MORPHOPHOMETRIC ANALYSES OF LUNAR IMPACT CRATERS.

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The Lunar Topographic Orthophotomaps (LTO's), produced from the Apollo metric photography (1), are the most accurate extraterrestrial topographic dataset. In order to provide insight into the processes of crater formation and modification, morphometric analyses of impact craters covered by the LTO's were undertaken. Interior volumes were calculated by the method described previously (2), and cross-sectional shape was analyzed by Fourier transform techniques (3). Cross-sections were digitized and scaled to the crater diameter to facilitate comparison of different-sized craters. Each section was transformed, producing a complex Fourier spectrum and a periodogram, illustrating how each wavelength of topographic variation contributes to the overall shape of the crater.

Sample. An initial sample of 60 simple craters on the *maria* was selected from the LPL Catalog of Lunar Craters (4). All were of degradational Class I (5). Thirty were classed as LPL type ALC (bowl or funnel shaped), while the other 30 were classed as type BIO (similar to ALC, but with flat floors) (4,6). Although the two crater types cover approximately the same diameter range, the BIO population has a larger mean diameter (6). In the present sample, the ALC craters ranged from 1.4 km to 10.4 km in diameter, the BIO's from 1.4 km to 13.8 km. In addition, a sample of 15 complex craters, ranging from 17.0 km to 41.0 km in diameter, was examined.

Analyses. Whenever possible, four cross-sections per crater were taken and transforms and periodograms were produced. The mean, standard deviation, and correlation coefficient (for harmonic amplitude with diameter) for each harmonic of the periodograms were calculated separately for the ALC and BIO sample groups. The first and second harmonics of these mean periodograms differed by only 7% and 2%, while the standard deviations were on the order of 15% to 20%. Averaged Fourier spectra were retransformed to produce average ALC and BIO cross-sections. These averaged sections were not significantly different in appearance. Both were of a shape intermediate between and the ALC and BIO types as defined in (4,6).

On detailed inspection of the original cross-sections, it was found that:

i) Some craters that were classed as ALC had a morphology more similar to that of a BIO, and vice versa.

ii) Some craters were highly irregular or asymmetric in cross-section (Figure 1 (a)).

iii) Some craters displayed flat floors of such limited extent that they could not be unabiguously classified as ALC or BIO. They appeared intermediate in morphology.

Together, these craters represented about 30% of the dataset.

Misclassified craters were reclassified and inappropriate or "intermediate" cross-sections were deleted from the sample. The standard deviations for the first two harmonics of the recalculated average periodograms ranged between 7% and 10%, a factor of two reduction from the values derived from the sample before reclassification. Retransformation of the average Fourier spectra of the two reclassified sample groups yielded profiles (Figure 1 (b), (c)) that were, *i*), clearly different from one another, and, *ii*), had morphologies corresponding to type ALC and BIO craters as defined in (4).

It is apparent that this procedure has the potential to provide a more rigorous classification system than one based solely on photographic interpretation (4,6). Nevertheless, the sizeable standard deviations associated with individual harmonics of the reclassified ALC and BIO average periodograms illustrate a fundamental point: even among a sample of craters of the same photogeologic type and degradational class, formed in the same terrain, there is considerable variation in shape.

It is not obvious from the average periodograms (Figure 1 (d), (e), (f)) which harmonics describe the difference between the ALC and BIO types. When the first ten harmonics of the average Fourier spectra are used to reproduce the craters, the difference between ALC and BIO types is well represented. This implies that some combination of the ten longest wavelength harmonics is responsible for the difference in shape between ALC and BIO. A multi-component analysis will be applied to determine which combination of harmonics control the shape difference.

As craters intermediate between the two types occur, it is possible that ALC's and BIO's do not represent a dichotomy in crater form. ALC and BIO craters could be end-members in a spectrum of simple crater morphology. If this is so, crater morphology is not a simple function of the energy of the cratering event, since ALC and BIO types occur over a similar diameter range. Other variables that may play a role are variations in initial impact conditions and/or subtle variations in the material properties of the mare.

There appears to be no dependence of the harmonic amplitude on diameter for the ALC type craters. This suggests that the shape of ALC type craters is independent of diameter. A weak correlation of the first harmonic amplitude with diameter was found, however, for BIO craters, possibly implying a decrease in depth to diameter ratio with increasing diameter.

Other Morphometric Parameters. The ratio of the rim crest depth (d) to the rim crest diameter (D) for the reclassified ALC and BIO sample groups were:

ALC:	$d/D=0.2082$	s.d.$=0.0228$
BIO:	$d/D=0.1966$	s.d.$=0.0174$

Student's t-test shows these means differ at the 99.95% confidence level. These d/D are higher than those determined by (6,7). This is the result of two factors: *i*), ambiguous and inappropriate craters were removed from the reclassified sample, and, *ii*), the d values above were maxima for a given section, while (6,7) used averages over the entire crater. The interior volumes (V_i) of the reclassified ALC and BIO samples can be described by the following relations:

ALC: $V_i=0.03855D^{3.15}$

BIO: $V_i=0.03882D^{3.21}$

These expressions give the interior volumes from crater floor to rim crest. They are, therefore, not directly comparable to those given in (8). From these expressions, it is seen that the difference in V_i for average ALC and BIO craters is of the same order as the scatter in V_i within each type.

Degraded Craters. A limited number of ALC (n=6) and BIO (n=4) of degradational class II (5) were studied. Inspection of the cross-sections reveals considerable variability in the degree of modification within class II. Class II craters seen on the LTO's varied from having negligible infill (appearing very similar to class I in cross-section) to having extensive infill (>50% by volume) compared to class I craters. Degradational class is judged primarily on rim morphology (5). It should be recognized that crater degradation as judged by the appearance of the rim may not be a particularly sensitve parameter to the overall erosional state of the crater.

Complex Craters. Preliminary analysis of the 15 complex craters indicates the amplitudes of at least three harmonics show correlations with diameter. These correlations are much stronger than any shown by the simple craters. Their significance for variations in crater formational processes with diameter is currently under investigation.

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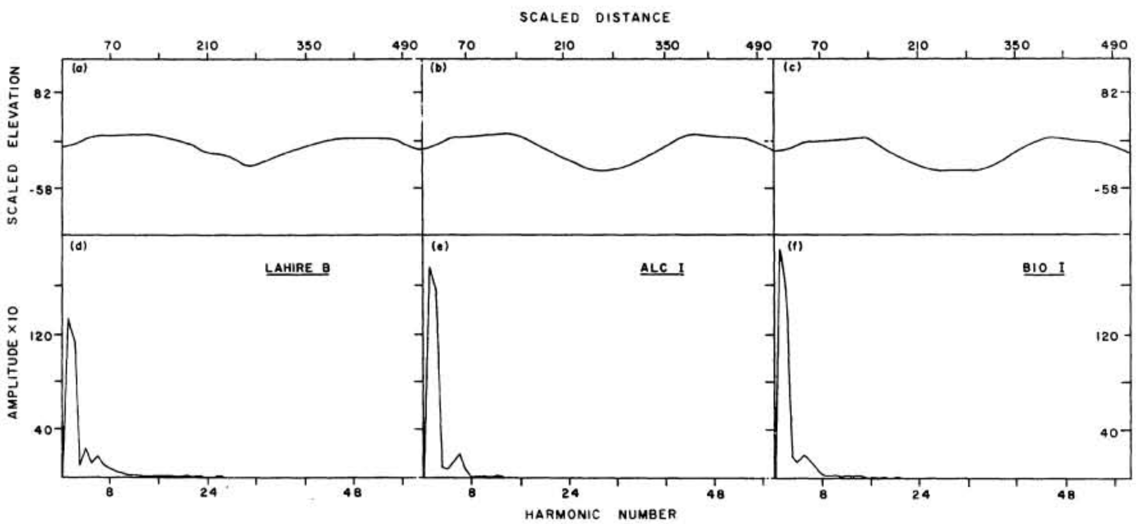

Figure 1. (a) An E-W cross-section of Lahire B, one of the craters deleted from the sample because of irregularity. (b) An average ALC class I cross-section, produced from the average Fourier spectrum of the reclassified ALC class I craters. (c) An average BIO class I cross-section, produced from the average Fourier spectrum of the reclassified BIO class I craters. (d) The periodogram of (a). (e) The periodogram of (b). (f) The periodogram of (c). Note: In (a), (b), and (c), the sharp slopes that make up the first and last tenth of each cross-section are not topographic features. They are artifacts introduced to aid in Fourier transformation.