Impactor fragmentation and capture laboratory experiments

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Direct collisions of solid bodies may result in sticking, rebound, erosion, and even shattering of the bodies. The smaller body (i.e., the impactor) may stick to the larger body (the target), rebound from the body, erode the surface (i.e., produce a crater) producing dust, penetrate beneath the surface, or be comminuted upon impact. The pieces generated by comminution of an impactor would be scattered over the surface of the larger body and mixed with the original materials. The Dawn mission detected dark material on the surface of asteroid 4 Vesta. This dark material was interpreted as fragments of carbonaceous chondrite impactors. In comparison, howardite–eucrite–diogenite (HED) meteorites, for which Vesta is potentially the parent body, contain carbonaceous chondrite clasts. Collectively, this evidence suggests that fragments from carbonaceous chondrite impactors were mixed with material from Vesta, consolidated, ejected from the surface of Vesta, and delivered to the Earth as meteorites. The mixing of solid materials of different origins depends on the efficiencies of fragmentation, penetration, and ejection of impactor materials. Although cratering and fragmentation of the larger body (the target) has been studied in a wide parameter space in laboratory experiments and numerical simulations, few studies have examined the fate of the smaller body (the impactor) due to the small size of the impactors and difficulty accelerating brittle projectiles in laboratory experiments.

We performed laboratory impact experiments using various impactors, including rocks, metals, and porous sintered materials, to examine the degree of fragmentation, penetration, and consolidation of impactors. The size of the impactors ranged from 1 to 3 mm in diameter, and the impact velocity from a few to several km/s. The impactor was accelerated using a two-stage light-gas gun at the Institute of Space and Astronautical Science (ISAS), JAXA, Japan.. The targets were simulated porous parent bodies consisting of silica sand, gypsum, or sintered hollow glass beads. We collected the impactor fragments in the targets, weighed the mass of the fragments, and observed the cut surface of the impactors.

The experiments showed that the impactors fragmented when the initial pressure roughly equaled the dynamic tensile strength of the impactor. The degree of impactor fragmentation increased with the initial pressure. However, when impactors struck fine sand at high velocity, consolidation of the impactor fragments themselves and of the fragments with sand particles occurred. This consolidation may have resulted from the temperature increase as well as from compression. Impactors with large initial porosity were compacted, and a larger fraction survived and could penetrate deeper into the target. Therefore, impactor survivability, as represented by the apparent largest fragment mass fraction, in high-velocity impact is greater than would be expected from the extrapolation of the results of previous lower-velocity experiments.