

A MONTE CARLO MODEL FOR LUNAR SURFACE PROPERTIES, J. R. Arnold,
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The mechanism of meteoritic impact has been a dominant one in the formation and evolution of the lunar regolith. At a given point on the lunar surface, small collisions have occurred many times, those of intermediate scale a few times, while the probability of the largest events is less than one. Such a situation invites the use of a Monte Carlo approach. The present model attempts to account for a very wide range of soil properties. Among them are the observed smoothness of the soil surface, the presence and distribution of layers in the cores, disturbance of the depth profiles of cosmogenic nuclides, and the observed nuclear track density distributions.

The basic input data (rates of impact, crater size and shape, etc.) are taken mainly from the work of Gault and co-workers (1973). Above one gram, the mass distribution law ($m^{-1.06}$ integral) is taken from Neukum (1971). It is the flattest plausible distribution. Collisions are assumed random in time and space. The depth/diameter ratio of craters is taken as 1/8 for material ejection. Craters formed by particles >1 g are assumed to have ejecta blankets whose diameter is three times that of the crater. Smaller craters are assumed to eject material with a mean velocity of 1 meter/sec (Gault, D. E., private communication), and a Maxwell distribution. Crater diameters in cm are related to projectile mass in grams by the law: $D = 30.9xm^{1/3}$. The ratio of mass ejected to projectile mass is therefore constant. Particle masses from 10^{-7} g (below which impact is effectively on "rock" rather than soil) to 10^{10} g are considered.

Three sorts of motion result from such impacts. First, there is the direct ejection of soil from the crater. Second, when slopes exceed the static angle of repose, slumping may occur. Finally, because of the low velocity of most of the ejected matter, there is a marked bias toward downhill motion which tends to smooth the surface and to keep the exposed rocks clean. About $2-3 \times 10^{-6}$ cm/year of material is moved about at this velocity. The model, unlike an earlier version (Arnold, 1975), reproduces the observed mean slopes. The results are consistent with Crozaz, et al (1975) for the rate of filling of meter-size grooves in the soil.

The model has been used to calculate values and distributions for a number of properties of the soil, especially those which measure the bombardment by external particles. The results are in general accord with observation. For example, the very broad distributions of track density are well accounted for.

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Distinct layers of 0.5 cm or more make up a large fraction of the regolith. This is in qualitative agreement with observations of soil cores. The predicted mean disturbed depth on a million year (Al^{26}) time scale is 2 cm, with a very wide distribution from place to place (see Gault, et al [1974] for a different approach).

One property is not reproduced by the model: the observed bombardment ages are shorter, by factors of 2 to 10, than we can account for. Fireman's (1974) explanation, massive ejection from the moon by collisions, seems inconsistent with impact data (Schneider, 1975). Most other simple explanations of the discrepancy can be ruled out. Explanations worth exploring further include (1) the non-selective loss of spallation rare gases from the lunar soil by some mechanism and (2) removal of material from the lunar surface by solar wind ion sputtering (Housley, 1975).

The mixing of a mare basalt component into the lunar highlands, and of highland material into the maria, presents a problem on a larger distance scale than we deal with. It might best be examined using the Monte Carlo model of Quaide and Overbeck (1975).

Although the results of the model calculations do not contradict the existence of non-impact mechanisms of soil transport (Criswell, 1973; Gold, 1960), they suggest that such processes play a minor role. Particle size sorting in core layers may be the most useful tool in clarifying this question.

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