Geological Structures Possibly Related to Lunar Craters

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The recent achievement of detecting a radar echo reflected from the surface of the moon has once again focused popular attention on the earth's satellite. Although a popular weekly magazine has stated that the "other side" of the moon is the greatest lunar mystery, this mystery is probably a poor second as compared to the enigma of the origin of the surface features on "this side" of the moon.

Astronomers, geologists, and other scientists, who have pondered the origin of the lunar craters and related features on the moon's face, have examined the earth's surface in search of features that may be genetically related to those of our satellite. Those who favor the meteoroidal impact theory of origin of the lunar craters point out the close resemblance between Meteor Crater, Arizona, and most of the small lunar crater pits. However, this terrestrial impact crater lacks a central hill such as is characteristic of many of the medium-sized lunar craters. Those who favor the volcanic theory of origin of the lunar craters point out aspects of resemblance between certain terrestrial volcanic craters and those of the moon. Terrestrial volcanic craters formed by explosion with little effusion of volcanic material most closely resemble lunar craters; yet, few of these have the high circularity and radial symmetry characteristic of the lunar features. Although previously overlooked, there is a third group of terrestrial structures which are similar in many respects to lunar craters and which may have been formed by similar processes. These features are the roughly circular areas of intensely disturbed and shattered rock in ancient geological formations which appear to be the result of a violent natural explosion. The source of the explosive force is problematical.

These explosion structures are, in general, characterized by: (1) a roughly circular outline and a radial symmetry which, in some cases, is slightly bilateral; (2) a variation in size of from less than a mile to at least eight miles in diameter and possibly up to as much as 75 miles in diameter; (3) an intensely shattered and jumbled central uplift surrounded by a ring-shaped depression and sometimes by other ring-shaped uplifts and depressions of diminishing amplitude forming a "damped-wave" structure; (4) the central part of these structures contains sheared, shattered, and powdered rock and, in some cases, "shatter-cones" which are indicative of explosive shock; (5) volcanic, plutonic, or hydrothermally altered rock is not found. Identified examples of these structures in the United States include the Flynn Creek disturbance in Tennessee,[1] the Wells Creek Basin structure in Tennessee,[2] the Howell disturbance in Tennessee[3], the Kentland structure in Indiana,[4] the Jeptha Knob structure in Kentucky,[5] the Serpent Mound structure in Ohio,[2], and the Sierra Madera structure in Texas.[6,7] These structures are sufficiently alike to suggest that they were all formed in a similar manner and they differ sufficiently from other known geological structures to indicate that they form a specific structural type. Until the mode of origin of these features is definitely established, the present writer suggests that they be termed "crypto-explosion" structures.

A resemblance between these crypto-explosion structures and lunar craters is most clearly apparent in the Paleozoic-aged Flynn Creek structure which, although filled and covered with later marine sediments, uplifted, and sub-aerially eroded in the few hundreds of millions of years that have elapsed since its formation, contains a nearly two-mile-wide explosion crater with a central uplift. Here, then, is an example of a terrestrial explosion crater with a central hill as well as other shape aspects such as a circular outline, radial symmetry, a rim of rock detritus, and a crater depressed below the surrounding terrain all of which are characteristic of lunar craters. As reconstructed by Wilson and Born,[1] the Flynn Creek crater probably bears a closer resemblance to a typical lunar crater than any present-day terrestrial feature.

A widely accepted belief is that these crypto-explosion structures are crypto-volcanic,[2] *i.e.,* produced by a deep-seated explosion of gases derived from a magmatic intrusion and without the extrusion of any volcanic material. According to this theory, if the explosion is strong and concentrated, an explosion crater is formed, and, if the explosion is weak and unconcentrated or "muffled," a jumbled domal uplift is formed. An explosion crater with a central uplift such as at Flynn Creek or at Steinheim Basin, Germany,[2] requires a strong explosion blowing out the crater followed at a later time by a "muffled" explosion producing the central uplift. Weaknesses of the crypto-volcanic theory are that: (1) the occurrence of a deep-seated explosion of this type is questionable; (2) if such an explosion can occur, it is likely that it would be accompanied by some igneous material and especially by alteration of the rock due to escaping gases; (3) these features are largely present in non-volcanic regions in the earth's crust.

An alternate explanation is that these crypto-explosion structures are the scars formed by the high-velocity and explosive impact of large meteorites[7] such as has been postulated to explain lunar craters. Most crypto-explosion structures lack an explosion crater so that, according to the impact theory, they must be interpreted as the exposed "root" structure remaining after erosion of the crater or as formed subaqueously on the floor of the shallow seas that covered parts of the continents many time in the geological past by the impact explosion on the surface of the sea. In other words, some crypto-explosion structures lacking an explosion crater may resemble the structure that might remain if Meteor Crater, Arizona, were hypothetically eroded and planed off to a depth of 1000 feet, whereas others may be jumbled sea-floor rock structures formed below a crater which had only ephemeral existence in the sea water. Boon and Albritton[8] have shown theoretically that the "damped-wave" form with an intensely jumbled center probably results from an explosive "backfire" following the elastic compression of water or rock by a missile traveling at many times the velocity of shock waves in terrestrial materials. The crater is formed by the blowing out of the central and the surface part of this rock structure in some manner which usually partially preserves the central uplift.

The greatest weakness of such an impact theory is that neither meteoritic fragments nor fused rocks have been found associated with these structures. However, it is unlikely that more than a few meteoritic fragments of the original mass would survive the impact. These fragments would be rapidly weathered and removed by erosion. Although it has been suggested that a large primary meteoroidal mass is buried beneath Meteor Crater, Arizona, the evidence is not convincing. It is more likely that meteoroidal impact structures contain no such primary mass.

Added strength is given to the impact theory by the Sierra Madera crypto-explosion structure which has been drilled to a depth of over two miles without revealing the presence of an igneous core. In fact, the structure appears to die out with increasing depth. Also, the present writer has noted that at the Kentland structure "shatter-cones" are oriented with their apices toward the top of the beds suggesting that the compressive deforming force came from above.

Thus, although the origin of these features is still open to question, further study of these terrestrial structures close at hand may help solve the origin of the lunar craters.

References Cited

[1] Wilson, C. W., Jr., and Born, K. E., The Flynn Creek disturbance, Jackson County, Tennessee, *J. Geol.*, 1936, **44**, 815-835.

[2] Bucher, W. H., Cryptovolcanic structures in the United States, *Rept. 16th Internat. Congr.*, 1933, 1055-1084.

[3] Born, K. E., and Wilson, C. W., Jr., The Howell structure, Lincoln County, Tennessee, *J. Geol.*, 1939, **47**, 371-388.

[4] Shrock, R. R., Stratigraphy and Structure of the area of disturbed Ordovician rocks near Kentland, Indiana, *Amer. Midland Naturalist*, 1937, 471-531.

[5] Bucher, W. H., Geology of the Jeptha Knob, Ky., *Ky. Geol. Surv.*, 1925, Ser. 6, **21**, 198-237.

[6] King, P. B., The geology of the Glass Mountains, Texas, Part 1, Descriptive geology, 1930, 3038, 123-125.

[7] Boon, J. D., and Albritton, C. C., Jr., Established and supposed examples of meteoritic craters and structures, *Field and Laboratory*, 1938, **6**, 52-53.

[8] Boon, J. D., and Albritton, C. C., Jr., The impact of large meteorites, *Field and Laboratory*, 1938, **6**, 57-64.

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