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Lateglacial to Early Holocene recursive aridity events in the SE Mediterranean Iberian Peninsula: The Salines playa lake case study

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ABSTRACT

Twelve pollen-inferred aridity major and minor events (S1 to S12) have been identified at Salines playa lake (SE Iberian Peninsula, 475 m asl, 38° 30′ 02″ N 00° 53′ 18″ W) from the Lateglacial to the Early Holocene (Boreal). These dry events consist of an increase in the aridity quotient calculated as a function of selected pollen taxa at 13.4, 13, 12.55, 12.2, 11.9, 11.45, 11, 10.6, 10.3, 10, 9.5 and 8.3 ka cal BP. These dry events correspond to the previous identified cold spells such as the Younger Dryas, as well as the 8, 7, 6 and 5 Bond events, and 11.4 and 9.3 events. This climate record highlights the complex glacial-interglacial transition in extra-tropical latitudes, with centennial-scale abrupt climate fluctuations, a signature scarcely recorded in other palaeoecological records of the SE Iberian Peninsula. This work has major implications for the study of human socio-ecological systems and resilience in SE Iberia during the Epipaleolithic and Mesolithic periods.

1. Introduction

Over the past years, human palaeoecology has highlighted the regionally variable impacts of Lateglacial and Early Holocene abrupt climate crises on prehistoric hunter-gatherers (González-Sampériz et al., 2009; Fernández-López de Pablo and Jochim, 2010; Crombé et al., 2011; Robinson et al., 2013; Wicks and Mithen, 2014). In this regard, two major methodological challenges arise when studying past socio-ecological systems: first, the chronological correlation between different sources of palaeoenvironmental evidence with records of human activity and land use; and second, the distinction between processes of gradual and punctuated environmental change in regional and micro-regional scenarios (Robinson et al., 2013).

In the Iberian Mediterranean region, the recovery of temperatures during the Lateglacial interstadials and the Early Holocene led to two major processes of gradual environmental change: the replacement of the open Lateglacial woodland formations by temperate forests (Burjachs et al., 1997; Moreno et al., 2014); and sea level rise, with the flooding of terminal Pleistocene coastal plains (Goy and Zazo, 1988; Zazo et al., 1994, 2003, 2013; Goy et al., 1996). Both changes were translated into an increasing importance of forest adapted ungulate species (red deer, roe deer and wild boar) in the Early Holocene that paralleled a decrease of leporids (Aura et al., 2009).

In this context, the impacts of Early Holocene abrupt climate events on Epipaleolithic and Mesolithic hunter-gatherers are much less understood. Much of the literature focuses on the Younger Dryas (Aura et al., 2011) and the 8.2 ka cold events (González-Sampériz et al., 2009; Fernández-López de Pablo and Jochim, 2010; Cortés-Sánchez et al., 2012), mainly due to the fact that these events are easier to identify in many palaeoclimate records. However, the identification of climate events both at regional and local scales faces some methodological challenges. For instance, many of the palaeoecological reconstructions from archaeological deposits are based on charcoal analyses (Carrión-Marco, 2003, 2010; Aura et al., 2005; Allué et al., 2007, 2009, 2012a, 2012b, 2013; Carrión et al., 2012) whose chronological resolution is contingent to erosive and stratigraphic discontinuities and hiatuses. This problem challenges the obtaining of continuous and robust climate reconstructions from the archaeological record and prompts the implementation of new research lines for correlating

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records of human activity with continuous palaeoenvironmental archives.

1.1. Archaeological settings

The central Mediterranean region of the Iberian Peninsula provides a privileged archaeological record for the study of human-environmental interactions from the Lateglacial to the middle Holocene. In this area, the current regional sequence is divided into 4 major archaeological taxonomical units according to the techno-typological evolution of the lithic assemblages (Martí-Oliver et al., 2009; Aura et al., 2011): a) the Epimagdalenian (c. 12.9–11.4 ky cal BP), characterised by micro-bladelet *debitage* and the dominance of backed bladelets and endscrapers amongst the retouched tools; b) the Epipalaeolithic with Sauveterrian microliths (c. 11.1–10.4 ky cal BP) such as triangles and crescents smaller than 10 mm; c) the Early Mesolithic (c. 10.1–8.6 ky cal BP), characterised by flake reduction strategies and a reduced set of formal tools dominated by notches and denticulates; and d) the Late Mesolithic (c. 8.5–8 ky cal BP) with bladelet *debitage* and geometric microliths (mainly trapezes with abrupt retouch) of Tardenoisian tradition.

Generally speaking, the Epimagdalenian and Epipalaeolithic with Sauveterrian microliths display traits of cultural and technological continuity regarding the previous Late Upper Magdalenian. The ibex and deer hunting, with a noticeable contribution of leporids among the small prey, is clearly prevalent during both periods (Aura et al., 2009; Morales-Pérez, 2013). In contrast, the Early Mesolithic represents an abrupt change in lithic technology and subsistence strategies, signified by the increasing hunting of other ungulate species (in addition to deer and ibex) such as the wild boar, chamois and roe deer. The patterns of exploitation of small prey also changed during the Early Mesolithic, with a significant decrease in leporids and a persistent use of edible land snails (Fernández-López de Pablo et al., 2011).

Whether the observed changes in the composition of faunal assemblages between the Epipalaeolithic and the Early Mesolithic were driven by Early Holocene environmental changes, such as the increase in temperature and the expansion of thermophilous woodland, or alternatively, by an increase in hunting pressure due to demographic factors, still remains an open question. In fact, both hypotheses are not completely mutually exclusive. Recent studies report the appearance of cemeteries in the study area during the Early Mesolithic (Gibaja et al., 2015) and the presence of funerary sites in both inland and coastal areas, yielding different palaeodietary signals inferring a reliance upon marine proteins (Salazar-García et al., 2014). Therefore, the current archaeological record suggests an increase in the socially mediated territorial behaviour during the Early Mesolithic expressed by the persistent use of funerary areas. Such behaviour is also supported by the funerary evidences dated to the Late Mesolithic (Fernández-López de Pablo et al., 2013; Olària, 2014).

Thus, the analysis of a continuous sedimentary record, such as Salines playa lake, holds a significant potential for the study of socio-ecological systems at regional scale for two reasons: (i) it provides an independent line of evidence to determine how the events of climate and environmental deterioration affected the primary biomass; and (ii) it allows us to determine the prevailing palaeoenvironmental conditions under which the most significant changes in the archaeological record appeared.

In addition, understanding how abrupt climate events have impacted hydrological systems and surrounding vegetation cover can provide essential information regarding human resilience, especially regarding changes in ecosystem carrying capacity. This fact is a critical issue in the Mediterranean façade of the Iberian Peninsula owing to the recurrent and persistent dry periods that have shaped the landscape for the last millennia (Jalut et al., 2000; Carrión et al., 2004; González-Sampériz et al., 2009; Vegas et al., 2010; Aranbarri et al., 2014).

In this paper, we present the first results of a multi-disciplinary research program (POSTGLACIAL-MED, Spanish MINECO) aimed at studying human–environmental interactions during the Lateglacial and Early Holocene periods on the south-eastern Iberian Peninsula. In this case study, we will focus on the re-evaluation of the Salines playa lake record which was the subject of previous multi-proxy investigations (Julià et al., 1994, 1998; Queralt et al., 1997; Giralt et al., 1999). The multi-disciplinary investigations by Giralt et al. (1999) and Julià et al. (1998) included mineral, pollen, isotope and ostracod analyses of this sedimentary record between 280 and 470 cm depth, to examine in detail the climate variability during the Pleistocene–Holocene transition. The present work incorporates a new aridity quotient based on pollen data that will be compared with new charcoal data using a revised bayesian chronological model to determine the signatures of subtle climate events not previously identified.

2. Site description

Lake Salines is a playa lake (Briere, 2000) inside an endorheic basin (475 m asl), covering an area of approximately 1.6 km^2, situated between and extending up to the foot of the Mesozoic ranges of Sierra de Salines and Cabrera in the SE Iberian Peninsula (Fig. 1). The Salines playa lake has a catchment area of about 71 km^2. The mean annual precipitation is 350 mm and the mean temperature is about 14 °C with abrupt daily and seasonal fluctuations. The annual evapo-transpiration rate measured in pan evapometers is about 1500 mm (Giralt et al., 1999). The lake was used as a salt-mineral resource over the last 400 years, although the main salt extraction was carried out during the nineteenth century. Later, it underwent a fall in its water level due to groundwater exploitation, when five wells were drilled to extract 12,000 m^3/day, between 1940 and 1950. This has resulted in the current dryness. Nevertheless, on occasions, it refills during rainy periods.

The landscape of this area of the SE Iberian Peninsula consists of open to shrub vegetation with some patches of woodland which can be found on the surrounding hills. The dominant tree species consist of *Quercus ilex*, *Pinus halepensis*, *P. pinea*, *P. pinaster* and *Rhamnus oleoides*. Shrubland species consist of *Quercus coccifera*, *Juniperus oxycedrus*, *J. phoenicea*, *Pistacia terebinthus*, *Daphne gnidium*, *Rosmarinus officinalis*, *Thymus vulgaris*, *Stipa tenacissima* (Rigual, 1984) and *Tetraclinis articulata*, an endemic species.

3. Materials and methods

3.1. Drill site

Three cores SAL-1, SAL-2 and SAL-3 were drilled in Salines playa lake in January, 1993. A 45.70 m continuous core, 10 cm in diameter, was obtained in PVC pipes with a rotopercussion corer. All cores were taken from the central part of the lake (Fig. 1). Afterwards, the cores were stored in a cool room (+4 °C) prior to analysis. The cores were split longitudinally for description and sampling. The detailed lithological description of all cores allowed us to construct a composite core with almost no sediment losses. The data presented here corresponds to the upper 5.50 m of that composite sequence.

3.2. Palynology

In total 98 samples of ~10 g sediment for pollen analysis were extracted from the inner part of the cores at intervals that ranged