MICROMETEOROID FLUX, MICROCRATER POPULATION DEVELOPMENT AND EROSION RATES ON LUNAR ROCKS, AND EXPOSURE AGES OF APOLLO 16 ROCKS DERIVED FROM CRATER STATISTICS. G. Neukum, Max-Planck-Institut für Kernphysik, Heidelberg.

The surfaces of 13 Apollo 16 rocks have been investigated for microcraters with central pit diameters >25 µm. Part of the results is given by Neukum et al.[1]. Consequences for the micrometeoroid flux, equilibrium behavior of microcrater populations on lunar rocks, exposure time and history, and abrasion rates are discussed here. The results of the Apollo 16 measurements are compared with those of previous missions.

1. Crater size distributions in production state. Exposed glass surfaces of the samples 60015, 60095, 60135, 64455 showed the cumulative crater size distributions displayed in Fig. 1 together with previous results[2,3,4,5,6]. These distributions are arbitrarily normalized (in the 50-150 µm range) to the crater density of sample 60015. New results[7] for the range $D<1$ µm are not included since this size is not considered here. The different steepness of the distributions can be explained by geometry arguments. Since the exposure age of 12024.8 is known ($2.5\cdot10^3$ years[6]) the crater distributions are equivalent to a distribution found on any sample having been exposed for $4.5\cdot10^4$ years.

The average distribution can be approximated by two functions with constant exponents $-\alpha$. In the range $D<100$ µm the number of craters per cm^2 follows the law $N\sim D^{-1}$. In the range $D>300$ µm there is valid $N\sim D^{-3.57}$. This steep distribution has been won by accounting for the results for the distribution behavior of craters with central pit diameters in the mm to cm size range on the other investigated crystalline and breccia Apollo 16 samples.

2. Interplanetary particle fluxes. The relation between central pit diameter D and mass of the particle responsible for the crater is $D=k\cdot m^{1/\beta}$. For spall diameters $D_s=k_s\cdot m^{1/\beta}$. For a mean impact velocity of 20 km/s and a density of 3 g/cm^3 for the particle we calculate k=6.2 and $\beta=2.65$ as a compromise between Gault's[8] and Neukum et al's[6] laboratory results. From the crater size distribution measurements we thus calculate cumulative fluxes $\phi_1=10^{-8.73}\cdot m^{-0.38}$ [$m^{-2}sec^{-1}$] ($10^{-12}g<m<10^{-7}g$) and $\phi_2=10^{-15.5}\cdot m^{-1.35}$ [$m^{-2}sec^{-1}$] ($m>10^{-5}g$, valid probably up to the order of grams).

3. Equilibrium crater densities. Equilibrium crater densities have the form (9,10,11) $N_E=A_1\cdot D^{-2}$ for $\alpha>2$ and $N_E=A_2\cdot D^{-\alpha}$ for $\alpha<2$. A is called areal density. The highest areal densities obtainable on lunar rocks are[1,12] $A_1=0.4-0.6$ in the range $D>300$ µm. For the region $D<100$ µm we obtain $N_E=8.4\cdot D^{-1}$ [cm^{-2}] (D in cm). In Fig. 2 the highest observed areal densities measured on Apollo 16 rocks are compared with previous results. The Apollo 16 measurements are about a factor of 3 higher. The areal density seems to be a function of rock type. Breccias show a higher crater density than crystalline rocks on the average.

4. Exposure ages. Exposure ages can be determined by using the crossover point of the equilibrium crater distribution and the tail of this distribution which is in production state [13] (cf. Fig.3). In terms of spall diameters, we obtain for the exposure time $t_A=\frac{\alpha}{a\cdot\beta}k_s^{-\alpha}\cdot Q$. a is the differential

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flux constant, $Q = A \cdot D_E^{-2}$, where D_E is the cross-over diameter. Normalized to a spall to pit ratio of 4.5 we obtain $t_A = \frac{\alpha}{a \cdot \beta} \cdot (k_s(\text{cryst.})^{-\alpha} Q_{norm}$. In Fig. 4 the areal density A is plotted against Q_{norm}. Since Q_{norm} is directly proportional to t_A we have a presentation of the relative age differences of the rocks. Breccias are generally older than crystalline rocks. The age spread of the investigated Apollo 16 rocks is about a factor of 50. Furthermore the areal density is not constant, but a weak function of time.

A calculation of absolute exposure ages using the derived flux expression for ϕ_2 gives results about a factor of ten less than track ages (for Apollo 12 rocks). The discrepancy can be due to a today's flux being a factor of 10 higher than in the past as suggested by others (14). To obtain absolute exposure ages for the investigated Apollo 16 rocks we normalize to the solar flare track age measurements on 12038 and 12017 (15,16). We predict the following exposure ages:

Rock No.	61156W	68415N	62235B	62295B	69935T	61015E
t_A (years)	$2.1 \cdot 10^5$	$8.8 \cdot 10^5$	$1.6 \cdot 10^6$	$2.3 \cdot 10^6$	$2.6 \cdot 10^6$	$6.0 \cdot 10^6$

Rock No.	61175T	66075S	60016N
t_A (years)	$1.0 \cdot 10^7$	$1.2 \cdot 10^7$	$1.2 \cdot 10^7$

5. Erosion rates. From ϕ_2 and $M_e = 10^{3.274} \cdot m^{1.133}$ (14), where M_e is the mass ejected per impact of a particle with mass m, we calculate a small scale erosion rate of 1 mm/10^6 years. It seems somewhat high compared to results by track studies. Thus, provided the exposure age of 12024,8 is correct, we conclude either the scaling laws of impact and mass ejection are wrong or the flux in the last $2.5 \cdot 10^3$ years is a factor of 10 higher than the average in the millions of years before.

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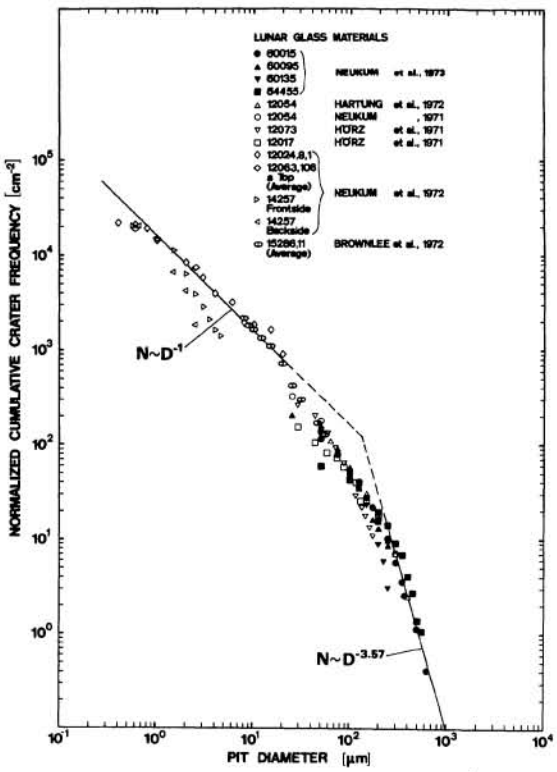


Fig. 1

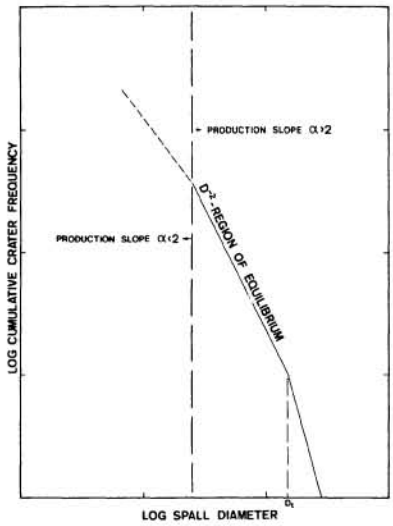


Fig. 3

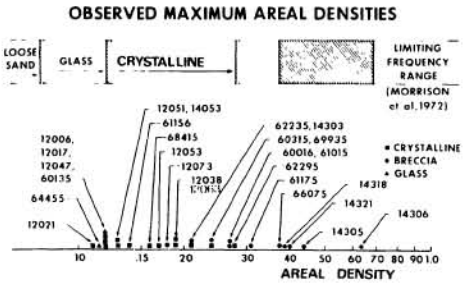
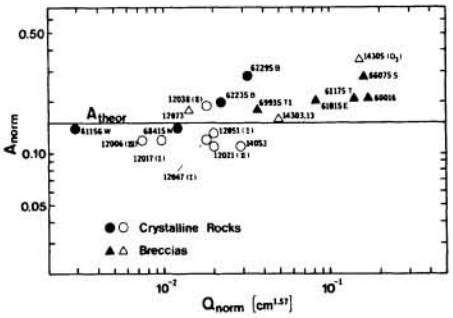


Fig. 2



Fig, 4