LETTER

Inconsistent redefining of the carbon spherule "impact" proxy

The recent article by Israde-Alcántara et al. (1) outlined a wide array of purported impact proxies from a lacustrine paleorecord in Lake Cuitzeo, Mexico. These findings were used to support the suggestion of a Younger Dryas (YD) impact event/s. Although most of the purported impact proxies have been described in previous publications (2, 3), this new work extended the range of such markers to Mexico. The article also allowed the proponents of the YD Impact Hypothesis [YDIH] to respond to the many critiques of the YDIH.

We wish to discuss Israde-Alcántara et al.'s (1) dismissal of Scott et al.'s (4) recent findings that the carbon spherules (CSp), a purported impact proxy from which nanodiamonds have been reported (1–3, 5), in fact represent charred fungal sclerotia. Israde-Alcántara et al. (1) claimed that the CSp from Cuitzeo and other Younger Dryas boundary sites have "smooth, glassy, highly reflective interiors with no evidence of filamentous structure observed in fungal sclerotia," showing images of one CSp that has a hollow interior matching this description (see their Figure S5). These new descriptions, however, are inconsistent with previous descriptions and figures of CSp in Firestone et al. (2) and Kennett et al. (3, 5). These authors describe CSp as having internal reticulate and/or well-organized honeycomb structures, with "interior vesicles that are typically a few micrometers in diameter" (3). All these original descriptions are perfectly consistent with the findings of Scott et al. (4) (Fig. 1 gives visual comparisons), who rigorously documented that modern charred fungal sclerotia match the characteristics of the Pleistocene CSp presented by Firestone et al. (2) and Kennett et al. (3, 5) on millimeter to nanometer scales. Coupled with this, the CSp described by Israde-Alcántara et al. (1) are smaller (20–160 μm, with an average diameter of 90 μm) than those in Firestone et al. (2), 150–2,500 μm, and Kennett et al. (3, 5), 400–1,500 μm, which are by contrast very consistent with size ranges of 200–2,000 μm described for modern fungal sclerotia by Scott et al. (4). Finally the presence of aluminosilicates (i.e., clays) within CSp does not rule out a biological source, particularly considering the CSp were processed only with water (1).

In addition to CSp, Israde-Alcántara et al. (1) also mentioned aciniform soot, a well-defined carbon proxy of burning. Perplexingly, no further description, evidence, or quantification of aciniform soot was attempted in either the main article or in the supplementary information (although a method for soot extraction was described); it is thus not possible to verify this claim.

To conclude, we note that a nontrivial number of the purported impact proxies and/or their allied interpretations originally presented in support of a YD extraterrestrial event (2) have either disappeared from the YDIH discourse or, like CSp, changed significantly from the original descriptions of the same evidence. We note with interest, for example, that two other forms of carbon evidence (which also purportedly contained impact-related nanodiamonds) put forward by proponents of the YDIH—glassy carbon and carbon "elongates" (2, 3, 5)—now seem to have joined the former.

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1. Israde-Alcántara I, et al. (2012) Evidence from central Mexico supporting the Younger Dryas extraterrestrial impact hypothesis. *Proc Natl Acad Sci USA* 109: E738–E747.
2. Firestone RB, et al. (2007) Evidence for an extraterrestrial impact 12,900 years ago that contributed to the megafaunal extinctions and the Younger Dryas cooling. *Proc Natl Acad Sci USA* 104:16016–16021.
3. Kennett DJ, et al. (2008) Wildfire and abrupt ecosystem disruption on California's Northern Channel Islands at the Ållerød–Younger Dryas boundary (13.0–12.9 ka). *Quat Sci Rev* 27:2530–2545.
4. Scott AC, et al. (2010) Fungus, not comet or catastrophe, accounts for carbonaceous spherules in the Younger Dryas "impact layer". *Geophys Res Lett* 37:L14302.
5. Kennett DJ, et al. (2009) Shock-synthesized hexagonal diamonds in Younger Dryas boundary sediments. *Proc Natl Acad Sci USA* 106:12623–12628.

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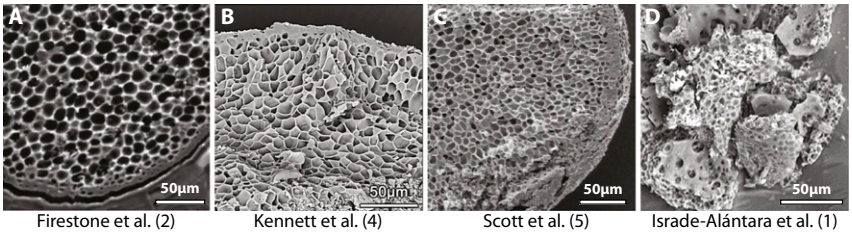

Fig. 1. SEM images of CSp and modern fungal sclerotia internal structures with source and year of publication. (*A*) Sectioned CSp from Bay T13, reproduced from ref. 2 (Figure 3*B* in ref. 2). (*B*) Sectioned CSp from Arlington Canyon, Santa Rosa Island, reproduced from ref. 5 (Figure S6*F* from ref. 5). (*C*) Sectioned modern fungal sclerotium of *Cenococcum geophilum* found within a burnt soil. Reproduced from ref. 4, by permission of American Geophysical Union. Copyright 2010 American Geophysical Union. (Figure 2*G* from ref. 4, but at a lower magnification.) (*D*) Broken CSp from Lake Cuitzeo that has a hollow interior with a smooth glassy surface, reproduced from ref. 1 (Fig. S5*B* from ref. 1).