No. 81 LUNAR CRATER COUNTS. II: THREE LUNAR SURFACE TYPE-AREAS

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April 5, 1967

ABSTRACT

Diameter distributions of lunar craters are presented for three type-areas: average mare, the wall of Alphonsus, and "pure upland." These define three distinct distribution curves with parallel branches. Normalizing to the average mare crater density, and considering that the maria show a variation in crater density, we find that the relative crater densities for these three regions are 0.6 to 1.5, 3, and 30, respectively. Because the diameter distributions are parallel, except for mare craters of diameter $D < 2$ km, the craters in these three regions are interpreted to be of predominantly the same origin, from the largest basins ($D > 400$ km) to craters as small as $D = 2$ km. These observations impose boundary conditions on any theory of lunar history.

1. Observations

Figure 1 presents crater counts for three different types of lunar surface: average mare, the wall of Alphonsus, and "pure upland." These data update crater counts presented by the writer in several earlier papers, including "Early Lunar Cratering," synopsized in this issue of the *Communications* (Hartmann 1966).

The counts on lunar maria are based on the four quadrants of the crater catalog of Arthur, *et al.* (1963, 1964, 1965, 1966). The counts were extended to small diameters by using Ranger and Orbiter photographs of representative mare surfaces.

The second type-region, the inner wall of the pre-mare crater Alphonsus, is discussed in Paper 1 of this series (p. 31 of this issue).

"Pure upland" or "pure continental" regions, the third of the type-areas, are regions that show little or no evidence of modification by partial mare flooding or tectonic processes. They are held to be the oldest surfaces for recording cratering events. The pure continental counts of "Early Lunar Cratering" were based on the first three quadrants of the Arthur catalogs. They showed a near-linear distribution on a log-log plot with a break at about $D = 20$ to 30 km. This feature was discussed in *Comm. LPL,* No. 38 (Hartmann 1964). In the course of a more recent study comparing far-side and near-side crater counts, data were gathered on far-side pure upland surfaces. These data indicate that the diameter distribution is linear over a wide range of diameters. The break found on the front side is now thought to be partly a result of some crater-destruction process such as partial flooding, as discussed in *Comm. LPL,* No. 38, and partly a result of observational incompleteness in the catalogs. The new Orbiter data, much more complete at small diameters than the earth-based data, show no break. Therefore, in Figure 1, the earth-based data are omitted for $D < 8$ km, where a slight turndown from the linear relation can already be seen.

2. Variations within Type-Areas

It is well known that apparently homogenous areas of presumably uniform age have non-uniform crater densities. The clusters of craters photographed by Ranger VII in Mare Cognitum are an example. Further, there are systematic variations from mare

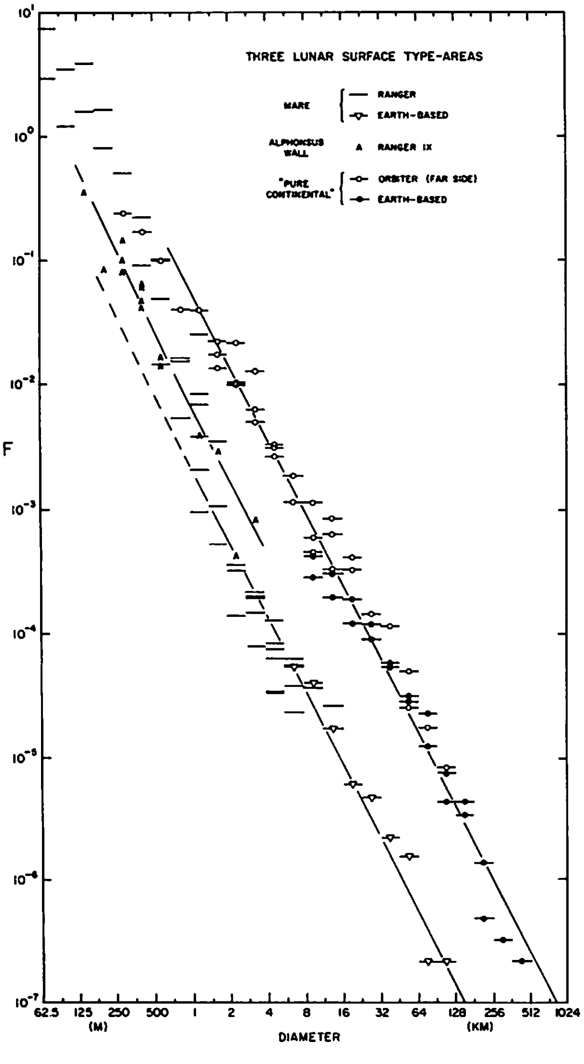

Fig. 1 Diameter distributions of craters in three type-areas of the lunar surface. Mare points represent an average over front-side maria. The dashed line is the inferred run of primary impact craters from Kuiper, Strom, and LePoole (1966) (modified on the basis of Alphonsus wall counts). F is the incremental number of craters per km^2.

to mare. The curve in Figure 1 represents an average over the major front-side maria, but a study of different individual maria, using both published and unpublished data, indicates that the range of variation in crater density amounts to a factor 2.5 from one major mare unit to another. The maria will be discussed in more detail in a later paper in this series.

Finally, even the pure upland areas are somewhat non-uniform, partly because of destructive processes, and possibly, partly because of a variable admixture of endogenous craters. For example, the far-side region studied in Figure 1 has a significant excess of craters in the range 8 km $< D <$ 64 km. Endogenous craters reach this dimension in the Orientale and Nectaris radial crater chains.

3. *Interpretation*

The data for the three regions (Fig. 1) are fitted by three parallel curves. Only the smaller mare craters, $D <$ 2 km, define a non-parallel branch with a much steeper slope, as has been known since the flight of Ranger VII (Shoemaker 1965; Kuiper 1965, see *Comm. LPL,* No. 58). The slope of these parallel curves is -2.0 for $D >$ 1 km, and steepens to as much as -2.3 at $D =$ 200 m.

The parallelism of the curves suggests that for the most part, the craters are of the same origin. The single origin most reasonably applied to all these surfaces is the impact of fragmented cosmic bodies. This is compatible with what is known of the mass distribution of asteroidal fragments (Hartmann 1964). Even the largest mare basins fit the pure upland curve and are interpreted as simply the largest examples of craters. I have argued in "Early Lunar Cratering" that the pure upland craters represent a non-asteroidal, early population of cosmic fragments possibly peculiar to the earth-moon system.

The steep increase in mare craters at $D <$ 2 km suggests that another crater-forming mechanism is involved in that range. Critical discussion of crater origins is beyond the scope of this paper, but it should be noted that the attempt of Kuiper, Strom, and LePoole (1966) to select only "sharp," primary impact craters from those of other origins yielded a curve shown schematically by the dashed line in Figure 1. (The dashed line parallels the other data points in this diameter range and may represent the distribution of primary craters more accurately than the original curve determined by Kuiper, Strom, and LePoole.)

The parallelism of the curves enables one to represent, by a simple sequence of numbers, the relative crater density of different regions. Normalizing so that unity is the average crater density on the maria, we have a range of about 0.6 to 1.5 for the major maria, about 3 for the wall of the pre-mare crater Alphonsus, and about 30 for the pure upland surfaces.

These figures place boundary conditions on any theory of lunar history. For example, if one assumes that the rate of crater production has been constant with time, then one must conclude that the maria are 1/30 the age of the uplands, i.e., presumably

1.5×10^8 years. On the other hand, I have argued in "Early Lunar Cratering" that the early cratering rate was much higher, which allows the ages of the maria to be much greater and more variable. This is in better agreement with the apparent great age of lunar structures, judged by the probable thermal history of the moon and by certain stratigraphic relations.

Acknowledgments. Many of the crater counts reported here were prepared by Mrs. Alice Agnieray and Mr. Charles A. Wood. This work was supported by an NSF Institutional Grant of the University of Arizona.

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