



# Reply to Ives and Froese: Regarding the impact-related Younger Dryas boundary layer at Chobot site, Alberta, Canada

Ives and Froese (1) challenge the identification of the Chobot black mat layer at the Younger Dryas (YD) boundary (YDB), claiming that no black mats have been documented in western Canada (2). To the contrary, Haynes, a lead investigator of YD-age black mats, mapped two YD-age mat sites in western Canada (figure 1 in ref. 3): one ~200 km south of the Chobot site at Vermillion Lakes in Alberta (12,719 ± 156 cal BP) and another at the Niske site in Saskatchewan (12,748 ± 020 cal BP).

Furthermore, Ives and Froese (1) claim the Chobot black mat is simply an organic layer of “surface leaf litter and humic materials” with no evidence for a “black algal mat.” We do not claim that the mat is algal in origin (2), nor is that a requirement. Haynes (3) describes YD black mats as being “dark gray to black because of increased organic carbon (0.05–8%)” and that sometimes, the mats are algal, but, often, the mats are simply enriched in charcoal, humates, diatomite, and other organics. Nonalgal black mats are present at Folsom, NM (3); Arlington Canyon, CA (2, 3); Sheriden Cave, OH (2); Lommel, Belgium (2); and Abu Hureyra, Syria (2); as well as at the Chobot site (2).

Ives and Froese (1) further maintain that a reported date of 3,645 ± 020 <sup>14</sup>C y BP (4) indicates the layer is not the YDB. However, Firestone (4) argued that the date is invalid, as are many “problematic radiocarbon dates reported at other YDB-age sites,” and he discusses several reasons for the erroneous dates (4). In particular, because of the shallow depth of the site, the YDB layer is currently

penetrated by living plant roots and animal borrows and has been cryoturbated by past and present freeze–thaw cycles. Those factors best explain how younger charcoal moved downward, producing a date that is stratigraphically inconsistent with the associated Clovis points. Alternatively, the Clovis points may be reworked, as Ives and Froese (1) suggest, but that is inconsistent with the closely associated YDB proxy peaks, which have never been found outside the YDB in similar quantities.

In summary, we agree with Ives and Froese (1) that the Chobot site is challenging because it is undated. We also agree that some lithics at the site are non-Clovis, but Chobot has three acknowledged Clovis points, which are more than at many Clovis sites. The inferred YDB layer contains five key markers: Clovis points associated with a black mat, along with abundance peaks in magnetic spherules and carbon spherules, containing nanodiamonds (2, 5). Few to none of those markers are found in strata above or below the YDB layer at Chobot or other YDB sites. The evidence from Chobot may seem unpersuasive as a single site but is highly consistent with the multicontinental YDB record. Similar coeval marker peaks occur at ~30 dated YDB sites in 10 countries on four continents. Thus, the best explanation is that Chobot contains the YDB layer where indicated.

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**1** Ives JW, Froese D (2013) The Chobot site (Alberta, Canada) cannot provide evidence of a cosmic impact 12,800 y ago. *Proc Natl Acad Sci USA*, 10.1073/pnas.1312333110.

**2** Wittke JH, et al. (2013) Evidence for deposition of 10 million tonnes of impact spherules across four continents 12,800 y ago. *Proc Natl Acad Sci USA* 110(23):E2088–E2097.

**3** Haynes CV, Jr. (2008) Younger Dryas “black mats” and the Rancholabrean termination in North America. *Proc Natl Acad Sci USA* 105(18):6520–6525.

**4** Firestone RB (2009) The case for the Younger Dryas extraterrestrial impact event: Mammoth, megafauna, and Clovis extinction, 12,900 years ago. *J Cosmol* 2:256–285.

**5** Kennett DJ, et al. (2009) Nanodiamonds in the Younger Dryas boundary sediment layer. *Science* 323(5910):94.

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The authors declare no conflict of interest.

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