HOW DUSTY ARE LUNAR ROCKS? EVIDENCE FROM TRACK PROFILES.

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A large number of particle track density vs. depth profiles have been measured in lunar rocks by several groups since the first samples were returned. In Fig. 1 we have plotted track density vs. the negative exponent of the depth profile measured at a depth of 100 μm for 31 rocks reported in 21 papers (references to be published.) Open circles refer to special samples chosen to yield the production profile, having an exponent of 1.8-2.5. Most rocks show much shallower profiles, varying over a wide range. It is generally assumed that these profiles within about 1 mm of the surface, produced by solar flare particles, are controlled by micrometeoroid erosion processes acting on clean rock surfaces. If this were strictly true the steepest erosion profiles, often measured to within 10 μm depth, would require an erosion mechanism which removes chips of size less than about 10 μm with a rate of 2 to 8 × 10^-8 cm/year (Crozaz and Dust [1], Fleischer et al. [2].)

Using a new detailed Monte-Carlo model for rock surface evolution described earlier by Comstock [3] we have verified that micrometeoroid impacts alone cannot produce this fine scale erosion. This is true whether or not a "kink" in the pit-size frequency distribution at 10-100 μm is assumed (Hörz et al. [4], Morrison and Zinner [5].) The observed track profiles are easily reproduced for depths greater than 100 μm, but not at ≤ 100 μm where the calculated exponent is only 0.2 - 0.3 less than the production exponent.

Increasing the micrometeoroid flux by a factor of ten does little good because most of the erosion occurs on too large a size scale. Also, the "recent" removal of large chips is too rare an event to be important for most of the samples in Fig. 1. A typical clean-rock model is given by the open circle in Fig. 2, for a track production exponent of 2.2 and an impact rate normalized to Φ = 5 events/cm²-m.y. with central pit diameter > 500 μm. It lies outside the envelope of normal rock data.

Lunar rocks reside in a dusty environment capable of providing some intermittent shielding for the rock surface. To evaluate this effect we included in the model a steady accumulation of fine dust described by an efficiency parameter η, defined to be the rate of dust accumulation divided by the rate of removal (erosion) due to impacts with central pits of less than 4 mm diameter. Values of η = 1 to 3 yield intermittent dust coatings up to 100 to 1000 μm thick, respectively, on a flat surface, and correspond to the sticking of only a fraction of the dust probably incident on the rock. This dust coating is controlled and occasionally cleaned off by impacts. With this model we can obtain the wide variation in track profiles observed, as shown in Fig. 2 for various values of the dust parameter η and two impact rates.

These results suggest that the dusty environment plays an important role in rock exposure history on the sub-millimeter scale, and that track profiles and microcrater population are in a quasi-equilibrium with a complex...
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interaction of dust accumulation and micrometeoroid impacts. Some questions remain: Track profiles alone do not tell us how much of the surface is clean on a scale much less 10 μm, when submicron pits and solar wind effects can accumulate. What constraints on variable dust coatings are placed by solar wind implanted gases? What is the theoretical relation between submicron pits and the 100 μm-depth track density observed by Morrison and Zinner (5)? Do electrostatic effects play an important role in dust retention? How much dust is removed in handling and how much would we expect to be retained in crevices and vugs?

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Fig. 2.

Track density at 100 \( \mu \text{m} \) vs. the negative exponent of the depth profile at 100 \( \mu \text{m} \) for some calculated rock surfaces. \( \eta \) is a dust accumulation rate parameter. \( \alpha \) is the track production profile exponent. \( \phi \) is the number of impact pits formed per cm\(^2\)-m.y. with pit diameter \( \geq 500 \mu \text{m} \).

The parallelogram encloses the normal rock data in fig. 1. Dashed arrows show effect of increasing dust accumulation rate and dotted arrows show effect of increasing impact rate.

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References