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N91-71206

LUNAR HYDROGEN SOURCES; John A. O'Keefe, Goddard Space Flight Center, Greenbelt, Maryland 20771.

Introduction: During the 1950's and 1960's, the idea that the moon is cold attained intellectual dominance, under the leadership of the founders of planetology. In terms of cold-moon thinking, the idea that the moon might contain economically significant reservoirs of hydrogen, at depths where they could be released, was inconceivable. The Surveyor data suggested, and the Apollo samples confirmed the fact that the moon has had a history of volcanic activity on a very large scale; but the new thinking has preserved the belief in a dead moon in our times; it is supposed to have ceased volcanic activity at about -3.0 b.y. Now, however, the seismic data make it clear that the moon remains hot in its interior; although it has a thicker crust than the earth, its asthenosphere seems to be nearer to melting than the earth's asthenosphere.

It is of great importance to re-examine critically the ideas of the cold-moon epoch in the light of the newer data.

Volcanic Origin of Ray Craters: In particular, we must re-examine the belief that most lunar craters are the product of impact. The most interesting craters here are the ray craters, like Tycho, Copernicus and Aristarchus, whose floors are, on any basis, much younger than 3 billion years.

What is known about Aristarchus is that it is now emitting small quantities of gas; the accompanying radon has been detected by Gorenstein (1). A large number of reports, going back for centuries and including some of the best observers (2) point to occasional displays, often of orange or reddish light, in Aristarchus, usually lasting less than an hour. A spectrogram obtained by N. A. Kozyrev (3) shows, he reports, lines of molecular hydrogen, including one measured at 463.4 nm + 0.1 nm, which presumably corresponds to the strong pair of lines at 463.2 and 463.4, both of intensity 9, and the only lines of this intensity in the visual spectrum to the violet of 490.0 in the H_2 spectrum.

The existence of the so-called bright rays, which radiate from these craters, is also evidence of continuing activity. The lunar surface is subject to deposition in most places, at a rate on the order of 1 g cm^{-2} $(my)^{-1}$ (4). It follows that observable markings on the moon ought to be obscured in a few million years at most. The only way that lunar rays could be imagined to survive is if there is some agency on the moon which from time to time sweeps the dust off parts of the surface. For instance, when the lunar module took off for the earth, the rocket exhaust cleared the dust off the local rocks in just this way, leaving a bright spot which was later photographed from orbit. The agency, presumably gas, which clears off the ray areas, clearly radiates from the ray craters. However, it does not come out from the center of the crater (as it would on the impact hypothesis), but from the walls, where much of the current activity appears to be (e.g. the lava flows, or some of the Aristarchus red glows). If we were to start from the data now available, with an open mind, it is very doubtful whether we would reach the conclusion that most lunar craters are due to impact, though some must be. In particular, the old argument that rays are rock flour, ground up by the impact, has lost its force; we now know that lunar fines are darker than the rock, not lighter.

Tektites: From the viewpoint of the cold-moon era, the idea that tektites, which are recent granitic differentiates, could come from the moon was anathema. We now know, however, that the moon does produce granitic glasses which bear the characteristic marks of tektites: low H_2O, low Fe^{+++}/Fe^{++}, low abundance of trace elements which are volatile at 1000°C, and, in the major elements, higher abundances of mafic oxides and lower abundances of alkalies (especially soda) than would be expected for the high SiO_2 content (5,6,7). Occasionally these glasses also resemble microtektites in their morphology and internal structure (7).

The popular idea that tektites are the product of meteorite or comet impact on the earth leads to a series of absurd or impossible conclusions (8) and must be given up. (E.g. craters 300 kilometers in diameter and, initially, 40 kilometers deep, or glass of good quality produced instantaneously in zero gravity).

The lunar origin of tektites demands volcanism (since tektites are not a random sample of the lunar surface). The volcano must be powered by hydrogen, because only hydrogen has an acoustic velocity at magmatic temperatures, which exceeds the lunar escape velocity of 2.4 km s^{-1}. Very large quantities of hydrogen are demanded, because the terrestrial strewn fields involve hundreds of millions of tons of glass; and in addition, one to two orders of magnitude more presumably never reach the earth, but go out into space.

It follows that underneath some of the lunar ray craters, there probably exist very large reservoirs of hydrogen.

On the Earth: Geothermal wells have been drilled to tap similar reserves of volcanic gases, chiefly steam. They have ranged from 300 to 1300 meters in depth (8). The wells do not have to be cased throughout their depth; there is always an impermeable rock on top of the reservoir. The probability of success is apparently much higher than with oil wells; in one field, out of 75 wells, only five were dry holes. Blowout preventers must be used in drilling. From the known oxidation potential of the rocks, it appears that at magmatic temperatures on the moon, the equilibrium is 80% hydrogen to 20% water.

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