MONTE CARLO SIMULATION OF LUNAR REGOLITH AND IMPLICATIONS.

Hans R. Aggarwal, Univ. of Santa Clara, Santa Clara, CA 95053, and V. R. Oberbeck, Space Science Div., NASA Ames Research Center, Moffett Field, CA 94035.

Introduction. It is important to know the evolution and thickness distribution of the lunar uplands megaregolith for at least two reasons. Previous estimates (1,2,3) indicate that it is a major lunar formation. Secondly, many workers have suggested that the structures of large craters and basins are caused by the interface between the megaregolith and the underlying coherent bedrock (1,2,4,5). In this paper, we present a realistic Monte Carlo model which simulates lunar impact craters ranging from 2 km to 1060 km in diameter distributed all over the moon and calculate thickness distribution of the megaregolith over rather a large area, from 45° N to 45° S and from 45° W to 45° E comprising a total area of 6.7×10^6 km^2, of the front surface of the moon. The computer program developed uses a method previously used by Oberbeck, et al., (6). It differs from all previous attempts in that it closely simulates the natural development of the impact-produced regolith. The model is further used to compute the expected frequencies of different structure types that would form as a result of megaregolith-interface. A comparison with the observed frequency polygons for each uplands crater type shows that the model partially supports the layering theory.

Computational Method. A crater production function given by: $N = 8.3 \times 10^3 D^{-2.16}$ for $D < 50$ km and $N = 1.6 \times 10^6 D^{-3.5}$ for $D \geq 50$ km, where N is the number of craters/10^6 km^2 per unit diameter at diameter D, recently found to be generating the lunar primary craters (7), is used in the simulation here. The calculations are performed in sets. For all minimum size crater diameters (MSCD) greater than or equal to 100 km included in the simulation, observed longitudes and latitudes of the centers of all craters are used to fix the position of each crater in the computer grid coordinates which consists of 130321 points taken at a quarter degree interval. These craters are also allotted their observed diameters. For MSCD less than 100 km, the coordinates of crater centers and their radii are assigned through a random number generator. As each crater is processed, the thickness of the regolith already produced by the earlier craters at its center is used to determine the structure of the crater using laboratory-determined conditions of forming different structures (8). Each particular crater structure defines a certain volume formula to be used to calculate the volume of the ejecta to be distributed and added to the pre-existing regolith. A necessary input to this calculation is the depth-diameter ratio of the crater at its formation. In this paper, we have used the crater depth-diameter relation given by Pike (9), assuming that it represents unmodified craters at excavation. The ejecta volume thus found is distributed according to the power function defined by $t = k(r/R)^{-3.7}$ which is similar to the power function suggested by McGetchin (10). After a crater is processed, thickness is calculated at all grid points of the net. The process is repeated until all craters in the population are processed and a final regolith thickness distribution is tabulated.

Results. The simulation first considers sets of craters with MSCD greater than or equal to 100 km. Successive simulations use smaller and smaller MSCDs. It is done to evaluate the effect of small craters on the growing regolith. The smallest MSCD used in our simulation in 2 kms in which case a total of 21664 craters are processed. Figs. 1 and 2 show the results of using successively smaller craters in the simulation. These figures show that it is the big craters and basins which mostly produce the megaregolith. Fig. 1 shows that the average value of the regolith thickness stays fairly constant

MONTE CARLO SIMULATION OF LUNAR REGOLITH

Aggarwal, H. R. et al.

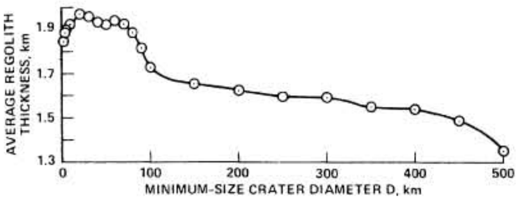
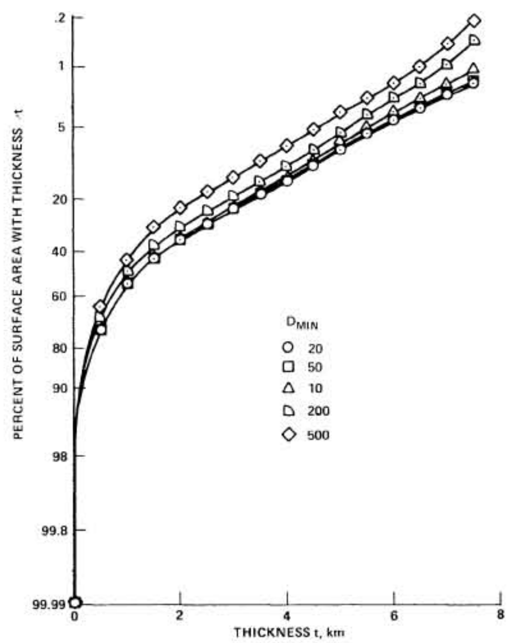


Fig. 1. Average regolith thickness as a function of minimum size crater diameter included in the simulation.

Fig. 2. Variation of regolith thickness distribution with minimum diameter as a parameter.



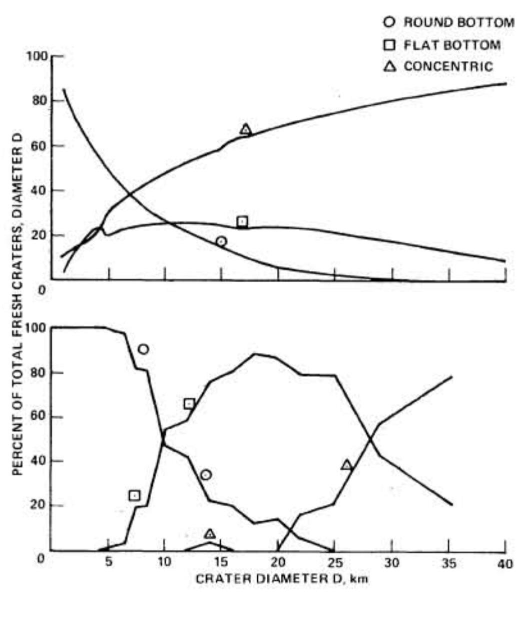


Fig. 3. Comparison of the distribution of lunar normal, flat bottomed and concentric craters predicted from the Monte Carlo cratering model with that of normal, flat bottomed and concentric craters observed in the uplands portion of the simulated area.

for MSCD $\leq$ 60 km, reaching a maximum of about 2 km at MSCD = 20 km. It compares favorably with the best thickness estimates, 1.5 to 2.4 km, given by Short and Forman (1) and 2-3 km given by Hartman (3). The value for the average regolith thickness declines slightly for MSCD < 20 km. This feature is also manifested by curves in Fig. 2. The reason for this is that small size craters are mostly formed in megaregolith and as such they tend to redistribute (rework) the regolith material. This reworking feature of the megaregolith by small size craters displayed by our model further lends support to its being a good model.

It has been suggested in literature (1,2,4,5) that layering of debris over coherent bedrock could be responsible for the observed structure of lunar craters. There has as yet been no test of this effect of the megaregolith-interface on crater structure. Using laboratory-determined conditions of forming different structure types (8) together with calculated regolith thickness distribution obtained here, we calculated the expected percentage of each crater type and size that would form in the megaregolith. To this end, we randomly distributed 10,000 craters, up to 100 km in diameter, over the simulated area and determined the morphology of each fresh crater. A comparison of this calculation given at top, Fig. 3, with crater classification of lunar uplands craters observed over a large area in southern highlands given at bottom shows the curves for the Monte Carlo results are relatively shifted to smaller crater size. It is, however, seen that the two sets of curves are similar in their behavior, viz., the most frequent small craters are round bottomed and as their relative frequency decreases, the frequency of flat-floored craters and of concentric craters increases. In this respect, our model partially supports the layering theory.

The fact that our model could not duplicate the positions of the frequency polygons of the observed uplands crater types, implies that Pike's depth-diameter relation (9) may not be representing craters of excavation as we assumed; or that secondary craters of large primaries must be included in a simulation like the one carried out here since it would considerably add more ejecta to the regolith layer contributed by the primaries alone (11).

References. (1) Short, N. M. and Forman, M. L. (1972) Modern Geology, 3, p. 69-91. (2) Head, J. W. (1976) Proc. Lunar Sci. Conf. 7th, pp. 2913-2929. (3) Hartman, W. K. (1973) Icarus, 18, p. 634-636. (4) Oberbeck, V. R., Quaide, W. L., Arvidson, R., and Aggarwal, H. R. (1977) J. Geophys. Res., 82, p. 1681-1698. (5) Wilhelms, D. E., Hodges, C. A., and Pike, R. J. (1977) Impact and Explosion Cratering, Pergamon Press, New York, p. 539-562. (6) Oberbeck, V. R., Quaide, W. L., Mahan, M. and Paulson, J. (1973) Icarus, 19, p. 87-107. (7) Oberbeck, V. R. and Aggarwal, H. R. (1978) Proc. Lunar Sci. Conf. 8th, p. 3521-3537. (8) Quaide, W. L., and Oberbeck, V. R. (1968) J. Geophys. Res., 73, p. 5247-5270. (9) Pike, R. J. (1974) Geophysical Res. Lett., 1, p. 291-294. (10) McGetchin, T. R., Settle, M. and Head, J. W. (1973) Earth and Planet. Sci. Lett., 20, p. 226-236. (11) Oberbeck, V. R., Hörz, F., Morrison, R. H., Quaide, W. L., and Gault, D. E. (1975) The Moon, 12, p. 15-94.