ORIGIN AND IMPLICATIONS OF THE IMBRIUM SCULPTURE. P. H. Schultz, Department of Geological Sciences, Brown University, Providence, RI 02912 (peter_schultz@brown.edu)

Introduction: The Imbrium Sculpture is a distinctive lineated facies surrounding the Imbrium basin but best expressed across the Southern Highlands (1, 2). Early mapping from Earth-based telescopes revealed a radial to subradial pattern converging within Imbrium. In fact, some lineations comprising the sculpture cross each other, exhibiting two different stages of formation (3).

Hypervelocity oblique impact experiments in the laboratory (Fig. 1) exhibit a very similar pattern and reflect the evolution from high-speed plating-out from jets, ricochet scouring by the decapitated pieces of the impactor (4), early-stage molten spray, and late-stage more radially directed excavation of the cavity. Impactor decapitation results from reduced peak pressure at first contact, thereby inducing spallation or siblings, that reimpact the target at low angles. Most downrange sibling grooves converge uprange, just beyond the crater rim. Nevertheless, one component fails to converge within a crater diameter, appearing to form a sub-parallel set of ricochet grooves. The width of this set approximates the diameter of the projectile (within 10%). This observation (coupled with high-speed imaging) indicates that such grooves are produced by lateral spalls, i.e., coming from both sides of the impactor where shock effects are minimal, just as produced by hypervelocity impacts into spheres (5).

Consequently, sibling grooves could provide a new strategy for assessing the impact angle, the evolving stages of excavation, and even the diameter of the impactor in a planetary context. As a test for this hypothesis, grooves and lineaments comprising the Imbrium Sculpture were mapped across the Moon. Each groove was also classified according to morphology (lineation, groove, or crater chain) and expression since each type may reflect different stages of formation: from scouring by early-stage decapitation siblings to late-stage secondary cratering and ejecta flow.

The slight elongation of the inner partial ring of Imbrium and the predominance of sculpture to the southeast, suggest an impact direction from the northwest (6, 7). Consequently a trajectory great circle (TGC) was selected. The intersection between the great circle from each lineament (LGC) and the TGC revealed an evolving source within Imbrium. Lineaments within the Frau Mauro Formation (resembling ejecta flow patterns at Orientale) converged near or downrange from the center of Imbrium. Deep, rimmed grooves (e.g., Boscovich), however, consistently converged uprange, as revealed by histograms in LGC/TGC intersections.

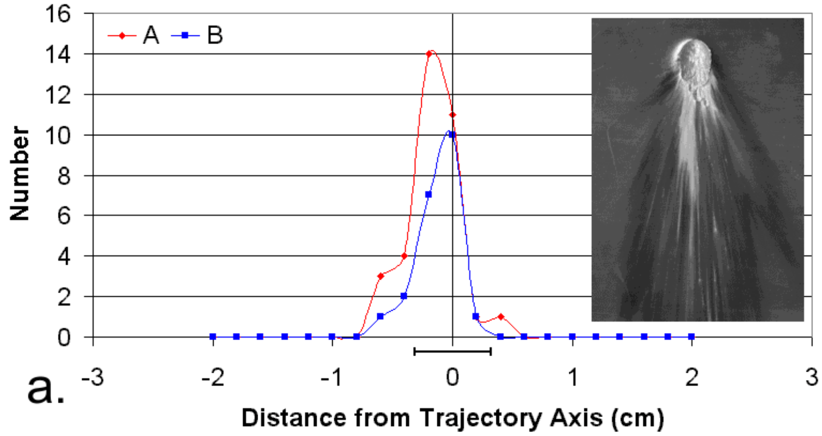
Interpretation and Significance*:* It is proposed that the Imbrium Sculpture (IS) is not simply ejecta from excavation of the Imbrium basin. Instead, these are the result of low-angle hypervelocity collisions by the fragmenting Imbrium impactor. As a result, the IS has two components: an early-stage grooving/scouring that precedes arrival of basin excavation, subsequent secondaries, and late-stage ejecta flow. This interpretation would help to account for: the enhanced expression south of Imbrium, the enigmatic crossing groove patterns, overprinting of two directions, the mare-centered basaltic volcanics within some groove systems (secondary craters should be low-pressure, shallow structures), and the contrasting degree of "sculpturing" by different systems.

The unusual expression of Imbrium Sculpture relative to other basins and craters represents the combined effect of scale and approach angle. The impactor to crater diameter ratio increases with scale, thereby enhancing effects from earlier stages of formation. Orientale also exhibits a similar convergence pattern but this basin is significantly smaller. At lower impact angles, decapitation fragments will more likely miss the downrange surface completely due to surface curvature, such as Crisium (7). Higher impact angles result in siblings striking inside the final crater/basin rim.

If this interpretation is correct, then perhaps the size of the Imbrium impactor can be estimated, just as for laboratory craters. Intersections between LGC's and a great circle perpendicular to the trajectory (PGC) were plotted as it was systematically moved uprange, along the trajectory. Just as in the laboratory examples, the number of intersections decreased with the PGC with a persistent set of intersections beyond the uprange Imbrium rim. This set had a typical width of 300-400 km (Fig. 2). If this width corresponds to the failed lateral spalls, then it reflects the approximate diameter of the Imbrium impactor.

A second strategy considered the onset distance of the deep grooves downrange, e.g., just northwest of Mare Vaporum. In this case, the decapitation fragments from the top of the Imbrium impactor retained their initial trajectory and began grooving the pre-impact surface horizon on a sphere. Simple geometry then reveals that the impact horizon near Vaporum (relative to the northwest side of Mare Imbrium, i.e., uprange) requires an impactor 380-500 km across, remarkably similar to the plan-view convergence approach. Moreover, the impact angle is estimated to have been between 30˚ and 39˚.

Conclusions*:* The enigmatic pattern of deep Imbrium grooves commonly called the Imbrium Sculpture may simply represent the downrange failure pattern from the Imbrium asteroid. The impact by siblings (spalls) downrange from such a major collision precedes basin excavation and ejecta deposition. Enhanced shock effects downrange, perhaps contributed to the formation of the enigmatic Procellarum Basin (8) and stripping/exposure of the subcrustal KREEP patterns south of Imbrium.



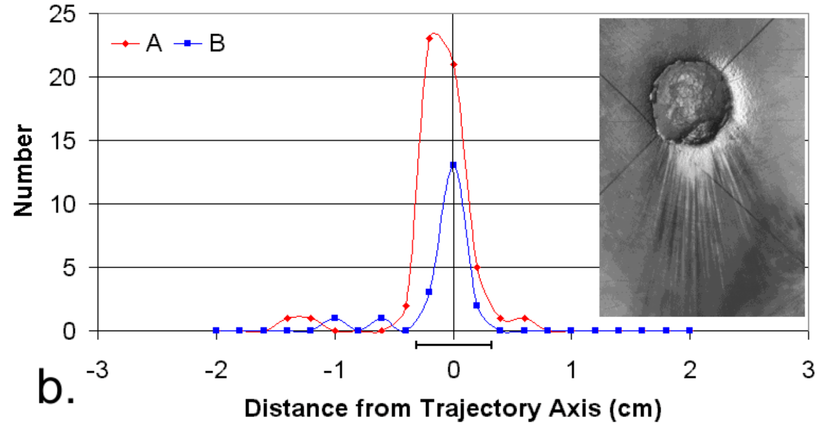


Figure 1. Convergence diagrams for 15˚ (Fig. 1a) and 30˚ (Fig. 1b) hypervelocity impacts into aluminum by 0.635cm aluminum spheres. Grooves created by hypervelocity ricochet debris converge and cross a reference line perpendicular to the trajectory at the uprange rim of the crater (A) and 1.5 projectile diameters uprange (B). Figure 1 shows a histogram of the number of crossings as a function of distance away from the trajectory axis. Well beyond the uprange rim (B), the spray originates from spalls from either side of the projectile and travels downrange with little relative velocities normal to the trajectory. Therefore, these components can be used to estimate the impactor diameter, consistent with 0.635cm (shown as a bar scale below).

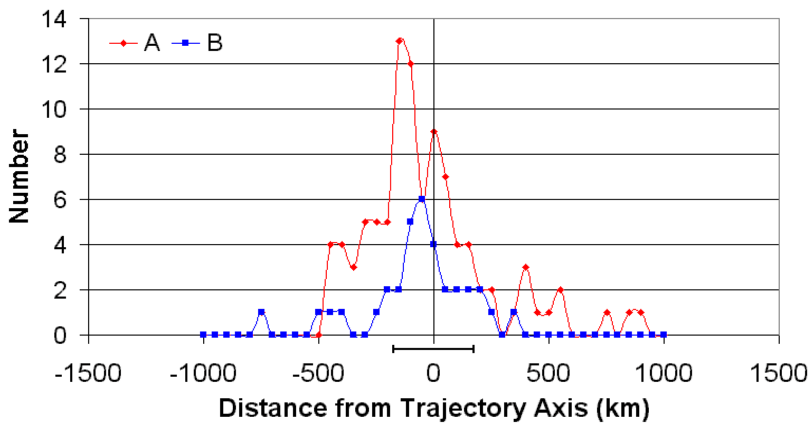


Figure 2. Convergence diagram for the Imbrium basin. Imbrium lineaments intersect a great circle perpendicular to an inferred trajectory axis (NW-SE) located at the basin center (A) and 800 km (B) uprange. Lineament sets converge uprange and are proposed to be the result of spalls from opposite sides of the Imbrum impactor, as in the laboratory experiments (Fig. 1). The width of this set provides a first-order estimate for the diameter of the Imbrium impactor (bar scale corresponding to 300-400 km).

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