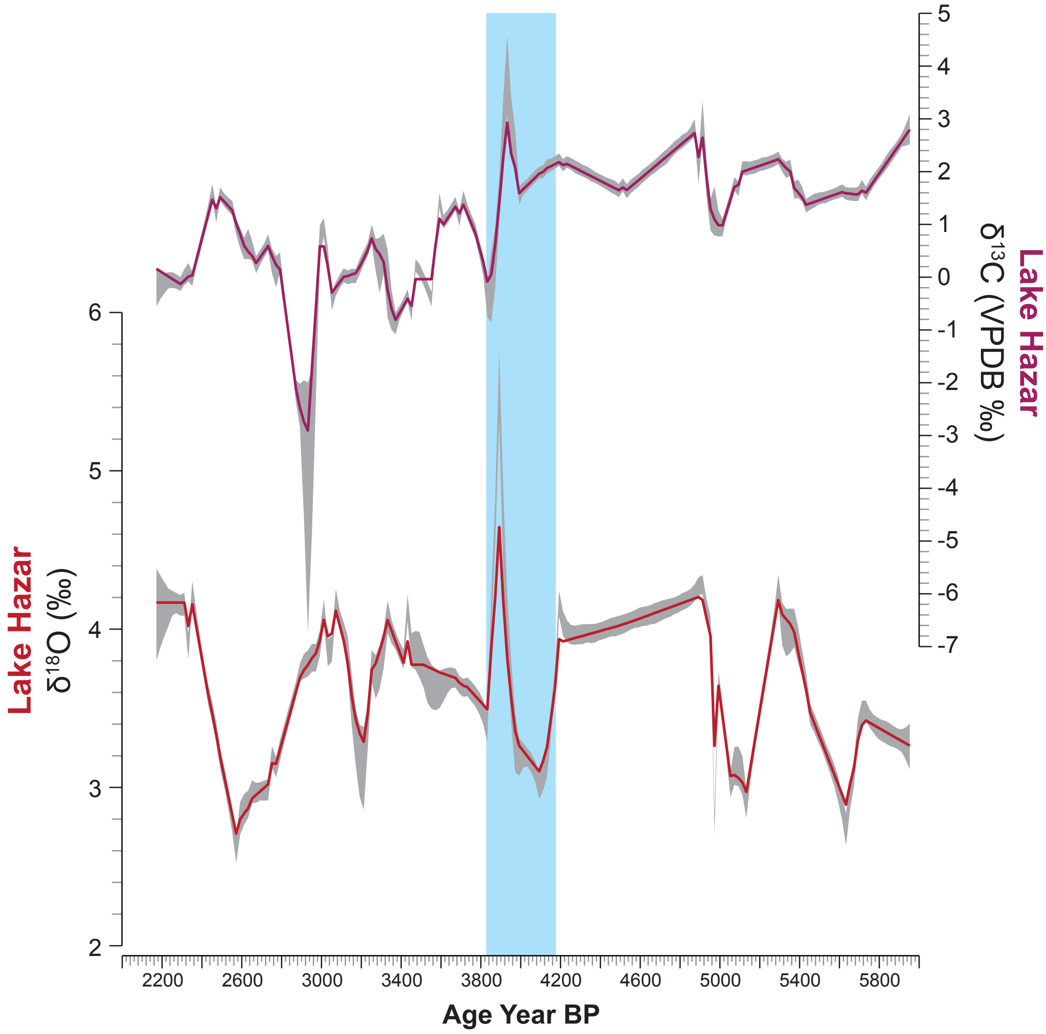

Fig. 2 Lake Hazar δ^{13}C and δ^{18}O at 4.2 ka BP **Weiss 2019 CP**

Karl Popper, Imre Lakatos, and the 4.2 ka BP event in the northern North Atlantic, Anatolia and the Indus

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What do we learn from Bradley and Bakke (2019)?

Bradley and Bakke (2019) state, “A review of paleoceanographic and terrestrial paleoclimatic data from around the northern North Atlantic reveals no compelling evidence for a significant climatic anomaly at ~4.2ka B.P.”, based upon their evaluation of their sample of northern North Atlantic proxies publications. They did not, however, consider about 50 available and relevant high resolution proxies, most of which document abrupt 4.2 ka BP events in Svalbard, Norway, Sweden, Denmark, Faroe Islands, Iceland, Greenland, and Ellesmere Island, and their proposed article, therefore, “does not approach the consensual standards for science publication” (Weiss 2019). Ön et al. (2019) proclaim jejunely that good science includes all data, that which supports and that which falsifies a theory, and remind us that Karl Popper (1962) claimed falsifiability as the test of scientific verisimilitude and veracity -- though Kuhn (1962: 77) had advised, “No process yet disclosed by the historical study of scientific development at all resembles the methodological stereotype of falsification by direct comparison with nature.” Similarly, Imre Lakatos (1978) famously revisited Popper’s claim with his “Methodology of Scientific Research Programmes,” pointing out that Popper’s criterion is too restrictive and would invalidate much of everyday scientific practice. Popper’s falsification demarcation has since been challenged and dismissed repeatedly (e.g., Hansson, 2006).

Skewed and truncated sampling meets the science standards of neither Popper nor Lakatos. Bradley and Bakke (2019) show it is easy to falsify a scientific claim by ignoring all the positive evidence. Surely, a meta-analytic study is one desideratum for further 4.2 ka BP event study but, of course, the selection criteria remain labile.

What do we learn from Lake Hazar, Anatolia?

The northern North Atlantic region is a small, but intensively studied, part of the Eurasian climate systems that are driven by the westerlies, the Indian Monsoon and the East Asian Monsoon. Ön et al (2018) believe that their Hazar Lake, Turkey sediment core disproves the 4.2-3.9 ka BP megadrought observations recorded globally, including in west Asia and its Anatolian plateau (Turkey). That is, Ön et al., (2018) believe they have provided the Anatolian Popperian falsifiability test for 4.2-3.9 ka BP megadrought across west Asia.

Fig. 1 lists the twelve Anatolian paleoclimate proxies for the 4.2 ka BP event. Two of the twelve proxy analyses report wet conditions at 4.2 ka BP. Sofular Cave (Göktürk et al., 2011) is, however, not a proxy for the Mediterranean westerlies; it represents the unique situation of the Black Sea and its intrusive, micro-region, northern precipitation. The only westerlies proxy analysis publication for Anatolia that presents a wet 4.2 ka BP period is the Ön et al (2018) Hazar Lake study that statistically analyses XRF data. The Hazar Lake sediment core, however, (a) has a sampling resolution of 175 years, (b) is constrained by two calibrated radiocarbon dates separated by four to five thousand years, and (c) is misrepresented by Ön et al., (2018). The $\delta^{13}C$ and $\delta^{18}O$ values at Lake Hazar record the 4.2 ka BP abrupt megadrought event (Fig. 2) – despite their study's poor resolution. In central Anatolia, the 4.2 ka BP event is recorded at Nar Gölü with 5 year sampling resolution (Dean et al., 2015), correcting the earlier Roberts et al. (2001) publication. The Anatolian 4.2 ka BP event data listed in Fig. 1 are sandwiched between the westerlies' 4.2 ka BP event proxies at the Mavri Trypa coastal Peloponnesian Greece speleothem, sampling resolution 5 years (Finné et al., 2017), the Beirut speleothem at Jeita Cave, sampling resolution 7 years (Cheng et al., 2015), and the Iranian plateau Gol-e Zard speleothem, sampling resolution 2-15 years (Carolin et al., 2019).

What have we already learned about the Mawmluh Cave speleothems and the Indian Summer Monsoon?

Ön et al. (2019) similarly claim that the very high resolution Mawmluh Cave speleothems' 4.2 ka BP events (Berkelhammer et al 2013; Kathayat et al 2018) need be subject to falsifiability testing. That testing has already been done. The Mawmluh Cave speleothem proxies are the product not of the westerlies, but the Indian Summer Monsoon. The six published ISM proxy studies providing high resolution 4.2 ka BP megadrought events are Staubwasser et al., 2003, Dixit et al., 2014; Nakamura et al., 2016, Dixit et al., 2018; Giosan et al., 2018; and Giesche et al., 2019. The westerlies and the ISM were synchronously and abruptly diminished, displaced, and/or diverted at 4.2 ka BP. So, too, of course, were the East Asian, Indonesian-Australian, African, North American and South American monsoonal systems, extending even to Antarctica (Weiss 2016).

References

Berkelhammer, M., Sinha, A., Stott, L., Cheng, H., Pausata, F.S.R., Yoshimura, K.: An Abrupt Shift in the Indian Monsoon 4000 Years Ago. Climates, Landscapes, and Civilizations, Geophysical Monograph Series 198, American Geophysical Union.10.1029/2012GM001207, 2012.

Boyer, P., Roberts, N., and Baird, D.: Holocene environment and settlement on the Çarşamba alluvial fan, south-central Turkey: Integrating geoarchaeology and archaeological field survey, Geoarchaeology, 21, 675-698, 2006.

Bradley, R. and Bakke, J.: Is there evidence for a 4.2 ka BP event in the northern North Atlantic region?, Clim. Past Discuss., https://doi.org/10.5194/cp-2018-162, in review, 2019.

Carolin, Stacy A., Walker, Richard T., Day, Christopher C., Ersek, Vasile, Sloan, R. Alastair, Dee, Michael W., Talebian, Morteza, Henderson, Gideon M.: 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, 10.1073/pnas.1808103115, 2019.

Cheng, H., Sinha, A., Verheyden, S., Nader, F. H., Li, X. L., Zhang, P. Z., Yin, J. J., Yi, L., Peng, Y. B., Rao, Z. G., Ning, Y. F., and Edwards, R. L.: The climate variability in northern Levant over the past 20,000 years, Geophys Res Lett, 42, 8641-8650, 2015.

Dean, J. R., Jones, M. D., Leng, M. J., Noble, S. R., Metcalfe, S. E., Sloane, H. J., Sahy, D., Eastwood, W. J., and Roberts, C. N.: Eastern Mediterranean hydroclimate over the late glacial and Holocene, reconstructed from the sediments of Nar lake, central Turkey, using stable isotopes and carbonate mineralogy, Quaternary Sci Rev, 124, 162-174, 2015.

Dixit, Y., Hodell, D. A., Giesche, A., Tandon, S. K., Gazquez, F., Saini, H. S., Skinner, L. C., Mujtaba, S. A. I., Pawar, V., Singh, R. N., and Petrie, C. A.: Intensified summer monsoon and the urbanization of Indus Civilization in northwest India, Sci Rep, 8, 4225, 2018.

Dixit, Y., Hodell, D. A., and Petrie, C. A.: Abrupt weakening of the summer monsoon in northwest India 4100 yr ago, Geology, 42, 339-342, 2014.

Filikci, B., Eriş, K. K., Çağatay, N., Sabuncu, A., and Polonia, A.: Late glacial to Holocene water level and climate changes in the Gulf of Gemlik, Sea of Marmara: evidence from multi-proxy data, Geo-Mar Lett, 37, 501-513, 2017.

Finné, Martin, Holmgren, Karen, Shen, C. C., Hu, H. M., Boyd, M., and Stocker, S.:Late Bronze Age climate change and the destruction of the Mycenaean Palace of Nestor at Pylos, PLoS One, 12, e0189447, 2017.

Giesche, Alena, Staubwasser, Michael, Petrie, Cameron A., Hodell, David A.: Re-examining the 4.2 ka BP event in foraminifer isotope records from the Indus River delta in the Arabian Sea, Clim. Past, 15, 73-90, https://doi.org/10.5194/cp-15-73-2019, 2019.

Giosan, Liviu, Orsi, William D., Coolen, Marco, Wuchter, Cornelia, Dunlea, Anne G., Thirumalai, Kaustub, Munoz, Samuel E., Clift, Peter D., Donnelly, Jeffrey P., Galy, Valier, Fuller, Dorian Q.: Neoglacial Climate Anomalies and the Harappan 1 Metamorphosis: Clim. Past, 14, 1669-1686, https://doi.org/10.5194/cp-14-1669-2018, 2018

Göktürk, O. M., Fleitmann, D., Badertscher, S., Cheng, H., Edwards, R. L., Leuenberger, M., Fankhauser, A., Tüysüz, O., and Kramers, J.: Climate on the southern Black Sea coast during the Holocene: implications from the Sofular Cave record, Quaternary Sci Rev, 30, 2433-2445, 2011.

Göktürk. O.M.: Climate in the Eastern Mediterranean through the Holocene inferred from Turkish stalagmites. Inauguraldissertation, Universität Bern, 2011.

Hansson, Sven Ove: Falsificationism Falsified, Foundations of Science, 11, 275-286, 2006.

Kathayat, G, Cheng, H., Sinha, A., Berkelhammer, M., Zhang, H., Duan, P., Li, H., Li, X., Ning, Y., and Edwards, R. L.: Timing and Structure of the 4.2 ka BP Event in the Indian Summer Monsoon

Domain from an Annually-Resolved Speleothem Record from Northeast India, Clim. Past, 14, 1869-1879, 2018.

Kuhn, Thomas: The Structure of Scientific Revolutions, Chicago, University of Chicago Press, 1962.

Kuzucuoğlu, C., Dörfler, W., Kunesch, S., and Goupille, F.: Mid- to late-Holocene climate change in central Turkey: The Tecer Lake record, The Holocene, 21, 173-188, 2011.

Lakatos, Imre: The Methodology of Scientific Research Programmes (Philosophical Papers: Volume 1), J. Worrall and G. Currie, (Eds.), Cambridge: Cambridge University Press, 1978.

Lemcke, G. and Sturm, M.: δ18O and Trace Element Measurements as Proxy for the Reconstruction of Climate Changes at Lake Van (Turkey): Preliminary Results. In: Third Millennium BC Climate Change and Old World Collapse., Dalfes H.N., K. G., Weiss H (Ed.), NATO ASI Series, 1: Global Environmental Change, Springer, Berlin, Heidelberg, 653-678, 1997.

Leng, M. J., Jones, M. D., Frogley, M. R., Eastwood, W. J., Kendrick, C. P., and Roberts, C. N.: Detrital carbonate influences on bulk oxygen and carbon isotope composition of lacustrine sediments from the Mediterranean, Global Planet Change, 71, 175-182, 2010.

Nakamura, A., Yokoyama, Y., Maemoku, H., Yagi, H., Okamura, M., Matsuoka, H., Miyake, N., Osada, T., Adhikari, D. P., Dangol, V., Ikehara, M., Miyairi, Y., and Matsuzaki, H.: Weak monsoon event at 4.2 ka recorded in sediment from Lake Rara, Himalayas, Quatern Int, 397, 349-359, 2016.

Ön, Z. B., Akçer-Ön, S., Özeren, M. S., Eriş, K. K., Greaves, A. M., and Çağatay, M. N.: Climate proxies for the last 17.3 ka from Lake Hazar (Eastern Anatolia), extracted by independent component analysis of μ -XRF data, Quatern Int, 486, 17-28, 2018.

Ön, Z. Bora, Greaves, Alan M., Akcer-Ön, Sena, Ozeren, M. Sinan: Comment on H. Weiss' review of "Is there evidence for a 4.2 ka B.P. event in the northern North Atlantic region?", Clim. Past Discuss., https://doi.org/10.5194/cp-2018-162-SC2, 2019.

Popper, Karl: Conjectures and refutations. The growth of scientific knowledge, New York, Basic Books, 1962.

Pustovoytov, K., Schmidt, K., Taubald, H.: Evidence for Holocene environmental changes in the northern Fertile Crescent provided by pedogenic carbonate coatings, Quaternary Res, 67, 315-327, 2007.

Roberts, N., Reed, J. M., Leng, M. J., Kuzucuoğlu, C., Fontugne, M., Bertaux, J., Woldring, H., Bottema, S., Black, S., Hunt, E., and Karabiyikoğlu, M.: The tempo of Holocene climatic change in the eastern Mediterranean region: new high-resolution crater-lake sediment data from central Turkey, The Holocene, 11, 721-736, 2001.

Ülgen, U. B., Franz, S. O., Biltekin, D., Çagatay, M. N., Roeser, P. A., Doner, L., and Thein, J.: Climatic and environmental evolution of Lake Iznik (NW Turkey) over the last ∼4700 years, Quatern Int, 274, 88-101, 2012.

Weiss, Harvey: Global megadrought, societal collapse and resilience at 4.2-3.9 ka BP across the Mediterranean and west Asia, PAGES Magazine 24, 62 - 63, 2016.

Weiss, Harvey: The 4.2 ka BP event in the northern North Atlantic. Clim. Past Discuss., https://doi.org/10.5194/cp-2018-162-RC2, 2019.

Anatolia 4.2 ka BP event paleoclimate proxy sites

Proxy site	Lat.	Long.	Publication	status	Resolution/yrs
Sofular Cave	41.417	31.95	Göktürk et al 2011	wet	5
Gulf of Gemlik	40.463	28.895	Filikci et al 2017	dry	>200
Lake Iznik	40.433	29.508	Ülgen et al 2012	dry	-
Lake Tecer	39.431	37.084	Kuzucuoğlu et al 2011	dry	-
Eski Acigöl	38.547	34.546	Roberts et al 2001	uncertain	85
Lake Hazar	38.5	39.3	Ön et al 2018	wet	175
Nar Gölü	38.34	35.456	Dean et al 2015	dry	5
Konya Lakes	37.483	33.45	Boyer et al 2006	dry	-
Koçain Cave	37.233	30.712	Göktürk 2011	cold	2
Göbekli Tepe	37.223	38.923	Pustovoytov et al 2007	dry	>100
Golhisar Gölü	37.117	29.6	Leng et al 2010	dry	98
Lake Van	38.592	42.847	Lemcke, Sturm 1997	dry	116

Fig. 1

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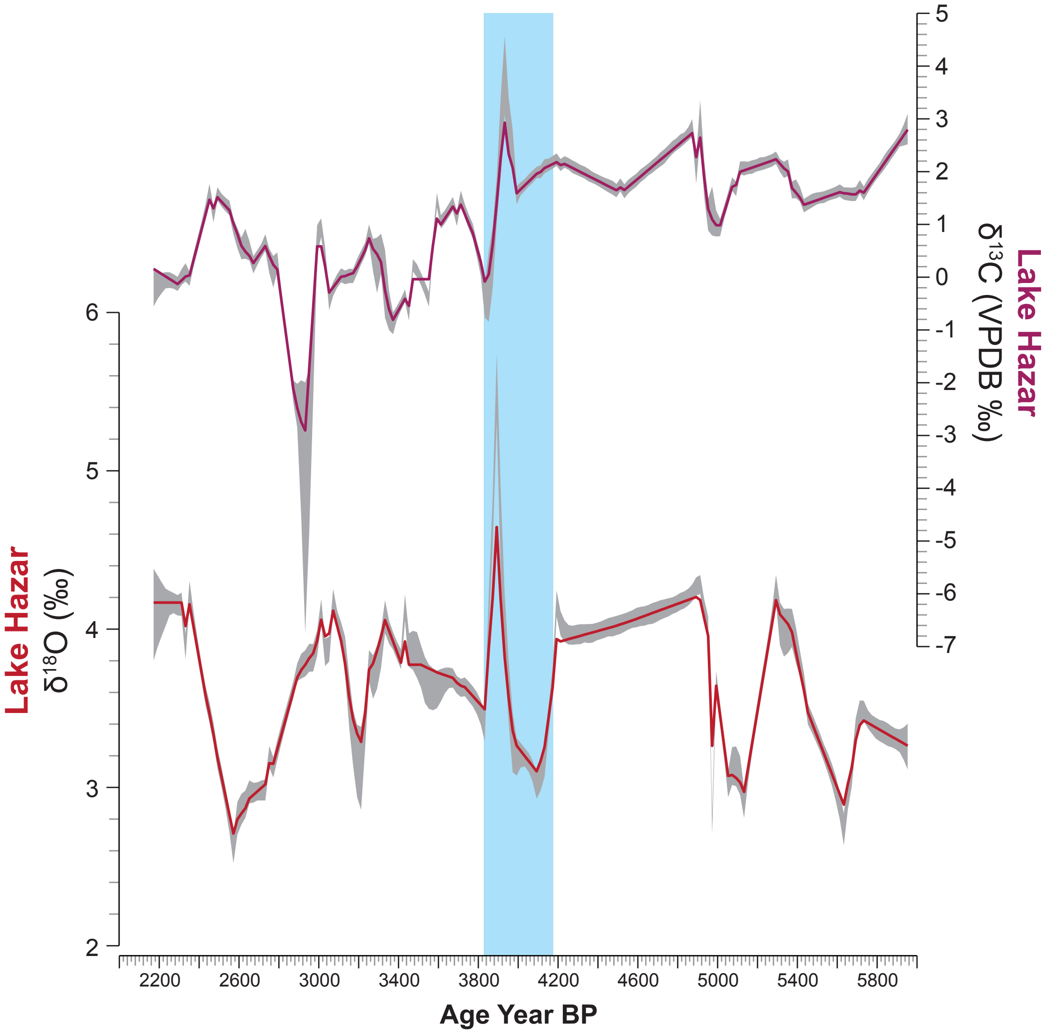

Fig. 2 Lake Hazar δ^{13}C and δ^{18}O at 4.2 ka BP **Weiss 2019 CP**