SOLAR FLARE ACTIVITY RECORD AS DERIVED FROM LUNAR MICROCRATER DATA

Herbert A. Zook, NASA Johnson Space Center, Houston, TX 77058; Jack B. Hartung, State University of New York at Stony Brook, Stony Brook, NY 11794; Dieter Storzer, Dept. of Min., Museum National d'Histoire Naturelle, 61, Rue de Buffon, Paris-5$^{\underline{e}}$, France

Hartung and Storzer (1) have measured the spatial density of solar flare tracks at a depth of 10 μm in the glass-lined bottom of each of 56 microcrater pits on lunar rock 15205. Because the impact shock melting associated with pit formation entirely erases the previous solar flare track record, tracks accumulate in the glass linings only from the time that each crater was created. This fact permitted them to deduce the time behavior of either the microcrater or the solar flare track production rate if the production rate of one was assumed constant. The result of their analysis, assuming that the production rate of solar flare tracks is constant in time, is that the microcrater production rate has recently increased (by a factor of ∿10) as is shown in Fig. 1.

There is other evidence, however, that indicates that the meteoroid cratering rate probably has not increased by such a large factor in the last 10,000 years. Southworth and Sekanina (2) found in a year long study of 20,000 radar meteors that only about a third of these meteors could be identified as belonging to one of 256 streams and no single stream accounted for more than 1% of the total number of meteors observed. Most newly created meteoroids probably are grouped into streams, especially streams associated with presently existing or extinct comets. Collision and Poynting-Robertson lifetimes for stream meteoroids in the radar mass range should exceed 10,000 years (3). Hence, large increases in meteoroid activity in the last 10,000 years should still be evident as dominant streams. Such dominant streams do not appear to exist, however.

There is, on the other hand, independent evidence from historical observations of sunspots and aurora and from C-14 relative to C-12 abundance in tree rings (4) that solar flare activity has varied greatly in the past few hundred years.

The preceding observations strongly suggest that solar activity may be more variable than meteoroid impact rates over time periods less than 10 or 20 thousand years. Therefore cumulative crater numbers (both raw data and corrected for thermal annealing) are plotted in Fig. 2 along the abscissa which is also taken to be the time axis and solar flare track densities form the ordinate. Only 17 craters are included in this figure as we have attempted to remove certain experimental biases by not including craters with pit diameters less than 40 μm. Also track density data on pits from one of the three chips were not included because these pits appear to have anomalously low track densities compared to the pits on the other two chips. The time scale is obtained from present-day spacecraft window meteoroid cratering data (5, 6) which show that the flux of meteoroids causing pits at least 40 μm in diameter is ≈0.0075/cm^2 yr. Hence it requires about 16,000 years to create 17 such pits on the 0.14 cm^2 associated area of rock 15205.

In Fig. 3, the cumulative corrected data of Fig. 2 is plotted to an expanded scale. Also plotted is the curve derived by differentiating the exponential fit to the cumulative curve. The solar flare track production rate as a function of time in the past is given by the "derivative" curve. The "recent activity" curve depicts how the historical auroral and sunspot observations might modify the derivative curve for the recent past. Fig. 3 indicates that solar activity has varied by a factor of perhaps 50, as averaged over 1000 year periods, during the past 16,000 years.

We conclude that of three possible explanations for the data trends shown in Figs. 2 and 3: (a) solar flare track production rate varies with time, (b) meteoroid cratering rate varies with time, (c) neither varies with time but the experimental procedure has introduced undetermined problems that (a) should be considered a highly probable one.

References:
(1) Hartung, J. B. and Storzer, D. (1974) Proc. Lunar Sci. Conf. 5th, p. 2527-2541.
(2) Southworth, R. B. and Sekanina, Z. (1973) NASA CR-2316.
(3) Whipple, F. L. (1967) In "The Zodiacal Light and the Interplanetary Medium", NASA SP-150, p. 405-426.
(4) Eddy, J. A. (in press) Science.
(5) Cour-Palais, B. G. (1974) Proc. Lunar Sci. Conf. 5th, p. 2451-2462.
(6) Zook, H. A., Flaherty, R. E., and Kessler, D. J. (1970) Planet. Space Sci. 18, p. 953-964.

Figure 1 courtesy Pergamon Press.

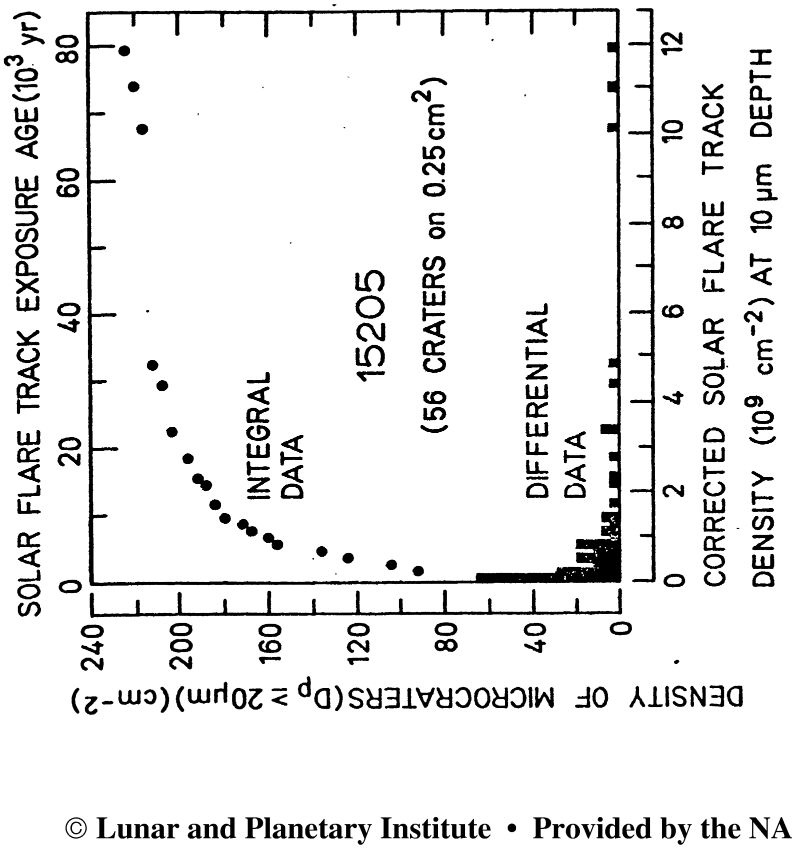

Fig. 1: Differential and integral age distributions for microcraters on sample 15205. The differential data indicate directly the instantaneous microcrater production rate (per 1000 yr) as a function of time in the past assuming a production rate of solar flare tracks that is constant in time. Figure is from Hartung and Storzer (1974).

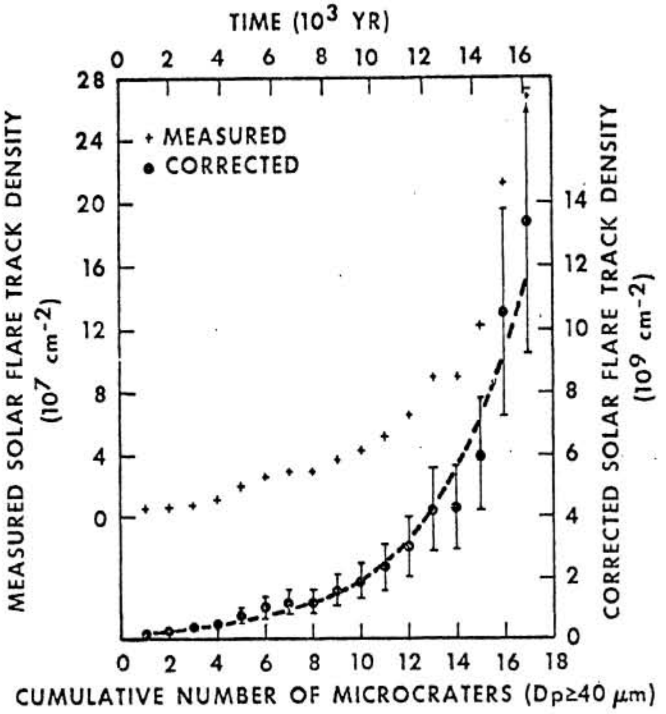

Fig. 2: Cumulative data for solar flare tracks as measured at a depth of 10 microns below the surface of 17 microcraters (left hand scale) and as corrected for thermal annealing (right hand scale). Time scale assumes meteoroid cratering rate is constant with time and is based on present-day spacecraft window data. Dotted line is a least squares fit of an expontial to the data.

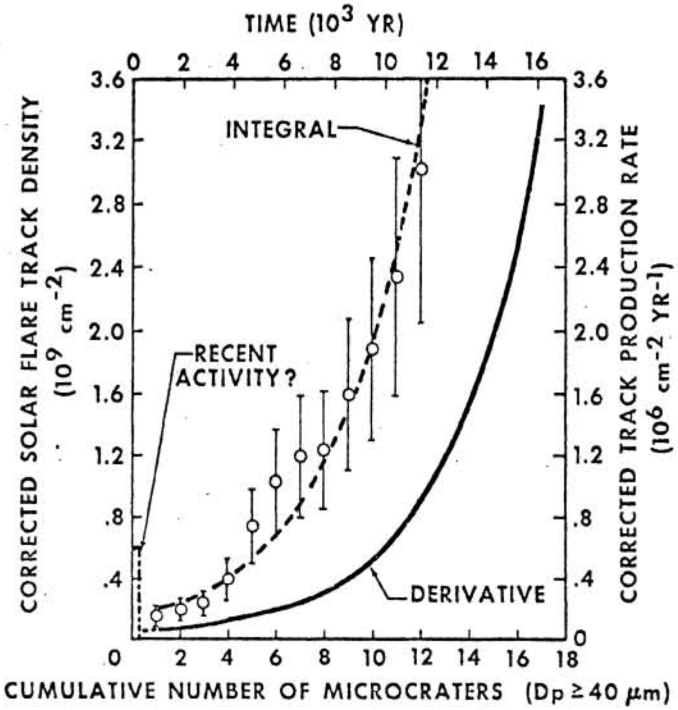

Fig. 3: Corrected solar flare track data of Fig. 2 at an expanded scale (left hand scale) versus cumulative number of craters (or time). The right hand scale refers to the curve obtained by differentiating the least squares fit to the cumulative data. The "recent activity" extension of the production rate or "derivative" curve is primarily based on historical sunspot and auroral data and is not derived by differentiating the cumulative curve (see text).