

Reply to Jaffe et al.:

## Paleoscience precision in an archeological or historical context

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Jaffe et al. (1) present some of the many challenges faced in attempting to integrate climate science and archeological records. We accept that these challenges exist, and thank the authors for their comments.

Our response to the four points made by Jaffe et al. (1) follows:

- a) Our study (2) provides evidence of aridity in the Mesopotamia region 4.2 kyr ago, particularly evidence for a regional ~300-y arid period and a much more precise age for the onset of this period [ $4.26 \pm 0.07$  (1 $\sigma$ ) ka] than was previously available. We stress that we do not confirm or deny climate change to be the cause of the termination of the Akkadian Empire (2), but that our record reveals a significant coincidence between the timing of settlement abandonment at Tell Leilan in northern Mesopotamia [ $4.19 \pm 0.02$  (1 $\sigma$ ) ka] (3) and the onset of the now precisely dated abrupt dust event, as well as the strikingly similar duration both of the abandoned settlements at this site and of the arid period. Our data support the possibility of a relation between the two in this instance, and we conclude that settlements in marginal areas in this region were vulnerable to variations in aridity (2).
- b) An important aspect of our study is that it demonstrates the regional nature of aridity 4.2 kyr ago. Although our site is, as Jaffe et al. state, ~800 km from Tell Leilan, the dust that our site records is sourced from the west: from northern Iraq and northeastern Syria where Tell Leilan is located. Our site complements climate records to the west of Tell Leilan (the Eastern Mediterranean and the Red Sea) and to the south (the Gulf of Oman) that indicate aridity at this time, confirming arid conditions across the broad region.
- c) Although our record provides the most precise assessment yet for the timing of aridity, there is, of course, uncertainty remaining in the age. At the precision we have achieved, however, we stand by the statement that the timing of the onset of the period of aridity is statistically indistinguishable from the timing of the urban settlement abandonment at Tell Leilan in north Mesopotamia (3).
- d) We did not seek to make any general point in our paper that aridity causes societal collapse. We appreciate that such socio-political changes can have a myriad of causes. Our analysis focuses specifically on the temporal relationship between the onset of an arid period and the coincident transformation of settlements in north Mesopotamia that were possibly in locations that were vulnerable to climate variability. Our record does not extend to the period discussed by Jaffe et al. (1) in this fourth point.

In closing, we emphasize Jaffe et al.'s (1) identification of the importance of achieving high-precision chronologies for archeological change in order to better complement the precise chronologies for climate change that stalagmite studies, such as Carolin et al.'s (2), are now able to provide.

1. Jaffe Y et al. (2019) Improving integration in societal consequences to climate change. *Proc Natl Acad Sci USA*.
2. Carolin SA, et al. (2019) Precise timing of abrupt increase in dust activity in the Middle East coincident with 4.2 ka social change. *Proc Natl Acad Sci USA* 116:67-72.
3. Weiss H, et al. (2012) Tell Leilan Akkadian imperialization, collapse, and short-lived reoccupation defined by high-resolution radiocarbon dating. *Seven Generations Since the Fall of Akkad*, ed Weiss H (Harrassowitz Verlag, Wiesbaden, Germany).

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