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Charred wood remains in the natufian sequence of el-Wad terrace (Israel): New insights into the climatic, environmental and cultural changes at the end of the Pleistocene

Valentina Caracuta [a, b, *], Mina Weinstein-Evron [c], Reuven Yeshurun [c], Daniel Kaufman [c], Alexander Tsatskin [c], Elisabetta Boaretto [a, b]

[a] Max Planck-Weizmann Center for Integrative Archaeology and Anthropology, 76100 Rehovot, Israel
[b] D-REAMS Radiocarbon Laboratory, 76100 Rehovot, Israel
[c] Zinman Institute of Archaeology, University of Haifa, Haifa 3498838, Israel

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ABSTRACT

The major social and economic changes associated with the rise of a sedentary lifestyle and the gradual transition to food production in the southern Levant are often considered to have been triggered by climate changes at the end of the Pleistocene (~20,000–11,000 years BP). This explanation, however, is biased by the scarcity of high-resolution climate records directly associated with human activity and the lack of refined palaeoecological studies from multi-stratified sites in the area.

Here, we present the results of an anthracological analysis, carried out on charcoals collected along a continuous column of archaeological sediments in the Natufian site of el-Wad Terrace (Mount Carmel, Israel). We also present the carbon isotopes analysis of ^{14}C-dated archaeological remains of *Amygdalus* sp.

The analyses of charcoal shows the predominance of an oak forest including *Quercus calliprinos* and *ithaburensis* around the site during the Early Natufian building phase (~14,600–13,700 cal BP), and the values of $\Delta^{13}C$ point to a high rainfall rate. This period is followed by a marked decrease in the local rainfall between ~13,700 and 12,000 cal BP). The reduction, culturally associated with the latest Early Natufian and the Late Natufian, is independently recorded by the speleothems of the region: Soreq Cave and Jerusalem Cave. This period incorporates an increase in drought tolerant species such as *Amygdalus* sp. Thermo-Mediterranean species, such as *Olea europaea* and *Ceratonia siliqua*, as well as *Pistacia palaestina*, which dominate the modern landscape, become established in the Holocene.

We conclude that the Natufian settlement at el-Wad Terrace flourished in the context of oak forests, and subsequently occupation intensity decreased in concurrence to the drying trend. This shift does not correspond to the cultural typology (i.e. Early Natufian *vs*. Late Natufian). Human response to climate change at the terminal Pleistocene Levant was multifaceted and localized. Its understanding requires the analysis of records that are well-tied to human ecology and behavior.

1. Introduction

The end of the Pleistocene was characterized by significant climate changes which, although global, impacted various human populations in different ways. This was a critical period in human cultural evolution including the appearance of the first sedentary communities in the southern Levant, foreshadowing the transition to agriculture. The interplay of environmental settings, as well as the level of social complexity and technological skills account for the specific responses of human populations to palaeoenvironmental changes.

The Epipaleolithic archaeological record of the southern Levant, namely the Kebaran, Geometric Kebaran and especially the Natufian cultures (~20,000–11,500 years BP) has provided rich information concerning human adaptations to the terminal Pleistocene environmental setting at the threshold to agriculture. Major climatic changes are recorded in the local natural proxies e.g., speleothems (Bar-Matthews et al., 1997) and several studies have tried to investigate the possible connections between the climatic variations and the cultural developments and changes in subsistence

* Corresponding author. Max Planck-Weizmann Center for Integrative Archaeology and Anthropology, 76100 Rehovot, Israel.
E-mail address: valentina.caracuta@weizmann.ac.il (V. Caracuta).

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strategies at the end of Pleistocene (*e.g.*, Bar-Yosef and Meadow, 1995; Henry, 2013). Nonetheless, the scarcity of palaeoenvironmental data available from the archaeological sites themselves and directly associated with human ecology makes it difficult to correlate the climate phases of the terminal Pleistocene to changes in material culture and socio-ecological patterns. Moreover, the lack of high resolution palaeoenvironmental datasets from stratified sites and the chronological uncertainty that arises from the use of radiocarbon dates often obtained from different sites, contexts and materials (charcoal, bone and shell) are major obstacles to establishing the relationship between climate and culture in the discussed period in the southern Levant (*e.g.*, Blockley and Pinhasi, 2011; Maher et al., 2011).

Here, we provide new well-dated palaeoenvironmental data based on the anthracological study and absolute radiocarbon dating of selected charred material collected along a continuous Natufian archaeological sequence in the site of el-Wad Terrace (Mount Carmel, Israel). Previous studies have already indicated the importance of anthracological analyses to reveal the presence, spatial and temporal distribution of specific tree taxa around archaeological sites that may otherwise go unrecorded, or are very poorly represented in other archaeobotanical records (e.g., Asouti and Kabukcu, 2014; Lev-Yadun, 2007). In this study we broaden the informative potential of the anthracological analysis by measuring carbon stable isotope ratios on the very same ^{14}C-dated charcoals of *Amygdalus* sp. in order to assess the timing, extent and intensity of past climate changes in the Carmel area. This paper presents ^{14}C-dated anthracological remains embedded within the el-Wad Terrace (eWt) sequence that includes all the stages of the Natufian culture and overlying deposits. The remains, studied using anthracological and isotopic approaches, constitute a unique proxy for human ecology in this critical period.

2. Previous palaeoclimate and archaeoenvironmental studies in the southern Levant

2.1. Speleothems as palaeoclimate proxies

Speleothems can provide high-resolution geochemical data ($\delta^{18}O$, $\delta^{13}C$, $^{87}Sr/^{86}Sr$) that in turn offer insights into past climates. In the region under study, Soreq Cave and Jerusalem Cave provide the most continuous records for the period included between 20,000 and 11,000 cal BP (Bar-Matthews et al., 1997; Frumkin et al., 1999, 2000; Ayalon et al., 2013). The speleothems that developed in the Mediterranean region of Israel show a general increase in temperature and rainfall after ~20,000 cal BP, a trend which continues until ~14,000 cal BP. Within this period, a cold/dry peak is recorded around ~16,500 cal BP. A relatively short, but significant colder/drier period, occurred between 13,200 and 11,400 cal BP (Bar-Matthews et al., 1999).

The other records available, speleothems from Ma'ale Efryaim and Tzavoa caves, come from the fringe of the desert (Vaks et al., 2003, 2006). While in the northern latitudes the reduction in rainfall results in changes of the isotopic values of the speleothems, as observed in Soreq Cave and Jerusalem Cave, in arid areas low rainfall is responsible for the interruption of speleothem deposition. The hiatus registered both in Ma'ale Efryaim Cave and Tzavoa Cave after 13,000 cal BP is likely to reflect low rainfall, while relative moister conditions probably prevailed between ~20,000 and 13,000 cal BP when the speleothems underwent a new phase of growth (Bar-Matthews et al., 1999; Vaks et al., 2003, 2006).

2.2. Pollen and the regional environment

A continuous pollen diagram from the Hula Basin (northern Jordan Valley) was originally considered to cover the period between ca. 17,000 and 9000 BP (~18,500–8200 Cal BP) (Baruch and Bottema, 1991), largely contemporaneous to the el-Wad sequence. However, a recent revisiting (Baruch and Bottema, 1999) questions the validity of the ^{14}C dating of the carbonates and the sequence is now considered Holocene and hence out of the Natufian chronological framework (Cappers et al., 2001).

A short palynological sequence from the Dor Lagoon, some 10 km south-west of el-Wad, indicated a rather dry period at the end of the Natufian followed by a wetter Pre-Pottery Neolithic A (PPNA) and a somewhat less-humid Pre-Pottery Neolithic B (PPNB) (Kadosh et al., 2004). An erosional gap between the pollen zones representing the two phases prevents further elaboration.

Archaeopalynological spectra for the end of Pleistocene are rare in the Levant, mostly derived from its semi-arid regions (e.g. Leroi-Gourhan and Darmon, 1991; Emery-Barbier, 1988) and, in some cases represent isolated samples, many of which comprise small numbers of pollen grains. These spectra are in many cases rich in Asteraceae pollen, which are known to prevail in samples the pollen of which was susceptible to selective preservation, and hence are probably at risk of various interpretational biases (Weinstein-Evron, 1994, 1998). The rare pollen spectra derived from the Mediterranean zone, the 'core area' of the Natufian (Bar-Yosef and Belfer-Cohen, 1989) are also sporadic (Henry, 2013; Leroi-Gourhan, 1981). Pollen spectra from the Early Natufian of the inner part of el-Wad Cave (Weinstein-Evron, 1994, 1998) suggest a typical Mediterranean maquis vegetation (with mainly *Quercus*, *Pinus*, *Olea*, *Pistacia*, *Crataegus*, *Ceratonia* and *Myrtus* pollen), with possible hydrophilous biotopes (river bank or marsh; *Tamarix* and *Sparganium*) and a developed ruderal environment (e.g., Asteraceae, Malvaceae, Dipsacaceae) near the site. Pollen spectra retrieved from a possibly Late Natufian human skull indicate a typical Mediterranean environment, with relatively high *Quercus calliprinos* levels and many *Pistacia* sp., *Olea europaea* and *Fraxinus* sp. pollen (Weinstein-Evron et al., 2007). Phytolith analysis at el-Wad indicated the exploitation of wood and bark of trees and bushes, but their specific identification was not possible (Portillo et al., 2010).

2.3. Charcoal and seed analyses

Anthracological data available for the region are limited to a few sites in northern Israel where some, Kebaran (KB), Early Natufian (EN) and Late Natufian (LN) sites have been studied: Ein Qashish South, which has both Kebaran and Early Natufian phases of occupation (Yaroshevich et al., 2014), el-Wad (EN) (Weinstein-Evron, 1998), Hayonim Terrace, Mallaha, Hilazon and Nahal Ein Gev II (LN) (Valla et al., 1989; Valla, 1984; Grosman et al., 2008; Bar-Yosef and Belfer-Cohen, 2000).

Ein Qashish South is located in the north-west corner of the Jezreel Valley, between the eastern slopes of Mount Carmel and the Shefaram-Tiv'on Hill (Yaroshevich et al., 2014). Remains of *Quercus ithaburensis* and *Amygdalus* sp. were found in the Kebaran and the Early Natufian layers of the site, respectively (**Caracuta and Boaretto interim report**).

Charcoal remains were found in el-Wad Cave in the layers dated to the Early Natufian (15,000–13,000 cal BP) (Weinstein-Evron, 1991). The thirty-two identified wood charcoals provide important insights into the wood species that grew in the surroundings of the site and the spatial biodiversity in the area (Lev-Yadun and Weinstein-Evron, 1993, 1994). Remains of Mediterranean trees such as *Q. calliprinos*, *Q. ithaburensis* and the shrub *Myrtus communis* were found associated with hydrophilous and marshy species, such as *Tamarix* sp. and *Salix* sp. and the coniferous wood of *Cupressus* sp. The composition of the charcoal assemblage accords