Quaternary Research

doi:10.1017/qua.2019.91

LETTER TO THE EDITOR

A multi-proxy study of changing environmental conditions in a Younger Dryas sequence in southwestern Manitoba, Canada: Response to comments by Breslawski et al., *Quaternary Research* Volume 94, 210–211

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(Received December 18, 2019; Accepted December 19, 2019)

Breslawski et al. (2020) claim to have found inconsistencies in Teller et al. (2019) in the reporting of radiocarbon dates associated with the Younger Dryas Boundary (YDB) layer. We address those points one by one below. Bolded sentences are directly quoted from Breslawski et al. (2019).

We believe that sample *PSU*AMS-88701 was intended to read *UCI*AMS-88701.

Breslawski et al. (2020) are correct. Although UCIAMS-88701 is correctly reported in Table 1 of Teller et al. (2019), the lab number for the same radiocarbon date is incorrectly listed on p. 68 as PSUAMS-8870. However, the radiocarbon date is listed correctly in both places, so there is no impact on the age-depth model.

Additionally, Teller et al. (2019, p. 67) list UCIAMS-29317 as a bulk sediment sample, whereas Kennett et al. (2015, SI-23) identify it as charcoal. Which sample material is correct?

The sample material is correctly described as "bulk sediment" in Table 1 of Teller et al. (2019).

Did the proxy-rich YDB layer contain one or two samples?

We examined six samples from the YDB layer from -30 to -33 cm, as shown in column F of Supplementary Table 6. Table 1 shows that we acquired radiocarbon dates on four of those six samples.

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. SI-23 from this reference). This is not mentioned by Teller et al. (2019).

This comment by Breslawski et al. is unclear, because the date in question is mentioned in Supplementary Table 2 as part of the YDB layer for the age-depth model. Part of the confusion by Breslawski et al. may result from the fact that Teller et al. acquired five *new* YDB layer samples, whereas Kennett et al. (2015) had access to only one sample at that time.

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.

Breslawski et al. express concern that, for their two alternative models, one model is at least ~20 yr younger and the other is at least ~80 yr younger than the modeled YDB age of 12,835–12,735 cal yr BP at 95% confidence interval (CI) reported by Kennett et al. (2015). We think their concern may result from an unjustified belief in the accuracy and precision of age–depth modeling. For example, discrepancies of up to 400 yr between radiocarbon age-depth models and varve layer counting were reported in a paper by Telford et al. (2004) titled "All age–depth models are wrong: But how badly?"

Cite this article: West, A., Kennett, J., Teller, J., Boyd, M. 2020. A multi-proxy study of changing environmental conditions in a Younger Dryas sequence in southwestern Manitoba, Canada: Response to comments by Breslawski et al., *Quaternary Research* Volume 94, 210–211. *Quaternary Research* 94, 212–213. https://doi.org/10.1017/qua.2019.91

All age–depth models are simply probabilistic approximations that are likely to be inaccurate in most natural systems, given the fact that sedimentary deposition is variable and complex, and past rates are essentially unknowable with high certainty. All three Lake Hind models mentioned by Breslawski et al. differ from one another, and all are almost certainly inaccurate to some degree. Thus, differences of ~20–80 yr are statistically insignificant.

Furthermore, Breslawski et al. assume an unwarranted precision and accuracy for the radiocarbon dates used to generate the age–depth models. While it is true that modern measurements of radiocarbon ages themselves are considered to have a high degree of certainty, that certainty applies only to the ages of the *material dated* but does not apply to the *ages of deposition* of the enclosing sediment. Dated *in situ* materials are easily moved around by bioturbation and/or reworked by erosion, frequently making the enclosing sediments appear either younger or older than they actually are. Teller et al. (2019) and others discuss this problem. Breslawski et al. (2020) identified 15 dates (58% of the 25 dates we used) that sit outside the 95% envelope, and conclude that they indicate "severe age reversal issues." There is simply far too much uncertainty in radiocarbon dating and age–depth modeling for Breslawski et al. to claim that a precision of ± 20 years is required in order for our model to be correct.

Telford et al. (2004) concluded that the age of any short-term event is best constrained by using dates from directly within the event layer. One radiocarbon age within the YDB layer of Lake Hind at -31 to -33 cm is 12,732 ± 23 cal yr BP (95% CI range: 12,765–12709 cal yr BP; PSUAMS1572). Acquired on 10 seeds (among the most reliable radiocarbon material) of *Carex rostrata* (bottle sedge), this age overlaps the published YDB age range of 12,835–12,735 cal yr BP (Kennett et al., 2015), suggesting that the age-depth model in Teller et al. (2019) is correct.

Other researchers have identified magnetic spherules in non-YDB contexts…but proponents have countered that *melted* spherules are only found in YDB-age layers…As such, the melted magnetic spherules appear to challenge their own conclusions and their previous claims that these objects are rare outside of impact layers.

Previous YDB papers have never claimed that melted spherules are found *only* in YDB-age layers. For example, Wittke et al. (2013, p. 4) wrote: "At stratigraphic levels more distant above or below the YDB, spherules were absent or rare, indicating that the influx of normal cosmic spherules was negligible. *Layers adjacent to the YDB typically contained lower concentrations of spherules, whose presence is most likely due to redeposition and/or bioturbation from the YDB layer*" (emphasis ours). To emphasize, spherules are "typically" found outside of the YDB layers and adjacent sediment.

Redeposition was identified as a major problem in Lake Hind by Teller et al. (2019, p. 66), who stated "deposition of subunit B1 may have coincided with turbulent hydrological conditions in the Lake Hind basin that produced erosion and redeposition." As discussed in the paper, sedimentological and geomorphological evidence, as well as the geological history of the region, provide a framework for events surrounding the YDB event, and offer an explanation not only for the anomalous ages of some radiocarbon dates, but for the distribution of melted spherules, platinum, iridium, macrofossils, and charcoal; some of these probably were transported from "upstream in the watershed and redeposited in Lake Hind during a turbid lake phase" (Teller et al., 2019, p. 71). These turbulent conditions during deglaciation resulted in episodic redeposition that continued for hundreds of years following the YDB impact event.

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