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ON THE QUESTION OF POLYGONALITY AND IRREGULARITIES OF THE SHAPE OF CERTAIN CRATERS ON THE MOON

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SUMMARY

On the basis of 160 examples the author shows that among the quasipolygonal objects on the Moon the prevailing ones are not completely polygonal. The noted correlation between the contours of polygonal craters and the direction of breaks is discussed. The opinion that explosive disintegration of anisotropic matter must lead to isotropy of shock wave propagation within the bounds of the disintegration radius is rejected.

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1. P. Puiseux noted at the beginning of the twentieth century that angular and even irregularly-shaped polygones are encountered among lunar craters [1]. Attempting to find a cause of such a singularity, Haroun Tazieff considers that large polygonal craters are the product of former convective cells [2].

It is well known that in laboratory conditions, when we heat a layer of viscous fluid, hexahedral cells are generated, which are close elements of convective heat transfer. However, even after the substance cooled off one can hardly obtain on its surface the profile of a lunar crater: the thermal expansion coefficient of the widespread minerals in nature will not provide a sufficient difference in height after cooling. Moreover, the facets of the cells always serve as boundaries between neighboring cells, while on the Moon solitary polygonal craters are encountered.

It appears to be possible to give another explanation to the polygonality of lunar craters of most different dimensions from the standpoint of the hypothesis about their explosive (possibly meteoric) origin. Let us turn to their observed properties.

On the basis of 160 examples found by the present author it is possible to assert that among quasipolygonal objects on the Moon those that prevail are not fully polygonal (see Plate). They usually consist of 3 – 4 or an incomplete number of sides of an hexagon, and more seldom of a pentagon. The remaining part

(*) K VOPROSU O POLIGONAL'NOSTI I NEPRAVIL'NOSTYAKH FORMY NEKOTORYKH KRATEROV NA LUNE

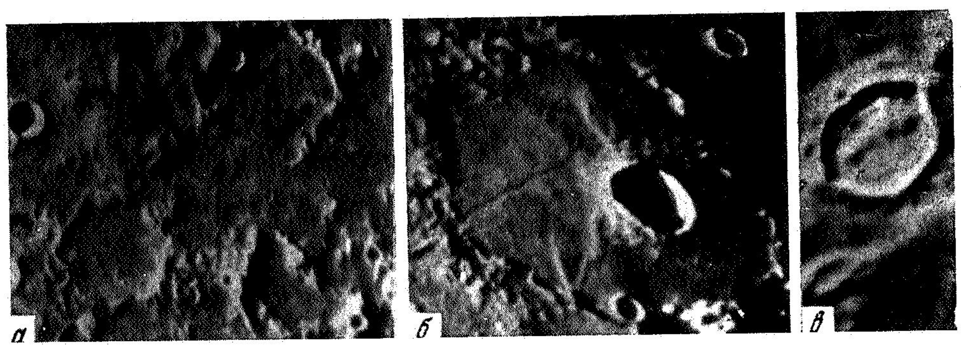

Рис. 1. Примеры многоугольных кратеров. *а* — Lade и Saunder; *б* — Lacus Mortis; *в* — **Encke**

of the swell, closing the figure, is either arched or has irregular contours. Thus, quasipolygonality is encountered, which is not necessarily of funnel radius in all directions, but in a limited sector, which may constitute any part of a full circumference. There are varieties of craters as though they were intermediate between annular and hexagonal shapes: they sides are arched and occupy an intermediate position between chords and circumferences. Exclusively rare are examples of quadrangular and triangular shapes, but they nevertheless exist. They are mostly related to intermediate varieties, those with arched sides. It is possible to bring forth examples of a more complicated and irregular angularity. Alongside with these there are nonangular craters with pear-shaped contours of swell's crest or with deformation of opposite type.

Gilvarry and Hill have shown [3, 4] that with a velocity sufficient to provoke an explosion upon impact, meteorites must form in the half-space of isotropic matter round craters, even when the impacts are inclined. It is obvious that in all cases of noncircular craters the anisotropy of the explosive disintegration may be assumed. There may exist two causes for that: the irregular strength of the soil at the area of disintegration and the anisotropy of the explosive wave propagation. The elongated shape or the contraction of separate craters in only one of the directions convey the hint that explosion took place near some inhomogeneity in the soil or at the interface between two soils of different acoustic-mechanical properties, or still near an obstacle "positive" or "negative".

We must now explain the periodicity of quasipolygonal dependence of the radius of the funnel on azimuth.

There is present in the spectra of γ-radiation of the Moon, registered on "LUNA-10", a component conditioned by the decay of natural radioactive elements K^{40}, Th and U. Comparison of this component's observed intensity with the results of calibration of the device on terrestrial rocks allows us to ascribe to lunar rocks the concentrations of K^{40}, Th and U, close to those of terrestrial basic rocks of basalt type [5]. Let us recall that each rock formation has its own characteristic system of joint cracks. Inherent to basalts is a polyhedral (and mostly hexa and pentahedral) columnar jointing. Every columnar joint and their ordered combination must have anisotropic properties relative to the propagation of the shock wave in the horizontal plane. First of all the fully crystallized basalts are anisotropic in the mass of each crystal. Secondly, the deformation in the shock wave is not fully transmitted from one basalt joint to another through the mutually contiguous faces. The deformation component, parallel to the surface of cracking in the basalt, may be amortized by the interfacial sliding, being to a different extent determined by the angle between the wave front and the face. These causes generate a dependence between the energy of shock waves and the direction of their propagation. The anisotropy of the explosion energy propagation must lead to the difference in funnel radii in various directions.

Taking into account the dependence of disintegration radius on explosion energy, $R = R_S W^{0\ 3}$ [6], we have: in case of a regular hexagonal shape of the funnel the specific energy of the wave in the direction of the short radius constitutes 65 percent of energy in the direction of the angle. Such a difference may be assured by quite small in expanse an ordered anisotropy.

Apparently, even in the case when the region of ordered anisotropy of the soil were present only at the place (or near) the central region of the future crater, it could define its noncircular contours along the entire perimeter (or correspondingly on a part of it). Under such circumstances the anisotropy of the shock wave may be partially smoothed out as a consequence of diffraction or other causes, and at the same time unequally in various directions in the general case of nonconcentricity of boundaries of the anisotropic region relative to the epicenter of the explosion.

The long ago noted correlation between the contours of polygonal craters and the direction of breaks in their vicinity [7] may speak in favor of the existence in separate regions of the lunar surface of comparatively large areas of soil's ordered anisotropy.

2. There exists the opinion that the explosive disintegration of anisotropic matter must lead to the isotropy of shock wave propagation within the limits of the disintegration radius. We shall show the invalidity of such a point of view.

a) In case of a three-dimensional problem (i. e. of a non-plane front) there follows directly behind the compression wave, propagating from explosion's epicenter, a rarefaction wave [8]. The impact-explosive disintegration of materials takes place precisely in the region of negative pressures [9], while the compression wave front precedes it.

b) In the leading region of the impact-compression variations of matter modification and phase transformations may take place when the wave has a large amplitude, and, in particular, fusion. The question of fusion in shock waves can not be considered as reliably studied. either experimentally or theoretically.[8]. Despite the fact that, according to computations in [3], pressures of the order of $10^4 - 10^5$ kbar and temperatures of $10^4 - 10^{5\circ}$ can develop at impacts of quite coarse meteorites with a velocity of 16 to 37 km/sec (which according to contemporary representations exceeds the fusion point of the soil at indicated pressures), one may succeed in detecting tracses of fusion in astroblems (gigantic meteor crater on Earth) exceptionally seldom. They are found in the sandy soil of the Arizona crater [6]. It is well known that in a loose and porous matter the explosive wave provides a substantially greater possibility of fusion than in a monolithic solid [8, 9]. According to radio-astronomical obeervations, in our problem the porous matter in the outer layers of the Moon is represented only in the outermost cover, of thickness not exceeding one meter, whereas the effective depth of the epicenter of meteoritic explosion has the order of the diameter of the intruding meteoritic mass [10]. In the scales of interest to us this diameter constitutes nundreds of meters and more (for example, 1 km for a 10 kilometer crater for a TNT equivalent of 1 : 1).

Therefore, for most of meteoritic explosions (or at least for a certain part) on the Moon there are no sufficient foundations to assure the reliability of the presence of fusion.

c) In a solid the shock wave front is usually considered as infinitely thin, for its width can be neglected during the solution of numerous problems. In reality it has a finite (though very small) width in the propagation direction. Indeed, the variation of mass velocity without acceleration is physically unthinkable. This is why the substitution of the notion of hydrodynamic break by that of mathematical break can be possible not with the equality sign but only with a certain approximation. Obviously, intermediate states are represented over the extent of the width of the shock wave front, through which passes the matter in the variation process from intial states to amplitude maximum. Fusion sets in no earlier than a specific quite high a level of temperature accretion, i.e. at passage of a certain specific phase of wave amplitude accretion and, consequently, it lags relative to the propagation of preceding phases which are situated in the region of elastic-plastic matter still maintaining the properties of anisotropy provided the latter were inherent to it initially. This is why the influence of the wave itself upon the mechanical properties of an anisotropic soil can not fully liquidate the anisotropy of propagation.

***** T H E E N D *****

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