PNAS LETTER

Reply to Weiss: Tree-ring stable oxygen isotopes suggest an increase in Asian monsoon rainfall at 4.2 ka BP

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Weiss (1) raises interesting points on our article (2). He observes that the Delingha tree-ring $\delta^{18}O$ record matches KM-A speleothem $\delta^{18}O$ record from the Mawmluh Cave in India, that defines the 4.2-ka event's global-type stratum (3). This event is also manifested as a multicentennial drought in the Iranian Gol-E-Zard speleothem record (4). Weiss further argues that the Delingha record is also consistent with the 4.2-ka anomaly recorded in low-resolution proxy records from northern China despite inherent limitations of these proxies.

Our Delingha $\delta^{18}O$ record shows a persistent transition following gradual drying that, instead, occurred during 4 ka to 3.5 ka. This is associated with generally wet conditions *ca*. 4.5 ka to 4.0 ka (Fig. 1), in contrast with the KM-A $\delta^{18}O$ record. We thus do not observe such a close correspondence between the two records in Weiss's (1) figure 1A and want to exercise caution in drawing conclusions based on a limited number of proxy records with considerable age uncertainties.

To complement the four speleothem $\delta^{18}O$ records presented by Weiss (1), we assembled a total of 24 additional records from eastern Asia and India covering Holocene hydroclimate dynamics. In western China, only one out of three speleothem records from Kesang cave, KS06-A-H (5), has a good dating accuracy to resolve centennial drought anomalies and shows dry climate conditions at 4.2 ka (see ref. 6). In northern China, all records except Dongshiya and Zhenzhu indicate an anomalously wet interval around 4.2 ka (6). Both exceptions are characterized by few and uncertain dating points and a coarse sampling resolution (6). In southern China, investigating the full set of records yields no clear picture (6). However, a composite based on six high-precision (Fig. 1) records shows generally wet conditions at 4.2 ka.

In India, two more-recent replicated speleothem $\delta^{18}O$ records from Mawmluh Cave with exceptional chronologic constraints and high sampling resolution have challenged the interpretation of KM-A (6). One of these records, ML.1, shows wet conditions at 4.1 ka to 4.0 ka (7), and the subsequent long-term multicentennial drying is consistent with our Delingha $\delta^{18}O$ record and with a long-term drying trend in a recent high-resolution speleothem $\delta^{18}O$ record from Sahiya Cave in northern India (8).

In conclusion, our well-replicated Delingha $\delta^{18}O$ record does not support a significant hydroclimate transition in our study region around 4.2 ka, or the notion that this rapid climate deterioration should be regarded as generalized climatic transition from the Middle to Late Holocene. There is the need for further development of accurate, replicated, and high-resolution proxy data, based on dense sampling, a mechanistic understanding of climatic controls, and representative chronological control points to elucidate the spatial–temporal dynamics of Holocene climate and cultural responses. Our Delingha $\delta^{18}O$ record makes considerable progress toward those aims.

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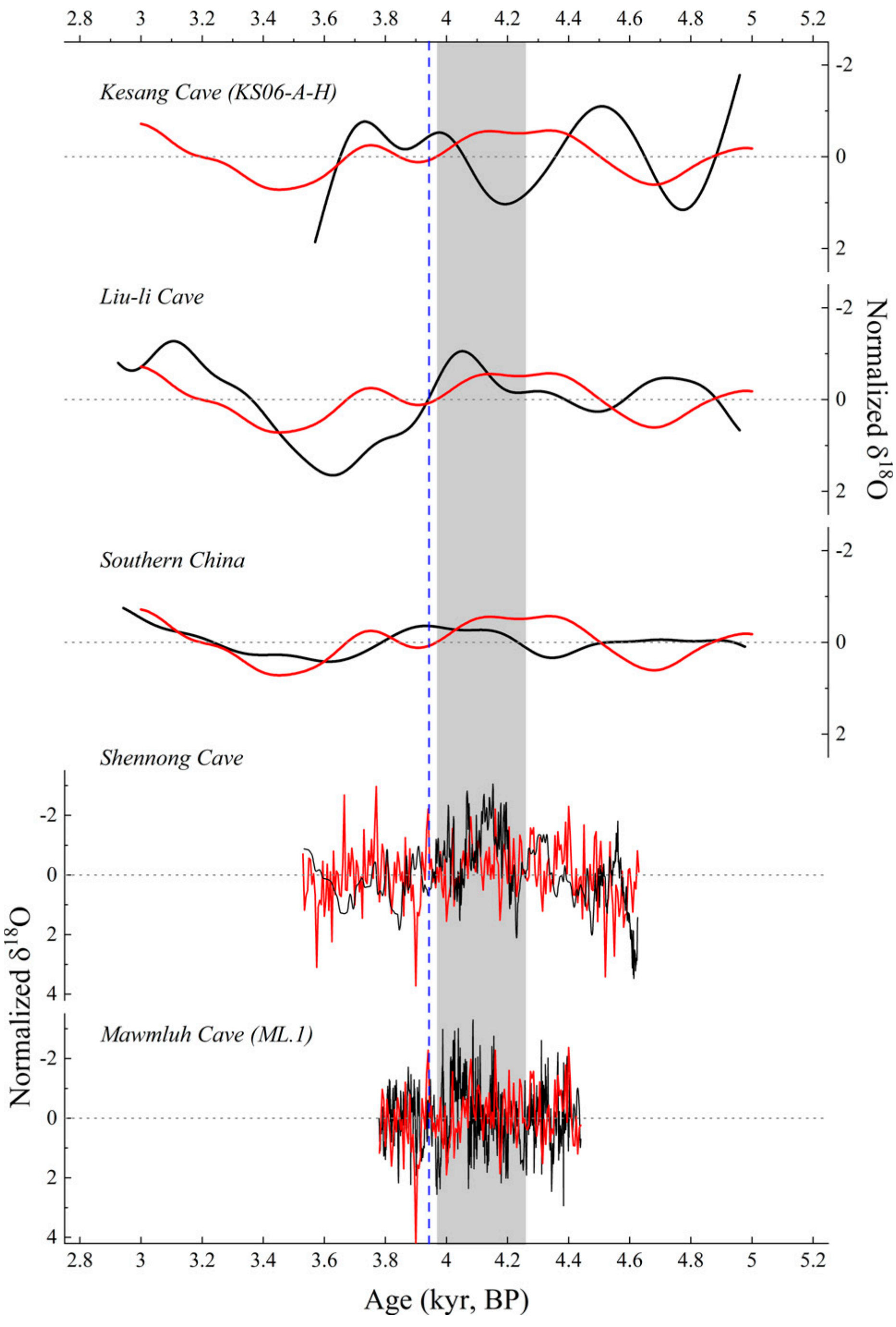

Fig. 1. The Delingha tree-ring δ^{18}O record (red line) and normalized speleothem δ^{18}O records collected from different parts of continental Asia spanning 5 ka to 3 ka. To place the 4.2-ka event in high-resolution and high-precision context, we constrained our analyses to speleothem records with coverage of 5 ka to 3 ka. A regional composite for southern China is shown, which is derived by averaging the six speleothem δ^{18}O series from Dongge Cave, Xianglong Cave, Wuya Cave, Sanbao Cave 43, Heshang Cave, and Shennong Cave using the Z-score method. Each of the six speleothem records has a temporal resolution better than 20 y, at least five U-Th ages, and dating precision higher than the 60-y average age error (2σ) in the 5- to 3-ka interval. Prior to averaging, each of the six records is first linearly interpolated annually, and then their long-term linear trends in the common period 5 ka to 3 ka are removed to highlight climate fluctuations on multidecadal to centennial timescales before normalization. See ref. 6 for details about each stalagmite record employed in the calculation. The Liu-li Cave in northern China and Kesang Cave (KS06-A-H) in western China speleothem δ^{18}O records are intentionally included for comparison in that both records have a dating point around 4.2 ka (6). The 100-point low-pass filters are shown for Kesang Cave (KS06-A-H), Liu-li Cave, and southern China records. The Shennong Cave and Mawmluh Cave (ML.1) speleothem δ^{18}O records have biannual and subannual resolution, and, therefore, we plot their unsmoothed series for comparison. All horizontal lines represent the long-term average calculated over the common period 5 ka to 3 ka. The vertical dashed blue line indicates the Middle to Late Holocene transition as defined by the Delingha δ^{18}O record via trend-point analysis (2). The gray bar covers the period 3.97 ka to 4.26 ka that is demonstrated as the 4.2-ka event in the midlatitudes of the Northern Hemisphere by the Iranian Gol-E-Zard speleothem record (4).

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