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ORIGINAL ARTICLE

Vegetation development and human activities in Attiki (SE Greece) during the last 5,000 years

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Abstract Pollen assemblages recovered from a 5 m sediment core from the Vravron coastal marsh suggest a close correlation between vegetation development and human presence in Attica, and provide the first complete record of middle to late Holocene vegetation history. Correlation of pollen with archaeological data attempts to decode the man–environment relations of the past, within the context of the known climatic variability of the mid-late Holocene, in the vicinity of ancient Athens, an area of high historical significance. The pollen record of Vravron denotes a rather variable landscape where open Mediterranean evergreen pine woods alternated with maquis shrublands and grasslands, where human activities and climate have left their imprints on vegetation. During the last 5,000 years agricultural practices displayed several variations: cereal cultivation appears more intense during the Bronze Age, especially in the Mycenaean, while a spread of *Olea* is observed during Geometric to Classical times. The gradual abandonment of *Olea* cultivation evidenced in our pollen diagram came as a result of the displacement of human activities in the interior of Mesogaia in Hellenistic and Roman times. *Olea* and cereal cultivation intensification is observed again during the Mesobyzantine period. In the upper part of the core evidence of intense soil erosion and expansion of Vravron wetland was recorded, coinciding with the Little Ice Age climatic event and the introduction of Arvanites populations in the area.

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Introduction

Coastal areas are of particular interest for palaeoenvironmental studies in the Mediterranean, as they are biodiversity hotspots and they exhibit environmental instability, being extremely sensitive to both anthropogenic impact and climatic change (Caroli and Caldara 2007; Mariotti Lippi et al. 2007b; Di Rita and Magri 2009). Furthermore their proximity to human settlement areas, in contrast with small mountainous basins, has contributed to their early exploitation in terms of water resources, animal husbandry, farming practices or ports (Mariotti Lippi et al. 2007a; Sadori et al. 2010a). In this respect, the study of coastal areas deposits combined with information from archaeological and historical sources contribute to our knowledge of natural and historic landscape interactions (Marinova and Atanassova 2006; Bellini et al. 2009; Pavlopoulos et al. 2010; Sadori et al. 2010b).

Mesogaia, the countryside of the city of Athens (Fig. 1), has been the setting of several archaeological investigations and excavations, given its great significance for the history of the Athenian Democracy. Vravron, lying on the east coast of Mesogaia, is an area of great historical significance, mainly famous for the Archaic and Classical sanctuary of Vravronia Artemis. The area, already inhabited in the Early/Middle Neolithic (Apostolopoulou-Kakavoyanni 2001a) contains important prehistoric settlements, which became a sacred place after Geometric times and was abandoned in Roman times. During the last millennia the area has experienced changes in palaeogeography related to the progradation of the

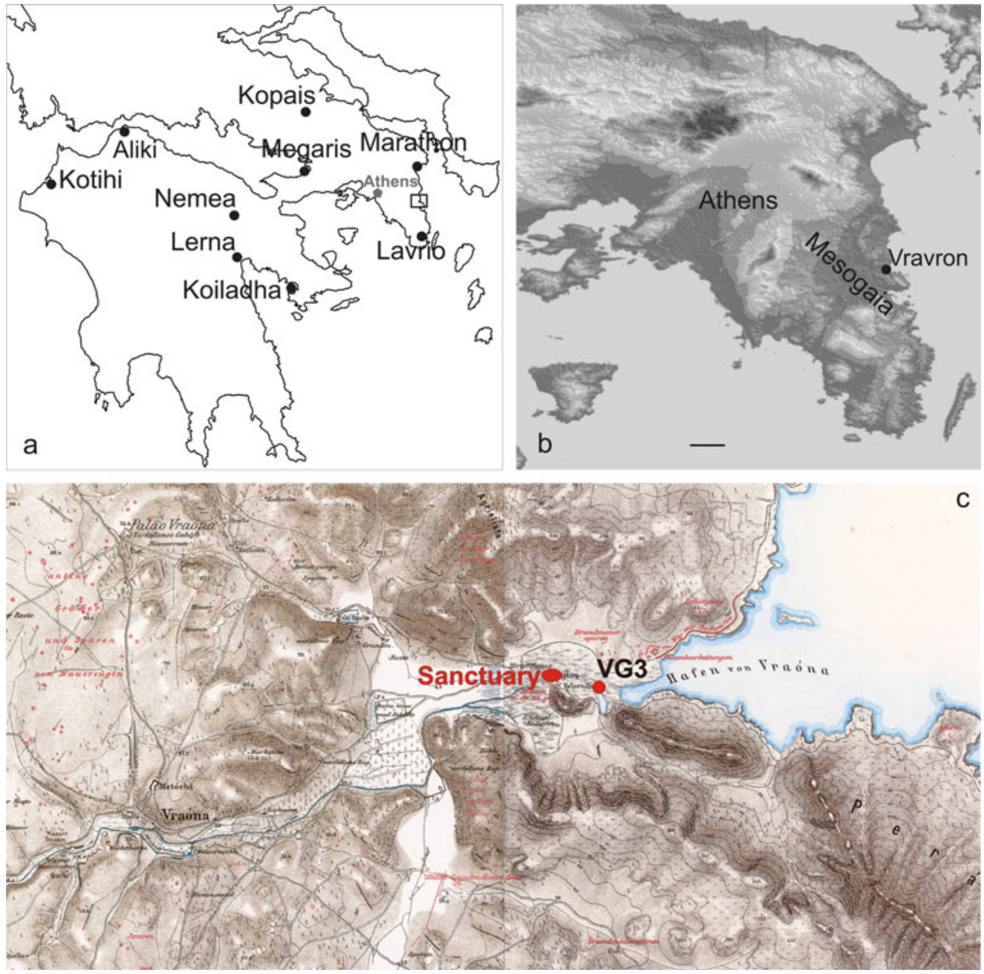

Fig. 1 **a** Location of the discussed Greek pollen sites, the Vravron area is indicated by a small rectangle. **b** Relief map of Attiki and **c** map of the Vravron area by Kaupert (1875–1894) where location of core VG3 is indicated

Erasinos River, fluctuations in sea level and sustained human impact on the ecosystem (Triantaphyllou et al. 2010).

The archaeological deposits of the Cave of Kitsos in Lavrio (Renault-Miskovsky 1981) and the marshy deposits of the Marathon coastal plain (Kouli et al. 2009) are the only sites that have been investigated in Attiki by means of palynology. Additionally a summary pollen diagram has been presented in Triantaphyllou et al. (2010). All other pollen sites (Fig. 1) are found at a distance of several kilometres in neighbouring basins, such as Kopais (Turner and Greig 1975; Allen 1990), Megaris (Jahns 2003) and in the Peloponnese (Argolis—Sheehan 1979; Koiladha—Bottema 1990; Lerna—Jahns 1993; Nemea—Atherden et al. 1993; Aliki—Kontopoulos and Avramidis 2003; Kotihi—Lazarova et al. 2009). Therefore considerable uncertainty exists about the Holocene vegetation history of Attica. In the present study, an effort to fill this gap by reconstructing the vegetation history since 3000 B.C. is attempted.

Given that pollen analysis of coastal sediments must consider the pollen input deriving from the vegetation of the entire river catchment, mixed together with the "local" component coming from the littoral vegetation (Mariotti Lippi et al. 2007a; Bellini et al. 2009; Sadori et al. 2010a), the palaeovegetational reconstruction, not only relates to the local environment of the site but also to the entire Mesogaia basin. Furthermore, through the correlation of information from pollen and archaeological data on both the environment and the cultural context, the decoding of man–environment relations of the past is progressing.

The setting of the area

The Vravron wetland, located on the eastern coast of the Attiki peninsula, 38 km east of the city of Athens, extends from the borders of the synonymous archaeological site to the coastal zone, following the Erasinos River. The Erasinos River has a catchment area of about 210 km^2, draining the central and southern parts of the Mesogaia basin. The basement of the broader Vravron area consists of the "NE Attika" geotectonic unit that represents a "relatively autochthonous" metamorphic sequence (Lepsius 1893; Mariolakos and Papanikolaou 1973), while a large part of Mesogaia is covered by Tertiary and Quaternary alluvial deposits (Lozios 1993). Late Miocene to Holocene lacustrine and terrestrial sediments occur along the Erasinos River on the Vravron coastal-estuarine plain, transgressing to marine deposits near the river mouth (Verginis 1995). A speleodoline with a rich assemblage of fossilized vertebrates, including *Canis lupo*, *Vulpes vulpes*, *Ursus arctos*, *Panthera leo*, Cervidae, herpetofauna and avifauna of an age of ca. 25–27 kyr, has been found in the hilly area, southwest of the coastal plain (Symeonidis and Rabeder 1995). The sea level rise of the area was estimated at a rate of about 0.74 mm/year during the last 4710 cal. year B.P., slightly different from that estimated by the Lambeck and Purcell (2005) model, due to the tectonic uplift of the area (Triantaphyllou et al. 2010).

The Vravron area records a long history of human settlement with Early to Middle Neolithic being the earliest finds (Apostolopoulou-Kakavoyanni 2001a). Archaeological investigation has shown that the small Early Bronze Age inhabitation developed into a flourishing community with a "city-like" organization in the Middle Bronze Age, and an acropolis during the Mycenaean (Apostolopoulou-Kakavoyanni 2001b, c; Polychronakou-Sgouritsa 2001). At the time Vravron bay was serving as a port (Apostolopoulou-Kakavoyanni 2001d; Polychronakou-Sgouritsa 2001). Tradition says that Greek troops left for Troy from Vravron bay. At the end of the Mycenaean period the collapse of the acropolis system led to the dispersal of the population into small agricultural communities (Apostolopoulou-Kakavoyanni 2001d). The start of the cult of Vravronia Artemis in Geometric times is connected with the return from Taurus of Iphigenia who served as the first "Ieria" (priestess) in the sanctuary. The sanctuary flourished in Archaic and Classical times (Kontis 1967; Steinhaouer 2001a, b) and was considered one of the most important sacred places for the Athenians. It was destroyed by the flooding of the Erasinos River at around the end of the third century B.C. and, despite several efforts to repair it by the Demos of Athens, it was buried under the Erasinos deposits (Papadimitriou 1948; Kontis 1967). During Roman times, the property system displaced the settlements further inland in Mesogaia, while most coastal areas, like Vravron, appear to have been deserted (Steinhaouer 2001c). Around A.D. 450 the Palaeochristianic basilica of St George was constructed in the area of the ancient sanctuary (Kontis 1967). The exact location of the famous sanctuary of Artemis was discovered and excavated by the archeologist I. Papadimitriou in 1948.

Today the climate of the area is typical Mediterranean with warm, dry summers and mild, humid winters. The mean annual precipitation for eastern Attica is 567 mm; the monthly air temperature ranges between 27 and 10°C with a mean annual value of 18°C (Hellenic National Meteorological Service, Marathon station, 1925–1995 interval). The area is exposed to NNE winds, mainly prevailing during summer.

The Erasinos River is a source of rich biodiversity as the lush vegetation on its banks provides nesting sites for several bird species and the brackish waters of its estuary hold large numbers of fish, providing prey for the birds. The vegetation of the restricted wetland consists mainly of *Potamogeton* sp., *Phragmites australis*, *Juncus* sp. and *Arundo donax*. Halophytic associations consisting of Juncetalia maritime and Arthrocnemetalia fructicosae grow all around the coastal marsh. On the sea cliffs the presence of *Limonium* spp. has been recorded. Around the wetland, the hilly areas are covered by maquis vegetation with *Juniperus oxycedrus*, *J. phoenicea*, *Pistacia lentiscus*, *Ceratonia siliqua*, *Olea europaea* and *Quercus coccifera*, and phrygana with *Sarcopoterium spinosum*, locally affected by grazing.

In the broader area the vegetation appears highly influenced by human activities. Mesogaia is predominantly under vine and olive cultivation. Other plants cultivated include pistachio and fig trees and various vegetables. Mediterranean pine forests with *Pinus halepensis* occur on the hilly and mountainous areas around the basin. During the last decades, especially after the transfer of Athens International Airport to the area, Mesogaia has turned into a rapidly developing urban area.

Materials and methods

Within the framework of joint environmental studies in the Vravron coastal area, systematic coring of the coastal marsh deposits has been carried out. In the present study a 5 m core (VG3), consisting of silts and fine sands, was selected as it represented the most complete sequence record. Micropalaeontological and sedimentological studies (Triantaphyllou et al. 2010) have recognized four lithostratigraphic units in the Vravron sequence. Units A (500–300 cm) and C (250–100 cm) correspond to an open marine depositional environment. Unit B (330–250 cm) is characterized by repeated flooding events recorded mainly by the abrupt decrease in epiphytic foraminifera species and marine ostracod species, and an increase in oligohaline ostracod species. The observed faunal changes are attributed to a reduction in water salinity due to intense freshwater input in the marine ecosystem during the end of Classical to Roman times (Triantaphyllou et al. 2010). Finally unit D (100 cm to the top of the sequence) displays a transition towards brackish environments (Triantaphyllou et al. 2010).

Four AMS radiocarbon datings of marine gastropods were carried out at Beta Analytic Inc. Miami, Florida. Marine gastropods turned out to be the only available dating material as no plant macroremains, organic rich sediments or tephra layers were recovered. Radiocarbon dates were calibrated using CALIB 5.0 (Stuiver and Reimer 1993) with a regional reservoir age correction of 149 ± 30 years for the Aegean (Facorellis et al. 1998). Calibrated and calendar ages are given in Table 1 (after Triantaphyllou et al. 2010). The chronological framework of the core is based on the radiocarbon dates obtained. In addition cross correlation of palaeoenvironmental data with the archaeological context of the area provides a more complete time frame.

In total 45 samples throughout the core available for pollen analysis were chemically treated with HCl (37%), HF (40%), acetolysed and sieved using a 10 μm sieve. A known quantity of *Lycopodium* exotic spores was added to estimate pollen concentration. Residues were mounted in silicon oil. Pollen and spores were identified using the key of Moore et al. (1991) and Reille's (1992–1998) pollen floras, while non-pollen palynomorph identification was based on Van Geel et al. (1989, 2003). Pollen preservation was good and total pollen concentration ranged from 160,000 to 3,000 grains/g, with an average of about 64,000 grains/g of dry sediment. A sum of ca. 350 pollen grains, excluding aquatics and spores was counted in each sample. Percentage pollen histograms were constructed based on a pollen sum of terrestrial pollen grains, excluding hydrophilous pollen and spores. In the diagram hydrophilous herbs include *Sparganium*, *Potamogeton*, *Typha latifolia*, *T. angustifolia*, Juncaceae and *Myriophyllum*.

Two pollen types of *Quercus* were distinguished: *Quercus* evergreen comprising *Q. ilex* and *Q. coccifera*, and *Quercus* deciduous that include all other oaks together with *Q. cerris* and *Q. suber*. *Carpinus orientalis*/*Ostrya* type includes both *C. orientalis* and *O. carpinifolia* as their pollen cannot be distinguished palynologically. *Carpinus betulus* has been distinguished but is not shown in pollen diagrams as its participation in the pollen spectra was very low and not continuous. Poaceae pollen were ascribed to Cerealia-type on the basis of grain (bigger than 40 μm) and annulus diameter size (bigger than 10 μm). Pollen grains of the halophytes *Hordeum maritimum* and *Elymus farctus*, occurring in the coastal vegetation of Vravron, could not be separated palynologically and therefore are included in Cerealia type. The pollen spectra yield several *Plantago* types with *P. major* being the most abundant followed by *P. media*. Both types are characterized by the absence of a distinct annulus and operculum in the pores and the small size of their pollen (Chester and Raine 2001). In the pollen diagram all *Plantago* pollen types are included in one curve. The identification of *Ranunculus acris* pollen was based on the irregular distribution of rounded scabrae and the occurrence of variation in thickness of the columellae (Moore et al. 1991).

Human activity is displayed based on the occurrence and abundance of pollen originating from crop plants such as Cerealia type, *Olea* and *Juglans* and ruderals or secondary indicator species (Behre 1990; Bottema and Woldring 1990). The latter are mainly comprised of *Plantago*, *Ranunculus acris*, *Sarcopoterium*, *Rumex* and Cichorioideae. The expansion of *Plantago*, *Sarcopoterium* and *Rumex* as well as the occurrence of Sordariaceae fungal spores are considered as indicative of pastoralism (Bottema and Woldring 1990; Eastwood et al. 1999; Knipping et al. 2008; Van Geel et al. 2003). Moreover a human/fire induced secondary vegetation community is suggested by the pyrophytic species *Juniperus*, *Sarcopoterium*, Ericaceae and Cistaceae (Kaniewski et al. 2007; Carrión et al. 2010b).

At the coastal site of Vravron the use of certain indicator species, like Chenopodiaceae, Poaceae or Brassicaceae is not possible as they also occur in the natural vegetation. Therefore their increased abundances mainly reflect the expansion of the halophytic habitat and they were not considered in the present study.

Results

Six local pollen zones, indicated with the prefix VRA and numbered from the bottom to the top of the core, were identified on the basis of qualitative and quantitative changes in the dominant terrestrial taxa (Figs. 2, 3). A brief description of the pollen assemblage zones, of the period they cover and of the vegetation change and anthropogenic signal is presented in Fig. 4.

VRA 1 (4.96–3.95 m; 2899–2630 B.C. at 4.78 m): The zone is characterized by a balanced association of both arboreal (AP: 36–68%) and non arboreal elements; abundant *Pinus* (32%), deciduous *Quercus* (9%), Cistaceae (13%), Asteraceae (20%) and Poaceae (5%). The presence of Ericaceae (3%), *Abies*, (2%), evergreen *Quercus* (2%), *Carpinus orientalis*/*Ostrya* type (1.5%), *Fagus*, *Fraxinus* and *Olea* is

Table 1 Radiocarbon dates from the Vravron VG3 core according to Triantaphyllou et al. (2010)

Lab. code	Depth (cm)	Lithostratigraphic unit	^{14}C age (year B.P.)	Calibrated age (cal. year B.P.)	Calibrated age (B.C./A.D.)
Beta-242239	65	D	950 ± 50	305–516	A.D. 1434–1645
Beta-242240	170	C	1730 ± 40	1016–1258	A.D. 692–934
Beta-211263	372	A	3430 ± 40	2953–3268	1319–1004 B.C.
Beta-211265	478	A	4690 ± 40	4579–4848	2899–2630 B.C.

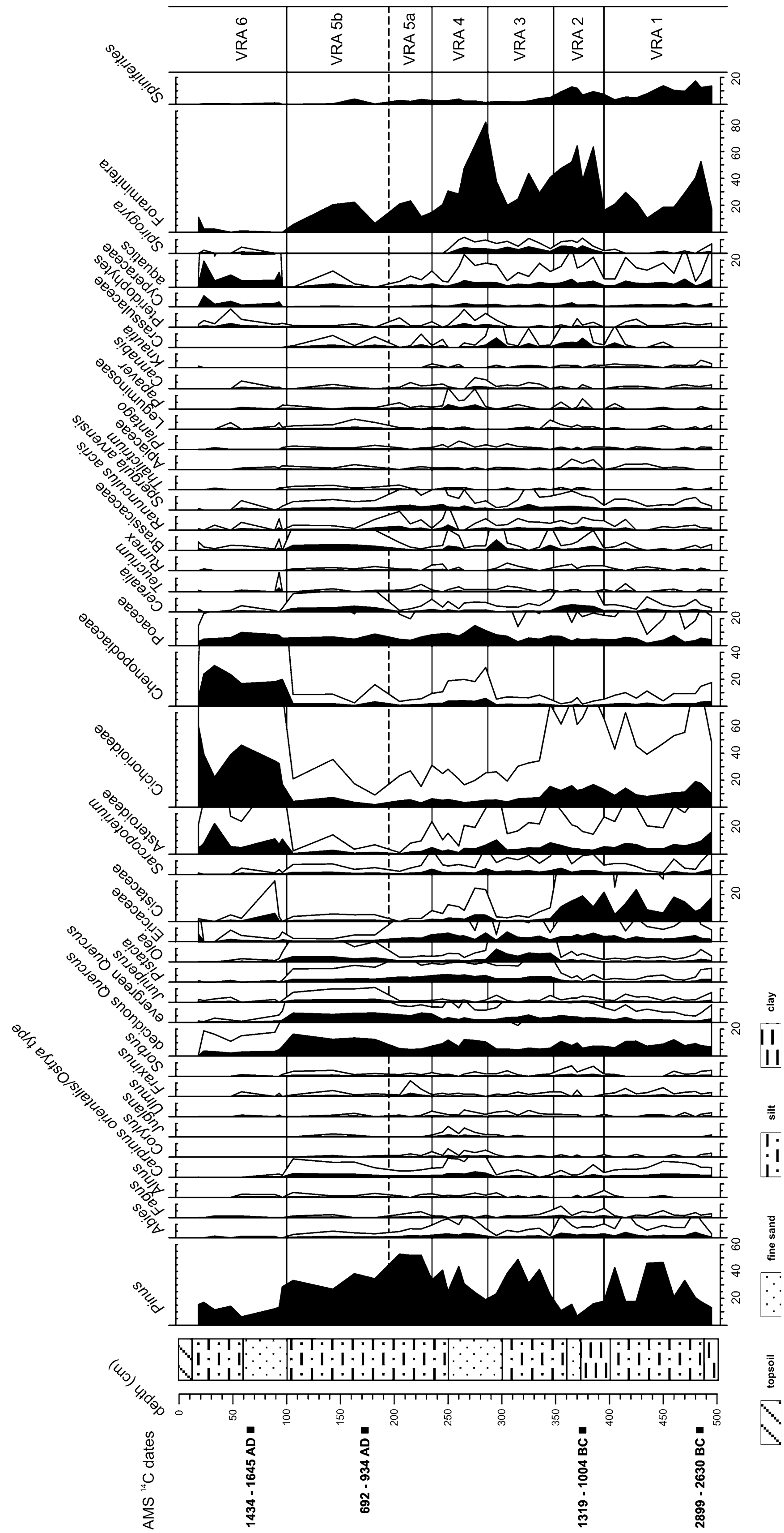

Fig. 2 Percentage pollen diagram from the Vravron site. Curves are exaggerated by a factor of 5

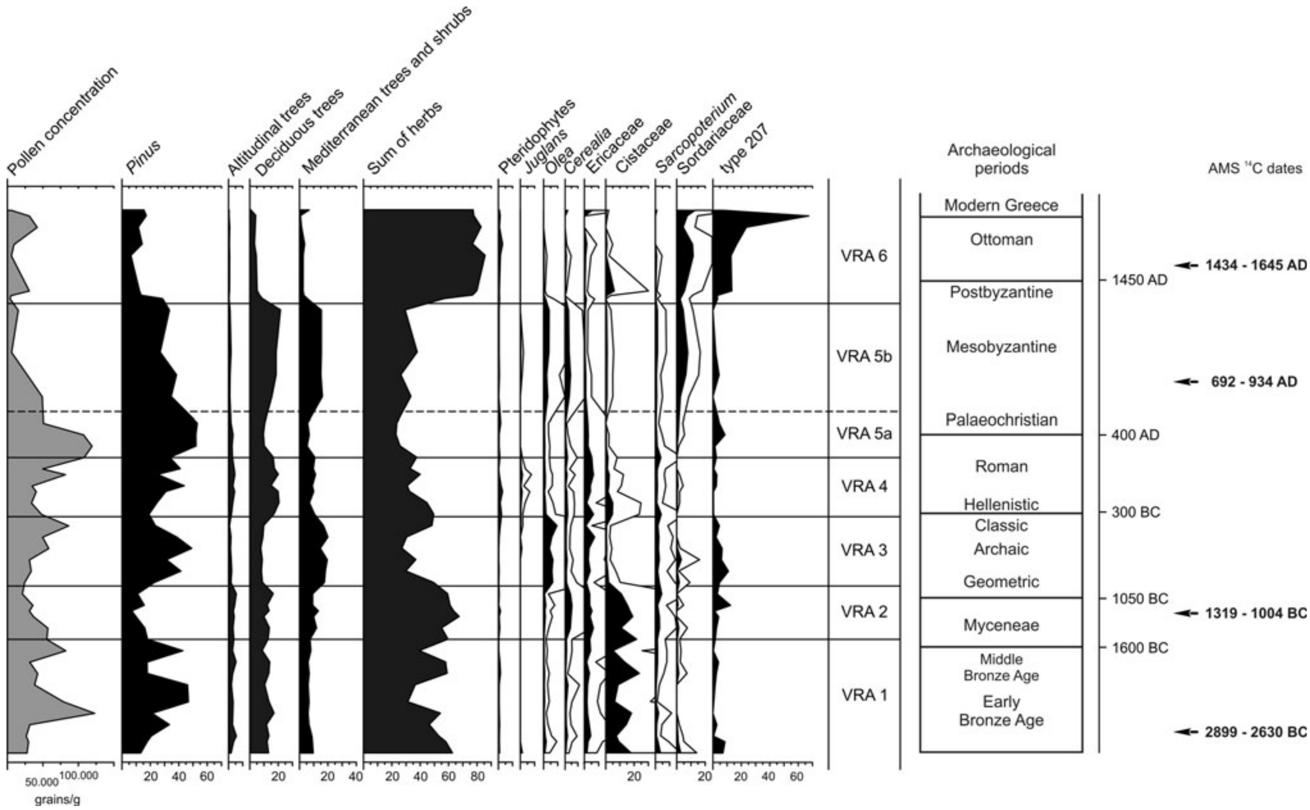

Fig. 3 Summary percentage pollen diagram from Vravron correlated with archaeological periods

notable. The curve of Cerealia-type fluctuates reaching percentages of 2%. The marine dinoflagellate *Spiniferites* spp., freshwater green algae *Spirogyra* and juvenile foraminiferal linings are added to the pollen spectra.

Zone VRA 2 (3.95–3.48 m; 1319–1004 B.C. at 3.72 m): This zone reflects a decrease in arboreal pollen (30–45%) due to the drop in *Pinus* percentages, while evergreen *Quercus* percentages are slightly increasing. Shrub pollen reaches high values, mostly due to the increase of Ericaceae (5%), Cistaceae (14%) and *Sarcopoterium*. Cerealia-type exhibits its highest percentages (5%) throughout the whole sequence. Cichorioideae, Brassicaceae and *Ranunculus acris* demonstrate an increasing trend. The presence of foraminifera linings and *Spiniferites* spp. appears increased.

Zone VRA 3 (3.48–2.87 m): An increase of arboreal pollen (57%) is observed, mainly attributable to the rise of *Pinus*. High abundances of *Pistacia* (max 3.8%) and *Olea* are recorded, with the later reaching a maximum of 9% towards the top of the zone. A marked drop in Cerealia-type abundances (0.5%) and a concurrent decrease in *Abies* (1%), *Fagus*, Cistaceae (1.3%), *Spiniferites* spp. and foraminifera linings are noted.

Zone VRA 4 (2.87–2.35 m): Abundances of deciduous *Quercus* (10%), *Carpinus orientalis*/*Ostrya* type (2.5%) and *Abies* (2.5%) appear increased during this interval, together with Cistaceae, Chenopodiaceae, Poaceae, hydrophilous herbs and fern spores. At the same interval a decline in the percentages of *Olea* and *Pistacia* is recorded, while the presence of *Juglans* is noteworthy. The curve of *Spiniferites* spp. exhibits a profound maximum.

Zone VRA 5 (2.35–1.00 m; A.D. 692–934 at 1.70 m): The zone is characterized by high arboreal pollen percentages (70%) and low Ericaceae and is subdivided into two parts. Sub-zone VRA 5a (2.35–1.95 m; A.D. 200–600) displays an increase of *Pinus* (52%) and evergreen *Quercus*, while a drop in deciduous *Quercus* (6%), *Carpinus orientalis*/*Ostrya* type (1%), *Abies* (1.4%), Ericaceae (3.4%) and Cistaceae values is recorded. During subzone VRA 5b (1.95–1.00 m; A.D. 600–1300) an increasing trend in *Quercus*, both deciduous and evergreen (14%), *Juniperus* (2%), *Olea* (1.5%) and deciduous arboreal pollen is seen.

Zone VRA 6 (1.00 m to top of core; A.D. 1434–1645 at 0.65 m): The zone is dominated by the presence of Cichorioideae (reaching 60%), Asteroideae (10%) and Chenopodiaceae (reaching 30%) and type 207 (Van Geel et al. 1989). Arboreal taxa, mainly represented by *Pinus*, exhibit very low abundances. Hydrophilous herbs appear increased, while marine indications like foraminifera linings and *Spiniferites* cysts are almost absent.

Zones	*Pollen assemblage*	*Vegetation type/changes*	*Anthropogenic signal*	*Archaeological periods*
VRA6	Dramatic decrease of AP (22%); increase of Asteraceae Asteroideae (10%), Cichorioideae (max 60%), Chenopodiaceae (max 30%) and Cyperaceae (3% of PS); Sordariaceae spores (15% of PS), type 207	Soil erosion Local expansion of wetland vegetation	Deforestation; animal husbandry	**Ottoman**
VRA 5	High AP (70%) and low Ericaceae values			**Byzantine**
VRA5b	Increase of deciduous and Mediterranean taxa: deciduous *Quercus* (14%), *Juniperus (2%), Olea* (1.5%), presence of *Juglans*, *Corylus* and *Alnus;*increase of Sordariaceae spores	Expansion of evergreen Mediterranean sclerophyllous vegetation	*Olea* and cereal cultivation, grazing evidence	
VRA5a	Increase of *Pinus* (52%) and evergreen *Quercus*; decrease of deciduous *Quercus* (6%), *Carpinus/Ostrya*-type (1%), *Abies* (1.4%), Ericaceae (3.4%), Cistaceae; *Juglans* absent	Expansion of *Pinus* forest; contraction of mixed deciduous and altitudinal forests	Declining human activity	Palaeochristian
VRA 4	AP (59%); increase of deciduous *Quercus* (10%), *Carpinus/Ostrya*-type (2.5%), *Abies* (2.5%). Increased Chenopodiaceae, Poaceae and Cistaceae abundances. Presence of *Corylus*, *Juglans* and *Alnus*; decrease of *Olea* (0.6%)	Modest expansion of mountainous and open mixed deciduous forest; wetland expansion	Reduction in *Olea* cultivation *Juglans* and *Corylus*	**Hellenistic-Roman** times Displacement of human inhabitation inland Sanctuary destruction
VRA3	AP increases (57%), high *Pinus*, *Pistacia* and *Olea* abundances; decrease of *Abies* (1%), *Fagus*, Cerealia-type (0.5%) and Cistaceae (1.3%); Sordariaceae , type 207	Expansion of *Pinus* forests and maquis with *Pistacia*, Ericaceae and *Olea*	Declining human activities, drop of cereal cultivation; extensive olive cultivation	**Archaic- Classical** Sanctuary flourishing **Geometric** Sanctuary establishment
VRA2	AP decreases, increase of Ericaceae (5%), Cistaceae, *Sarcopoterium* and evergreen *Quercus*; Cerealia-type maxima, increase of Sordariaceae spores, type 207	Expansion of Mediterranean sclerophyllous vegetation in the lowlands	Increase of human activities, intensification of cereal cultivation, systematic olive cultivation, grazing-burning evidence	**Mycenean** Acropolis, port
VRA1	Balanced association of both arboreal and non arboreal elements; *Pinus* (32%), deciduous *Quercus* (9%), Asteraceae (20%), Cistaceae (13%) and Poaceae (5%). Notable presence of Ericaceae (3%), *Abies* (2%), evergreen Quercus (2%), *Carpinus/Ostrya*-type (1.5%), *Fagus, Fraxinus* and *Olea*	Mosaic of open Mediterranean evergreen woodland alternated with *Juniperus* and *Pistacia* shrublands and open areas with grasslands. Occurrence of thermophilous deciduous and altitudinal forests	Cereal and olive cultivation evidence	**Middle Bronze Age** flourishing agricultural community **Early- Bronze Age** flourishing agricultural community

Fig. 4 Summary of the pollen assemblage zones for Vravron, vegetation changes and anthropogenic signal and archaeological phases

Discussion

The rich pollen flora recovered includes representatives from all modern phytogeographic zones, indicating the complexity of the plant communities that occurred in the area and outlining the vegetation development since the Early Bronze Age. Human presence in the area of Vravron, documented by archeological studies, appears to have been continuous since at least the Early Neolithic (Apostolopoulou-Kakavoyanni 2001a) and is regarded as an important environmental factor in the discussion of the Vravron pollen diagram (Figs. 2, 3).

Bronze Age agricultural activities and mid-Holocene aridity (ca. 3000–1500 B.C.)

The pollen assemblages of VRA 1 denote a diverse floral mosaic where open Mediterranean evergreen woods with *Pinus* and evergreen *Quercus* alternated with shrublands with *Juniperus*, *Pistacia*, Ericaceae and Cistaceaeae, and with grasslands exhibiting a large variety of herb taxa. In some parts of Mesogaia, thermophilous deciduous mixed forests of deciduous *Quercus*, *Carpinus orientalis*/*Ostrya* type and *Fraxinus* occurred and in the nearby mountains altitudinal conifer and broadleaved forests with *Abies* and *Fagus* existed. The presence of altitudinal forests has also been recorded on the nearby Marathon coastal plain (Kouli et al. 2009). Part of the lowland open vegetation areas was used for rural activities as shown by several indicator species that were recognized: Cerealia-type, *Ranunculus acris*, *Plantago* and coprophilous Sordariaceae spores (Van Geel et al. 2003) provide clear evidence about cultivation and stock breeding activities in the area. The presence of type 207, an erosion indicator fungal spore (Van Geel et al. 1989) is also indicative of human disturbance. The lower part of zone VRA 1 is radiocarbon dated to 2899–2630 B.C., thus VRA 1 corresponds to the Early and Middle Bronze Age. The occurrence of *Olea* is indicative of olive cultivation during the Bronze Age. The exploitation of olive in Greece during the Bronze Age has been documented both by archaeological remains (Asouti 2003; Margaritis and Jones 2008) and in numerous pollen spectra (Athanasiadis et al. 1996; Jahns 1993; Bottema and Sarpaki 2003; Pavlopoulos et al. 2007b; Lazarova et al. 2009). The overall vegetation pattern with the dominant presence of maquis vegetation with Ericaceae and Cistaceae is in good accordance with pollen records from the Peloponnese (Koiladha bay—Bottema 1990; Kleonai—Atherden et al. 1993; Lerna—Jahns 1993; Kotihi lagoon—Lazarova et al. 2009), western Greece (Lake Voulkaria—Jahns 2005) and other coastal sites in southern Italy (Di Rita and Magri 2009) and Sicily (Noti et al. 2009; Tinner et al. 2009). This raises the question whether this type of vegetation recorded after ca. 5000 B.P. is a result of mid- to late-Holocene increased aridity, or of human impact (Sadori and Narcisi 2001; Caroli and Caldara 2007; Pérez-Obiol and Sadori 2007; Sadori and Giardini 2007; Sadori et al. 2008; Di Rita and Magri 2009; Noti et al. 2009; Carrión et al. 2010a). The complexity of climatic conditions in the Mediterranean around 4300–3800 cal. year B.P. is the subject of several recent studies using primary climate proxies (e.g. isotopes or lake levels: Magny et al. 2009; Giraudi et al. 2011; Roberts et al. 2011), pollen data (Mercuri et al. 2011; Sadori et al. 2011), or pollen-based quantitative climatic reconstructions (Peyron et al. 2011) from terrestrial deposits. Between 5400 and 4300 cal. year B.P., a very distinct mid-Holocene humid phase followed by increased aridity has been recognized by Triantaphyllou et al. (2009b) in the marine deposits of the SE Aegean Sea. This warm and humid phase led to the deposition of a more recent sapropelic layer (SMH) than the S1 sapropelic layer. In any case the proximity of our site to the Vravron Bronze Age settlement does not allow a climatic interpretation of the Vravron record (Kouli and Dermitzakis 2008).

Cereal cultivation during the Mycenaean (ca. 1500–900 B.C.)

The low values of *Pinus* pollen combined with the increase of Ericaceae recorded around 1150 B.C. (cal. year 1319–1004 B.C.) imply the retreat of pine forests and the expansion of heath shrublands. Ericaceae are considered to be favored by human activity, mainly grazing and burning (Bottema and Woldring 1990; Atherden 2000; Bottema and Sarpaki 2003; Carrión et al. 2010a), and Cistaceae exhibit a high tolerance of fire (Engel et al. 2009; Knipping et al. 2008). At the same time a marked increase in agricultural and grazing activities is also suggested by the rise in Cerealia-type, Cichorioideae, *Ranuncus acris* and *Sarcopoterium*. Cerealia-type especially exhibits its highest percentages throughout the whole sequence. This vegetation pattern must be ascribed to intensification of human activities, particularly as this period corresponds to the Mycenaean inhabitation and the development of a network of settlements with an acropolis in the area (Polychronakou-Sgouritsa 2001). As far as the local environment of Vravron bay is concerned, the presence of abundant foraminifera linings and marine dinoflagellate cysts of *Spiniferites* spp., together with the freshwater algae *Spirogyra* confirm the existence of an open shallow marine environment with constant freshwater input. This was also concluded from foraminifera and ostracod analysis (Triantaphyllou et al. 2010). The bay was known to have been used as a port by the Mycenaeans (Polychronakou-Sgouritsa 2001).

Declining human activity during the Geometric (ca. 900–300 B.C.)

After 1150 B.C. the increase of *Pinus* observed in the Vravron pollen diagram is a feature common to several other pollen diagrams of southern Greece (Bottema 1990; Atherden et al. 1993; Jahns 1993; Lazarova et al. 2009) and on the nearby Marathon coastal plain (Kouli et al. 2009). Although pine expansion has been attributed to the spread of pine woods in coastal areas (Jahns 1993), where they still flourish today, in Vravron it coincides with the fall of the Mycenaean acropolis and the dispersal of the population into small agricultural communities during the Geometric "dark" ages (Apostolopoulou-Kakavoyanni 2001d). The expansion of *Pinus* should be connected with this context, more particularly when the concurrent decrease of herb vegetation observed suggests declining anthropogenic activity in the area (Noti et al. 2009). The peak values of *Olea* and the drop in Cerealia-type recorded mark a significant turn in agricultural activities, as cereal cultivation seems to be limited, while olive cultivation is favored. There is also evidence of intensification of *Olea* exploitation in Argolis (Sheehan 1979; Jahns 1993), Kotihi lagoon (Lazarova et al. 2009) and Messenia (Engel et al. 2009) during Geometric, Archaic and Classical times, implying a general change in farming practices. The foundation of the Artemis cult and the building of the first Geometric sanctuary fall into this period (Kontis 1967). It is difficult to determine whether the observed change of agricultural activities should be ascribed to cultural or religious causes or whether it was driven by the 3500–2500 cal. year B.P. cool and dry climatic event (Migowski et al. 2006; Triantaphyllou et al. 2009a).

Deciduous forest expansion (ca. 300 B.C.–A.D. 200)

During zone VRA 4 the increased abundances of deciduous *Quercus*, *Carpinus orientalis/Ostrya* type and *Abies* are regarded as a modest expansion of the thermophilous deciduous forest and altitudinal conifer forest. The spreading of Poaceae, Chenopodiaceae, fern spores and hydrophilous herbs represents an expansion of Vravron wetland. During this period, the micropalaeontological study of the Vravron deposits recorded intense freshwater and terrestrial organic matter influx in the coastal area, based on the increased presence of *Elphidium* and the abrupt decrease in epiphytic foraminifera (Triantaphyllou et al. 2010). Nevertheless the decrease in type 207 (Van Geel et al. 1989) indicates that terrigenous eroded material reaching the coastal area was reduced. This freshwater input has been attributed to an increased fluvial activity of the Erasinos River that resulted in the destruction and burial under flood deposits of the sanctuary of Artemis at the end of the Classical period (Papadimitriou 1948; Kontis 1967). Similarly intense fluvial activity and deltaic systems progradation between the Roman and post Roman period (Fouache et al. 2005), was important and strong enough to completely fill the Oeniades ancient harbour on the Acheloos delta (Vött 2007; Vött et al. 2007) which was active at least until 210 B.C. During this time interval, corresponding to Hellenistic and Roman times, the decline in the abundance of *Olea* is presumed to indicate the contraction of olive cultivation. Furthermore the appearance of *Juglans* and *Corylus* in the pollen spectra should be due to human activity. Both these light demanding taxa are part of the natural thermophilous deciduous forest in several sites in southern Greece (e.g. Lerna—Jahns 1993), but their occurrence in pollen diagrams is considered to be an indicator of man (Bottema 1980). The presence of these taxa in the Vravron pollen diagram coincides with expansion of the deciduous woodland. As this time interval is characterized as a period of increased human activity in the interior of Mesogaia (Steinhaouer 2001c), the vegetation pattern should be attributed to an increase in precipitation, corresponding to the so-called *Roman Climatic Optimum* (Lamb 1997; Telelis 2008). A similar vegetation pattern of deciduous woodland regeneration has been observed in Lake Voulkaria (Jahns 2005) after the end of the Classical City of Palairos.

Evergreen vegetation expansion during the Byzantine Age (ca. A.D. 200–1300)

The increase of arboreal taxa and the simultaneous decrease in shrub vegetation observed during zone VRA 5 denote a rather variable landscape in which the tree cover was modifying its composition, suggesting a period of climatic instability that has also been recorded in several palaeoenvironmental and historical archives (Telelis 2008). At the lower part of the zone (subzone VRA 5a) the contraction of mixed deciduous and altitudinal forest permits the expansion of *Pinus* that occupied most of the habitats. The observed decrease of Cerealia-type and *Olea*, together with the reduction in herb vegetation, should be connected with declining anthropogenic activity in the area. Indeed little is known about the Palaeochristianic and Protobyzantine inhabitation of Mesogaia (Gini-Tsofopoulou 2001a). Around A.D. 692–934, the increasing trend of Mediterranean shrubs is recognized as expansion of evergreen Mediterranean sclerophyllous vegetation under the pressure of human disturbance (Bottema and Woldring 1990). An expansion of maquis vegetation ca. A.D. 800 has also been recorded in Argolis pollen diagrams (Sheehan 1979), while a distinct rise of *Juniperus* in Lake Lerna ca. A.D. 1000 has been considered to indicate pasture (Jahns 1993). Similarly the increases observed in *Olea*, Cerealia-type and Sordariaceae spores suggest expansion of agricultural and pastoral activities. The extensive rural exploitation of Mesogaia is well documented by the discovery of large storage facilities (e.g. cellarage, vessels) in excavations of Mesobyzantine farmhouses (Gini-Tsofopoulou 2001b).

Soil erosion and wetland expansion (since ca. A.D. 1300)

In the upper part of the investigated core, the high Cichorioideae abundances observed in the Vravron coastal marsh deposits are indicative of the occurrence of conditions which let to the corrosion of other pollen grains around A.D. 1434–1645. Such high percentages often coincide with colluvial clay deposition, usually caused by human activity like ploughing (Bottema 1975; Bottema and Sarpaki 2003). Soil erosion is also evidenced by the high maximum in type 207 spores (Van Geel et al. 1989). At the same time a marked increase in abundance of Chenopodiaceae and hydrophilous herbs was documented indicating the expansion of the coastal marsh, while the presence of Sordariaceae spores suggests the presence of flocks in the area (Van Geel et al. 2003; Pavlopoulos et al. 2007a). This period coincides with the introduction of Arvanitic communities into the area by the Latin rulers of Attica in order to repopulate the abandoned landscape (Gini-Tsofopoulou 2001c), and with the Little Ice Age. During this period an increase in flood frequency and alluvial aggradation, correlated with hydroclimatic changes, has been observed all over Mediterranean Europe (Camuffo and Enzi 1996; Grove 2001) and in Northern Greece (Lespez 2003).

Conclusions

The pollen record of the Vravron coastal marsh represents a complex environment where human activities played an important role in shaping the landscape. The whole sequence denotes a rather variable landscape where open Mediterranean evergreen pine woods alternated with maquis shrublands and grasslands.

Vegetation exploitation by human societies in the area displays several fluctuations. The continuous presence of Cerealia-type throughout the sequence is indicative of cereal cultivation since the Early Bronze Age. Cereal cultivation activities appear intensified during the Mycenaean inhabitation, while since Geometric times a reduction in Cerealia-type is observed. Olive cultivation is already evidenced during the Early Bronze Age in accordance with other pollen diagrams from Greece. Olive exploitation appears to have intensified during Geometric to Classical times, indicating a significant change in agricultural activities from cereal to olive cultivation.

The gradual abandonment of *Olea* cultivation evidenced between the Roman and Early Byzantine ages coincides with the expansion of the Vravron wetland and of deciduous woodland in the interior of Mesogaia during a period of increased humidity. During the same interval a displacement of human activities in the interior of Mesogaia has been recorded in historic archives. During Mesobyzantine times, there is evidence of *Olea* and cereal cultivation intensification, while shortly before A.D. 1450 extensive soil erosion attributed to a rise in human activities such as ploughing and herding coincides with the introduction of Arvanites populations to the area and the Little Ice Age climatic event.

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References

Allen H (1990) A postglacial record from the Kopais basin, Greece. In: Bottema S, Entjes-Nieborg G, Van Zeist W (eds) Man's role in the Shaping of the Eastern Mediterranean landscape. Balkema, Rotterdam, pp 173–181

Apostolopoulou-Kakavoyanni O (2001a) The Neolithic (6000–3000 B.C.). In: Aikaterinidis G (ed) Mesogaia, history and civilization of Mesogaia Attika. International Athens Airport Publications, Athens, pp 18–27

Apostolopoulou-Kakavoyanni O (2001b) The Early Bronze Age (3000–2000 B.C.). In: Aikaterinidis G (ed) Mesogaia, history and civilization of Mesogaia Attika. International Athens Airport Publications, Athens, pp 35–42

Apostolopoulou-Kakavoyanni O (2001c) Mesogaia during Middle Bronze Age (1600–1050 B.C.). In: Aikaterinidis G (ed) Mesogaia, history and civilization of Mesogaia Attika. International Athens Airport publications, Athens, pp 43–44

Apostolopoulou-Kakavoyanni O (2001d) Mesogaia during Geometric times (1100–700 B.C.). In: Aikaterinidis G (ed) Mesogaia, history and civilization of Mesogaia Attika. International Athens Airport publications, Athens, pp 68–73

Asouti E (2003) Wood charcoal from Santorini (Thera): new evidence for climate, vegetation and timber imports in the Aegean Bronze Age. Antiquity 77:471–484

Athanasiadis N, Gerasimidis A, Panagiotidis S (1996) The presence of olive in pollen diagrams and their archaeological interpretation. In: Proceedings of the working meeting on "Olives and olive oil", Kalamata, 7–9 May 1993, pp 78–91

Atherden M (2000) Human impact on the vegetation history of southern Greece and problems of palynological interpretation: a case study from Crete. In: Halstead P, Frederick C (eds) Landscape and land use in Postglacial Greece. Sheffield Studies in Aegean Archaeology, vol 3, Sheffield, pp 62–78

Atherden M, Hall J, Wright JC (1993) A pollen diagram from the northeast Peloponnese Greece: implications for vegetation history and archaeology. Holocene 3:351–356

Behre K (1990) Some reflections on anthropogenic indicators and the record of prehistoric occupation phases in pollen diagrams from the Near East. In: Bottema S, Entjes-Nieborg G, Van Zeist W (eds) Man's role in the Shaping of the Eastern Mediterranean landscape. Balkema, Rotterdam, pp 219–230

Bellini C, Mariotti-Lippi M, Montanari C (2009) The Holocene landscape history of the NW Italian coasts. Holocene 19:1,161–1,172

Bottema S (1975) The interpretation of pollen spectra from prehistoric settlements (with special attention to Liguliflorae). Palaeohistoria 17:257–288

Bottema S (1980) On the history of walnut (*Juglans regia* L.) in southeastern Europe. Acta Bot Neerl 29:343–349

Bottema S (1990) Holocene environment of the Southrn Argolid: a pollen core from Koiladha Bay. In: Wilkinson TJ, Duhon ST (eds) Excavations in Frachthi cave 6. Indiana University Press, Bloomington, pp 117–138

Bottema S, Sarpaki A (2003) Environmental change in Crete: a 9000-year vegetation history and the effect of the Santorini eruption. Holocene 13:733–749

Bottema S, Woldring H (1990) Anthropogenic indicators in the pollen record of the Eastern Mediterranean. In: Bottema S, Entjes-Nieborg G, Van Zeist W (eds) Man's role in the shaping of the Eastern Mediterranean landscape. Balkema, Rotterdam, pp 231–264

Camuffo D, Enzi S (1996) The analysis of two bi-millenian series: Tiber and Po river floods. In: Jones PD, Bradley RS, Jouzel J (eds) Climatic Variations and forcing mechanisms of the last 2000 years. NATO ASI Series Vol I 41. Springer, Berlin, pp 433–450

Caroli I, Caldara M (2007) Vegetation history of Lago Battaglia (eastern Gargano coast, Apulia, Italy) during the middle-late Holocene. Veget Hist Archaeobot 16:317–327

Carrión JS, Fernández S, Jiménez-Moreno G, Fauquette S, Gil-Romera González-Sampériz P, Finlayson C (2010a) The historical origins of aridity and vegetation degradation in southeastern Spain. J Arid Environ 74:731–736

Carrión Y, Kaal J, López-Sáez JA, López-Merino L, Martínez-Cortizas A (2010b) Holocene vegetation changes in NW Iberia revealed by anthracological and palynological records from a colluvial soil. Holocene 20:53–66

Chester PI, Raine JI (2001) Pollen and spore keys for quaternary deposits in the northern Pindos Mountains, Greece. Grana 40:299–387

Di Rita D, Magri D (2009) Holocene drought, deforestation and evergreen vegetation development in the central Mediterranean: a 5500 year record from Lago Alimini Piccolo, Apulia, southeast Italy. Holocene 19:295–306

Eastwood WJ, Roberts N, Lamb HF, Tibby J (1999) Holocene environmental change in southwest Turkey: a palaeoecological record of lake and catchment-related changes. Quat Sci Rev 18:671–695

Engel M, Knipping M, Bróckner H, Kiderlen M, Kraft JC (2009) Reconstructing middle to late Holocene palaeogeographies of the lower Messenian plain (southwestern Peloponnese, Greece): coastline migration, vegetation history and sea level change. Palaeogeogr Palaeoclim Palaeoecol 284:257–270

Facorellis Y, Maniatis Y, Kromer B (1998) Apparent 14C ages of marine mollusc shells from a Greek island: calculation of the Marine Reservoir Effect in the Aegean Sea. Radiocarbon 40:963–973

Fouache E, Dalongeville R, Kunesch S, Suc J-P, Subally D, Prieur A, Louzouet P (2005) The environmental setting of the harbor of the classical site of Oeniades on the Acheloos Delta, Greece. Geoarchaeology 20:285–302

Gini-Tsofopoulou E (2001a) Palaeochristianic and protobyzantine period. In: Aikaterinidis G (ed) Mesogaia, history and civilization of Mesogaia Attika. International Athens Airport Publications, Athens, pp 150–165

Gini-Tsofopoulou E (2001b) Mesobyzantine period. In: Aikaterinidis G (ed) Mesogaia, history and civilization of Mesogaia Attika. International Athens Airport Publications, Athens, pp 166–181

Gini-Tsofopoulou E (2001c) Postbyzantine period. In: Aikaterinidis G (ed) Mesogaia, history and civilization of Mesogaia Attika. International Athens Airport Publications, Athens, pp 182–197

Giraudi C, Magny M, Zanchetta G, Drysdale RN (2011) The Holocene climatic evolution of Mediterranean Italy: a review of the continental geological data. Holocene 21:105–115

Grove J (2001) The Little Ice Age and its geomorphical consequences in Mediterranean Europe. Clim Chang 48:121–136

Jahns S (1993) On the Holocene vegetation history of the Argive Plain (Peloponnese, southern Greece). Veget Hist Archaeobot 2:187–203

Jahns S (2003) A late Holocene pollen diagram from the Megaris, Greece, giving evidence for cultivation of *Ceratonia siliqua* L. during the last 2000 years. Veget Hist Archaeobot 12:127–130

Jahns S (2005) The Holocene history of vegetation and settlement at the coastal site of lake Voulkaria in Acarnania, western Greece. Veget Hist Archaeobot 14:55–66

Kaniewski D, Paulissen E, De Laet V, Dossche K, Waelkens M (2007) A high resolution Late Holocene landscape ecological history inferred from an intramontane basin in the Western Taurus Mountains, Turkey. Quat Sci Rev 26:2,201–2,218

Knipping M, Müllenhoff M, Brückner H (2008) Human induced landscape changes around Bafa Gölü (Western Turkey). Veget Hist Archaeobot 17:365–380

Kontis ID (1967) Artenis Vravronia. Archeologiko Deltio 22:156–206 (in Greek)

Kontopoulos N, Avramidis P (2003) A late Holocene record of environmental changes from the Aliki lagoon, Egion, North Peloponnesus, Greece. Quat Int 111:75–90

Kouli K, Dermitzakis MD (2008) Natural and cultural landscape of the Neolithic settlement of Dispilio: palynological results. Hell J Geosci 43:29–39

Kouli K, Triantaphyllou M, Pavlopoulos K, Tsourou T, Karkanas P, Dermitzakis MD (2009) Palynological investigation of the Holocene palaeoenvironmental changes in the coastal plain of Marathon (Attica, Greece). Geobios 42:43–51

Lamb H (1997) Climate: present, past and future. Routledge, London

Lambeck K, Purcell A (2005) Sea-level change in the Mediterranean Sea since the LGM: model predictions for tectonically stable areas. Quat Sci Rev 24:1,969–1,988

Lazarova M, Koutsios A, Kontopoulos N (2009) Holocene vegetation history of the Kotihi lagoon (northwest Peloponnesus, Greece). Quat Int. doi:10.1016/j.quaint.2009.10.036

Lepsius R (1893) Geologie von Attika. Reimer, Berlin

Lespez L (2003) Geomorphic responses to long-term land use changes in Eastern Macedonia (Greece). Catena 51:181–208

Lozios S (1993) Tectonic analysis of Northeastern Attica metamorphic formations. Ph.D. Thesis, University of Athens

Magny M, Vanniere B, Zanchetta G, Fouache E, Touchais G, Petrika L, Coussot C, Walter-Simonnet A-V, Arnaud F (2009) Possible complexity of the climatic event around 4300–3800 cal. BP in the central and western Mediterranean. Holocene 19:823–833

Margaritis E, Jones M (2008) Crop processing of *Olea europaea* L.: an experimental approach for the interpretation of archaeobotanical olive remains. Veget Hist Archaeobot 17:381–392

Marinova E, Atanassova J (2006) Anthropogenic impact on vegetation and environment during the Bronze Age in the area of Lake Durankulak, NE Bulgaria: pollen, microscopic charcoal, non-pollen palynomorphs and plant macrofossils. Rev Paleobot Palynol 141:165–178

Mariolakos I, Papanikolaou D (1973) Observations on the tectonics of west Penteliko, Attika. Bull Hell Geol Soc X:134–179

Marriotti Lippi M, Bellini C, Trinci C, Benvenuti M, Pallecchi P, Sagri M (2007a) Pollen analysis of the ship site of Pisa San Rossore, Tuscani, Italy: the implications for catastrophic hydrological events and climatic change during the late Holocene. Veget Hist Archaeobot 16:453–465

Marriotti Lippi M, Guido M, Menozzi BI, Bellini C, Montanari C (2007b) The Massaciuccoli Holocene pollen sequence and the vegetation history of the coastal plains by the Mar Ligure (Tuscani and Liguria, Italy). Veget Hist Archaeobot 16:267–277

Mercuri AM, Sadori L, Uzquiano Ollero O (2011) Mediterranean and north-African cultural adaptations to mid-Holocene environmental and climatic changes. Holocene 21:189–206
Migowski C, Stein M, Prasad S, Negendank JFW, Agnon A (2006) Holocene climate variability and cultural evolution in the Near East from the Dead Sea sedimentary record. Quat Res 66:421–431
Moore PD, Webb JA, Collinson ME (1991) Pollen analysis. Blackwell Science, Oxford
Noti R, Van Leeuwen JFN, Colombaroli D, Vescovi E, Pasta S, La Mantia T, Tinner W (2009) Mid- and late-Holocene vegetation and fire history at Biviere di Gela, a coastal lake in southern Sicily, Italy. Veget Hist Archaeobot 18:371–387
Papadimitriou J (1948) Excavations in Vravron Attica. Praktika Archeologikis Etaireias 42:81–90
Pavlopoulos K, Triantaphyllou M, Karymbalis E, Karkanas P, Kouli K, Tsourou T (2007a) Landscape evolution recorded in the embayment of Palamari (Skyros Island, Greece) from the beginning of the Bronze Age until recent times. Geomorphol Relief Process Environ 1:37–48
Pavlopoulos K, Theodorakopoulou K, Bassiakos Y, Hayden B, Tsourou T, Triantaphyllou M, Kouli K, Vandarakis D (2007b) Plaeonevironmental evolution of Istron (N.E. Crete), during the last 6000 years: depositional environment, climate and sea level changes. Geodin Acta 20:219–229
Pavlopoulos K, Triantaphyllou MV, Karkanas P, Kouli K, Syrides G, Vouvalidis K, Palyvos N, Tsourou T (2010) Paleoenvironmental evolution and prehistoric Human environment, in the embayment of Palamari (Skyros Island, Greece) during Middle-Late Holocene. Quat Int 216:41–53
Pérez-Obiol R, Sadori L (2007) Similarities and dissimilarities, synchronisms and diachronisms in the Holocene vegetation history of the Balearic Islands and Sicily. Veget Hist Archaeobot 16:259–265
Peyron O, Goring S, Dormoy I, Kotthoff U, Pross J, De Beaulieu JL, Drescher-Schneider R, Vannière B, Magny M (2011) Holocene seasonality changes in the central Mediterranean region reconstructed from the pollen sequences of Lake Accesa (Italy) and Tenaghi Philippon (Greece). Holocene 21:131–146
Polychronakou-Sgouritsa N (2001) The Mycenaean Mesogaia. In: Aikaterinidis G (ed) Mesogaia, history and civilization of Mesogaia Attika. International Athens Airport Publications, Athens, pp 45–67
Reille M (1992–1998) Pollen et spores d' Europe et d' Afrique du Nord. Laboratoire de Botanique Historique et Palynologie, Marseille
Renault-Miskovsky J (1981) Analyse pollinique des sediments de la grotte de Kitsos (Lavrion-Greece). In: Lambert N (ed) La grotte Prehistorique de Kitsos (Attique). Ecole Francaise d'thenes, Paris, pp 633–655
Roberts N, Eastwood WJ, Kuzucuoglu C, Fiorentino G, Caracuta V (2011) Climatic, vegetation and cultural change in the eastern Mediterranean during the mid-Holocene environmental transition. Holocene 21:147–162
Sadori L, Giardini M (2007) Charcoal analysis, a method to study vegetation and climate of the Holocene: the case of Lago di Pergusa (Sicily, Italy). Geobios 40:173–180
Sadori L, Narcisi B (2001) The postglacial record of environmental history from Lago di Pergusa, Sicili. Holocene 11:655–670
Sadori L, Zanchetta G, Giardini M (2008) Late Glacial palaeoenvironmental evolution at lago di Pergusa (Sicily, Southern Italy). As inferred by pollen, microcharcoal, and stable isotopes. Quat Int 181:4–14
Sadori L, Giardini M, Giraudi C, Mazzini I (2010a) The plant landscape of the imperial harbour of Rome. J Archaeol Sci 37:3,294–3,305
Sadori L, Mercuri AM, Lippi MM (2010b) Reconstructing past cultural landscape and human impact using pollen and plant macroremains. Plant Biosyst 144:940–951
Sadori L, Jahns S, Peyron O (2011) Mid-Holocene vegetation history of the central Mediterranean. Holocene 21:117–129
Sheehan MC (1979) The postglacial vegetational history of the Argolid peninsula. Ph.D. thesis, University of Indiana
Steinhaouer G (2001a) The Archaic Mesogaia (7th-6th century B.C.). In: Aikaterinidis G (ed) Mesogaia, history and civilization of Mesogaia Attika. International Athens Airport Publications, Athens, pp 74–79
Steinhaouer G (2001b) The Classical Mesogaia (5th-4th century B.C.). In: Aikaterinidis G (ed) Mesogaia, history and civilization of Mesogaia Attika. International Athens Airport Publications, Athens, pp 80–139
Steinhaouer G (2001c) Mesogaia during Roman times (1st–3rd century A.D.). In: Aikaterinidis G (ed) Mesogaia, history and civilization of Mesogaia Attika. International Athens Airport Publications, Athens, pp 74–79
Stuiver M, Reimer PJ (1993) Extended C-14 data-base and revised Calib 3.0 C-14 age calibration program. Radiocarbon 35:215–230
Symeonidis N, Rabeder G (1995) Das Jungpleistozän in der «Höhle» von Vraona auf Attica in Griechenland. Ann Géol Pays Hell 36:1–109
Telelis I (2008) Climatic fluctuations in the Eastern Mediterranean and the Middle East A.D. 300-1500 from Byzantine documentary and proxy physical palaeoclimatic evidence—a comparison. Jahrb der Osterreichischen Byz 58:167–207
Tinner W, Van Leeuwen JFN, Colombaroli D, Vescovi E, Van der Knaap WO, Henne PD, Pasta S, D'Angelo S, La Mantia T (2009) Holocene environmental and climatic changes at Gorgo Basso, a coastal lake in southern Sicily, Italy. Quat Sci Rev 28:1,498–1,510
Triantaphyllou MV, Antonarakou A, Kouli K, Dimiza M, Kontakiotis G, Papanikolaou M, Ziveri P, Mortyn G, Lianou V, Lykousis V, Dermitzakis MD (2009a) Comparing Late Glacial–Holocene Plankton ecozones and Pollen Assemblage Zones: Basis for a multi-proxy ecostratigraphy in the south-eastern Aegean Sea (E. Mediterranean). Geo-Mar Lett 29:249–267
Triantaphyllou MV, Ziveri P, Gogou S, Marino G, Lykousis V, Bouloubassi I, Emeis KC, Kouli K, Dimiza M, Rosell-Mele A, Papanikolaou M, Katsouras G, Nunez N (2009b) Late Glacial-Holocene climate variability at the south-eastern margin of the Aegean Sea. Mar Geol 266:182–197
Triantaphyllou MV, Kouli K, Tsourou T, Koukousioura O, Pavlopoulos K, Dermitzakis MD (2010) Paleoenvironmental changes since 3000 B.C. in the coastal marsh of Vravron (Attiki, SE Greece). Quat Int 216:14–22
Turner J, Greig JRA (1975) Some Holocene pollen diagrams from Greece. Rev Paleobot Palynol 20:171–204
Van Geel B, Coope GR, Van der Hammen T (1989) Paleoecology and stratigraphy of the Late Glacial type section at Usselo (The Netherlands). Rev Palaeobot Palynol 60:25–129
Van Geel B, Buurman J, Brinkkemper O, Schelvis J, Aptroot A, Van Reenen G, Hakbijl T (2003) Environmental reconstruction of a Roman period settlement site in Uitgeest (The Netherlands), with a special reference to coprophilous fungi. J Archaeol Sci 30:833–873
Verginis S (1995) Geomorphologie und Geologie im Bereich der Höhle von Vraona. Ann Géol Pays Hell 36:8–15
Vött A (2007) Silting up Oiniadai's harbours (Acheloos River delta, NW Greece)—geoarchaeological implications of late Holocene landscape changes. Geomorphol Relief Process Environ 1:19–36
Vött A, Schriever A, Handl M, Brückner H (2007) Holocene palaeogeographies of the central Acheloos River delta (NW Greece) in the vicinity of the ancient seaport Oiniadai. Geodin Acta 20:241–256