LETTERS TO THE EDITORS

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Origin of Tektites

The Moon as a source of tektites is accepted by Varsavsky[1] on the basis of calculations which indicated to him the probability that ejecta from meteorite impacts on the Moon could reach the Earth. All other evidence to the contrary was either ignored or misinterpreted. In *Nature* recently, O'Keefe[2] and Gold joined Varsavsky in support of such an origin.

As pointed out by Urey, in a following communication, and by me[3], it is improbable that the Moon could furnish material having the composition of tektites. The distribution of tektites on Earth furnishes other objections to such an origin.

If tektites are ejecta from meteorite impacts on the Moon, then the slow spiralling of this lunar material to Earth, as suggested by O'Keefe, should result in a fairly uniform distribution of tektites in a broad zone about the Earth, as well as a fairly uniform distribution in geological strata from the time of the arrival of the first tektite on Earth. This is not the case. Tektites came to rest in groups, not as individuals arriving randomly as happened with ordinary meteorites. Various groups are widely separated in time with no individuals as yet found to have arrived in between such times.

Other tektite groups will undoubtedly be found, and the margins of known tektite-strewn fields will be widened as search continues; however, it seems very unlikely that a world-wide distribution of tektites, such as must be postulated for slow inward spiralling of lunar material, will be found. Many of the Australian finds are in unpopulated areas where people seldom go, yet in most populated areas of the world no tektites have been found. After my article[4] appeared in a service publication which reaches most geologists and geophysicists in the United States, many glass objects were received by me for identification, but none was of tektite origin. The chance therefore of finding tektites elsewhere in the United States would seem to be limited.

Every instant of geological time since the first tektite came to rest is preserved in the stratigraphic succession in many places throughout the world, and in places the thickness of rock accumulated during this time amounts to miles. If tektites arrived continuously, then tektites should be found throughout this succession instead of at fewer than a dozen levels, each limited to a very small part of the Earth. In Texas, for example, the rock succession during this interval is fairly complete yet tektites have been found only on rocks of Jackson age or in alluvium derived therefrom. I have mapped in detail several thousand square miles in Texas and visited virtually every part of the State without finding a single tektite specimen except in seven counties for a distance of 120 miles along the Jackson belt of outcrop. If tektites are uniformly distributed, it seems unlikely that they would have been missed in all these other localities.

A few tektite groups have characteristics distinguishing them from all other tektite groups. Libyan Desert glass, for example, is nearly pure silica of a transparent, straw-yellow colour; moldavites are a transparent, clear green; and australites include button forms. Each of these characteristics is peculiar to the group concerned and is found in no other group. Such a segregation of tektites displaying distinctive characteristics should be sufficient in itself to discredit the theory of the slow spiralling of lunar material to Earth.

Varsavsky's origin is different from that of O'Keefe. Varsavsky suggests that ejecta from meteorite impacts on the Moon would come directly to Earth. Each tektite group, then, would represent a separate ejection, and the nearly pure silica glass of the Libyan Desert would be just one of the ejections. It seems preposterous in the light of geological knowledge to assume that nearly pure silica could have segregated on the surface of the waterless, airless Moon.

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[1] Varsavsky, C. M., Smithsonian Institution Astrophysical Observatory, Tech. Rep. No. 4 (1957).

[2] O'Keefe, J. A., Varsavsky, C. M. and Gold, T., *Nature*, **181**, 172 (1958).

[3] Barnes, V. E., *Geochim. Cosmochim. Acta* (in the press).

[4] Barnes, V. E., *GeoTimes*, **1**, 6, 16 (1957).

Recent communications in *Nature*[1], defending the lunar origin of the tektites, appear to do so on somewhat questionable grounds, and their reasoning could easily be misunderstood. Thus the fact that Varsavsky (*op. cit.*) apparently succeeded in constructing admissible mass-particle trajectories connecting the Moon and the Earth does not, by any means, prove the lunar origin of the tektites or even make it probable; for any point on the Earth can be so reached from an arbitrary point of lunar surface, provided only that the initial velocity-components are appropriately chosen. As is well known, such space trajectories are governed by three simultaneous differential equations of second order; and, hence, six boundary conditions are required for complete specification. If three are set apart to specify the position of an arbitrary point of ejection on lunar surface, the remaining three can be committed to specify an arbitrary point of impact on the Earth: the initial velocity-components are then uniquely determined; but owing to the non-linearity of the underlying dynamical problem they cannot be solved for directly in terms of the selected space co-ordinates at both ends, and must be established numerically by trial and error.

The foregoing statements imply, of course, a tacit assumption that the magnitude of the initial velocity-vector is such that the surface of zero velocity of the restricted problem of three bodies, consisting of the Earth, Moon and mass-particle, is not closed around the Moon. For a mass-ratio Earth : Moon of 81·31, this will be true provided that the value of the Jacobian constant $C < 3{\cdot}188..$, or that the initial launching velocity exceeds 2,322 m./sec. (as compared with the parabolic velocity of escape of 2,434 m./sec. if the Moon were alone in space. The presence of the Sun will, furthermore, diminish this velocity of escape by as much as a further 250 m./sec. above the centre of the full-moon disk). If, moreover, the Jacobian constant $C < 2{\cdot}988..$ (that is, if the launching velocity exceeds 2,367 m./sec.), the surface of