IGNEOUS VS IMPACT PROCESSES FOR THE ORIGIN OF
THE MARE LAVAS

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Abstract. In spite of chemical and petrological data furnished by the early Apollo missions, disagreement has persisted as to the ultimate origin of the mare lavas - were they true igneous magmas or impact melts? Examination of Lunar Orbiter and Apollo photographs of Tsiolkovsky, Mare Orientale and Humboldt crater, as examples of mare-filled impact structures, has suggested the answer.

It has been found that the mare lavas possibly stem from internal melting because a considerable time interval has elapsed between the time of basin excavation and basaltic extrusions. This was most effectively shown by crater counts on the ejecta blanket and mare filling of Mare Orientale. The central mare filling is distinctly younger than the ejecta cover, as shown by the lower crater densities on the mare surface as compared with the ejecta. Furthermore, many craters on the ejecta blanket of Orientale were flooded by lava long after the impact had occurred.

Mare-type lavas are not only confined to large circular impact basins, but also fill irregular depressions, like Mare Australe, where evidence for different flooding episodes has been observed.

1. Introduction

The 'hot' vs 'cold' Moon controversy persisted until quite recently, in spite of the availability of Apollo 11 and 12 lunar samples. Although the rocks returned by the astronauts clearly have crystallized from a melt, the important distinction between internally-generated magmas as opposed to molten rock produced by meteorite impacts had not been completely resolved.

Mare basins lie at the end of a continuous progression extending from micro-pits on lunar glass beads and rocks, to small surface impact craters, to larger ones like Tycho, then to partially mare-filled craters, like Tsiolkovsky and finally to the completely flooded basins like Mare Imbrium. A photogeological study of Lunar Orbiter and Apollo photographs has investigated the modification of impact structures by apparent igneous processes, in order to determine whether mare lava melted as a consequence of impact explosions, true volcanic activity, or a combination of both ('impact-induced volcanism'). Representative examples in this sequence have been examined in detail. These include Tycho, Aristarchus, Humboldt, Tsiolkovsky, Mare Orientale and Mare Australe.

The circular maria have developed in at least two distinct stages: (1) excavation of the basins; (2) subsequent filling of these depressions by dark, smooth lava (Baldwin, 1963).

The time gap exemplified by those craters that formed after the mare basin, but before its flooding (e.g., Archimedes in Mare Imbrium), is a general feature of all mare-highland contacts. Mare flooding was accompanied by subsidence of craters toward the mare (e.g., Doppelmayer in Mare Humorum). This hiatus suggests that the mare lavas did not melt instantaneously but were emplaced by internal igneous
activity or impact-induced volcanism. Mare basins were created over a period of time as determined by overlap of ejecta blankets and the degree of morphological preservation.

2. Tycho and Aristarchus – Fresh Impact Craters

Tycho (84 km diam) and Aristarchus (40 km) represent examples of young, unequivocal impact craters with well-preserved features. Features resembling terrestrial lava flows have been observed on their flanks (L.O. V 125–128 and V 194–201). The radial distribution of the flows around the craters has been mapped from lunar photographs. Flows emanate at the rim crests, whether or not they continue into or outside the crater. These features were originally molten, as shown by the ropy texture, contraction fractures (shrinkage cracks) and flow lobes. They could have originated by impact melting, or internal igneous activity, perhaps triggered by impact. Smooth material fills hollows on the rims of these craters (‘lava pools’).

Strom and Fielder (1970) find, from crater counts, that the succession of flows on the outer rims of Tycho and Aristarchus extended over a considerable time interval, and that they are therefore volcanic in origin.

3. Humboldt Crater

Humboldt crater (200 km diam) on the Moon’s southeast limb forms another link in the sequence from undisputed impact craters to the lava-filled circular maria. Humboldt exhibits most of the characteristics of fresh impact craters (ejecta cover, scalloped slump terraces and central peaks). Although it is relatively young (probably of Eratosthenian age – it is rayless, but secondary craters are still visible), its floor has undergone extensive post-impact modification, but extrusion of mare-type lava has only reached an incipient stage (Figure 1a).

The rough, hilly unit on the northern half of the floor may represent the remnant of the original surface (compare with the floors of Aristarchus or Tycho). To the south and east, it is blanketed by a smooth, light plains-forming unit, like the Cayley Formation (Figure 1b). The plains-forming unit was probably not a fragmental, erosional layer (regolith) which otherwise would have covered the entire floor uniformly. Its confinement to the southern half of the crater, which coincides with the distribution of rilles, may suggest internal causes such as perhaps an ash flow unit. The floor, including the central peaks, and particularly on the plains formation, is dissected by a complex rille system resembling a spider-web. The rilles in turn have been truncated in several locations by patches of mare material, presumably basaltic lava, which may have issued from the fractures they conceal (Figure 1c). The rille system consists basically of radiating and concentric fractures that could have formed in response to slow isostatic uplift of the floor. The crust may have been thinner or less viscous than elsewhere. Stresses were confined to the crater and were not part of a larger system. Apparently, forces of internal origin have contributed to the post-impact development of Humboldt.