Human management and landscape changes at Palaikastro (Eastern Crete) from the Late Neolithic to the Early Minoan period

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ABSTRACT
On the east Mediterranean island of Crete, a hierarchical society centred on large palatial complexes emerges during the Bronze Age. The economic basis for this significant social change has long been debated, particularly concerning the role of olive cultivation in the island’s agricultural system. With the aim of studying vegetation changes and human management to understand the landscape history from Late Neolithic to Bronze Age, two palaeoenvironmental records have been studied at Kouremenos marsh, near the site of Palaikastro (Eastern Crete). Pollen, NPP and charcoal particles analyses evidenced seven phases of landscape change, resulting from different agricultural and pastoral practices and the use of fire probably to manage vegetation. Moreover, the Kouremenos records show the importance of the olive tree in the area. They reflect a clear trend for its increasing use and exploitation from 3600 cal yr BC (Final Neolithic) to the Early Minoan period, that is coeval with an opening of the landscape. The increase of Olea pollen was due to the expansion of the tree and its management using pruning and mechanical cleaning. The onset of olive expansion at c. 3600 cal yr BC places Crete among the first locales in the eastern Mediterranean in the management of this tree. Between c. 2780 and 2525 cal yr BC the landscape was largely occupied by olive and grasslands, coinciding with an increase in grazing practices. The high Olea pollen percentages (40–45%) suggest an intensive and large-scale exploitation of the olive tree. The results suggest that a complex and organized landscape with complementary land uses and activities was already in place since the Final Neolithic. The notable expansion of olive trees suggests the relevance of olive exploitation in the socio-economic development of Minoan towns of eastern Crete. Other crops, such as cereals and vine, and activities such as grazing have also played an important role in the configuration of the past landscape.

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1. Introduction

During the Bronze Age, the island of Crete saw the emergence of the Minoan civilization, a culture characterized by a complex social and political organization, with the development of urban centres and state structure. The central role that the agricultural system as well as the control, storage and redistribution of food surplus by a centralized authority played in the growth of Minoan society has been the subject of much debate since the seminal work by Renfrew (1972a) (e. g. Galaty et al., 2011; Halstead, 1992, 1997; Halstead and O’Shea, 1982). Renfrew suggested that the specialized and large-scale cultivation of olives and grapes in particular was key in shaping the Early Bronze Age (EBA) of Crete (Renfrew, 1972a). According to this interpretation the intensive exploitation of olive and vine allowed the colonization of marginal land and hillsides, which otherwise would be unsuitable for food crops such as cereals, leading to surpluses and the growth of inter-regional exchange, among other socio-economic changes (Renfrew, 1972a).

Archaeobotanical data in support of the extensive cropping of olive and vine and the production of olive oil and wine in the EBA are inconclusive. Some evidence of olive and vine exploitation has been found in Neolithic and Early Bronze Age contexts, such as some grape pips and/or olive stones (e.g. at Knossos, Myrtos, Petras.
Kephala, Mochlos), charcoal fragments (e.g. at Myrtos) and organic residues, such as oil traces on pottery at Afroditē's Kephali (Koh and Betancourt, 2010; Livarda and Kotzamanis, 2013; Margaritis, 2013; Rackham, 1972; Valamoti et al., 2017). The nature and general paucity of these and other material culture data in the EBA, however, have led several researchers to question the role of these crops and their by-products in the emergence of social complexity (Halstead and O'Shea, 1982; Hamilakis, 1996; Hansen, 1988; Runnels and Hansen, 1986; Sarpaki, 1992). According to these scholars, the large scale systematic, intensive/extensive management of olive trees and vineyards for the production of oil and wine has only been observed during the Late Minoan period (1700–1450 BC), which is when we find a set of artefacts related to their use, such as stone olive presses, spouted clay tubs, oil storage containers, and more abundant organic material, such as olive stones and carbonized olive wood (Hamilakis, 1996; Riley, 2002, 2004; Runnels and Hansen, 1986; Sarpaki, 2012). At the same time, several studies have highlighted both the general paucity of archaeobotanical studies for prehistoric Crete, especially for the Neolithic period, and the limitations of the archaeobotanical data that are available when it comes to discussing the scale of olive oil and wine production (Livarda and Kotzamanis, 2013; Sarpaki, 2012). The relevance of the Neolithic period to the later palatial periods is increasingly recognized, with some scholars arguing that changes in the Final Neolithic prefigure some of the key processes occurring many centuries later (e.g. Nowicki, 2002, 2008; Sarpaki, 2012; Tomkins, 2004).

Due to our poor knowledge of the Neolithic period and the lack of clear indications of the beginning of olive and vine management or culture, several authors have highlighted the need to diversify the nature of the evidence to properly address these questions (Hamilakis, 1996; Livarda and Kotzamanis, 2013; Margaritis, 2013; Sarpaki, 2012). In this regard, landscape and palaeoenvironmental studies have the potential to furnish new evidence that can significantly contribute to this debate. Multi-proxy palaeoenvironmental studies, including pollen, non-pollen palynomorphs (NPP) and charcoal data, can help us understand the interaction of people with their territories, highlighting human impacts on vegetation and providing information on land use practices and human exploitation of plant resources, such as olive crops (Faegri and Iversen, 1989; Mercuri et al., 2013, 2015). Multi-proxy palaeoenvironmental data can also provide important information on the practices employed by human communities to transform their environments through, for instance, agriculture and livestock management. Despite the intensive archaeological exploration of Bronze Age Crete, its landscape and vegetation history remain poorly understood. This lacuna is especially problematic in Eastern Crete, where only one palaeoenvironmental study has been published (Pavlopoulos et al., 2007); this study did not result in a continuous record, due to the very poor pollen concentration (Pavlopoulos et al., 2007). Other palaeoenvironmental sequences in the island include few other proxies apart from pollen and present time-depth models of limited reliability. Some palynological sequences have been studied in the western and central part of the island, such as Aghia Galini (Bottema, 1980), Akrotiri peninsula (Moody et al., 1996), Kouras-Delphinous region (Bottema and Sarpaki, 2003; Jouffroy-Bapicot et al., 2017), and Asia Gonia, at high elevation in the White Mountains (Atherden and Hall, 1999; Jouffroy-Bapicot et al., 2016). These studies have addressed several questions such as: a) the plant landscape configuration before the human arrival on the island; b) the role of shrubland/forest communities; c) the native presence/absence of olive trees; d) the dynamics and causes of olive expansion; e) the agriculture-related deforestation; f) the role of pastoralism in shaping the landscape; and g) the high variability of landscape histories in the island, among others. However, the small number of sequences analyzed, together with their low chronological resolution and control hampers an in-depth understanding of these issues, which remain largely unresolved. This is a concerning state of research given the centrality of the island in past and current discussion on the emergence of social complexity and the potential it has for the study of the environmental impact of the first states and towns on Mediterranean island environments. This paper reports the first high-resolution records in eastern Crete carried out on sedimentary cores recovered from the Kourmenos wetland, near the village and archaeological site of Palaiastro. The palaeoenvironmental records include the study of pollen, non-pollen palynomorphs (NPP) and charcoal particles. This study covers the time-span from the Late Neolithic to the EBA.

2. The study area

The study area is located in the far east of Crete, the largest island of the Aegean Sea. The sedimentary records were obtained from the Kourmenos wetland (35° 12′ 14″ N, 26° 16′ 21″ E) at the Kourmenos deltaic plain, at about 50 m from the shoreline and at an altitude of 0.5 m.s.l. (Fig. 1). The plain is near the archaeological site of Palaiastro (Fig. 1), a large Bronze Age (Minoan) town located 750 m to the south. Topographically, the area is characterized by limestone ranges reaching to the sea, configuring a rocky coast with only small littoral plains, such as that of Kourmenos.

The climate of the island is typically Mediterranean, with hot and dry summers, and mild damp winters. Precipitation is mainly concentrated during the colder period (November to March); from June to August rainfall is rare. Many variations in precipitation and temperature occur in the island due to its topography: the eastern and southern parts of the island being drier than the north and west (Barclay, 1986; Rackham and Moody, 1996). Our study area is one of the driest regions of Crete, characterized by a semi-arid Mediterranean climate regime, with mean annual precipitation between 300 and 500 mm (c. 475 mm at the town of Sitia, 19 km west of Palaiastro, -Hellenic National Meteorological Services; Voudouris et al., 2006-). Summer monthly temperatures at Sitia reach c. 30 °C, and 10 °C in winter months (Fassoulas, 2013; Hellenic National Meteorological services: Rackham and Moody, 1996). Strong winds are common in the region, especially during July and August.

The flora of Crete consists of approximately 1800 plant species (Barclay, 1986; Zohary and Orshan, 1965), c. 10% of which are endemic, most of them in the mountain areas. The current vegetation is thought to be highly disturbed by human activities, resulting predominantly in a mosaic of maquis, undershrub formation of garigue (phrygana), and steppe-like grasslands, with some deciduous woodland and coniferous forest in the mountains and more protected areas (Bottema, 1980; Moody, 1987; Zohary and Orshan, 1965). The maquis, in the broad sense of communities of shrubs and low stature trees, expand between 0 and 600 m. This major vegetation type is usually no more than 1000 masl, but may reach to 1000 masl. Two major types are recognized (Bottema, 1980; Zohary and Orshan, 1965). In the lower zones and coastal plains until c. 400 masl maquis communities are mainly dominated by mastic (Pistacia lentiscus), with the presence of carob (Carobonea siliqua), Phoenician juniper (Juniperus phoenicea), and wild olive (Olea europea var. sylvestris) (Bottema, 1980; Turland et al., 1993; Zohary and Orshan, 1965). A second maquis community is found usually above 300 m and is formed by kermes oak (Quercus coccifera) together with strawberry tree (Arbutus unedo), tree heath (Erica arborea), spiny broom (Calicotome villosa), Cretan dwarf broom (Chamaecytisus creticus), sage-leaved rockrose (Cistus salviifolius), French broom (Genista monspessulana) and broom (G. acanthoclada) (Bottema, 1980; Moody, 1987; Turland et al., 1993;
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