Quaternary Research

doi:10.1017/qua.2019.79

LETTER TO THE EDITOR

A multi-proxy study of changing environmental conditions in a Younger Dryas sequence in southwestern Manitoba, Canada — Comment on the paper by Teller et al., *Quaternary Research* Volume 93, 60–87

Ryan P. Breslawski*, Abigail E. Fisher, Ian A. Jorgeson

Department of Anthropology, Southern Methodist University, Dallas, Texas 75275-0235, USA
*Corresponding author e-mail address: rbreslawski@smu.edu (Ryan P. Breslawski)

(Received November 17, 2019; Accepted November 21, 2019)

Key words: Younger Dryas; Extraterrestrial impact; Manitoba; Glacial lake; Age–depth model

Teller et al. (2019) present radiocarbon analyses and paleoenvironmental data for a stratigraphic section at Lake Hind, Manitoba, Canada. The article expands on previous ones (Firestone et al., 2007; Kennett et al., 2015) arguing that extraterrestrial impact proxies are present at Lake Hind, comprising a Younger Dryas Boundary layer (YDB), and that this layer is synchronous with similar layers at other sites. However, we note three significant problems that cast doubt on their conclusions.

First, there are inconsistencies in the reporting of radiocarbon dates purported to be associated with the YDB. Teller et al. (2019) state that middle Subunit B1 corresponds to the deposition of YDB impact proxies. They further report that this layer yielded "one calibrated radiocarbon age of 12,630 ± 78 cal yr BP (PSUAMS-88701, 10,470 ± 35 ^{14}C yr BP)" (Teller et al., 2019, p. 68) (we believe that sample *PSU*AMS-88701 was intended to read *UCI*AMS-88701). They indicate that this sample is associated with the hypothesized event. Curiously, prior work indicates that sample UCIAMS-29317, with an age of 10,610 ± 35 ^{14}C yr BP, was also recovered "from directly within the proxy-rich YDB sample" (Kennett et al., 2015, p. E4349; see also p. SI23 from this reference). This is not mentioned by Teller et al. (2019), although they describe the date as originating somewhere from within middle Subunit B1. Additionally, Teller et al. (2019, p. 67) list UCIAMS-29317 as a bulk sediment sample, whereas Kennett et al. (2015, p. SI23) identify it as charcoal. Which sample material is correct? Did the proxy-rich YDB layer contain one or two samples?

Second, we note that the inferred age of the Lake Hind YDB layer is, in part, a result of decisions made in the construction of their age–depth model. Their inferred YDB age is reported as 13,059–12,682 cal yr BP (95% interval; Teller et al., 2019, Supplementary Table S2). Age–depth models can be fit with a variety of methods and software packages that will yield different results (Trachsel and Telford, 2017; Blaauw et al., 2018). As such, we also fit Bayesian age–depth models to the Lake Hind dates using alternative software, the Bchron (Haslett and Parnell, 2008) and rbacon (Blaauw and Christen, 2019) R packages. The code used to fit these models is available at https://github.com/taphocoenose/Lake-Hind.

Because Bchron uses sampling depth thickness, we used the dates from Table 1 of Teller et al. (2019). Following their description, we treated dates from upper and lower Subunit B1 (but not those from middle Subunit B1) and date UCIAMS-29317 as outliers. We assigned an outlier probability of 0.5 to these samples and the default outlier probability of 0.01 to the remaining samples. Unlike Teller et al.'s (2019) age–depth model, this Bchron model did not find that the start boundary of middle Subunit B1 (i.e., the YDB) was deposited synchronously with YDB layers at other sites (Supplementary Fig. S1). Rather, this modeled Lake Hind YDB age is ∼80–350 yr younger than the hypothesized Younger Dryas impact and ∼20–570 yr younger than Teller et al.'s (2019, Supplementary Table S2) modeled Lake Hind YDB age.

The rbacon age–depth model also infers a YDB age that is younger than the hypothesized Younger Dryas impact, in this case by ∼20–150 yr (Supplementary Fig. S2). We fit this model using the software's default parameter settings. The

Cite this article: Breslawski, R. P., Fisher, A. E., Jorgeson, I. A. 2020. A multi-proxy study of changing environmental conditions in a Younger Dryas sequence in southwestern Manitoba, Canada — Comment on the paper by Teller et al., *Quaternary Research* Volume 93, 60–87. *Quaternary Research* 94, 210–211. https://doi.org/10.1017/qua.2019.79

rbacon modeled boundary is between ~40 yr older and ~370 yr younger than the OxCal-modeled boundary. Notably, the model also identified 15 dates (58%) with 95% intervals that sit outside the 95% envelope of the model, indicating severe age-reversal issues. In sum, neither alternative software produced age–depth models supporting the hypothesis that the Lake Hind YDB age is synchronous with similar layers at other sites. They both suggest a younger age for the bottom of middle Subunit B1. Choosing between alternate age–depth models requires either well-justified support for the assumptions of a specific model or, if no one model is well justified, consideration of results from multiple plausibly justifiable models.

Finally, we question whether the melted magnetic spherules presented in this paper support the impact hypothesis. Previous papers (Firestone et al., 2007; Bunch et al., 2012; Israde-Alcantara et al., 2012) have argued that magnetic spherules are best explained by the high temperatures resulting from an extraterrestrial impact or airburst and are not produced by lower temperatures associated with noncatastrophic events. Other researchers have identified magnetic spherules in non-YDB contexts (Surovell, et al., 2009; Pinter et al., 2011; Pigati et al., 2012; Holliday et al., 2016), but Younger Dryas impact hypothesis proponents have countered that *melted* spherules are only found in YDB-age layers (LeCompte et al., 2012; Wittke et al., 2013; Teller et al., 2019). Thus, we are surprised that in the current contribution, only 2 of 11 *melted* magnetic spherules were recovered from the YDB layer at −33 to −30 cm. The other nine were recovered from a sample collected at a depth of −27 to −26 cm (12,510 ± 113 and 12,287 ± 111cal yr BP, ~200–550 yr younger than the age of the YDB in their age model). As such, the melted magnetic spherules appear to challenge their own conclusions and their previous claims that these objects are rare outside impact layers.

These problems call into question the Lake Hind chronology and YDB impact proxies. Given that the Younger Dryas impact hypothesis requires YDB layer synchroneity across multiple sites and that these layers should be defined by distinct impact proxies, it is critical that Lake Hind has a reliable chronology supported by accurate radiocarbon data and clear associations between spherules and the YDB layer.

ACKNOWLEDGMENTS

We thank David Meltzer for advice. This work was completed without funding.

SUPPLEMENTARY MATERIAL

The supplementary material for this article can be found at https://doi.org/10.1017/qua.2019.79.

REFERENCES

Blaauw, M., Christen, J.A., 2019. rbacon: Age-Depth Modelling using Bayesian Statistics. R Package Version 2.3.9.1. Accessed October 29, 2019. https://CRAN.R-project.org/package=rbacon.

Blaauw, M., Christen, J.A., Bennett, K.D., Reimer, P.J., 2018. Double the dates and go for Bayes—impacts of model choice, dating density and quality on chronologies. *Quaternary Science Reviews* 188, 58–66.

Bunch, T.E., Hermes, R.E., Moore, A.M.T., Kennett, D.J., Weaver, J.C., Wittke, J.H., DeCarli, P.S., *et al*., 2012. Very high-temperature impact melt products as evidence for cosmic airbursts and impacts 12,900 years ago. *Proceedings of the National Academy of Sciences USA* 109, E1903–E1912.

Firestone, R.B., West, A., Kennett, J., Becker, L., Bunch, T., Revay, Z., Schultz, P., Belgya, T., Kennett, D., Erlandson, J., 2007. Evidence for an extraterrestrial impact 12,900 years ago that contributed to the megafaunal extinctions and the Younger Dryas cooling. *Proceedings of the National Academy of Sciences USA* 104, 16016–16021.

Haslett, J., Parnell, A.C., 2008. A simple monotone process with application to radiocarbon-dated depth chronologies. *Journal of the Royal Statistical Society, Series C: Applied Statistics* 57, 399–418.

Holliday, V., Surovell, T., Johnson, E., 2016. A blind test of the Younger Dryas Impact Hypothesis. *PLoS ONE* 11, e0155470.

Israde-Alcantara, I., Bischoff, J.L., Dominguez-Vazquez, G., Li, H.-C., DeCarli, P.S., Bunch, T.E., Wittke, J.H., *et al*., 2012. Evidence from central Mexico supporting the Younger Dryas Extraterrestrial impact hypothesis. *Proceedings of the National Academy of Sciences USA* 109, E738–E747.

Kennett, J.P., Kennett, D.J., Culleton, B.J., Aura Tortosa, J.E., Bischoff, J.L., Bunch, T.E., Daniel, I.R., *et al*., 2015. Bayesian chronological analyses consistent with synchronous age of 12,835–12,735 cal B.P. for Younger Dryas boundary on four continents. *Proceedings of the National Academy of Sciences USA* 112, E4344–4353.

LeCompte, M.A., Goodyear, A.C., Demitroff, M.N., Batchelor, D., Vogel, E.K., Mooney, C., Rock, B.N., Seidel, A.W., 2012. Independent evaluation of conflicting microspherule results from different investigations of the Younger Dryas impact hypothesis. *Proceedings of the National Academy of Sciences USA* 109, E2960–E2969.

Pigati, J.S., Latorre, C., Rech, J.A., Betancourt, J.L., Martinez, K.E., Budahn, J.R., 2012. Accumulation of impact markers in desert wetlands and implications for the Younger Dryas impact hypothesis. *Proceedings of the National Academy of Sciences USA* 109, 7208–7212.

Pinter, N., Scott, A.C., Daulton, T.L., Podoll, A., Koeberl, C., Anderson, R.S., Ishman, S.E., 2011. The Younger Dryas impact hypothesis: a requiem. *Earth-Science Reviews* 106, 247–264.

Surovell, T.A., Holliday, V.T., Gingerich, J.A.M., Ketron, C., Haynes, C.V., Hilman, I., Wagner, D.P., Johnson, E., Claeys, P., 2009. An independent evaluation of the Younger Dryas extraterrestrial impact hypothesis. *Proceedings of the National Academy of Sciences USA* 106, 18155–18158.

Teller, J., Boyd, M., LeCompte, M., Kennett, J., West, A., Telka, A., Diaz, A., *et al*., 2019. A multi-proxy study of changing environmental conditions in a Younger Dryas sequence in southwestern Manitoba, Canada, and evidence for an extraterrestrial event. *Quaternary Research* 93, 60–87. https://doi.org/10.1017/qua.2019.46.

Trachsel, M., Telford, R.J., 2017. All age-depth models are wrong, but are getting better. *The Holocene* 27, 860–869.

Wittke, J.H., Weaver, J.C., Bunch, T.E., Kennett, J.P., Kennett, D.J., Moore, A.M.T., Hillman, G.C., *et al*., 2013. Evidence for deposition of 10 million tonnes of impact spherules across four continents 12,800 y ago. *Proceedings of the National Academy of Sciences USA* 110, E2088–E2097.