Quaternary Science Reviews 123 (2015) 215–230

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Abrupt climate variability since the last deglaciation based on a high-resolution, multi-proxy peat record from NW Iran: The hand that rocked the Cradle of Civilization?

Arash Sharifi [a, b, *], Ali Pourmand [a, b], Elizabeth A. Canuel [c], Erin Ferer-Tyler [c], Larry C. Peterson [b], Bernhard Aichner [d], Sarah J. Feakins [d], Touraj Daryaee [e], Morteza Djamali [f], Abdolmajid Naderi Beni [g], Hamid A.K. Lahijani [g], Peter K. Swart [b]

[a] *Neptune Isotope Laboratory (NIL), Department of Marine Geosciences, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149-1098, USA*
[b] *Department of Marine Geosciences, Rosenstiel School of Marine and Atmospheric Science (RSMAS), University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149-1098, USA*
[c] *Virginia Institute of Marine Science, College of William & Mary, P.O. Box 1346, Gloucester Point, VA, USA*
[d] *University of Southern California, Department of Earth Sciences, 3651 Trousdale Pkwy, Los Angeles, CA 90089-0740, USA*
[e] *Samuel M. Jordan Center for Persian Studies and Culture at the University of California, Irvine, CA 92697, USA*
[f] *Institut Méditerranéen de biodiversité et d'Ecologie (IMBE – UMR CNRS 7263 / IRD 237), Europôle Méditerranéen de l'Arbois, BP 80, 13545 Aix-en-Provence cedex 04, France*
[g] *Iranian National Institute for Oceanography and Atmospheric Science (INIOAS), Marine Geology Division, P.O. Box 14155-4781 Tehran, Iran*

ARTICLE INFO

Article history:
Received 21 January 2015
Received in revised form 22 June 2015
Accepted 2 July 2015
Available online 15 July 2015

Keywords:
Holocene climate
Compound-specific biomarker
Cradle of Civilization
Atmospheric dust
Ombrotrophic peat
Younger Dryas
Iran

ABSTRACT

We present a high-resolution (sub-decadal to centennial), multi-proxy reconstruction of aeolian input and changes in palaeohydrological conditions based on a 13000 Yr record from Neor Lake's peripheral peat in NW Iran. Variations in relative abundances of refractory (Al, Zr, Ti, and Si), redox sensitive (Fe) and mobile (K and Rb) elements, total organic carbon (TOC), $\delta^{13}C_{TOC}$, compound-specific leaf wax hydrogen isotopes (δD), carbon accumulation rates and dust fluxes presented here fill a large gap in the existing terrestrial paleoclimate records from the interior of West Asia. Our results suggest that a transition occurred from dry and dusty conditions during the Younger Dryas (YD) to a relatively wetter period with higher carbon accumulation rates and low aeolian input during the early Holocene (9000–6000 Yr BP). This period was followed by relatively drier and dustier conditions during middle to late Holocene, which is consistent with orbital changes in insolation that affected much of the northern hemisphere. Numerous episodes of high aeolian input spanning a few decades to millennia are prevalent during the middle to late Holocene. Wavelet analysis of variations in Ti abundances as a proxy for aeolian input revealed notable periodicities at 230, 320, and 470 years with significant periodicities centered around 820, 1550, and 3110 years over the last 13000 years. Comparison with palaeoclimate archives from West Asia, the North Atlantic and African lakes point to a teleconnection between North Atlantic climate and the interior of West Asia during the last glacial termination and the Holocene epoch.

We further assess the potential role of abrupt climate change on early human societies by comparing our record of palaeoclimate variability with historical, geological and archaeological archives from this region. The terrestrial record from this study confirms previous evidence from marine sediments of the Arabian Sea that suggested climate change influenced the termination of the Akkadian empire. In addition, nearly all observed episodes of enhanced dust deposition during the middle to late Holocene coincided with times of drought, famine, and power transitions across the Iranian Plateau, Mesopotamia and the eastern Mediterranean region. These findings indicate that while socio-economic factors are traditionally considered to shape ancient human societies in this region, the influence of abrupt climate change should not be underestimated.

* Corresponding author. Neptune Isotope Laboratory (NIL), Department of Marine Geosciences, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149-1098, USA.
E-mail address: osharifi@rsmas.miami.edu (A. Sharifi).

http://dx.doi.org/10.1016/j.quascirev.2015.07.006
0277-3791/

1. Introduction

Since the beginning of the Neolithic Era, the area in West Asia that extends from southwestern Iran and the Arabian Peninsula to the eastern and southeastern Mediterranean Sea, also referred to as the "Cradle of Civilization" and the "Fertile Crescent", has witnessed the birth of agriculture and development of some of the earliest human societies (Leick, 2010; Mellaart, 1975; Riehl et al., 2013). Evidence is mounting that abrupt climate change during the Holocene epoch (beginning 11700 before present, BP) may have played a transformative role in the growth and deterioration of human civilizations (Brooks, 2006; Cullen et al., 2000; deMenocal, 2001; Riehl, 2009). Although the amplitude of climate variability was reduced during the Holocene relative to the last glacial period (Grootes et al., 1993), episodes of abrupt climatic change have been documented in marine and terrestrial records throughout the Holocene in both hemispheres (see review by Mayewski et al., 2004).

On a regional scale, the climate of West Asia is governed by complex interactions between the mid-latitude Westerlies, the Siberian Anticyclone and the Indian Ocean Summer Monsoon (Fig. 1). While a number of paleoclimate studies have drawn potential links between abrupt climate change and the rise and fall of civilizations across the Fertile Crescent (Cullen et al., 2000; Staubwasser and Weiss, 2006), high-resolution (sub-decadal to centennial) terrestrial archives of climate variability with well-constrained age models are scarce from this region (Nicoll and Küçükuysal, 2013). Such records are needed in order to address the uncertainty regarding the timing and regional significance of climatic transitions and their potential influence on early human societies, and the extent to which anthropogenic activities may have influenced the climate of the last deglacial period.

Interpreting the available proxy reconstructions of Holocene climate variability in the interior of West Asia is not straightforward. For example, Stevens et al. (2001) found disagreement between relatively lower $\delta^{18}O$ values from Lake Zeribar during the early Holocene, which are generally interpreted to represent wetter conditions (Roberts et al., 2008), and pollen and macrofossil data for this period from Lake Zeribar, which were interpreted to indicate drier conditions during this period. They concluded that lower $\delta^{18}O$ values may have been due to a shift in the timing of precipitation (i.e., protracted summers). Other explanations that have been suggested for this discrepancy include underestimating human impact on vegetation during the early Holocene, and the delayed reaction of biomes to postglacial climate change (Djamali et al., 2010; Roberts, 2002). Stevens et al. (2006) further examined geochemical and biological evidences from Lake Mirabad in western Iran during this period and concluded that the early Holocene was dry. Based on microfossil assemblages and pollen data, Wasylikowa et al. (2006) concluded that Zeribar lake levels were variable during the early Holocene. Pollen and ostracod assemblages from lakes in Turkey, Iran and Georgia suggest that continental (dry and variable) climate dominated over the interior of West Asia during the early to middle Holocene (Connor and Kvavadze, 2008; El-Moslimany, 1982; Griffiths et al., 2001; Wasylikowa, 2005). Available records of palaeo-vegetation changes, however, fall short of disentangling human *versus* climate impact (Djamali et al., 2009a), indicating the need for high-resolution palaeoclimate reconstructions that are independent of vegetation types that may have been influenced by agriculture as well as climate (Roberts et al., 2011).

In this contribution, we present inorganic and organic proxy reconstruction of aeolian input and palaeohydrological changes over the last 13000 Yr from an ombrotrophic (rain fed) peat mire located at the periphery of Neor Lake in NW Iran. We examine the possibility of an atmospheric teleconnection during the last glacial termination and the Holocene by comparing our results with records from the North Atlantic, African lakes and eastern Mediterranean. We further investigate the potential influence of abrupt climate change on major early human societies from West Asia by comparing our findings with historical and archaeological records from this region.

2. Study area

Neor Lake (37°57′37″ N, 48°33′19″ E) is a seasonally recharged body of water formed over a tectonic depression on the leeward flank of the Talesh (Alborz) Mountains in NW Iran (Fig. 1 and Fig 2A). The tectonic depression, which formed within an andesitic bedrock as a result of displacements during the Eocene (Madadi et al., 2005) does not receive water from any permanent rivers and has fostered a peripheral peat mire in primarily southern section of the lake for at least the last 13000 years. Precipitation in this high-altitude peat mire (~2500 m above sea level, m.a.s.l.) consists of rain and snow. Water leaves the lake through an incision in the north that has been artificially dammed for the last few decades. The lake surface area is reduced by more than 50% during periods of low precipitation (Fig. 2B) (Madadi et al., 2005). Mass accumulation in the peat mire is primarily driven by accretion of decomposing biomass and wet and dry aeolian deposition.

The mean annual precipitation (30-years average) recorded at the nearest meteorological station in Ardebil, located at 1332 m.a.s.l. and 50 km NE of the lake, exceeds 300 mm. Precipitation is highest in May and November (Fig. 2B) and the dry season lasts from July to September. Mean annual temperature at the station is 15.4 °C and the mean maximum and minimum temperatures of the warmest and coldest months of the year are 25 °C (July) and −7.9 °C (January), respectively. As Neor peat mire is 1200 m higher than the meteorological station, it is not unreasonable to expect higher annual precipitation and lower temperature at Neor relative to the weather station. Vegetation in the lake basin is composed of Irano-Turanian mountain steppe, dominated by thorny-cushions plants. Local nomado-pastoral communities exploit both the steppe and the Neor peat mire vegetation.

3. Materials and methods

3.1. Peat cores

In the summer of 2010, we recovered a 7.5-m core from the southwest part of Neor peat mire (Fig. 1), as well as two additional cores of similar length from within 2 m of the main core. Half-barrel cores were collected in 1-m increments of 7-cm diameter using a Russian split corer until the basal bedrock was reached. The final segment of the core included dense, laminated gyttja and a mixture of andesitic gravel from the bedrock. The cores were photographed on site and transferred into PVC core liners, sealed in non-reactive plastic sheets and stored at 4 °C and constant humidity at the core repository of the Rosenstiel School of Marine and Atmospheric Science (RSMAS), the University of Miami. The physical properties of the core segments were logged, and changes in core dimensions were closely monitored throughout the course of the study as peat water content tended to vary with time. Each core segment was transferred into an especially-designed polymethyl methacrylate core holder and PVC liner with scale bars for reference. The cores were subsequently imaged using a Geotek Multi-Sensor Core Logger (GeotekMSCL) at the Department of Marine Geosciences (MGS), RSMAS and the images were calibrated for cross-core resolution, light intensity and white balance. The position of each sample taken for discrete organic and inorganic geochemical analyses was determined based on comparing down-core XRF