New Physical Evidence for a Cosmic Impact with the Earth at 12.9 ka (poster)

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New Physical Evidence for a Cosmic Impact with the Earth at 12.9 ka

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Introduction

Firestone et al. (2007) and Kennett et al. (2009a, 2009b) presented a new hypothesis based on the identification of shock impact proxies (including nanodiamonds) consistent with a cosmic impact (crater forming or aerial detonation) at the onset of the Younger Dryas cooling episode ~12.9 ka. Impact markers are found in a thin layer, called the Younger Dryas Boundary (YDB), at 51 locations across North America, Greenland, Europe, and Syria, although not all markers are present at every site. This hypothesis has been met with contentious arguments from some members of the impact community, mostly based on probability statistics and absence of a crater. We summarize here, observations, experiments, and analyses that support the impact hypothesis. The most significant lines of evidence for impact in the YDB are: presence of (1) nanodiamonds (ND) and other exotic carbon phases, (2) compositions of magnetic and silicate spherules **(Figs. 1, 2)**, (3) spherule morphology (aerodynamic shapes, accretionary and collisional features), and (4) high-temperature melt products.

Nanodiamonds & Other Carbon Phases

Five allotropes of diamonds (cubic, hexagonal, *p*-diamond, *n*-diamond, and *i*-carbon) are produced by experimental high explosive detonations (Yamada and Sawoaka, 1994) and by carbon vapor deposition. All five have been found at the YDB, and at the Cretaceous-Tertiary Boundary (KTB), now known as the Cretaceous-Paleogene (KPg) boundary, produced by the Chicxulub impact. Most diamond allotropes have also been observed in other impact craters and in shocked meteorites. (See poster by West et al. 2011, this meeting, for nanodiamond details). Other carbon phases (aciniform soot, fullerenes, carbon spherules, glass-like carbon and graphite) have been observed in detonation experiments. All of these are found together with nanodiamonds in the YDB and KPg boundary, but nowhere else together (Gilmour, 1998).

Spherule Compositions

For the many spherules found in the YDB, bulk compositions and REE abundances are unique and inconsistent with the compositions of micrometeorites and volcanic or anthropogenic spherules. YDB magnetic spherules range from ~1 to 500 µm in diameter, averaging about 60 µm, and typically appear as highly reflective, black spheroids. Although we refer to them as "spherules," shapes such as ovals, doublets, dumbbells, and tear-drops occur frequently. SEM observation of outer surfaces of all magnetic spherules analyzed reveals a surficial crystalline pattern that is typically dendritic or polygonal like a soccer-ball. These are indicative of melting with rapid quenching (Petaev, 2004), which precludes diagenetic, biogenic, or detrital origin.

Spherule Morphology

Within an impact plume, melt droplets, rock particles, dust, and partially melted debris collide with a wide range of velocities. High-speed collisions can be destructive, resulting in annihilation or surface scarring that leaves small craters (Prasad and Kledehar, 2003) or constructive, whereby partially molten and plastic spherules grow by accretion of smaller melt droplets (Kyte, 2010). Microtektites commonly show the effects of high velocity interparticle collisions (Prasad and Kledehar, 2003; Prasad et al., 2010), which resulted in microcraters that have less brittle fracturing and lower velocity craters that have less discernible cratering features, but have a higher population of oblique impacts that formed elongated craters and very low impact "furrows" **(Fig. 3)**. Other moderately high velocity impacts occur when spherules collide with partial penetration and partial melting (**Fig. 4**). With very low velocities, collisions became accretionary and range in characteristics from disrupted projectiles with outward splatter to partial burial in and flattening of projectiles on the accreting host. The least energetic accretions are exemplified by gentle welding together of tacky projectiles and/or hosts. Accretion impacts are the most common collisions observed in 36 Meteor Crater glassy impactites and 246 YDB spherules, microtektites, and impactites, examples are given in **Fig. 5**. In addition to spherule accretions, another type is in the form of irregular melt drapings or splatter (Mirsa et al., 2009) (**Fig. 6**). Melt drapings are also common on Meteor Crater and YDB spherules and impactites that are also illustrated in **Fig. 5.** (Low velocity (<500 m sec^{-1}) micro-impact craters are found on the surface of YDB glassy spherules, as well as evidence for penetrating collisions among these objects. Such features are known only among microtektites and impact-melt spherules (Prasad and Kledehar, 2002).

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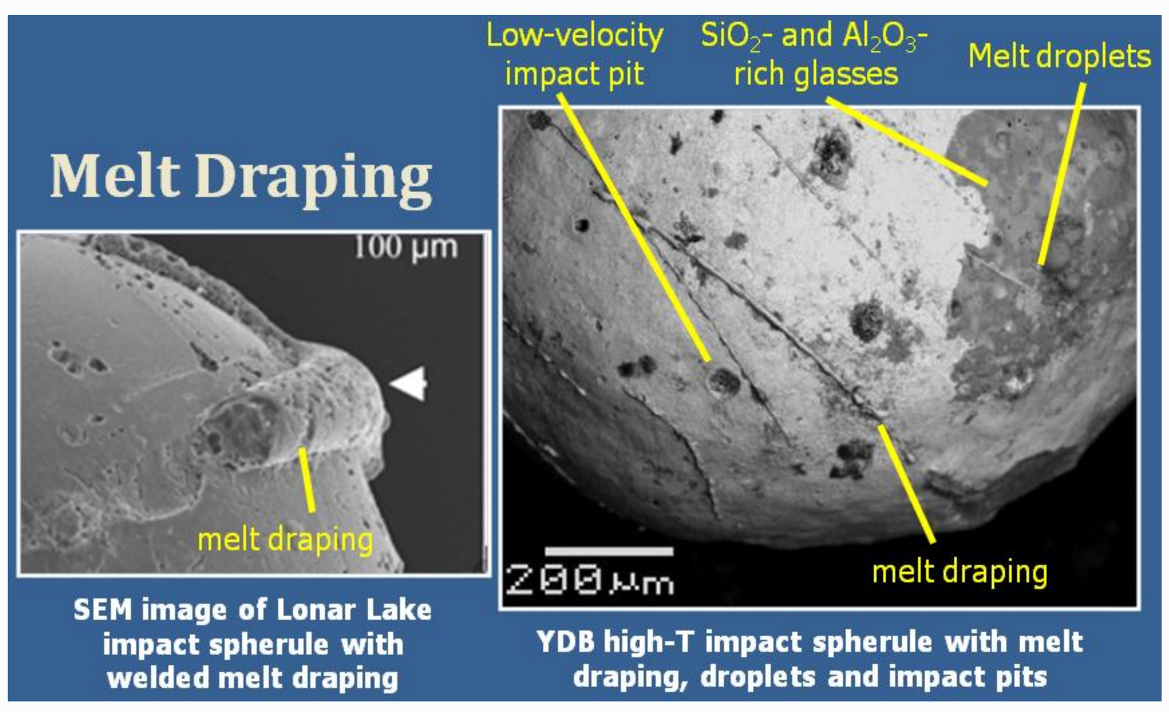

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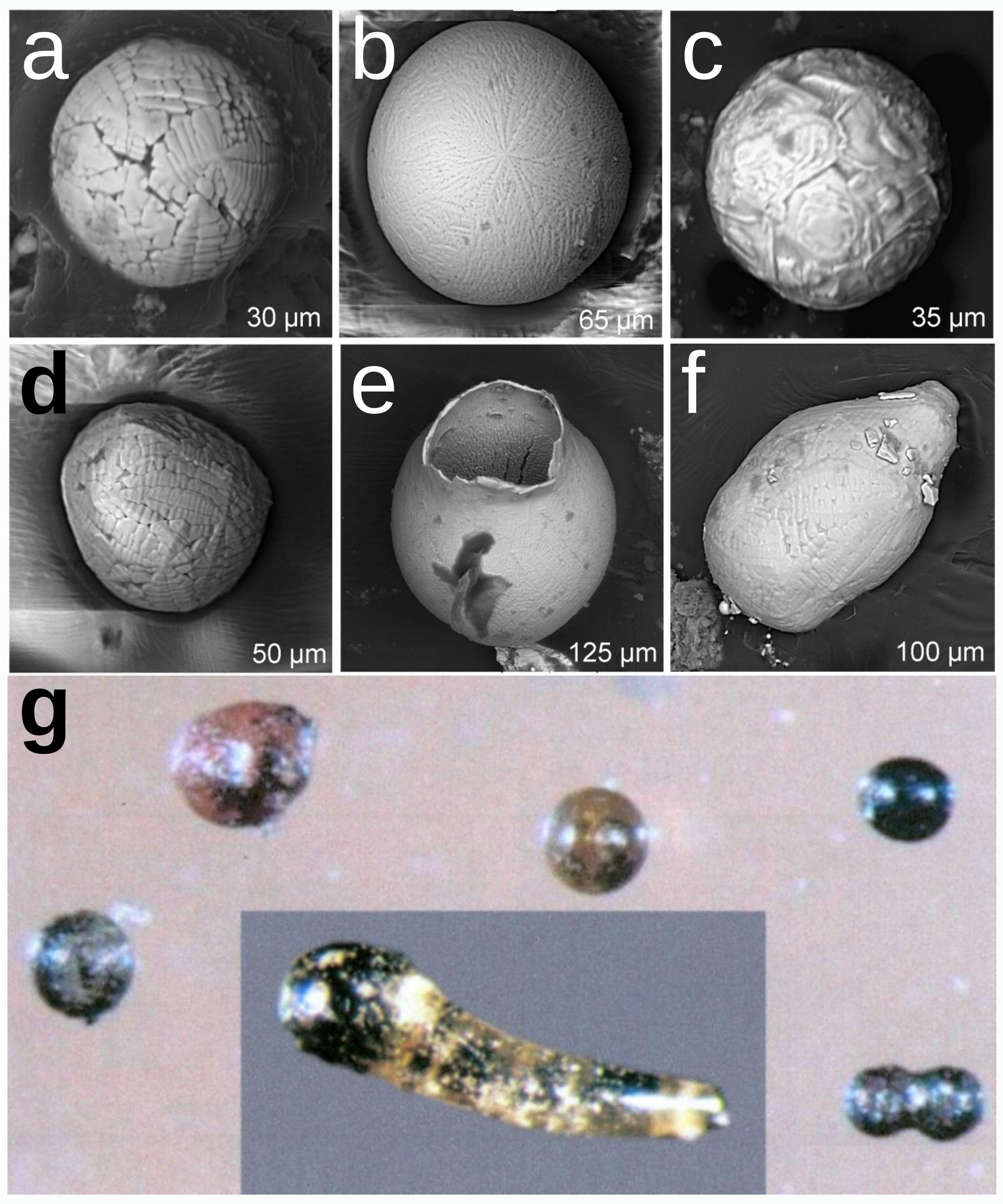

Figure 1. Magnetic spherules (Figs. a-d) that show a range of quenched surface features, most are hollow, a few show "blowouts" (internal vapor pressure exceeded enclosing atm pressure) (Fig. e). Bottle-shaped objects are uncommon (Fig. f). Glassy spherules, including teardrop (Fig. g).

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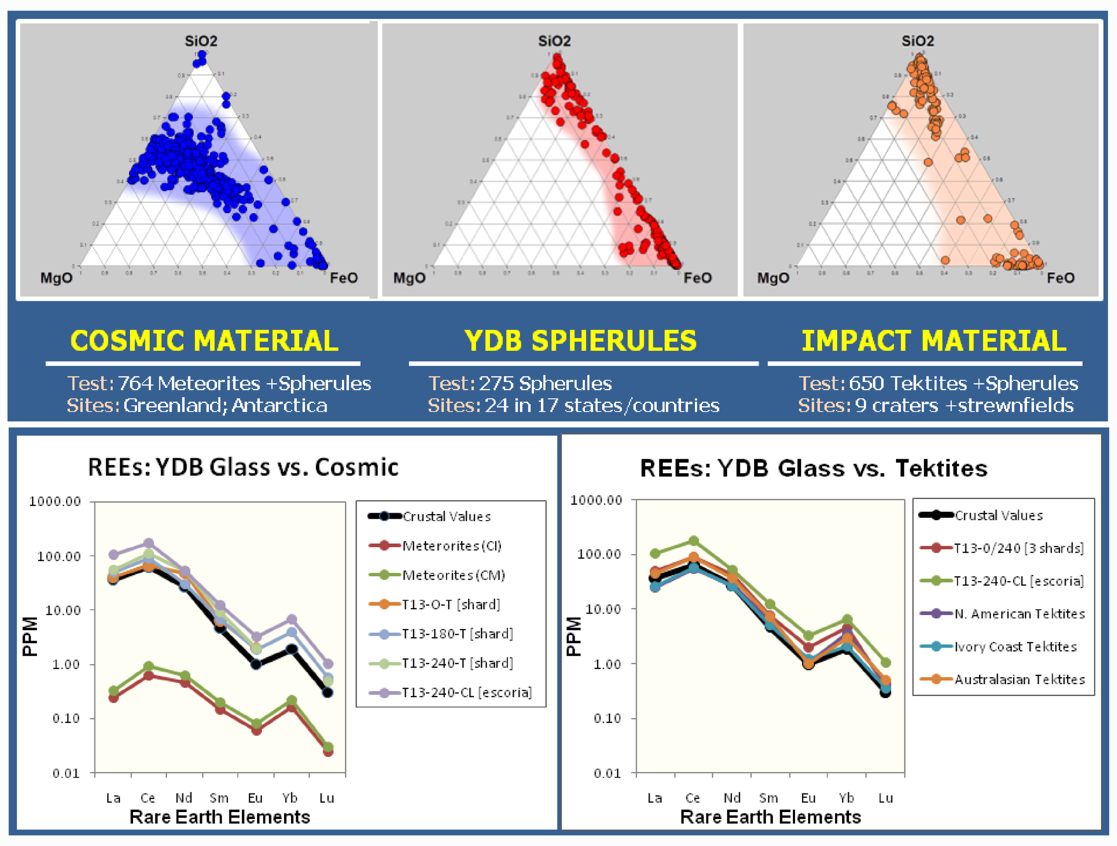

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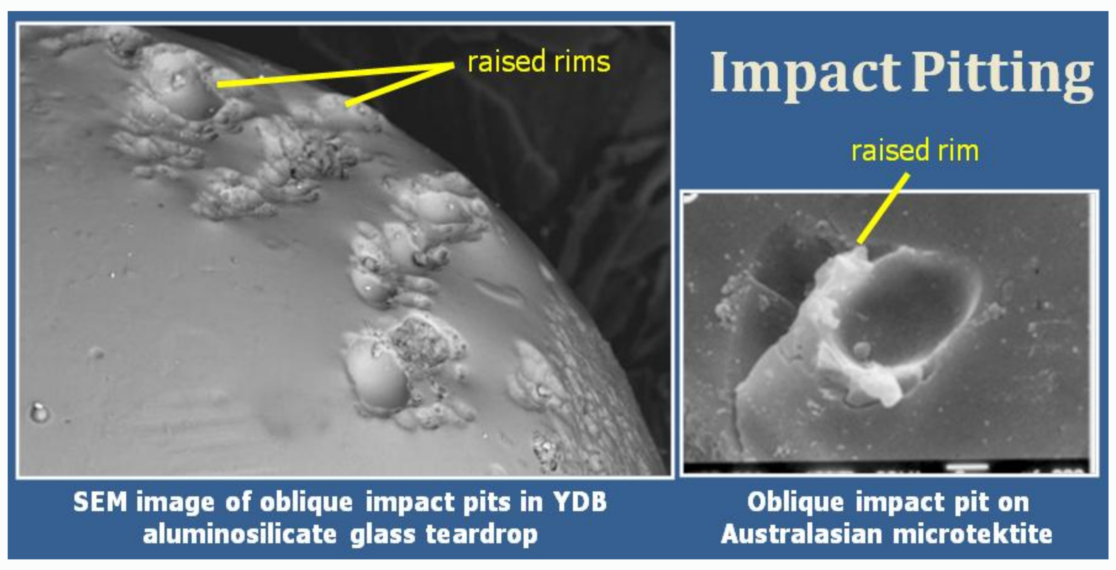

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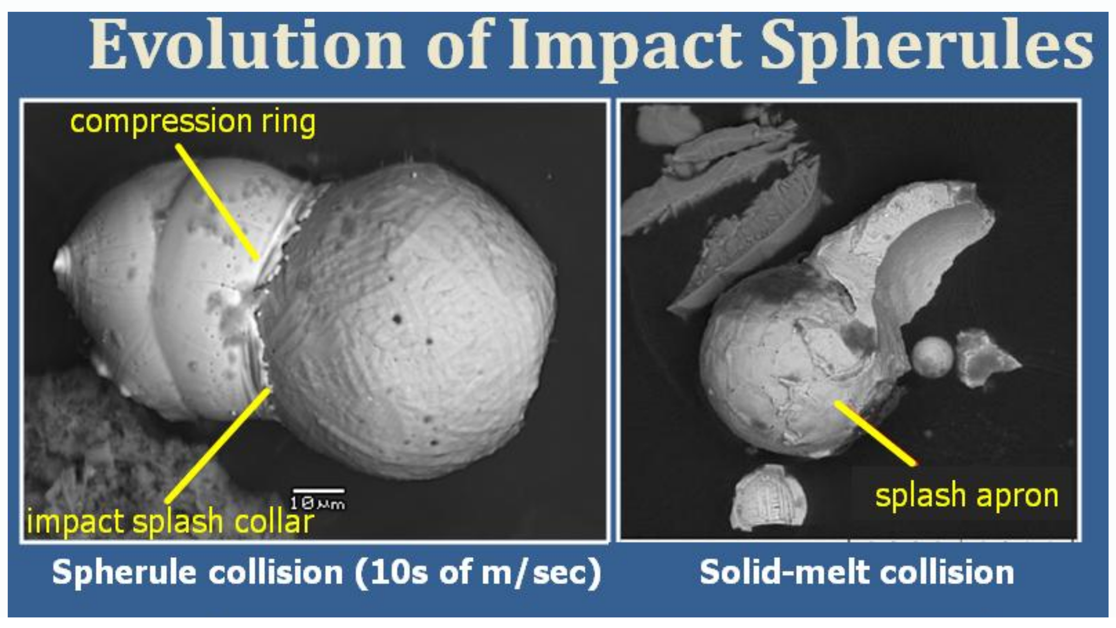

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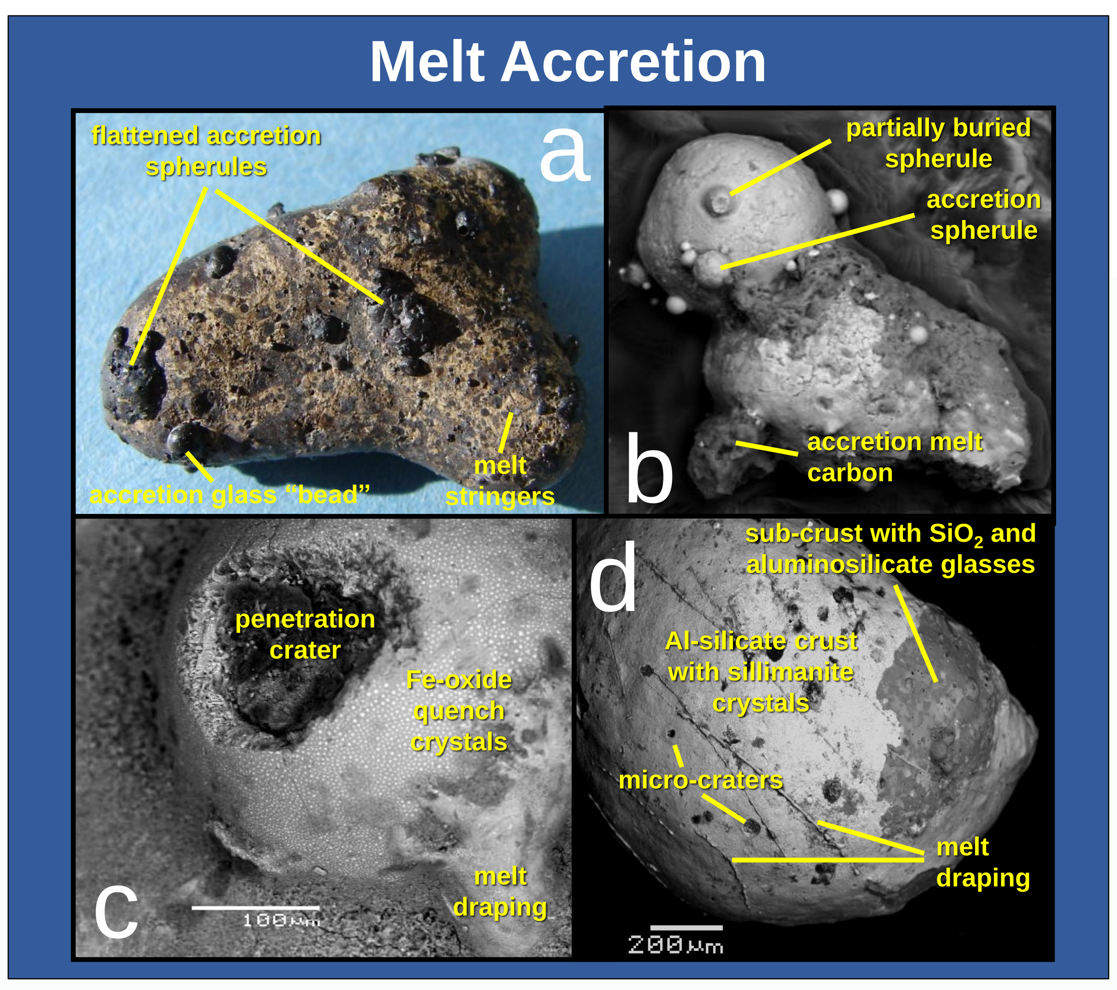

Figure 5. Variety of impact plume impact features. (a) Meteor Crater impactite with accretion spherules and melt drapings. (b) YDB accretion features. (c) Meteor Crater impact spherule. (d) YD teardrop impact melt glass.

Some glassy objects from the YDB are aerodynamically shaped into teardrops and dumbbells (among other shapes), morphologies not found in micrometeorite collections. These shapes are common to microtektites and macrotektites from the Southeast Asian tektite strewnfields and to melt materials from the Trinity nuclear detonation.

High-Temperature Melt Products

Melting SiO_2 produces flow-textured lechatelierite grains, in addition to SiO_2 spherules, which are found in the YDB. These grains are unique only to impact and fulgurite production due to the formational need of very high temperature flash heating (2200 to 5000º K).

Perhaps the most convincing evidence for producing high temperature melt glasses from an aerial burst is from the detonation of the world's first atomic bomb at the Alamogordo Bombing Range, NM in 1945. The device was detonated atop a 100-foot tower and melted about 1 to 3 cm of the desert soil for a radius of 1000 feet. The blast site, since called Trinity, was littered with green glass fragments, small glass beads, teardrop and dumbbell shaped "microtektite"-like glasses that were ejected miles from the site. These glasses, called trinitite **(Fig. 7)**, are similar to the Australasian tektites and YDB glassy objects in shapes and rapid melting/cooling rates. The very high temperatures of many thousands of degrees and very short melting time of 3 seconds for the Trinity explosion are very similar to the conditions postulated for aerial burst flash melting of tektites and YDB glasses (**Fig. 8**).

Discussion

The above characteristics are individually and collectively unique to impact pressures and/or very high temperatures and extremely rapid quenching rates. They cannot be products of forest fires or micrometeorite origins as some workers have speculated. The existence of a crater appears unnecessary to form the YDB impact proxies based on the comparison to similar proxies found associated with the widely accepted aerial burst at Tunguska (10^{17} J energy), the proposed, larger aerial burst(s) responsible for the Australian tektite strewn field (10^{21} J energy) (Wasson, 2003), formation of Libyan Desert glass, and the known Trinity nuclear airburst. We propose a potential solution to the YD impact mechanism. Napier (2010) suggested that the Earth encountered a dense trail of material from a large disintegrating comet at 12.9 ka, giving rise to catastrophic cluster impacts. Napier provided compelling evidence that such a comet entered the inner planetary system between 20,000 and 30,000 years ago. Far from being a rare occurrence, many comets are known to have fragmented in recent times, giving rise to a number of closely related meteor streams (e.g., the Perseids, Taurids, Geminids, Lyrids, Aquarids, Orionids, and Leonids) through which Earth passes once or twice a year.

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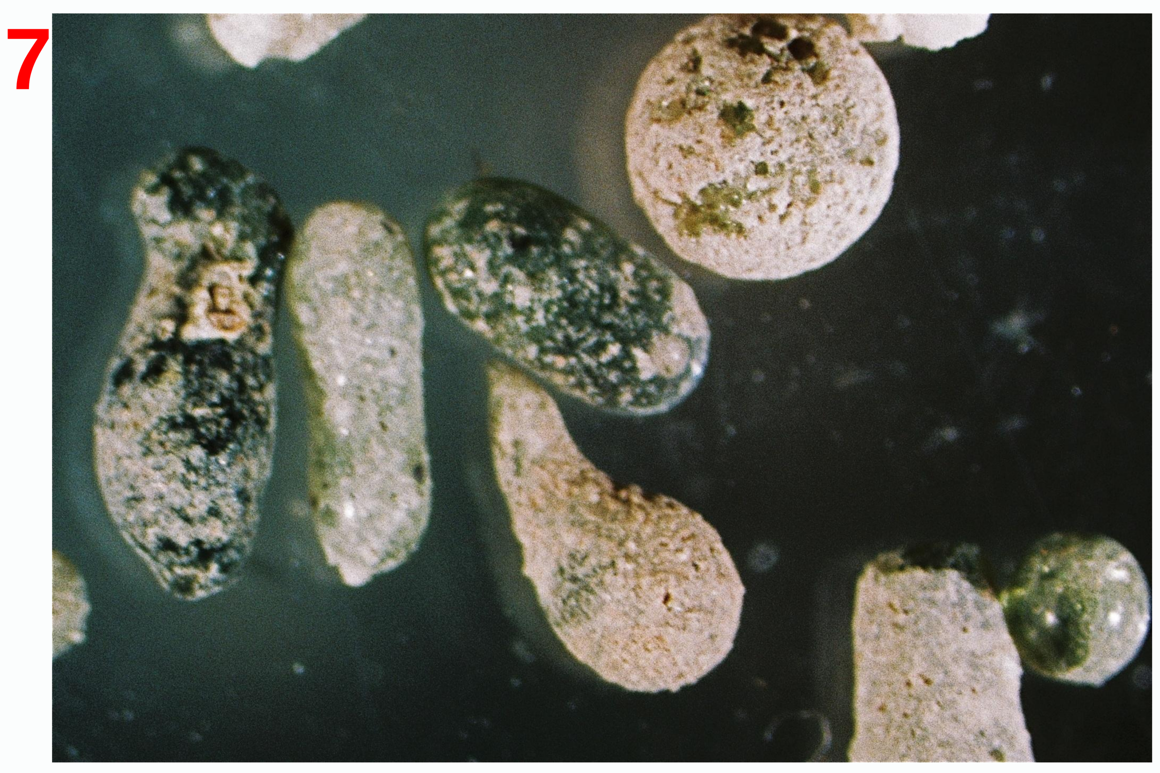

Figure 7. Trinitite glassy objects.

8