EVOLUTION OF MARE SURFACE

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ABSTRACT-- Photographic and seismic evidence argue against bedrock lying closely beneath the lunar soil. Layers in the core sample and other features suggest that surface transportation of lunar fines is a continuing process. If this transportation is driven by electrostatic effects, then the difference between near and far sides of the moon can be understood as following from the electron bombardment in the magnetic tail of the earth.

NO EVIDENCE FOR GENERAL BEDROCK AT SHALLOW DEPTH

Photography of the lunar surface from orbit shows in general an absence of stratification on most steep surfaces. Almost everywhere the material seems to be very homogeneous to a depth of several kilometers. Craters are frequently very precisely circular and bowl shaped. The cases where there are ledges or particularly densely strewn boulder fields around craters may be a local exception, or they may represent a compaction and induration of the lunar soil with depth. There is no evidence that anything other than lunar soil, differently compacted and cemented in different locations, fills all the mare basins.

SEISMIC EVIDENCE FAVORS DEEP DEPOSIT OF GRADUALLY INCREASING COMPACTION

The seismic evidence cannot be understood except with an absence of widespread bedrock at shallow depth, and instead, the presence of a medium of much slower sonic velocity over an interval of several kilometers of depth. Lunar soil gradually compacted with depth would account very well for the whole range of seismic phenomena seen (Gold and Soter, 1970).

IMBEDDING OF STONES AND CORE TUBE LAYERS SHOWS THAT DEPOSITION OF SOIL HAS BEEN FASTER PROCESS THAN PLOWING OVER BY METEORITES

Stones on the lunar surface are in general clean, though partially imbedded. Material around them has been moved and filled in level to a rather sharp shoreline around each stone. At the same time the stones have not been showered over by any kind of spray. A surface transportation mechanism is required to account for this, where the flow in general takes place within less than two centimeters of the surface (Gold, 1970).

Plowing over by meteorite impact has been thought of as being the major surface activity. It has been estimated, for example, that the ground has been plowed over a hundred times to a depth of 40 centimeters in the lifetime of the mare surface (Shoemaker et al., 1970). The core tube evidence makes clear that the ground at that site has not even been plowed over once to a depth of 40 cm. There is clear evidence that the core has striations in height noticeable in optical properties, in chemical differences and in differences of the size distribution of the grains. This can only be understood by supposing that the surface has been added to at a rate that exceeds the plowing by meteorites. If one supposed a plowing rate to 40 cm depth of once in 40 million years, one would require a deposition rate faster than 1 cm per million years. The average rate required to fill a mare basin in 4 billion years would be 1 cm in ten thousand years, assuming an initial depth of 4 kilometers after the hydrostatic adjustment following the impact.

Mare surface in general is clearly not saturation bombarded since the crater density is quite variable in different regions. This can be understood again as a sign that material is laid down in the mare regions and that the final appearance represents the equilibrium between this deposition process and the impact cratering.

ROCKS AND SOIL IN THE SAME LOCALITY DO NOT HAVE THE SAME ORIGIN

The compositional differences between soil and rocks in the same region make clear that the soil is not local bedrock ground up with the rocks being pieces of that same bedrock. This would have been the expected situation if bedrock existed at a shallow depth and if the soil were merely the consequence of its local pulverization.

If instead the soil has suffered some surface creep over big distances, while the rocks are pieces thrown out from major craters and originally represent material at various depths, then such compositional differences can indeed be expected. The nuclear age dating of rocks and powder similarly require some differences in the origin of these two components (Albee et al., 1970).

DISCUSSION

The mare basins represent deep deposits three to six kilometers in depth (judging from the seismic evidence and from the appearance of submerged craters) and those deposits may consist of a similar material as is found on the surface, though somewhat compacted and cemented at the greater depths. There is crystalline rock below this, at least in some regions. Within this deep deposit rocks have been distributed by major impacts in which they were either generated, or previously existing crystalline rock at some depth was excavated. The origin of the crystalline rock may be early volcanism, or perhaps more likely it was produced by the heating of very major impacts such as the ones that created the mare basins. During the entire accumulation process of the mare basin the surface would have looked much as it does now, with a sprinkling of rocks among the deposit of fine powder.

The required surface transportation and deposition mechanism is most likely electrostatic. Electrostatic agitation of a surface is readily produced in the laboratory by electron bombardment in the energy range of a few hundred electron volts. Higher or lower electron energies, or proton beams, have not led to any observable effects, while electrons in the energy range of the secondary emission cross-over point are found to be remarkably effective in stirring up the surface and causing it to creep. The effect is due to the very large electric fields generated between adjacent particles when the potential of one is driven far positive through the emission of more than the primary number of electrons, while another, being to the other side of the cross-over point, is driven negative by the absorbed electrons. Large scale surface motion has been demonstrated in the laboratory, both with a variety of powders and with actual lunar soil (Fig. 1).

<u>The difference between the front and the back of the moon</u>. If indeed electron bombardment in the energy range of a few hundred volts is responsible for the major surface transportation process, then one would expect the front and the back of the moon to have

had a very different treatment. The moon is enveloped approximately four days each month in the magnetic tail of the earth, and it is there that electrons in this energy range occur as a consequence of the solar wind impingement on the magnetosphere. In the free solar wind stream electron energies are generally very low. The front of the moon is preferentially subjected to this electron bombardment, and any effects of it would thus be expected to dominate greatly on this side. The observed difference between the front and the back of the moon is indeed very great and demands an explanation. The difference is just of the kind that the mare ground predominates on the front side and is rare or absent on the back. If the back has any large low basins, they appear not to have been filled in. It is suggested therefore that the difference between the two hemispheres could be due to the surface transportation caused by magnetospheric tail electrons. A quantitative evaluation of the rates of transportation is difficult since it depends very sensitively on the surface electrical properties of the lunar soil, both with regard to the secondary emission coefficients and the conductivity, and measurements on material extraordinarily free from contamination and surface adsorption effects would be required.

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Fig. 1. Surface configuration of insulating rock powder after being exposed to an electron beam of 2 kilovolt energy. The terrain has been changed totally several times over by electrostatic transportation processes so that no features have much to do with the original deposition of the powder. The actual surface area seen on the picture is 6 X 12 cm.