LETTER

Age models and the Younger Dryas Impact Hypothesis

Israde-Alcántara et al. (1) drew on interpretations of a core from Lake Cuitzeo, Mexico to support the Younger Dryas (YD) Impact Hypothesis. A key aspect of their study was identifying and dating the YD interval in the sediments. The authors stated that they recovered impact indicators from a 10-cm-thick zone dating to 12.9 kcal BP but provided no direct numerical age control or chronological uncertainties for this interval. Depending on the carbon sources, ^{14}C ages of bulk lake sediment can be offset by several centuries (2). However, even though the study used bulk ^{14}C dates, no offset was quantified. Dating of the section was accomplished by interpolating through >1 m of undated sediment, because the six dates in that interval were rejected. Even so, the rejected dates were in stratigraphic order, and there seems no a priori basis to exclude them. Their age model was anchored by a tephra layer identified as the Cieneguillas rhyolitic tephra, dated elsewhere as ~31 kcal BP (3), but no geochemical evidence was provided to support this tephra identification.

The age model of Israde-Alcántara et al. raises several concerns. First, we digitized their curve (Fig. 1) and found that their inferred YD event (2.82 m) starts at ~14.0 kcal BP, not at the accepted age of 12.9 kcal BP provided from Greenland ice cores. Second, a fifth-order polynomial through the midpoints of their dates (the model chosen by the authors) yields an age of ~15.0 kcal BP. Third, the authors calibrated their ^{14}C dates using the outdated calibration curve IntCal04 and CalPal-2007, whereas recalibration with the currently recommended IntCal09 curve (4) indicates offsets of up to several centuries. Fourth, the scatter of the dates and the low dating resolution (especially in the critical interval between 3.10- and 2.05-m depth where all dates were rejected as outliers) suggest other plausible age models than the one published. For example, a smooth spline gives a 95% age range of ca. 21.2–16.0 kcal BP for 2.82-m depth. Fifth, Israde-Alcántara et al. claimed that pollen events from other regional lakes support a YD age of their 2.82-m layer; however, those events were either dated using very few ^{14}C dates or simply through tuning them to the YD. In summary, the layer investigated by Israde-Alcántara et al. is not demonstrably or securely dated to the start of the YD, and indeed according to the evidence presented is most likely several millennia older.

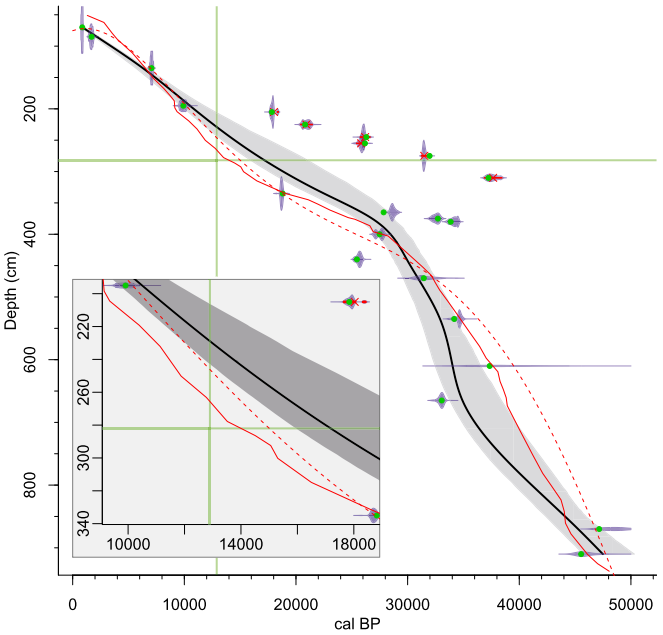

Fig. 1. Light green lines indicate the start of the YD (vertical) and the depth of the section identified as their initial YD event at 2.82 m by Israde-Alcántara et al. (1) (horizontal). Green dots indicate midpoints of IntCal04-CalPal–calibrated ^{14}C dates, and blue outlines show updated IntCal09-calibrated distributions. Dates with red crosses were considered outlying. Continuous red line is the age model digitized from figure 1 of Israde-Alcántara et al. (1), dashed red line is a fifth-order polynomial calculated through their IntCal04-CalPal–calibrated ^{14}C dates, black line with gray 95% confidence intervals shows a smooth spline using IntCal09 [smoothing parameter 0.6, produced using clam (5)]. Inset shows detail.

***Maarten Blaauw*[a,1], *Vance T. Holliday*[b], *Jacquelyn L. Gill*[c], *and Kathleen Nicoll*[d]**

[a]*School of Geography, Archaeology and Palaeoecology, Queen's University Belfast, Belfast BT7 1NN, United Kingdom;* [b]*School of Anthropology and Department of Geosciences, University of Arizona, Tucson, AZ 85721;* [c]*Department of Geography, University of Wisconsin–Madison, Madison, WI 53706; and* [d]*Department of Geography, University of Utah, Salt Lake City, UT 84112*

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. Björck S, Wohlfarth B (2001) ^{14}C chronostratigraphic techniques in paleolimnology. *Tracking Environmental Change Using Lake Sediments. Basin Analysis, Coring and Chronological Techniques. Developments in Palaeoenvironmental Research*, eds Last WM, Smol JP (Kluwer, Dordrecht), Vol 1, pp 205–245.
3. Pradal E, Robin C (1994) Long-lived magmatic phases at Los Azufres volcanic center, Mexico. *J Volcanol Geotherm Res* 63:201–215.
4. Reimer PJ, et al. (2009) IntCal09 and Marine09 radiocarbon age calibration curves, 0-50,000 years cal BP. *Radiocarbon* 51:1111–1150.
5. Blaauw M (2010) Methods and code for 'classical' age-modelling of radiocarbon sequences. *Quat Geochronol* 5:512–518.

Author contributions: M.B. and V.T.H. designed research, performed research, and analyzed data; and M.B., V.T.H., J.L.G., and K.N. wrote the paper.

The authors declare no conflict of interest.

[1]To whom correspondence should be addressed. E-mail: maarten.blaauw@qub.ac.uk.

www.pnas.org/cgi/doi/10.1073/pnas.1206143109