IMPACT CRATERING ON STONY AND ICY BODIES: DIFFERENT MECHANISMS OF CENTRAL PEAK FORMATION?
A.T. Basilevsky; V.I. Vernadsky Institute of Geochem. and Analyt. Chem., USSR Academy of Sci., Moscow, and B.A. Ivanov; O. Yu. Schmidt Institute of Physics of Earth, USSR Academy of Sci., Moscow

The shapes of fresh lunar craters change in parallel with their diameter from 1-2 km up to several hundreds km in the sequence: bowl-shaped → flat-bottomed → central-peaked → ringed basins (e.g. 1). Similar changes are well known for fresh craters of Mercury, Mars and Earth (e.g. 2,3). Pike (4) has shown that value of diameter, at which simple bowl-shaped morphology changes into complex flat-bottomed and central-peaked one, depends inversely on the gravity acceleration on the given planet: $D_t = 3300g^{-1.0}$. Pike has considered data on 6 planetary bodies, gravity acceleration on which lies within the rather narrow range: from 114 for Callisto to 981 cm/s^2 for Earth. Voyager images of Saturn satellites give a possibility to widen this range and to study crater morphology on bodies with extremely low gravity. Viking pictures of Deimos and Phobos were also used for the study. First results were published in (5).

The results of the present study are given in Table I and Fig. I. Density and gravity acceleration for all bodies except the Saturn satellites are from (6-8). Sizes and average densities of Saturn satellites were taken from (9) and then used to calculate gravity values. Boundary diameters of craters in which complex central-peaked morphology as well as rings appear for the Moon, Mercury, Mars and Earth were taken from (2). For other bodies they were determined from pictures and slides kindly given to us by American colleagues and published in (10,11,12) also. Among the 14 bodies considered on 7 (Deimos, Phobos, 1980 S3, Mimas, Enceladus, Dione, Rhea) ringed basins are not observed and on 3 (Deimos, Phobos, 1980 S3) central-peaked craters are not observed. Strictly speaking Phobos has several central-peaked craters but they obviously belong to another category not considered in our paper. They should be compared to small lunar craters which display complex morphology when their bottoms are near to the regolith - rock basement boundary (13).

The data given in Table I and Fig. I show that dependence of crater morphology on gravity acceleration has non-monotonic character and is subdivided into two branches. For craters on silicate targets of the Moon, Mercury, Mars, and Earth the boundary diameter of appearance of central-peaked craters can be approximated as function of gravity as D_{cp} (km) = $10^{3.6}$ g^{-1} (cm/s^2), that is practically the same as in (4). For craters on the essentially icy targets of the Saturn satellites (except Enceladus) as well as on Ganymede and Callisto this dependence is more gently sloping: $D_{cp}=10^{1.67}$ g$^{-0.25}$. Data on Enceladus craters diverge somewhat below the latter dependence. Maybe it reflects unusual properties of the Enceladus target that can be suspected based on its unusually high albedo (9). The dependence for boundary diameter of appearance of ringed basins on silicate targets of the Moon, Mercury, Mars, and Earth can be approximated as $D_r = 10^{4.5}$ g^{-1}. For icy bodies these data are scarce but it is clear that this dependence is more gently sloping than for silicate targets and can be roughly approximated as $D_r=10^{2.7}$ g$^{-0.25}$.

One of the most developed models of changes of crater form due to scale phenomenon is the model (14-16) of failure of stability of the transient cavity in the gravity field. Theoretical analysis (14-16) shows that stability of crater's form is determined by parameter $c/\rho gh$, where c is cohesion of the target material, ρ - its density, g - gravity acceleration, h - crater depth. If we suppose an approximate constancy of cohesion of target of some type (silicate or icy) then the boundary diameter for the morphology change should be in inverse proportion to gravity. Data on silicate target bodies confirm this conclusion. Diverging data on icy target bodies from the silicate target dependence forces to suppose that: either mechanism of central peaks and rings formation on icy targets is different compared to silicate ones (1) or effective cohesion of targets on icy bodies decreases progressively in parallel with reduction of surface gravity acceleration (2).

TABLE I.

N	NAME	D, km	Dens, g/cm^3	Grav, cm/s^2	D_{cp}	D_r
1	Deimos	11.4	1.9	0.06	n.o.(2)[1]	n.o.
2	Phobos	21.8	1.9	0.1	n.o.(8)[1]	n.o.
3	1980 S3	120	1.2	2	n.o.(38)[1]	n.o.
4	Mimas	390	1.2	6.5	27-33	n.o.(130)[1]
5	Enceladus	500	1.3	10	8-16	n.o.
6	Tethys	1050	1.3	21	?	<400[2]
7	Dione	1120	1.4	22	17-22	n.o.
8	Rhea	1530	1.3	27	11-16	n.o.(160)[1]
9	Moon	3476	3.35	162	15-25	140-200
10	Mercury	4880	5.46	363	10-20	100-130
11	Callisto	5000	1.6	114	10-20	<300[2]
12	Ganymede	5280	1.9	144	10-20	<175[2]
13	Mars	6787	3.92	373	7-15	100-130
14	Earth	12756	5.52	981	3-5	23-60

1 - in brackets is given a diameter (km) of the largest crater observed on the body; 2 - diameter of the smallest observed ringed crater.

© Lunar and Planetary Institute • Provided by the NASA Astrophysics Data System

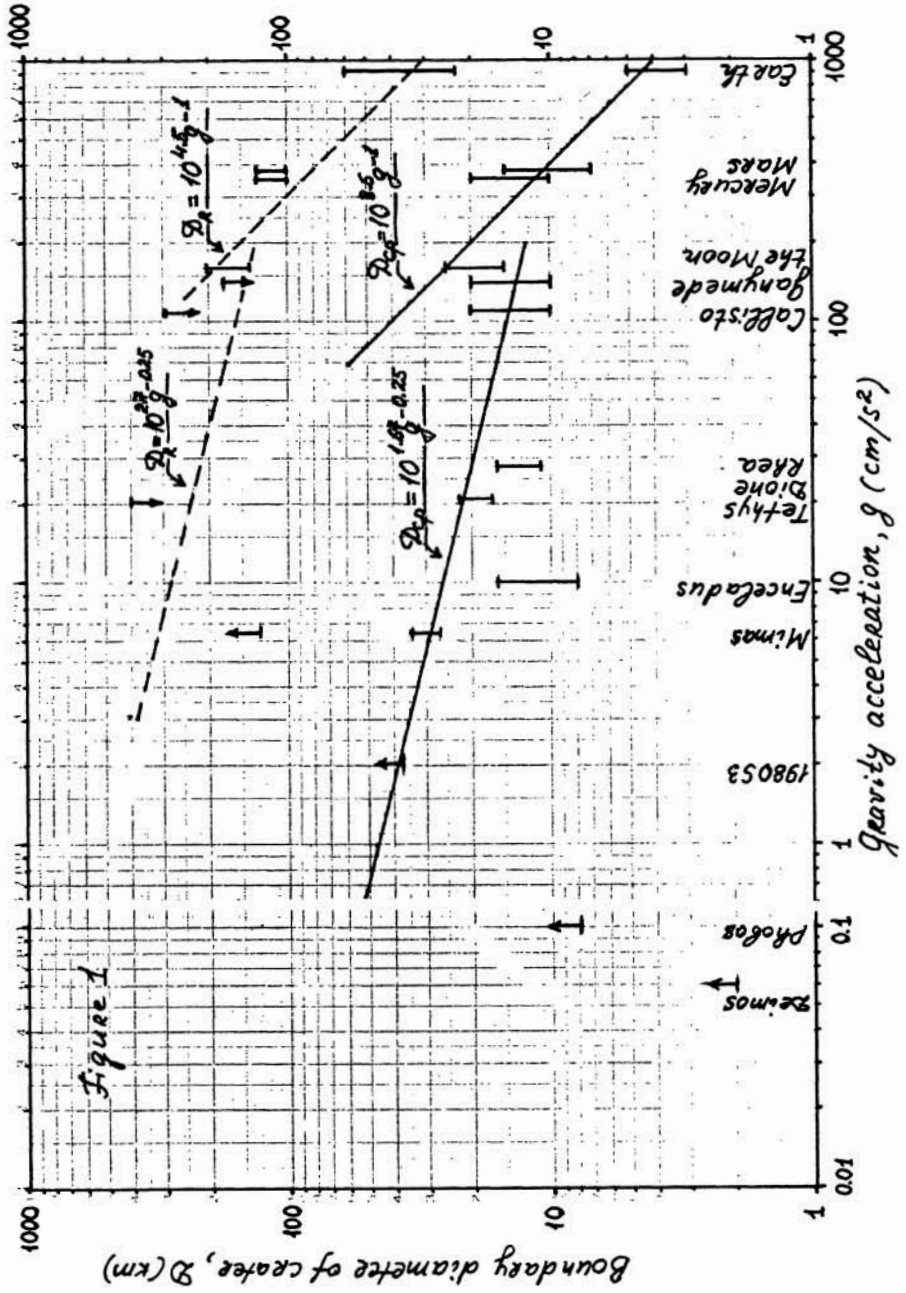

Figure 1

REFERENCES: (1) C.P. Florensky et al. (1976) The Moon, 16, N 1, 59-70. (2) C.P. Florensky et al. (1981) Studies of comparative planetology, Moscow, Nauka Press (in Russian). (3) B.A. Ivanov, A.T. Basilevsky (1979) Lunar and Planetary Science X, 607-609. (4) R. Pike (1980)PLPSC 11, 2159-2189. (5) A.T. Basilevsky (1981) Doklady AN SSSR, 258, N2, 323-325 (in Russian). (6) H. Alfven, G. Arrhenius (1976) Evolution of the solar system, NASA, Washington D.C. (7) C. Sagan (1975) The solar system, Freeman and Co. (8) V.I. Moroz (1978) Physics of the Mars planet, Moscow, Nauka Press (in Russian). (9) B. Smith et al. (1980) Science, 212, N 4491, 163-191. (10) B. Smith et al. (1979) 204, N 4396, 951-972. (11) B. Smith et al. (1979) Science, 206, N 4421, 927-950. (12) Vogager Bulletin. Mission Status Report, N 65, 1981. (13) W. Quaide, V. Oberbeck (1968) JGR, 73, N 16, 5247-5270. (14) W.B. McKinnon (1978) PLPSC 9th, 3965-3973. (15) H. J. Melosh, W. B. McKinnon (1978) Geophys. Res. Lett. 5, N 11, 985-988. (16) H. J. Melosh, W. B. McKinnon (1979) LPS X, 830-832.

© Lunar and Planetary Institute • Provided by the NASA Astrophysics Data System