8) Is our knowledge of the regolith site specific, or may it be applied generically to any site on the lunar surface?; 9) What data will be needed to characterize a site for a lunar base?; 10) How may the regolith properties modify the design of geophysical experiments from the lunar base?; 11) Are there terrestrial analogues for the geophysical properties of the lunar regolith?

The lunar regolith is a an essentially continuous layer, typically several meters in thickness, which covers the entire lunar surface *(2)*. Any surface activities on the Moon, and any geological studies of the Moon are therefore strongly affected by the properties of the regolith. It is a mantle of fragmental and unconsolidated rock material of highly varied character, ranging from very fine dust to blocks of several meters in diameter. All lunar landings (Apollo and Luna), and all photographic studies of the Moon indicate that the regolith completely covers the underlying bedrock, except perhaps where bedrock may be exposed on some very steep-sided crater walls and lava channels. The finer components of the lunar regolith (<10 mm) are often informally referred to as lunar "soil", but this term must be used carefully as there are fundamental differences between terrestrial regoliths, of which soils are one group, and the lunar regolith.

Available data indicate that there is significant lateral heterogeneity in the lunar regolith, and that the base of the regolith is poorly defined and is probably very irregular. This heterogeneity exists both with respect to small-size particle distributions (<1 mm), which may affect bulk material properties, and with respect to the random distribution of large-sized particles (>100 mm), which need to be considered for mining and excavation operations. There is also heterogeneity in particle shapes, ranging from spherical to extremely angular, and these different shapes have significant implications on regolith physical properties, such as density, compressibility, and shear strength. Hypervelocity impacts typically form poorly sorted angular fragments, but spherical fragments may be formed by impact melts, and some pyroclastic and other volcanic deposits are well sorted. Vertical layering of the regolith is expected at most sites, and considerable vertical heterogeneity may also be expected.

Detailed site-specific surveys are recommended at all sites where mining and excavation operations are planned. These surveys should include sub-surface profiling, for which radar techniques appear to be most easily adapted, to determine the density and distribution of large, consolidated particles. This profiling should also determine the degree of subsurface layering. Core samples will be required to determine small-sized particle properties if significant layering is recorded. Trafficability appears to be primarily restricted by surface topographic features, although problems of raising the loose surface regolith must be considered. These problems appear to be associated with ballistic trajectories associated with surface activities which disturb the surface, and with electrostatic attraction by the lighter particles to charged surfaces. No terrestrial analogue adequately covers the range of properties likely to be experienced in the lunar regolith, but analogues for different physical and mechanical properties may be found.

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References Cited *(1)* Carrier, W. D., III, Olhoeft, G., and Mendell, W. (1990) In *Lunar Source Book* (G. Heiken, D. T. Vaniman and B. M. French, eds.), Cambridge University Press, in press. *(2)* McKay, D. S., Heiken, G., Basu, A., Blanford, G., Simon, S., Reedy, R., French, B. M., and Papike, J. (1990) In *Lunar Source Book* (G. Heiken, D. T. Vaniman and B. M. French, eds.), Cambridge University Press, in press.