LETTER

Reply to Holliday and Boslough et al.: Synchroneity of widespread Bayesian-modeled ages supports Younger Dryas impact hypothesis

Holliday (1) rejects age-depth models for the Younger Dryas boundary layer (YDB) in Kennett et al. (2), claiming that they are incorrect for several reasons, including age reversals, high age uncertainties, and use of optically stimulated luminescence (OSL) dating. These same claims previously were presented in Meltzer et al. (3) and were discussed and refuted in Kennett et al. (2). These criticisms apply to nearly all dated archaeological and geological sequences, including the Odessa meteorite impact crater, where paradoxically, Holliday et al. (4) modeled an impact age using OSL dating (>70% of dates used) with large uncertainties (to >6,000 y) and age reversals (>40% of dates are reversals). Thus, Holliday (1) argues against a practice that he and many other researchers have used and continue to use today. In an ideal world, all dates would be in perfect chronological order with high accuracy and certainty, but such scenarios are rarely possible (2). It is because of such dating difficulties that Bayesian analysis is a powerful chronological tool, and is rapidly becoming the archaeological standard.

Holliday (1) also claims to "provide evidence for multiple horizons with 'impact proxies' at times other than the YDB." Those claims have been refuted in detail (2, 5–7). In every case, those contradictory studies have serious flaws, including: (*i*) correct protocols were not followed, and (*ii*) the evidence was not analyzed using electron microscopy, an essential requirement. Independent workers who followed the correct procedures (e.g., ref. 5) confirmed the presence of YDB impact proxies at multiple sites, with few to no proxies above and below. Contrary to Holliday's (1) claims, no interval other than the YDB layer in 23 widely separated stratigraphic profiles, spanning up to 50,000 y, contains the same broad assemblage of proxies (2).

Boslough et al. (8) question why Kennett et al. (2) did not create a Bayesian age-depth model for the Gainey site in Michigan. As previously explained (2), Bayesian analysis is most robust when the available dataset meets certain criteria, including having deeply stratified deposits with numerous dates bracketing the stratigraphic level of interest. Gainey, a site with near-surface, bioturbated deposits, does not meet those criteria, and so it was not modeled. Most importantly, all available dates are on a single stratum, making it impossible to create an age-depth model. Even so, the Gainey YDB layer contains thousands of high-temperature magnetic spherules, glassy spherules, and nanodiamonds, intermixed with thousands of Paleoindian lithics having a widely accepted age of ∼12,800 Cal B.P. (2, 7, 9). Previous studies concluded that the proxy-rich, lithics-rich stratum at Gainey is consistent with the YDB layer (7). We continue to support that conclusion.

Boslough et al. (8) also claim that their single young ^{14}C date (calibrated to 207 ± 87 Cal B.P.) proves that Gainey does not contain the YDB stratum. Because this young date was from carbon intermixed in the same stratum with Paleoindian lithics dating to ∼12,800 Cal B.P., the two ages are mutually exclusive, and one must be rejected. In this case, the 12,800-y-old lithics are indisputably in situ, making it certain that the younger ^{14}C date Boslough et al. (8) mention is on carbon that intruded from younger surficial deposits. Out-of-sequence ^{14}C dates are a common dating problem that is solved by discounting outlying young dates. Because Paleoindians were certainly not living at Gainey ∼200 y ago, this younger date cannot reasonably be used to reject Gainey as a YDB site.

We reaffirm the validity of the Bayesian statistical analyses in Kennett et al. (2) demonstrating that the age of the YDB layer on four continents is synchronous within an age range of 12,835–12,735 Cal B.P., within the confines of dating uncertainties (95% confidence interval). Only the YDB layer in stratigraphic sections at 23 sites contains abundance peaks in a variable assemblage of proxies, including magnetic and glassy impact-related spherules, high-temperature minerals and melt glass, nanodiamonds, carbon spherules, aciniform carbon, and osmium (e.g., refs. 2, 5–7, 9). The Bayesian-modeled YDB age range also overlaps that of an extraterrestrial platinum peak, independently identified in the Greenland ice sheet (2) that coincides unequivocally with the onset of the Younger Dryas cooling episode, supporting a causal connection between the Younger Dryas impact event and major climate change (2).

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