MORPHOMETRY OF BASINS ON THE MOON: NEW RESULTS FROM CLEMENTINE LASER ALTIMETRY

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The laser altimeter on the Clementine mission provided us with topographic information on the shape and dimensions of large, multi-ring basins on the Moon [1,2]. Until now, only partial data were available for depths and rim heights of these large structures and volumes could only be crudely estimated. With the new global Clementine data, we can collect information to compare the dimensions of basins with similar parameters of the large craters of the Moon [3]. Initial results suggest that basin depths and volumes follow and extend the morphometric trends seen for large craters on the Moon. Several basins are filled to depths of several kilometers with mare basalt. No correlation is seen between basin rim height and any other parameter, including relative age, suggesting that attempts to relatively date basins through this technique are not valid.

Method. Basin-centered equal area topographic maps with a 500 m contour interval were produced from the laser altimetry data for 21 lunar basins ranging in size from 326 km to 2600 km in diameter. Basin volumes were measured by tracing the areal extent of different contours on the computer produced images. The data for individual contours were converted to a volume element with thickness of one contour interval (500 m). These "plates" of volume were then summed to estimate the volume of the basin. For each basin, the morphologic features of rim height, average depth, and average rim elevation were measured. This procedure involved mapping the basin rim crest and defining the basin center (Table 1; [4, 5]). Radials were then drawn from each center and elevations were determined outward along each profile. Certain azimuths were determined to be best representative of the original basin morphology, based on geologic setting and the proximity of neighboring features. Basin depth was defined as the average elevation of the rim crest minus the elevation of the basin center. Rim height was defined as the rim elevation minus the average terrain elevation along radials out from the rim to about a basin radius from the rim crest. These parameters were compiled and analyzed for 21 basins; a selection of these data is given here in Table 1.

Results The volume data closely follow the relation derived previously for complex craters. Croft [6] found that for complex craters with $D > 100$ km, $V_i = 0.238D_r^{2.31}$, where V_i is the volume of the interior crater and D_r is the rim diameter. Our results show a similar trend with comparable slope; for the craters and basins, $V_i = 1.17\ D_r^{2.12}$ ($r^2 = 0.95$). Croft's sample of complex craters [6] was heavily weighted to smaller features ($D < 300$ km), whereas our sample contained many more true basins ($D > 300$ km), a consequence of the newly available Clementine altimetry.

The depth-diameter plot shows clear evidence of a linear trend, but it is also evident that some basins fall below this trend, probably because of infilling by mare lava. If these basins are excluded, the relation derived is similar to that derived previously for complex craters [3], $d_i = 0.3\ D_r^{0.437}$ ($r^2 = 0.75$), where D_r is the rim diameter and d_i is the depth of the interior. The Australe basin is unusual in that it is not mare filled, but is anomalously shallow; it may have formed early in lunar history when the crust was much more plastic than it was during most of the era of basin formation or it may have formed under unusual conditions of impact.

No correlation of rim height with diameter or relative age is observed. This result is in contrast to the claim of Baldwin [7] that basin rim height is inversely correlated with age. Our results suggests that the topography of basins have not significantly relaxed since their creation 4 billion years ago. The fact that very large impact features do not show an increase in rim height with increasing diameter [3, 8] suggests that basin rim crests occur outside the zone of maximum structural uplift, which largely accounts for rim height in smaller, bowl-shaped craters [8]. This result supports the idea that the transient crater for basin-sized impacts is a feature smaller than the presently expressed basin rim crest.

Conclusions. The volume of lunar basins scales according to same relation as complex lunar craters, suggesting that they form a continuum population with smaller impact features. The proportionality of volume increase supports the concept that volume is determined during the excavation stage and preserved during collapse at a constant rate; such a relation is a prediction of the proportional-growth model of basin formation [5, 9]. Rim heights compared to volume, depth, relative age, and diameter of the basins do not vary systematically for basin sized features, suggesting that rim height in basins is caused dominantly by ejecta thickness, not structural uplift

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as for smaller craters. On the basis of the newly derived depth-diameter relation for unfilled basins determined from these new data, we can estimate the approximate thickness of basalt in the mare-filled basins, such as Serenitatis. Lavas are on order of 1-2 km thick in Lomonosov-Fleming basin (filled with ancient mare basalts covered by highland plains [10]) to as much as 3-4 km thick in the deeply flooded Imbrium basin. These estimates tend to be greater than some previous work would suggest [11], but are not as great as predicted by model studies of the flooding of a hypothetical lunar crust [12].

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TABLE 1. DEPTHS, VOLUMES, AND RIM HEIGHTS OF SELECTED LUNAR BASINS

Basin	*Center*	*D (km)*	*Depth (km)*	*Volume (10^6 km^3)*	*Rim height (km)*
Birkhoff	59° N, 146° W	326	3.83	0.14	1.27
Mendeleev	6° N, 141° E	365	4.78	0.30	1.98
Moscoviense	26° N, 148° E	420	5.96	0.33	1.72
Coulomb-Sarton	52° N, 123° W	440	3.92	0.23	0.63
Korolev	4° S, 158° W	440	4.60	0.66	0.95
Hertzsprung	2° N, 128° W	570	4.50	0.64	1.06
Freundlich-Sharonov	18° N, 175° E	600	3.57	0.83	0.55
Lomonosov-Fleming	19° N, 105° E	620	2.44	0.62	0.27
Mendel-Rydberg	50° S, 94° W	630	5.56	1.23	2.14
Humboldtianum	59° N, 82° E	650	4.37	1.10	1.83
Nubium	21° S, 15° W	690	1.63	0.58	--
Fecunditatis	4° S, 52° E	690	1.84	0.26	0.47
Smythii	2° S, 87° E	740	5.00	1.88	1.35
Crisium	18° N, 59° E	740	4.57	1.13	1.81
Humorum	24° S, 39° W	825	2.24	1.34	0.30
Nectaris	16° S, 34° E	860	5.38	2.11	1.31
Australe	52° S, 95° E	880	2.13	1.17	0.14
Serenitatis	26° N, 18° E	920	2.14	1.79	0.16
Orientale	19° S, 95° W	930	6.04	3.09	1.24
Imbrium	35° N, 17° W	1160	2.90	3.25	2.00
South Pole-Aitken	56° S, 180° E	2600	9.44	23.40	1.78