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Holocene climatic and environmental evolution on the southwestern Iberian Peninsula: A high-resolution multi-proxy study from Lake Medina (Cádiz, SW Spain)

Tabea Schröder [a, *], Jasmijn van't Hoff [b], José Antonio López-Sáez [c], Finn Viehberg [b], Martin Melles [b], Klaus Reicherter [a]

[a] Institute of Neotectonics & Natural Hazards, RWTH Aachen University, Germany
[b] Institute of Geology & Mineralogy, University of Cologne, Germany
[c] Research Group Archaeobiology, Institute of History, CSIC, Madrid, Spain

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ABSTRACT

The climatic and environmental history of the SW Iberian Peninsula is explored to fill in the gap of continental palaeoclimate data by a high-resolution study of Lake Medina sediments from core Co1313. A multi-proxy approach comprising sedimentary facies analysis, elemental geochemistry, mineralogy, palynology and micropaleontology was employed to reconstruct the complex limnological response to climate change and catchment dynamics since the early Holocene. The further definition of abrupt climate change events was supported by a robust age model and rapid sediment accumulation rate at the study site. Proxies indicate arid and warm climate conditions during the Early Holocene, from around 9.5 to 7.8 cal ka BP, with a desiccation event at 8.8 cal ka BP as well as tentative evidence for the regional expression of a cold and abrupt arid climate event centering on ca. 8.2 cal ka BP. The Holocene Climate Optimum, from around 7.8 to 5.5 cal ka BP, is characterized by a humid climate and maximum lake level. Anoxic bottom water conditions are indicated by the preservation of sediment laminae and the occurrences of Sulfur mottles, which were observed for the first time within Holocene sediments of saline lakes. Mid-to Late Holocene times are governed by the 4.2 cal ka BP dry event as well as progressive aridification accompanied by the development of typical Mediterranean low-land vegetation. During recent times, further progressive loss in precipitation as well as fluctuating but overall increasing anthropogenic influence on Lake Medina sediments is observed.

1. Introduction

The western Mediterranean region, one of the most sensitive regions to climate change due to pronounced seasonal contrasts and its peculiar location at a climatic boundary (Lionello et al., 2006; Jiménez-Moreno et al., 2015), is predicted to be warmer and drier in future times (Giorgi and Lionello, 2008; Met Office et al., 2011). As a consequence a northward extension of arid lands is expected during the next decades (IPCC, 2014). Total consumption of ground water in Spain exceeds the annual input by 163%, reflecting a clear overuse of the aquifers (Puigdefábregas and Mendizabal, 1998). Predictions of future developments, however, are hampered by an insufficient understanding of past relationships between climate, vegetation history and human land-use (MET Office et al., 2011; Jiménez-Moreno et al., 2015).

The restricted knowledge of the Holocene climatic and environmental history in southern Spain is a consequence of discontinuous terrestrial climate archives (Roberts et al., 2008). The few archives available that cover the entire Holocene do suffer either from restricted age control or palaeoenvironmental sensitivity (Carrión et al., 2001, 2010; Reed et al., 2001; Fletcher et al., 2007; Schröder et al., 2017). In addition, only a few studies in continental Iberia show necessary chronological control for identification of short-term climate fluctuation (Ortiz et al., 2004) and most of them are located in elevated areas such as the Sierra Nevada (Anderson et al., 2011; Jiménez-Moreno et al., 2015; Ramos-Román et al., 2016, 2018). Moreover, multiple studies deal with a large variance of proxies, making a data combination or comparison difficult. Even

* Corresponding author.
E-mail address: tabea.schroeder@rwth-aachen.de (T. Schröder).

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more, the indices do differ in climate response times (Fritz and Anderson, 2013; Lane et al., 2013) and the interference of proxies with the ecosystem is complex (Birks and Birks, 2006). Our knowledge about Holocene climate history on land is mainly based on information from distal marine sediment cores (Combourieu Nebout et al., 1998, 2002; 2009; Voelker et al., 2006, 2009; Voelker and De Abreu, 2013) which are often of low temporal resolution (Fletcher et al., 2010).

Among the promising archives for investigating the climatic and environmental history of the southern Iberian Peninsula (IP) are sedimentary records from small and shallow endorheic lakes. These sediments are usually highly sensitive to the smallest climatic changes (Reed et al., 2001; Valero-Garcés et al., 2006; Martín-Puertas et al., 2010, 2011; Moreno et al., 2012), for instance, changing amounts of precipitation directly lead to strong variation in lake level and brine concentration (Fritz, 1996; Beklioglu et al., 2007; Davis and Stevenson, 2007).

Lake Medina (36°37′04″N, 6°03′13″W, 16 m a.s.l, Fig. 1) constitutes a low-lying, small, shallow and endorheic salt lake, located in the province of Cádiz within the Atlantic region of Andalusia (López-Sáez et al., 2002). A 10 m sediment core composite was previously retrieved in 1993 by Reed et al. (2001), showing that limnic sediments were continuously deposited in Lake Medina during the last 9.0 cal ka BP. This record was investigated for diatoms, ostracods, foraminifera, molluscs, aquatic pollen as well as lithology. Furthermore, the lake was investigated for stable isotopes by Roberts et al. (2008).

This study is based on a new high-resolution core composite of 25.7 m length that was obtained within the central part of the lake during two coring campaigns in 2014 and 2015. This study presents a multi-proxy approach applied to the Co1313 core, involving sedimentological, mineralogical, geochemical and palaeoecological methods to gain a detailed understanding of changes of the lake system over time and, by inference, Holocene climate change. Due to its exceptionally high temporal resolution, the record reflects not only long-term, millennial-scale climatic and environmental changes, but offers the possibility for comparison to also short-term, centennial-scale events from around 9.5 cal ka BP onwards.

2. Regional setting

Lake Medina is the second largest playa lake in the region of Andalusia in southern Spain (De Vicente et al., 2012) (Fig. 1 c, red star), located within the thermomediterranean bioclimatic belt (Quézel and Médail, 2003). Since the Ramsar Convention in 1989, the lake is part of a protected Nature Reserve (Fig. 1 d), declared as a Wetland of International Importance (De Vicente et al., 2012), even though lake water was recently used for irrigation. Lake Medina today is surrounded by agricultural land dominated by orchards of olive trees and cultivation of cereals and sunflower (Reed et al.,

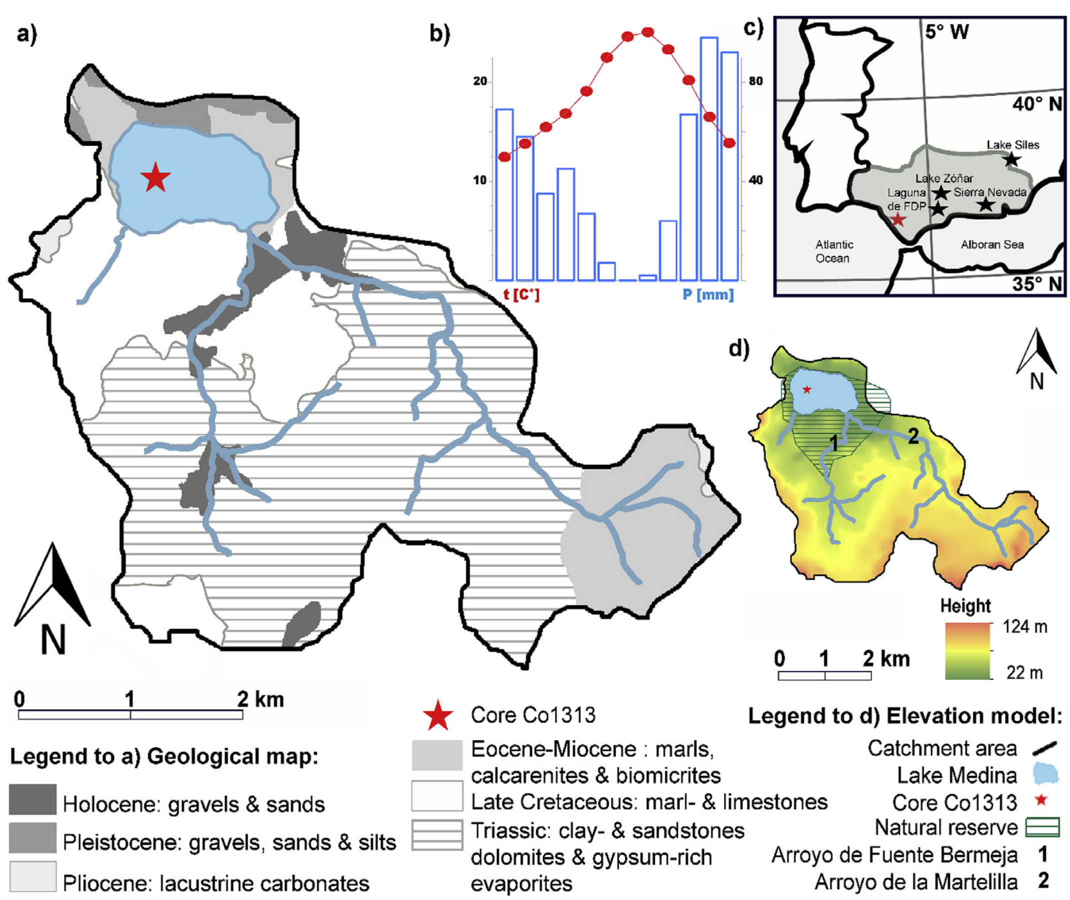

Fig. 1. a) Geological map of the catchment area of Lake Medina, b) Average monthly temperature T [C°] [displayed by red dots] and average monthly rainfall P [mm] [displayed in blue bars] from January to December measured at Cádiz between 1981 and 2010 (AEMET, Agencia Estatal de Meteorología), c) Overview map showing the location of the lake (red star) within the western Mediterranean and the region of Andalusia (in grey) on the southern Iberian Peninsula, together with some locations mentioned within the discussion, Lake Zóñar, Lake Siles, Laguna de Fuente de Piedra (FDP) and the Sierra Nevada, d) elevation model for the catchment area of Lake Medina also showing the area of the Natural Reserve, the location of the core Co1313 and the major temporal inlets (for names see legend). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)