

# THE IMBRIUM BASIN AND ITS EJECTA

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While an impact origin for the Imbrium Basin is generally accepted, there are diverse opinions about the record of the event contained in the returned lunar samples. The strong thermal metamorphism in many Apollo 14 breccias has been attributed by some to heat generated by the Imbrian impact (1,2); others consider that previously metamorphosed material was simply disrupted, mixed and re-distributed by the impact (3,4). These differences in interpretation reflect the uncertainties in extrapolating physical conditions deduced from large terrestrial craters to impact structures with Imbrian dimensions. However, as the Apollo 15 site is closer to Imbrium than the Apollo 14 site any general model requires that the high grade effects of the Imbrian impact be more prominent in samples from the Apennine Front than in those from the Fra Mauro formation.

Our analyses of material probably derived from the Apennine Mountains include glass and breccia fragments in the 1-2 mm fraction of soils 15302,20, 15222,3 and 15532,7 and similar clasts in breccias 15467,4 and 15565,92. We agree with others in finding relatively few distinctly annealed breccias or igneous-textured rocks, other than mare basalts, but an abundance of ultramafic green glasses which clearly formed a thick surficial deposit, and relatively homogeneous re-worked breccias derived from them. The differences and similarities of the 14 and 15 samples as they pertain to the Imbrian event suggest the following hypothesis: the feldspathic breccias at both sites are equivalent to terrestrial impact breccias of the Bunte breccia type (5), possibly including local material (6), and the Apollo 15 green glasses and Apollo 14 "howardite" glasses (7) are representatives of Imbrian impact melt ejecta.

Structurally the closest analogs to the Imbrium Basin are large (>20 km) complex terrestrial impact craters. Models of the latter indicate that the initial excavation forms a transient cavity of parabolic shape (8). Extrapolation to Imbrian dimensions yields a transient crater almost 700 km in diameter and approximately 230 km in depth (Fig. 1, A&B). Immediate modification along ring faults produces a central uplift and a ring depression. In the figure, the moon is shown with a 50 km crust so that the central uplift brings mantle material close to the surface where, together with later mare basalts, it contributes to the central mascon (Fig. 1B).

Material close to the point of impact, the shaded hemisphere in Fig. 1A, would be vapourized or melted. The remainder, almost 90%, would be moderately to weakly shocked and form low temperature ejecta deposits resembling Bunte breccia. Both crust and mantle are involved in the volume melted and deposits of impact melt can be expected to vary in composition with distance from the crater. The initial high velocity ejecta (trajectories 1&2 in Fig. 1A) would consist entirely of crustal material with an added small meteoritic component and would not be distinguishable from the ejecta of smaller local craters.

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Melt travelling in trajectory 3, however, would contain a major mantle component, which would become dominant to almost total in 4 and 5. Therefore, we suggest that the green glasses of approximately howarditic composition at the Apollo 14 site are Imbrium melt ejecta with about 75% mantle component, while the large amounts of ultramafic green glass at the Apennine Front are Imbrium ejecta with close to 90% mantle component.

The two Ar 39/40 age determinations on the green glass disagree for as yet undetermined reasons. One at 3.38 b.y. is close to the age of the local Apollo 15 mare basalt extrusion (9). The other at 3.79 b.y. (10) argues in favour of the hypothesis of the green glass as Imbrium impact melt. Observations advanced in favour of a volcanic origin for the green glass include: (1) the absence of xenocrysts, (2) the presence of microphenocrysts of olivine, (3) surface morphology suggesting lava fountaining (11). However, these data are equally compatible with an impact event of this magnitude. Material following trajectory 4 (Fig. 1A) would have a velocity of approximately 1 km/sec and would be part of a thick sheet of melt within the transient cavity for several minutes. During this period there would be sufficient time to dissolve shocked inclusions of plagioclase and mafic minerals and, with cooling, to grow olivine microphenocrysts. During later ejection the still liquid melt sheet tore apart and effects similar to those in a volcanic lava fountain would be produced.

Experiments indicate that green glass compositions may result from 40-60% partial melting at 1450°C and 15 kb of pyroxenitic mare basalt source material (12). Therefore, if a volcanic product, it is necessary to transport a volatile-free, non-super heated "green glass" partial melt liquid from depths of approximately 300 km to the lunar surface with little or no heat loss and eject it with sufficient force to form a lava fountain. We suggest that this unique set of conditions, if not unrealistic, is at least difficult to envisage. In the impact model presented here the local concentrations of "howardite" and green glass in the Apollo 14 and 15 samples respectively are defined by the selenographic relationship of these sites to the Imbrium impact. Both are total melts and approximate the composition of the upper lunar mantle with minor crustal contamination. The green glass is the deeper product and has the least crustal contamination. As a sample of the lunar mantle it is in good agreement with the predicted composition of Gast (13).

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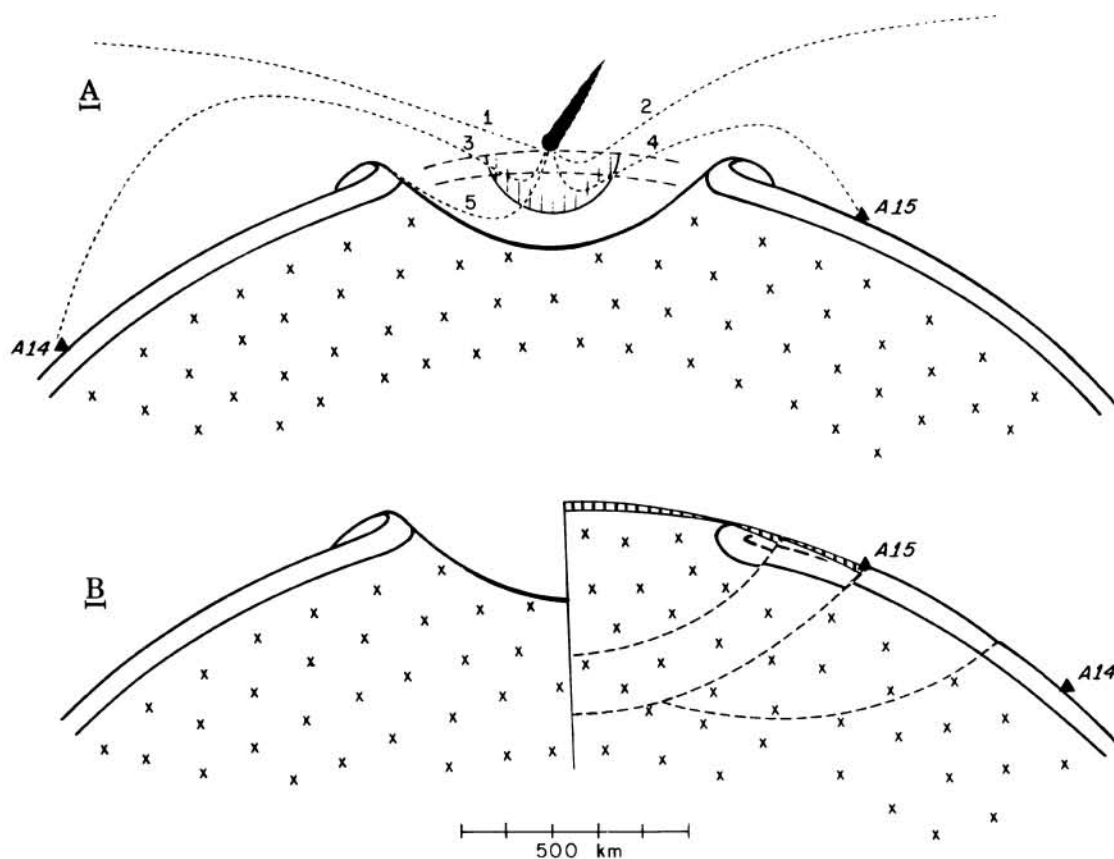


Fig. 1 (A and B). Schematic cross sections, drawn to scale, of the Imbrian impact into a moon with 50 km crust overlying an ultramafic mantle (\*\*). In A the vertically-shaped hemisphere within the transient cavity outlines the volume melted or vaporized. Representative trajectories 1, ...5 indicate relative proportions of crust and/or mantle in ejecta with different ejection velocities. In B dimensions of the transient cavity are compared with the suggested present configuration, with central uplift of mantle, depressed rim and filling of mare basalt (vertical bars). The relative radial positions of Apollo 14 and 15 sites are shown in A and B (right).