Field Evidence and Implications of Dynamic Entrainment and Survival of Asteroid Fragments in Sedimentary Target Impact Ejecta

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Introduction: Identification of the asteroids involved in hypervelocity impacts typically involves either the collection of nearby spallation fragments for relatively small events or the determination of fingerprints assayed from the bulk geochemistry of ejecta and fallback material for large ones. Only in the rare case of Morokweng has a substantial piece of the bolide been recovered from a melt sheet [1]. Although such a find provides a unique opportunity to study the petrology of the impactor, it is a small portion that may not be representative of the entire body.

Over the last decade, we have been involved in investigations of a number of impacts, of a variety of sizes, that occurred into soft sedimentary targets or targets characterized by thick sedimentary cover sequences. We proposed that such targets "trap" a variety of unique components from both the target and impactor [2], and we have demonstrated that they indeed can preserve volatiles [3] and biomass [4]. They also can preserve grain-scale assemblages of the asteroids that can facilitate both bolide identification and provide clues to parent body petrogenesis. In that they are dynamically emplaced "dust", they likely represent a random sampling of a more complete profile of the impactors than has been observed previously. Given the observation of contact binaries and Itokawa-like asteroids in the population of NEAs, recognizing these tiny survivors of sedimentary impacts may be our best way of evaluating the record of those asteroids colliding with Earth. It also is likely that similar survivors occur in ejecta deposits on other planetary surfaces and could be detected by both remote sensing and sample return [5].

Cenozoic Pampean Impacts: Of the seven distinct impact melt breccia deposits we have identified in the Argentine Pampas [6-9], at least four contain microscopic impactor debris. The 445 ka melt breccias contain troilite/oxide/silicate assemblages that presently could be paired with a variety of iron and chondritic sources. The 3.27 Ma melt breccias contain phosphorous-rich olivine with Fe/Mn and Fe/Mg systematics indicative of a mesosiderite component. The 9.24 Ma melt breccias contain exotic Ba-rich basaltic debris that currently is under investigation. The 5.28 Ma Bahía Blanca glasses contain the most robust suite of survivors, dominated by a distinctly angrite-like assemblage that recently has been shown to contain fassaitic pyroxene druses reminiscent of D'Orbigny [10]. An eighth glass occurrence, provisionally dated by Ar-Ar at about 1.2 Ma, contains olivine clasts exhibiting HED affinities.

Devonian Alamo Impact: Shocked quartz grains in the distal eject from the Alamo impact on the Late Devonian shelf of western North America contain ubiquitous hematite inclusions that formed after pyrite. Petrographic investigations indicated that the precursors most likely were injected into the quartz contemporaneously with the formation of planar deformation features (PDFs). [11] proposed that the original grains were iron sulfides of meteoritic origin. Detailed geochemical work might constrain bolide identification.

Cretaceous-Paleogene Impact Boundary: Similarly, quartz grains within altered impact spherules at the K-Pg boundary in South Carolina are impregnated with native iron and nickel shrapnel [12]. The spherules also contain Ni-graphite-bearing ferropseudobrookite that could either be directly from the bolide or alternatively formed by ultra-high temperature transformation of Fe-Ti oxides from the asteroid that were encased in hot carbonate.

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