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The Diameter-frequency Relations for Craters on Planets and Satellites

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The diameter-frequency relations for craters on Mars and on Phobos have been derived and compared with those relations for craters on the Moon, Mercury and the Earth.

О распределении кратеров на поверхности планет и спутников. Определены распределения кратеров на поверхности Марса и Фобоса. Эти зависимости сравнены с аналогичными распределениями кратеров на поверхности Луны, Меркурия и Земли.

Autoři odvodili závislosti počtu kráterů na jejich průměru na jednotku plochy pro Mars a Phobos a tyto závislosti porovnávali s obdobnými závislostmi pro krátery na Měsíci, na Merkuru a na Zemi.

The study of the diameter-frequency relations for craters on the surfaces of planets and its satellites may be, according to some authors, very important for solving some questions concerning the origin and the age of these features. In the recent years, many authors have derived the diameter-frequency relations for craters on the Moon (e. g. [1], [2]) and some authors have also studied this relations for craters on Mars (e. g. [3], [4]) and on Mercury [5].

The present authors investigated the diameter-frequency relation for craters on Mars using the Mariner 9 Mars Map. This map was prepared in cooperation with the Jet Propulsion Laboratory, the California Institute of Technology, and the National Aeronautics and Space Administration (1972). It is, up to date, the best map of the surface of Mars.

Craters on three different regions on this map were chosen for the investigation, as shown in Table 1. Fig. 1 shows the relations of incremental craters (N) vs. diameter

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(*D*) for these three regions. It is evident that there are some differences between the diameter-frequency relations for craters in the three regions considered. These differences are not too large and may be caused by a somewhat different ratio of impact and of endogenic craters, and also by different crater obliteration effects in the three regions concerned on the Martian surface.

Table 1

Region	Latitude	Longitude	Area (km^2)	No of Measured Craters
(*S*) Southern Hemisphere	$-40°$ to $-60°$	320° to 20°	6 628 900	1151
(*N*) Northern Hemisphere	$+10°$ to $+30°$	290° to 30°	6 559 800	955
(*E*) Equatorial Region	$+10°$ to $-10°$	300° to 360°	4 200 200	566

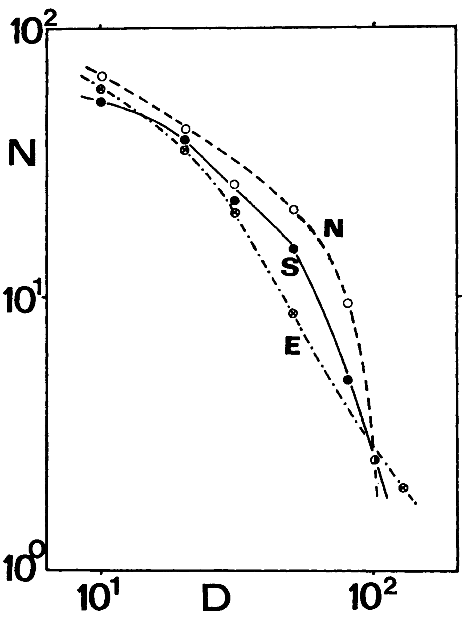

Fig. 1. Frequency distribution of crater diameters on Mars. *N* – northern hemisphere, *S* – southern hemisphere, *E* – equatorial region. (*N* in 10^6 km^2, *D* in km.)

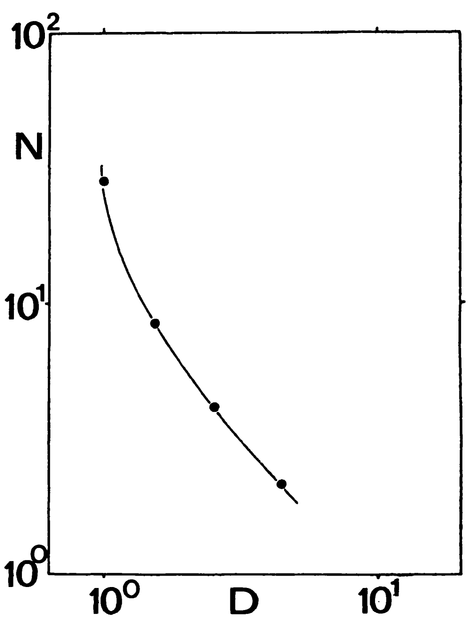

Fig. 2. Frequency distribution of craters on Phobos. (*N* in 10^3 km^2, D in km.)

The diameter-frequency relation has also been investigated for craters on the surface of one of the Mars satellites, Phobos, using the map by Duxbury [6]. This relation is shown in Fig. 2. It must be considered that it was derived from a very poor observation material of 64 craters only.

Fig. 3 shows the diameter-frequency relations for craters on Mars (mean values from Fig. 1, and by Hartmann [4]), on Phobos, on the Moon [1], [2], on Mercury [5] and on the Earth (39 craters, from which 29 are probably of impact origin and 10 possibly of impact origin; [4]). From this figure it is evident that the diameter-frequency relation for Martian craters found by the present authors is in a relatively good agreement with the relation by Hartmann [4], especially for craters of mean diameters ($\sim$ 50 km) in

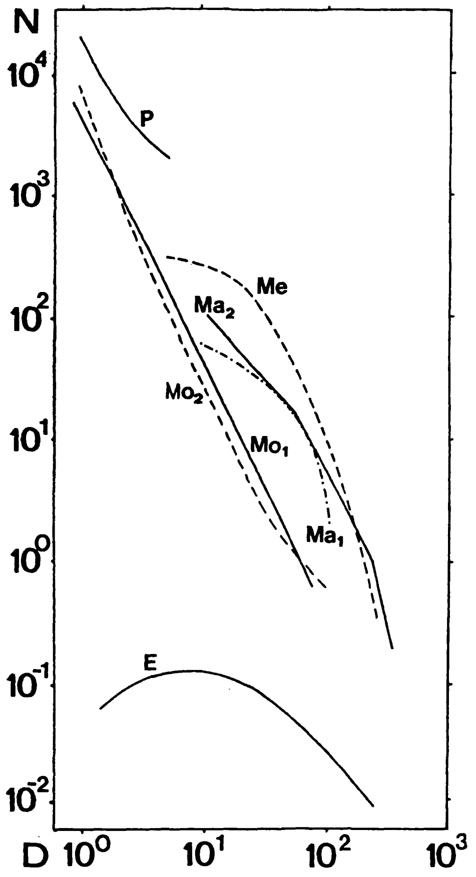

Fig. 3. Crater densities on Phobos (*P*) and Mars (*Ma_1*) (by the present authors) compared with those on Mars (*Ma_2*) [4], on Mercury (*Me*) [5], on the Earth (*E*) [4] and on the Moon (*Mo_1*) [1], (*Mo_2*) [2]. (*N* in 10^6 km^2, *D* in km.)

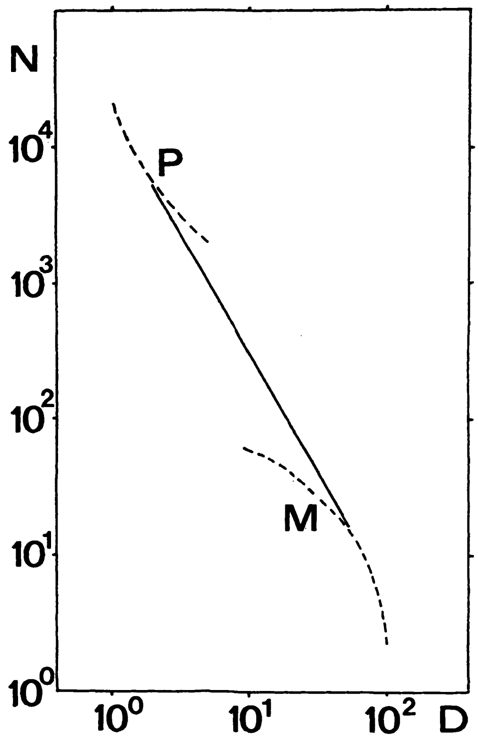

Fig. 4. Diameter-frequency relation for craters on Mars (*M*) and on Phobos (*P*). The solid line has slope — 1,8. (*N* in 10^6 km^2, *D* in km.)

Martian desserts and maria, and does not differ substantionaly from the relation for larger craters on Mercury. But the diameter-frequency relations for Martian craters differs substantionaly from the relations for craters on the Moon, and especially for craters on the Earth.

The interpretation of the cratering curves of Fig. 3 is rather difficult. Supposing that all the considered craters on Mercury, Mars, Earth, Moon and Phobos are of impact origin (impact of asteroid fragments some 4 aeons ago), the differences in the crater diameter-frequency relations must be explained by different states of the crater obliteration on different planets and satellites. It is evident that such an obliteration may be neglected for craters on the Moon, on Phobos and probably on Mercury on the one hand, and must be taken into account for craters on Mars and especially for those on the Earth on the other hand. Many small Martian craters have been evidently destroyed by erosion and deposition of dust. These effects, especially the erosion, are undoubtedly very important for the obliteration of craters on the Earth. Further, a fraction of craters on Mars (and perhaps on Mercury) must be of endogenic origin, all craters on Phobos are evidently of impact origin because vulcanism could not occur on such small satellite. Moreover, also the observation errors must be taken into account because all the small craters are not observable. The last effect is probably also the reason of the deformation of the diameter-frequency relation for the small craters on Mars and on Mercury besides the effects of crater obliteration. Another possibility is that there is an effect of time-dependent distribution of impacts of bodies of different masses (or energies), so that the large amount of small craters was erased due to impacts of larger bodies at the end of the cratering epoch.

Remarkable are also the differences between the densities of craters of nearly identical diameters on the different bodies. The density of craters of diameters $\sim$ 10 km on Mercury is about the factor $\sim$ 10 larger than on the Moon, on Mars it is nearly the same as on the Moon. The density of craters of diameter $\sim 10^2$ km is nearly the same on Mars as on Mercury, but on both of these bodies it is about the factor $\sim$ 10 larger than on the Moon. Also the density of craters of diameters $\sim$ 1 km on Phobos is about the factor $\sim$ 5 larger than on the Moon. Preliminary crater densities on Phobos and on Deimos have been compared by Pollack et al. [7] with those in the lunar highlands and in two regions on Mars (Mare Sirenum and Nix Olympica). The number densities of craters on Phobos and on Deimos were found to be comparable to those found for uplands on the Moon. The densities of craters of diameters $\sim$ 1 km on both the Mars' satellites seem to be roughly the same, but about the factor 10^1 to 10^2 larger than on Mars. These different crater densities could probably be in connection with a somewhat different cratering mechanism and origin of craters on different planets satellites.

If both the diameter-frequency relations for craters on Phobos and for craters of mean diameters on Mars are extrapolated, a common relation for craters on Mars and on Phobos may be obtained, shown in Fig. 4, for which

$$\mathrm{d} \log N \,/\, \mathrm{d} \log D = -\ 1{,}8.$$

For the craters on the Moon the corresponding value is very similar,

$$\mathrm{d} \log N \,/\, \log D = -\ 2{,}0,$$

and for Mercury is

$$\mathrm{d} \log N / \mathrm{d} \log D = -2{,}6.$$

The nearly identical values of d log N / d log D for craters on Mars and on Phobos on the one hand, and for craters on the Moon on the other, is remarkable. This fact may be considered as an evidence for the common origin of craters on Mars and on Phobos (which is very probable) on the one hand, and perhaps for craters on the Moon and on Mars + Phobos on the other. However, it must be born in mind that according to Hartmann [3] the original surface of Mars is not preserved due to obliteration processes. In the contrary, on Phobos and on the Moon the craters cannot be destroyed since the accretion erea because the erosional mechanism was undoubtedly absent on the surfaces of these satellites.

From all the above reasons, it is a questionable if the crater diameter-frequency relation can alone be considered to be an important evidence for a common origin of craters on planets and on its satellites.

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