MICROCRATER STUDIES ON 60015 DO NOT SUPPORT TIME VARIATION OF METEOROID FLUX

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Considerable attention has been given to the question of whether meteoroid and/or solar flare particle fluxes are time-variable over periods of $10^3$ to $10^6$ yr. By comparing observed effects of meteoroid impacts, rates of soil turnover and rock destruction and erosion, and those expected based on the known present-day meteoroid flux, Gault et al. (1) found the long-term ($\sim 10^6$ yr) average meteoroid flux may be less than the present value. Assuming the solar flare particle flux was a known constant, Hartung and Storzer (2) measured tracks in individual microcrater pits and concluded that meteoroid flux had been lower in the past. A similar result was obtained by McDonnell and Flavill (3) based on an assumed constant sputter erosion rate for lunar surface material. In contrast, an analysis of the problem by Crozaz et al. (4) yielded "no compelling evidence...showing a drastically reduced flux of micrometeoroids in the past." Based on analysis of solar flare particle tracks and microcraters on the same carefully selected samples Hutcheon (5) and Morrison and Zinner (6) have concluded the average meteoroid flux over the past $\sim 10^4$ and $\sim 10^6$ years is approximately the same as that measured today.

We have analyzed the microcrater and accretionary disk (7) populations on a sample of rock 60015. The results obtained do not support the idea of a significant time variation in the meteoroid flux. A photograph of the surface we studied is shown in Fig. 1.

We measured the relative times of formation of large microcraters (pit diameters $\geq 1 \times 10^3$ µm) using two different approaches:

1. by measuring the areal densities of µm-sized pits inside the large pits, and
2. by measuring the areal densities of somewhat larger accretionary disks on the surfaces of large pits.

Analysis of solar flare tracks in each of the large pit glasses is planned for the future.

The distribution of the relative ages of large microcraters based on µm-sized pit densities is shown in Fig. 2. The character of the distribution is similar to that measured by Hartung et al. (8) on sample 12002,100. In that case, the exponential-decay character of the distribution was explained as being due to microcrater superposition because the surface was in equilibrium. The surface of 60015,38 is definitely not in equilibrium, so another explanation must be found. One could argue that the formation rate of large microcraters was higher recently, relative to µm-sized microcraters, than in the more distant past. This explanation is not entirely satisfactory because it is generally believed that the µm-sized meteoroids either have the same source as, or are derived from, the larger meteoroids, thus large differences in their relative fluxes are not expected.

The distribution of the relative ages of large microcraters based on areal densities of accretionary disks is shown in Fig. 3. The familiar exponential-decay character for the distribution is obtained. Again, one could argue the
formation rate of large microcraters is higher now, relative to that for disks, than in the past, but this argument becomes even more untenable when the source of disks is considered. Disks are present on all lunar surfaces exposed sufficiently long to space and are most likely the products of impacts. The size range of meteoroids contributing the most mass, and therefore the most energy, and thus also the most accretionary disks, to the lunar surface is centered at $10^{-8}$ g (9, 10). The diameters of corresponding microcrater pits are about 100 to 1000 μm (10, 11). Consequently, the large microcraters and the accretionary disks within the large microcrater pits may be expected to be derived from the same population of impacting meteoroids. If this is the case, it would not be possible for the formation rates of large microcraters and accretionary disks to vary relative to one another.

The exponential-decay character of relative age distributions of large microcraters based on the two measures of relative time used here, densities of μm-sized pits and accretionary disks, seems not to be explainable in terms of a lower meteoroid flux in the past. However, Hartung and Storzer (2) used a similarly shaped relative age distribution, where relative time was based on the density of possible solar flare particle tracks at a depth of 10 μm, as a basis for concluding that the meteoroid flux had changed. We now suggest that whatever the process is that causes the shapes of the distributions presented here, the same process may be responsible for the similar shape for the possible solar flare track age distribution. This suggestion is justified because all three measures of relative time considered are affected equally by the dominant lunar surface erosion or destruction process. The possibility that the features measured earlier (2) were not iron-group solar flare particle tracks is the subject of a separate abstract (12).

If a layer or coating of dust is responsible for the particular character of these relative age distributions, then these distributions enable a partial description of that dust layering or coating process. A single event providing 100% coverage of the ≈1 cm² surface is not possible, because this would result in a random or uniform relative age distribution, which is not observed. A slow covering of the surface by many small-scale (μm-sized) events occurring at a uniform rate is not acceptable, because this would lead to a similar, non-zero, exposure age for all large pits, which is also not observed. The type of process consistent with the data is one that covers most large pits relatively quickly, but allows some pits less than a few mm away to remain uncovered several times longer than the average. A covering process random in space and time, dominant on a scale of ≈1 mm, and not significant at smaller and larger scales would be acceptable. For such a process the "decay constant" for the age distribution would correspond to a half-life against covering of a particular microcrater pit. Possible mechanisms for providing the dust coatings with just the right characteristics include microcratering in the regolith and electrostatic transport (13, 14).

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MICROCRATER STUDIES ON 60015

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References

Fig. 1

Fig. 2

AREAL DENSITY OF IMPACT PITs (diameter ≈ 0.7 μm)
INSIDE LARGE PITS (cm⁻²)
(MICRON-SIZED-PIT EXPOSURE AGE)

Fig. 3

AREAL DENSITY OF ACCRETERARY DISKS (diameter ≈ 1-4 μm)
INSIDE LARGE PITS (cm⁻²)
(ACCRETIONARY-DISK EXPOSURE AGE)