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Abstract

Full Text

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ON THE MECHANISM OF THE ORIGIN OF THE LUNAR MARIA

(Presented by Academician V. V. Menner on 20 IX 1967)

There are several hypotheses concerning the origin of the lunar maria and circuses. The most convincing view seems to be that the maria and the flat floors of circuses are composed of lavas, most likely of basic composition ⁽¹²⁾. The peculiarities of the distribution of these lavas over area and elevation have not yet received a sufficient explanation.

The surface of the young maria of the Moon (lava plains), as a rule, has no abrupt changes in elevation. It is either horizontal or gently

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curved, and the bends are usually associated with the general deviation of the selenoid surface from a regular sphere ^(10,14). Apparently, a significant part of this deviation arises from the curvature of the surface of the gravitational potential ⁽¹⁾; in that case, with respect to the gravitational field, a considerable part of the maria is situated horizontally. Within each individual mare, however, its surface may be regarded as lying practically at one level. The multilevel remnants of the underlying rocks protruding from the mare merely emphasize this uniformity of the surface. At the boundary with the continent, the maria form complex bays and festoons, penetrate into continental depressions in tongues, and enter craters. It seems that enormous masses of very fluid lavas spread over great distances from the central depression and flooded all the depressions in their path. But the following features of the distribution of lavas do not correspond to the mechanism of "spreading from the center."

1. Depressions on the margin of a continent, flooded with mare material, sometimes lie higher than the mare itself, and the surface of the material flooding them rises somewhat toward the continent (Mare Nubium

west of Alphonsus). If lava did spread, it should have moved from these depressions toward the mare, and not the reverse.

2. In places, mare “channels” and “bays” are intertwined with continental areas into a labyrinth with narrow passages (the region south of Tabr). It is difficult to believe that lavas could have spread in such a way as to flood all these winding corridors.
3. The youngest dark lavas, which are clearly visible because they overlie the rays of Copernican craters, are situated without any connection to the centers of the mare depressions; rather, on the contrary, they are confined to the margins of the maria (Mare Serenitatis).
4. There are many small areas, each of which is bounded on all sides by continental ridges and yet is nevertheless flooded with mare material. Sometimes the annular wall of a crater is visible in a mare, the floor of which is covered by mare material of the same age as the material surrounding the mare. But the wall is nowhere breached, and it remains unclear how the mare material entered the crater (Figs. 1, 2). It is still more remarkable that the level of the mare surface inside and outside the crater remains one and the same. The same is also observed for depressions of irregular shape: the mare material covering them has the same, or a nearly the same, level as the adjacent mare, although each such area is isolated (Fig. 3). Of course, this is not a universal rule, but rather a tendency; such formations occupy an intermediate position between craters in which the mare material lies below the surrounding level and craters of the Argentine type with an excess of lavas. Similar phenomena are also noted for ancient maria. Thus, the floor of Cyrillus, filled with ancient-mare formations, lies at the level of the surrounding terrain, although originally this crater must have had a depth comparable with that of the young crater Theophilus. Between the craters Alphonsus and Albategnius, complex continental structures seem to be submerged, flooded with dark-gray material, the surface of which maintains a single level (Fig. 4).

Fig. 2. Profiles across the craters Archimedes—pre-mare (top) and Copernicus—post-mare. The mare material inside and outside Archimedes is at the same level. The vertical scale is 10 times greater than the horizontal.

Fig. 3. Shore of Mare Humorum. Dark lavas occupy the margin of the mare depression and fill depressions between light continental structures ⁹.

There are many such examples, and the explanation based on lava flowing out from a single region is inapplicable to them. Suggestions have been made that the flooded areas arose through complete melting from below, so that only floating “icebergs” of continental structures remained ¹³. But

amid such a planetary melt, it is impossible for a single orientation of ruptures in pre-mare remnants to have been preserved, just as it is impossible for thin, undistorted crater rings to have been preserved. It is more probable that lava

Fig. 4. “Drowned” relief between the cirques Alphonsus and Albategnius ⁽¹²⁾

Figure 2: Fig. 4. “Drowned” relief between the cirques Alphonsus and Albategnius ⁽¹²⁾

was supplied to each separate area of “flooding” through “individual” channels and fissures.

The localization of such feeder channels is of interest. In Alphonsus, photographs from “Ranger 9” revealed 8 small craters sitting on fissures, predominantly along the rims of this caldera-like structure ⁽¹²⁾. Each of them is surrounded by a dark spot 5–10 km across, formed by volcanic products of recent eruptions. The general pattern of fissures on the floor of Alphonsus indicates uneven subsidence of the entire floor within the ring rampart as a whole. On the rampart of the cirque, formations are visible that resemble lava “lakes” between Alphonsus and Albategnius: depressions with a flat floor, partly bounded by concentric ruptures of the rampart. Similar lakes lie on the ledges of the inner slope of the rampart of Copernicus ⁽²⁾. Along the inner margin of the rampart of Aristarchus a red luminous band was observed, explained by an outpouring of lava ⁽¹¹⁾. If these phenomena are indeed connected with outpourings, then it follows that the volcanic activity of such cirques is localized in the zone along the rampart of the cirque. The fact that some movements occur on the inner side of ring ramparts explains many features of cirques. Thus, the craters Sabine and Ritter reveal ring terraces, ledges, and ditches. In many cirques, ruptures form subconcentric structures (Pitatus, Arzachel). There are cirques in which pre-crater structures are visible inside the ring rampart, and they are lowered along a rupture running along the edge of the floor. A considerable share of the subsidences that gave rise to the young maria also arose because of movements along marginal faults. The ring of the newest lavas surrounding the Mare Serenitatis, the concentric ramparts and fissures of the Mare Humorum, the cliffs of coastal cordilleras—all this can be explained by the fact that weakened fractured zones pass along the margins of the maria.

Fig. 4. “Drowned” relief between the cirques Alphonsus and Albategnius ⁽¹²⁾

Thus, the lavas flooding the maria and the floors of cirques are unlikely to come from a single center. Their feeder channels are probably scattered over the entire area of the forming depression, with a concentration along its margins. But all these channels must be fed from a single source; otherwise it is difficult to explain why they act at one and the same time (geologically) and form lava shields at the same level. Two limiting variants of such a source are possible: 1) a melt lens of small diameter but situated deep down (when ring ruptures converge into a cone with a dip angle of 60–70°, the depth of a point source is comparable with the diameter of the surface structure); 2) a shallow melt lens with a diameter comparable to the diameter of the surface structure. With respect to caldera-like cirques, both variants are possible; but the ring structures of the maria have diameters averaging 300–600 km, and a single belt of maria

stretches across the entire visible hemisphere, extending onto the far side of the Moon. Therefore, for

the second variant is preferable for the maria, i.e., the melting centers must have diameters on the order of several hundred kilometers.

Thus, the structure of the lunar surface (provided its volcanic origin is assumed) gives grounds for supposing that on the Moon, at a relatively shallow depth, there lies a continuous layer, if not of melt, then of material ready to melt with a slight rise in temperature or decrease in pressure. If, for example, the pressure decreases under the action of tidal forces, then in the equatorial belt a chain of molten lenses of enormous extent will arise. The hydrostatic pressure, identical for the entire center, will ensure a relatively uniform supply of material to the surface and will lead to the formation of common levels of plateau-basalts, even in small isolated areas coinciding with the general level of the maria. This mechanism resembles the principle of communicating vessels, but, of course, only in the most general sense.

Such an abundance and such dimensions of melting centers have no analogues on Earth. Evidently, the main reason for this difference lies in the smaller force of gravity and, correspondingly, in the six-times lower pressure in the interior of the Moon. Therefore, in the case of an identical distribution of temperature with depth, the melting point for the Moon will be reached at much shallower depths than for the Earth (~ 4). Calculations of the possible temperature distribution for the Moon have been carried out repeatedly ($^5-8$). The initial data for these calculations can vary within broad limits. This concerns the age of the Moon, the content of radioactive substances, the manner in which they are transported to the surface, etc. The values of the heat flux used in the calculations, which are derived from observations in the radio and infrared ranges, also differ. Nevertheless, however much the temperature curves for the present time differ, they all intersect the melting curve of dunite in the depth interval 250–600 km (~ 8). The melting of basalt should occur at lower temperatures (~ 3), i.e., at depths of 100–400 km. In this case the greatest depths are obtained if the calculation is based on data on a large heat flux, which are now being disputed (~ 6). It should also be taken into account that radioactive substances are carried out into the solid shell by intrusions and outpourings, which should raise the boundary of the molten layer. In any case, the available data on the thermal regime of the Moon do not contradict the idea expressed here of a lenticular layer of melt that supplies the lunar surface with volcanic products.

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CITED LITERATURE

- ^1 E. L. Akim, *Kosmich. issl.*, **4**, issue 6 (1966).
- ^2 *Amerika*, No. 126 (1967).
- ^3 V. V. Belousov, *Zemnaya kora i verkhnyaya mantiya materikov*, Moscow, 1966.
- ^4 V. N. Zharkov, V. Sh. Berikashvili, *Zemlya i Vselennaya*, No. 6 (1965).
- ^5 B. Yu. Levin, S. V. Maeva, *DAN*, **133**, No. 1 (1960).
- ^6 B. Yu. Levin, *Zemlya i Vselennaya*, No. 4 (1967).
- ^7 S. V. Maeva, *AN SSSR, Komissiya po fizike planet*, issue 5, 1965.
- ^8 O. I. Oranskaya, Ya. I. Al' ber, *Astr. zhurn.*, **44**, No. 1 (1967).
- ^9 G. P. Kuiper, *Lunar Atlas*, 1960.
- ^10 *Lunar Chart*, United States Air Force, 1964.
- ^11 P. Moor, *Ann. N. Y. Acad. Sci.*, **123** (1965).
- ^12 *Ranger VIII, IX*, Washington, Nat. Aeronaut. and Space Administration, 1966.
- ^13 J. E. Spurr, *Geology Applied to Selenology*, 1945.
- ^14 G. Schruttko-Rechtenstamm, J. Hopmann, *Acad. Wissenschaft., Math.-Natur. Klasse*, abt. 2, **67**, H. 8-10 (1958).

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