TOWARD A LUNAR MICROCRATER CLOCK

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Because microcratering is the dominant erosion mechanism on lunar rocks (1), a clock based on the accumulation of microcraters measures the time the outer-most surface not affected by those microcraters is exposed. Iron-group solar flare particles penetrate a few hundred microns. Because this penetration is less than the scale for the dominant microcratering events, particle track densities yield comparable exposure time information. Exposure times based on galactic cosmic ray track densities and cosmogenic inert gas concentrations are not comparable because the measurable quantities are produced at depths of millimeters to tens of centimeters and not at the exposed surface.

An exposure time clock requires the measurement of a time-proportional parameter (density of craters or track etch pits) and independent knowledge of a production rate (meteoroid or solar flare particle flux). Production rates for tracks and microcraters are known from analyses of Surveyor 3 mirror glass and satellite-borne meteoroid detection experiments, respectively. Therefore, one type of clock, solar flare track or microcrater, may be used to check or improve the accuracy of the other. The important measurement which provides a basis for the comparison and improvement of the two methods is the ratio of the number of craters to the number of tracks produced in the same sample during the same exposure interval. Our objective is to establish that ratio.

Iron-group solar flare tracks and microcraters have been measured on several surfaces not in equilibrium with respect to cratering (2,3,4). Average crater density to track density ratios over about 10^4 to 10^5 yr are obtained in this way for each sample. We have measured the track density in a number of glasses or annealed zones from recently formed, individual, microcrater pits. This approach yields the variation of the crater to track density ratio with time. The density of tracks is corrected upward to account for track annealing according to the relationship, $F = -8.9 + 2 \log \delta_{10}$, where F is the correction factor, δ_{10} is the observed solar flare track density (cm^{-2}) at a depth of 10 microns, and 8.9 and 2 are constants obtained from a comparison of track densities in glass and pyroxene crystals included within the glass and empirical results of track annealing studies (5).

We interpret the non-linear behavior of the variation of microcrater density with solar flare track density shown in figure 1 in terms of a recent increase in meteoroid flux, although a higher solar flare activity in the past or some combination of effects is possible.

The ratio of crater to track densities we obtain for recent times is essentially equivalent to that based on independent meteoroid and

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solar flare flux measuring experiments, which yield 0.06 meteoroids $(m \geq 1.7 \times 10^{-10} g)/cm^2 \cdot yr \cdot 2\pi$ ster (6) and 3×10^4 tracks/$cm^2 \cdot yr \cdot 2\pi$ ster at a depth of 10 microns (7), respectively. Absolute values for both rates or fluxes remains dependent upon accurate measurements from present-day, in situ, standardization experiments of either solar flare or meteoroid flux.

Attempts have been made to develop a surface-exposure-time clock based on the areal density of microcraters with pits 0.1 to 1 mm in diameter observed on rock surfaces not clearly in production at these crater sizes (3,8,9). We deny the general validity of this approach basically because the observed crater populations are not necessarily representative of the population of craters formed on a randomly selected exposed surface. Rock surfaces collected from the lunar surface are "selected" in the sense that only those surviving catastrophic rupture (6,10) can be picked up; and these are statistically depleted in the large, destruction-producing, cratering events. Output from a Monte Carlo simulation of crater population development (10), shown in figure 2, illustrates an "observed" population of microcraters on a <u>selected</u> surface, with a characteristic steepening at larger crater sizes, which is not directly related to the actual production of craters on a <u>random</u> surface. The magnitude of this selection effect depends on the slope of the microcrater production size distribution and a factor, M, given as follows from probability theory.

$$M = \frac{1}{n} \cdot \frac{\log n}{\log n - \log(n - 1)}$$

where M is the selection effect factor and n is the ratio of the number of rocks initially available for destruction to the number surviving at the time of collection. For example, almost 200 rock-destroying impacts are required to destroy 49 out 50 rocks initially present, which corresponds to a selection effect factor of about 4. Populations of rocks exposed recently suffer a negligible selection effect; and only rocks from these populations yield valid microcrater exposure ages.

A correlation between track and 0.1-to-1-mm pit densities may be used as an argument supporting the validity of using craters of this size indiscriminately as a basis for a microcrater clock. Such a correlation is expected and observed on surfaces exposed a short time, less than 10^6 yr, because both parameters are indeed time dependent. However, even after equilibrium with respect to cratering is reached, a correlation between these parameters still may be expected because both track and microcrater densities are dependent upon the rate of erosion or erodability, which may differ from rock to rock (11).

Prospects for a lunar microcrater clock usable over an exposure time range of about 10^3 to 10^6 yr appear good, although somewhat complicated by a time-varying meteoroid flux.

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Figure 1. Relative change in microcrater and solar flare track density with increasing time in the past (exposure age)

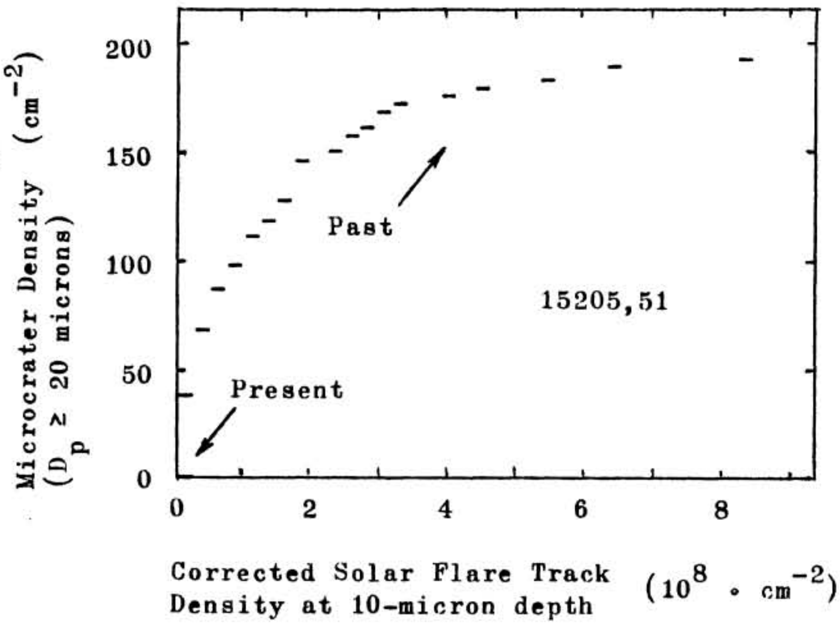
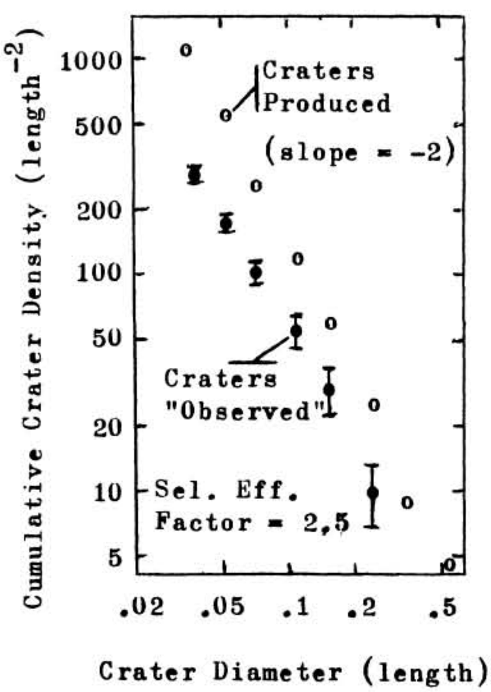


Figure 2. Monte Carlo output illustrating steepening at large crater sizes due to selection effect



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