On the Inapplicability of Baldwin’ s Relation for Determining the Causes of the Origin of Lunar Craters

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On the Inapplicability of Baldwin' s Relation for Determining the Causes of the Origin of Lunar Craters

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Important arguments in favor of the meteorite hypothesis of the formation of lunar craters are considered to be the relations established by Baldwin (^1), who showed that, for craters from bombs, shells, terrestrial meteorite craters, and lunar craters, the relation between the diameter of the crater and, respectively, the depth of the floor, the height of the rim, and the energy of the explosion constitutes a single sequence. Baldwin's conclusions were accepted by supporters of the meteorite hypothesis ([2-]5), despite the fact that they indicate only the explosive character of crater formation (^6).

The largest volcanic objects morphologically similar to lunar craters are calderas. According to the mechanism of formation, one distinguishes: a) collapse calderas (Glen Coe type) and b) explosion calderas (Krakatau type) (^7). For calderas whose formation was accompanied by the eruption of enormous quantities of pumice and ignimbrites, most authors assume an explosive genesis.

The question of the volcanic (caldera) genesis of lunar craters has been considered more than once ([8,]9). I. Yokoyama, on the basis of gravimetric work, estimated the energy involved in the displacement of volcanic material during eruptions that led to the formation of calderas, and established an empirical dependence of eruption energy on caldera size (^10). In Fig. 1A a combined graph is given of the dependence of energy on diameter, compiled from the data presented in the works of Baldwin (^1) and Yokoyama (^10). As is seen from this graph, calderas fall on the curve established for shell, meteorite, nuclear, and lunar craters. The same conclusion also proves valid for the dependence relating the depth of craters (craters, calderas) to their diameter (Fig. 1B). The results obtained are quite natural, since deformations of the terrestrial (lunar) surface as a result of a near-surface explosion depend only on the physico-mechanical properties of the medium and on the energy of the explosion, but do not depend on the type of explosion: chemical, nuclear, meteorite, or volcanic. Thus, from the fact that lunar craters satisfy the relations established for explosive craters, it does not follow that their origin was meteoritic, since for volcanic objects

Fig. 1. A —dependence of explosion energy on crater diameter. a —meteorite craters, b —nuclear craters, c —calderas. B —dependence of crater diameter on depth (after Baldwin (1)); a —meteorite craters, b —areas of calderas

Figure 1: Fig. 1. A —dependence of explosion energy on crater diameter. a —meteorite craters, b —nuclear craters, c —calderas. B —dependence of crater diameter on depth (after Baldwin (1)); a —meteorite craters, b —areas of calderas

these relations are also valid. Other criteria are needed for assigning craters to meteorite or volcanic origin.

The dependences established by Baldwin are statistical in character; for lunar as well as for terrestrial craters the deviations from a strict regularity are sufficiently noticeable. The opinion of B. Yu. Levin (ˆ5) that "for calderas this scatter is incomparably greater" (for the depth–diameter relation) is not confirmed by calculations. B. Yu. Levin regards as calderas "collapse formations on the summits of volcanoes," i.e., he considers only the insignificant group of so-called summit calderas, whereas calderas proper are extensive depressions up to 20–25 km in diameter, and in recent years ring-shaped volcanic depres-

sions with diameters of 30–50 km (11). Secondly, the depth of calderas, as taken from topographic maps, is underestimated, since calderas (especially summit calderas) are filled with deposits from subsequent volcanic activity. For those cases in which the true depth of a caldera has been determined by geophysical methods (12, 13), the dispersion is smaller than for lunar

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objects. In Fig. 1 **B** the interval of depths d is taken from the minimum values read from the map (!), to the maximum values determined by geophysical methods, i.e., the selected area is broadened along the abscissa axis. However, even in this case the dispersion for calderas practically does not differ from the dispersion for lunar craters.

In addition to calderas, during aerial photographic surveying in the Eastern volcanic belt we identified a number of explosive volcanic formations, morphologically similar to lunar craters and satisfying Baldwin' s relation, among which should be named the Valentin maar (Fig. 2 **A**), a maar in the caldera of Uzon, the Galya maar on the southern shore of Kronotskoe Lake (Fig. 2**B**), the Shtyubel crater in the Ksudach caldera, a chain of craters on the northern slope of the caldera of the Krasheninnikov volcano (14), and others. The number of such examples can be extended. They will be considered in greater detail in another paper.

Analysis of the available data shows that an alternative formulation of the question of the causes that determined the formation of the relief of the lunar surface does not make it possible to obtain a satisfactory explanation of all the observed facts. At the present time, when detailed large-scale photographs of areas of the lunar surface have been obtained, it is necessary to proceed to a detailed morphological analysis of lunar objects and to compare them with meteoritic and volcanic forms, with the aim of developing criteria for distinguishing them. The simultaneous formation of meteoritic forms and the prolonged, multiphase character of volcanic activity are undoubtedly reflected in the morphology of craters.

Fig. 2. Valentin maar in the area of Karymsky volcano (**A**) and Galya maar on the southern shore of Kronotskoye Lake (**B**)

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Note: Figure translations are in progress. See original paper for figures.