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# Early seafaring activity in the southern Ionian Islands, Mediterranean Sea

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ABSTRACT

This paper summarises the current development in the southern Ionian Islands (Kefallinia and Zakynthos) prehistory and places it within the context of seafaring. Archaeological data from the southern Ionian Islands show human habitation since Middle Palaeolithic going back to 110 ka BP yet bathymetry, sea-level changes and the Late Quaternary geology, show that Kefallinia and Zakynthos were insular at that time. Hence, human presence in these islands indicates inter island-mainland seafaring. Seafaring most likely started some time between 110 and 35 ka BP and the seafarers were the Neanderthals. Seafaring was encouraged by the coastal configuration, which offered the right conditions for developing seafaring skills according to the "voyaging nurseries" and "autocatalysis" concepts.



## 1. Introduction

One of the key issues in current research on human maritime activity is focused on the questions of when seafaring started in the Mediterranean Sea and, what was the logic behind it.

Convincing evidence regarding the sea-going ability of hominins in the Mediterranean Sea comes from Sicily, Sardinia, Cyprus and recently from Crete. The presence of Aurignacian stone-tools in Sicily dated at around 30 ka BP (Mussi, 2001), Upper Palaeolithic tools in Sardinia, dated at between 22 and 18 ka BP (Melis and Mussi, 2002) and the Kebaran/Natufian industry in Cyprus, dated at between 13 and 11 ka BP (Ammerman, 2010), together with the proven insularity of these islands at the relevant time (Shacketon, 1987; van Andel, 1989) indicate without any doubt, the sea-going ability of *Homo sapiens* (Broodbank, 2006). Recently, the discovery of stone-tools in Crete, found in a flight of uplifted terraces and alluvial fans dated between 130 and 45 ka BP and, the likely insulation of Crete from the surrounding land masses since the Miocene, suggests that sea-going in the Mediterranean was started much earlier by pre-Sapiens hominins (Strasse et al., 2011).

Cherry (1990, 1984, 1981) and Patton (1997) examined the colonization of the Mediterranean Islands in the light of their palaeo-geography and biogeography. Broodbank (2006, 2002, 1999) discussed the colonization of the Aegean Sea islands in relation to the configuration of the islands and of the surrounding mainland.

The presence of human occupation from Middle Palaeolithic to Mesolithic in Epirus and in Peloponnesus on the western Greek mainland (Higgs and Vita- Finzi, 1966; Chavaillon et al., 1969, 1967; Darlas, 1999, 1995, 1994; Bailey, 1999; Bailey et al., 1992; Runnels et al., 1999; Runnels and van Andel, 2003 and Tourloukis, 2010) (Fig. 1) and in the southern Ionian Islands of Lefkada (Dousougli, 1999), Kefallinia (Kavvadias, 1984; Foss, 2002) and Zakynthos (Sordinas, 2003, 1970, 1968; Kourtessi-Philipaki, 1999) (Fig. 1) suggests that there was mobility between the Greek mainland and these islands during this period. However, before attempting to presume evidence of sea crossings to the islands, or discussing any seafaring ability from Middle Palaeolithic to Mesolithic, the insularity of these islands from the Greek mainland at the time in question, has to be proven.

The aim of this paper is to examine the insularity of the southern Ionian Islands (Fig. 2) and to present a detailed reconstruction of palaeo-shoreline migration and configuration from Middle Palaeolithic to Mesolithic, where evidence of human occupation occurs, so as to provide a framework for discussing the impacts of such changes in stimulating seafaring activity.

## 2. Geomorphological-geological setting

The southern Ionian Island chain includes four large islands: Lefkada, Kefallinia, Ithaka and Zakynthos, which lie at the shelf-edge bordering western continental Greece (Fig. 2). On the map, the four islands appear as an arc-like string of islands, separated

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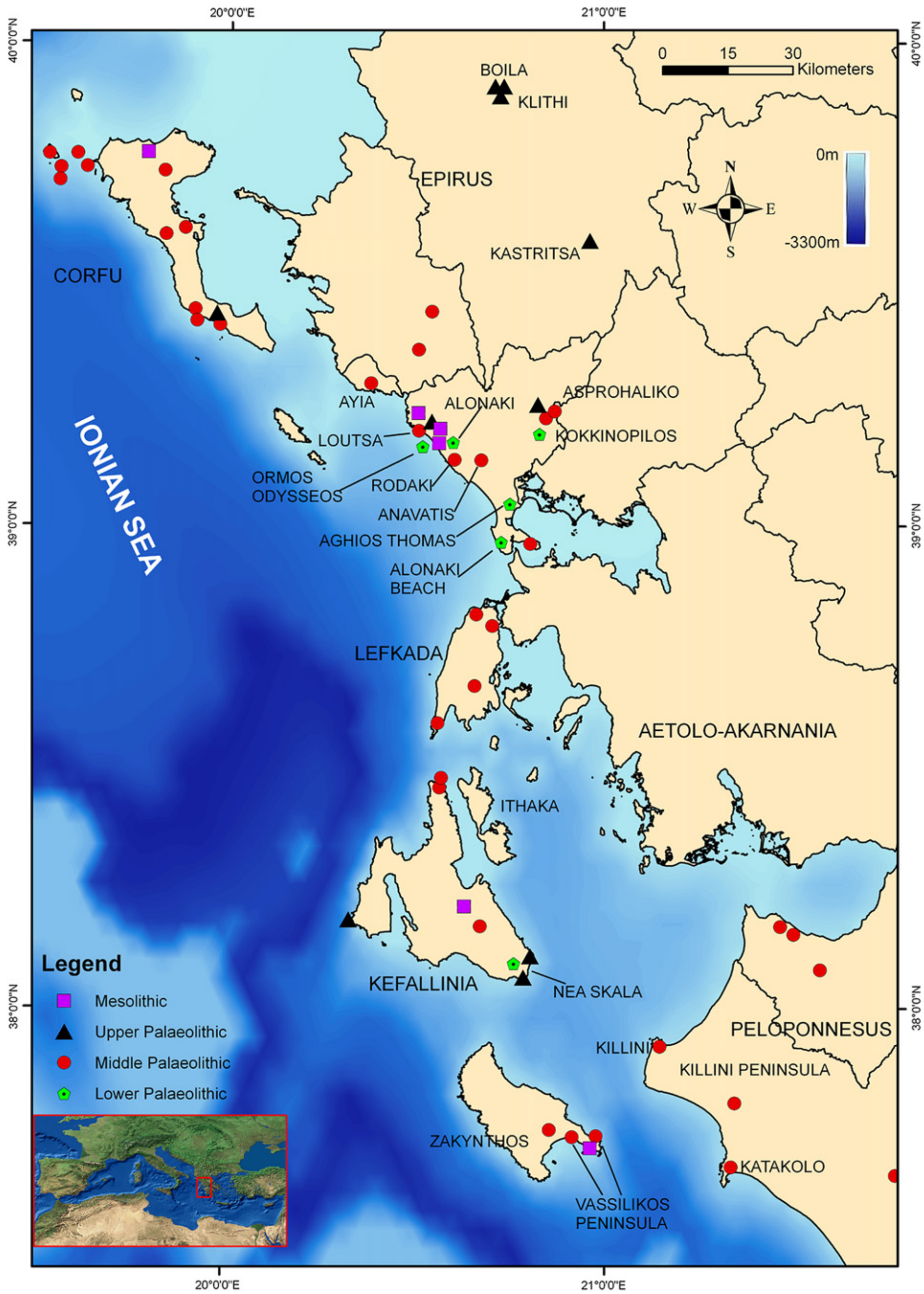


**Fig. 1.** Lower Palaeolithic to Mesolithic sites in the Ionian Islands and Greek mainland. Inset: Map of the Mediterranean Sea showing the study area.

from each other by straits of between 8.5 and 15 km wide, encompassing the mainland, thereby creating an almost land-locked sea about 100 km long and 45 km wide between the islands and the mainland (Fig. 2).

The land geology and seismic profiles show that the shelf is affected by ENE–WSW and N–S trending compressional and extensional stresses respectively, from Pliocene to present (Monopolis and Bruneton, 1982; Brooks and Ferentinos, 1984; Kokinou et al., 2005; Kokkalas et al., 2006). The compressional stresses have resulted in the formation of two elongated en-echelon synclinal basins oriented in an NNW–SSE direction, the Zakynthos, and Kefallinia basins, which lie along the longitudinal axis of the shelf (Fig. 2) and the extensional stresses have resulted in the formation of an E–W oriented direction basin, the Lefkada basin, which cuts across the Kefallinia and Lefkada islands (Fig. 2).

## 3. Palaeolithic and Mesolithic human presence in the western Greek mainland and Ionian Islands

Middle and Upper Palaeolithic as well as Mesolithic sites have been found all around the western Greek mainland and in the Ionian Islands (Fig. 1). The sites discussed here are based on a variety of published sources (Higgs and Vita- Finzi, 1966; Chavaillon et al., 1969, 1967; Sordinas, 2003, 1970, 1968; Kavvadias, 1984; Darlas, 1999, 1994; Bailey, 1999; Bailey et al., 1992; Runnels et al., 1999; Kourtessi-Philipaki, 1999; Dousougli, 1999; Foss, 2002; Runnels and van Andel, 2003; and Tourloukis, 2010). A few sites are rockshelters with well stratified and precise relative chronologies but the majority is open-air non-stratified and/or poorly stratified sites lacking precise dating. The stone-tools age in the aforementioned sites have been identified on the basis of: (i) typological analysis, (ii)

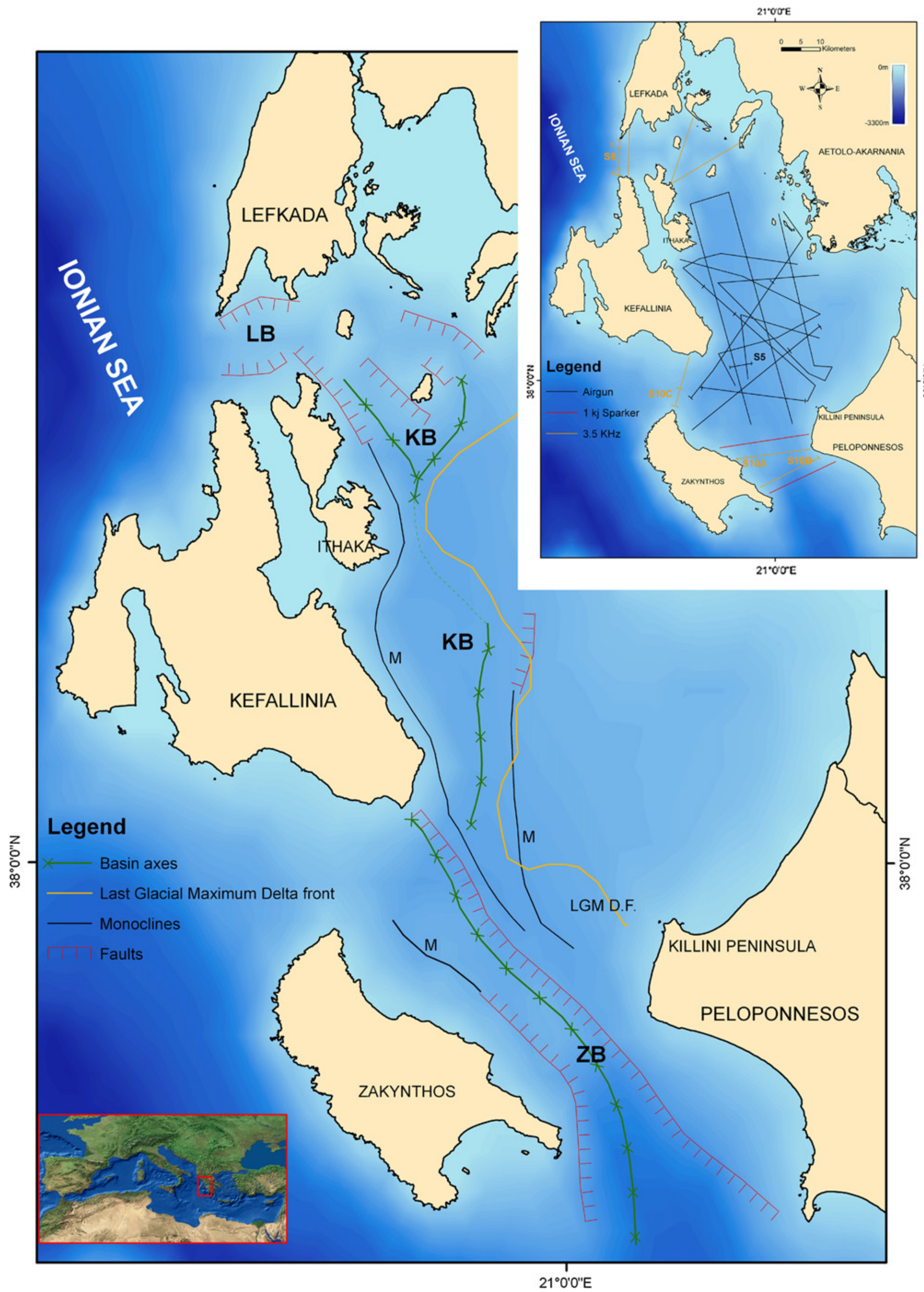


**Fig. 2.** Structural map of the southern Ionian Islands shelf showing the major tectonic features and their control on the bathymetry. ZB: Zakynthos Basin, KB: Kefallinia Basin, LB: Lefkada Basin. Thick lines with numbers indicate seismic lines shown in Figs. 4–6. Inset: Map of the Mediterranean Sea showing the study area.

chronostratigraphic criteria and (iii) radiometric dating using $^{14}C$, Thermal Luminesence (TL) and Infrared Stimulated Luminesence (IRSL).

The Middle Palaeolithic sites in Epirus are open-air sites (eg. Kokkinopilos, Anavatis, Alonaki, Rodaki, Ayia, Loutsa) only one is a rockshelter (Asprochaliko) (Fig. 1) (Higgs and Vita- Finzi, 1966; Bailey et al., 1992; Runnels et al., 1999; Runnels and van Andel, 2003 and Tourloukis, 2010). The artefacts found in the sites are characterized by a typical Middle Paleolithic Mousterian industry (Runnels et al., 1999; Runnels and van Andel, 2003). The artefacts found in Rodaki are a special variant of Mousterian, resembling the Pontinian Mousterian in Italy (Runnels and van Andel, 2003), which is dated between 110 and 35 ka (Kuhn, 1995).

The Mousterian industry in Epirus dates from about 98 to 30 ka BP based on radiometric and chronostratigraphic dating (Bailey, 1999; Runnels and van Andel, 2003).

The Upper Paleolithic sites in Epirus are mainly related to rockshelters (Klithi, Asprochaliko, Kastritsa, Boila etc) (Fig. 1). The artefacts found in the sites based on their typology, are assigned to Aurignacian, Gravettian and Epigravettian industry and their age, measured by $^{14}C$, is between 29 and 10 ka BP (Bailey et al., 1992; Huxtable et al., 1992; Bailey, 1999; Runnels and van Andel, 2003).

Mesolithic sites in Epirus are open-air sites (Fig. 1). The Mesolithic artefacts found are similar to those found at Corfu and Franchthi in Greece and at Konispol in Albania (Runnels and van

Andel, 2003). The Mesolithic in Epirus is dated by Thermal Luminencence between 10.5 and 9.4 ka BP (Runnels and van Andel, 2003) whereas in the nearby Corfu and Konispol, the Mesolithic is dated between 8.5 and 8 ka BP.

Middle and Upper Paleolithic sites in Elis and Achaia in the Peloponnesus are open-air sites. Middle Paleolithic sites are more abundant than those of Upper Palaeolithic. The Middle Palaeolithic artefacts are characterized by a typical Mousterian industry (Chavaillon et al., 1969, 1967; Darlas, 1999, 1994). The artefacts were found in marine terraces, but in two sites Katakolo and Killini (Fig. 1) they are found embedded in marine sediments dated ca 125 ka BP (Tyrrhenian) and 75 ka BP (Neo-Tyrrhenian) (Kowalczyk and Winter, 1979).

In the southern Ionian Islands, Lefkada, Kefallinia and Zakythos a total number of fifteen (15) Middle Palaeolithic to Mesolithic open-air sites have been detected (Sordinas, 2003, 1970, 1968; Kavvadias, 1984; Kourtessi-Philipaki, 1999; Dousougli, 1999; Foss, 2002) (Fig. 1.). Based on the stone-tool typology, ten (10) sites were assigned to Middle Palaeolithic: four (4) sites in Leflada (Dousougli, 1999); three (3) sites in Kefallinia (Kavvadias, 1984) and three (3) sites in Zakythos (Kourtessi-Philipaki, 1999). All Middle Paleolithic sites were open-air ones and related to a typical Mousterian industry. Furthermore, Runnels et al. (1999) and Kourtessi-Philipaki (1999) suggest that the Middle Palaeolithic stone-tools found in Vassilikos Peninsula (Aghios Nikolaos and Gerakas) in the island of Zakynthos and at Rodaki in Epirus have the same typological characteristics and resemble the littoral Mousterian (Pontinian) in Italy, which is dated at between 110 and 35 ka BP (Kuhn, 1995).

Mesolithic was found in one site in Kefallinia and in one site in Zakynthos (Sordinas, 2003). Both sites were open-air sites. According to Sordinas (1970) the stone-tools found in Zakynthos resemble the stone-tools found in Corfu and their age based on $^{14}C$ dating is assigned to 7770 ± 340 ka BP.

## 4. Methodology

The insularity of the southern Ionian Islands from the Greek mainland and the palaeo-shoreline migration and configuration from Middle Palaeolithic to Mesolithic was examined with the use of the hydrographic charts and by plotting the palaeo-sea-levels, as inferred by the sea-level curve mathematically modelled by Lambeck (1996) for the Aegean Sea (Fig. 3), which takes into consideration the glacio-hydrostatic effect on the earth's crust but does not compensate for regional and local vertical tectonic movements. Furthermore, changes in the palaeo-bathymetry by geological processes on the seafloor between the islands and the Greek mainland which occurred during this time interval have also been examined by studying the late Quaternary geological evolution of the area (Brooks and Ferentinos, 1984; Hasiotis et al., 2005).

The reconstruction of the palaeo-shoreline position and configuration was compiled for the following time windows of human cultural evolution:

1. The Lower/Middle Palaeolithic transition
2. The Middle/Upper Palaeolithic transition
3. The Upper Palaeolithic/Mesolithic transition and
4. The Mesolithic/Neolithic transition

The first transition took place at around 100 ka BP, the second transition took place at around 30 ka BP, the third transition at around 10 ka BP, and the fourth transition at around 8.0 and 7.5 ka BP (Runnels, 2001). These dates are considered as a good average approximation of the time that all the cultural transitions mentioned above occurred, since these transitions did not take place simultaneously in the Balkans and the Eastern Mediterranean (Runnels, 2001). According to Lambeck's sea-level curve (Fig. 3) at the above mentioned time-slices, the sea level was standing at −20, −60, −50 and −20 m below the present one, respectively. Furthermore, the palaeo-shoreline configuration was compiled at: (i) the Tyrrhenian Interglacial at 125 ka BP when the sea level was standing at approximately the same level as at present, (ii) towards the termination the First Glacial Maximum when the sea level was at −80 m, of and (iii) the Last Glacial Maximum at 18 ka BP when the sea level was at −120 m (Fig. 3). This curve was chosen as the best available as there is not a sea-level curve within the area under examination, compiled by geological and archaeological data going back to Middle Palaeolithic.

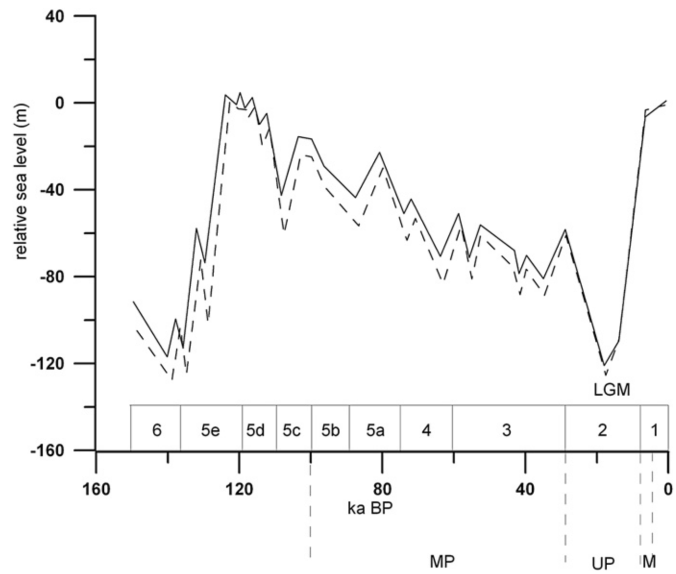


**Fig. 3.** Predicted relative sea-level curve (dashed line) in central Aegean Sea compared to eustatic sea-level curve (solid line). Modified from Lambeck (1996).

## 5. Data presentation

### 5.1. Island insularity

The insularity of the southern Ionian Islands from the Greek mainland during the Middle Palaeolithic, Upper Palaeolithic and Mesolithic period is examined by studying the overall late Quaternary geological evolution of the Zakynthos Kefallinia and Lefkada basins. The overall configuration of the Zakynthos and Kefallinia basins, the water depth, the sediments thickness and the basin fill architecture, as appeared in the seismic profile shown in Fig. 4 in this paper and in the seismic profiles of Figs. 7, 8 and 11 of Brooks and Ferentinos (1984) and Fig. 4 of Hasiotis et al. (2005), indicate that the basin floor was continuously subsiding and, during the time concerned submerged.

The Lefkada basin is bounded on both sides by faults with a total throw of at least 200 m on each side (Fig. 5). The seafloor is at a water depth between 250 and 350 m, is flat and covered by a sedimentary sequence consisting of well layered and parallel reflectors with a thickness of more than 50 m (Fig. 5). This is indicative of continuous marine sedimentation. The time length needed for the 50 m thick sequence to deposit is estimated to be between 100 and 500 ka, based on sedimentation rates between

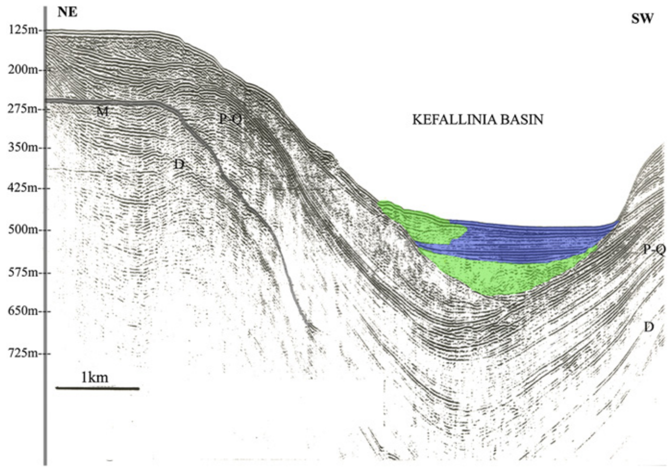


**Fig. 4.** Air-gun profile S5 across the Kefallinia basin showing the basin controlled by monoclines and underlain by a sedimentary succession made up of successive inclined and axially diverging layers. The upper part of the succession in the axial part of the basin is interspersed with debris flows. Shaded blue are layers of turbiditic and/or hemipelagic origin. Shaded green are debris flows. See Fig. 2 for location. P–Q: Plio-Quaternary, M: Seafloor multiple, D: Diapir. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

0.04 and 0.22 mm/year that have been observed in most of the shelf basins of the Aegean and Ionian Seas (Geraga et al., 2000, 2005, 2008; Piper and Perissoratis, 2003; Giresse et al., 2003; Rousakis et al., 2004). Therefore the Lefkada basin was submerged during the time concerned. However, for higher sedimentation rates like those observed in the nearby Corinth and Patras basins, which are between 1 and 2–3 mm/year (Chronis et al., 1991; Lykousis et al., 2007; Bell et al., 2009), the time length for the 50 m thick sedimentary sequence to deposit is between 16.6 and 50 ka. This time length is less than the time length under consideration. In this case and in the absence of seismic profiles with penetration deeper than 50 m, the palaeo-depth (palaeo-bathymetry) in the Lefkada basin is estimated by examining the palaeo-seafloor level in relation to palaeo-sea level over the last 100 ka at the time windows of 8, 10, 20, 30, 59 and 100 ka. The palaeo-seafloor level in the basin must be adjusted in relation to the present day depth, taking into consideration the subsidence of the seafloor due to the vertical movement along the bounding faults and the sediment accumulation at the aforementioned time windows. In the former case the palaeo-seafloor level was standing at higher levels than at present day seafloor level and in the latter case was standing at lower levels. The expected slip rate on the faults bounding the Lefkada basin, based on estimated slip rates on faults bounding the nearby tectonically active Patras and Corinth basins, is between 1 and 5 mm/year for the late Pleistocene and Holocene (Chronis et al., 1991; Lykousis et al., 2007; Bell et al., 2009). The sedimentation rate in the basin for the same time period is between 1 and 2–3 mm/year, as mentioned above.

The palaeo-depth (paleo-bathymetry), based on the above mentioned, is expressed by the equation:

$$P_d = D - P_{sl} - T_{sub} + S_{th}$$

where $P_d$ is the palaeo-depth, $D$ is the present day depth, $P_{sl}$ is the palaeo-sea level, $T_{sub}$ is the seafloor subsidence due to the fault activity over the last 125 ka and $S_{th}$ is the thickness of the accumulated sediment over the same period. $T_{sub}$ is a function of the fault slip rate and is given by $T_{sub} = 2/3S_{lr}{*}t$ where $S_{lr}$ is the slip in mm/year and '$t$' is the time from present, in ka. The coefficient 2/3 is based on an uplift to subsidence ratio of 1: 2, observed in the Patras and Corinth basins (Bell et al., 2009). $S_{th}$ is a function of the sedimentation rate and is given by $S_{th} = S_r{*}t$ where $S_r$ is the sedimentation rate in mm/year and '$t$' the time from present, in ka. The palaeo-depth and the palaeo-seafloor levels are estimated at the aforementioned time windows for low (1 mm/year), medium (2 mm/year) and high (5 mm/year) slip rates and high sedimentation rates of 1 and 3 mm/year (Table 1). The estimated palaeo-depths ($P_d$) over the Lefkada basin range from 19 to 601.7 m (Table 1) suggesting that the Kefallinia Island was insular at the aforementioned time windows and therefore all over the last 125 ka.

### 5.2. Palaeo-shoreline migration and configuration

The study of the Last Glacial Maximum (LGM) transgression surface and isotopic stage 2 delta over the shelf shows that they

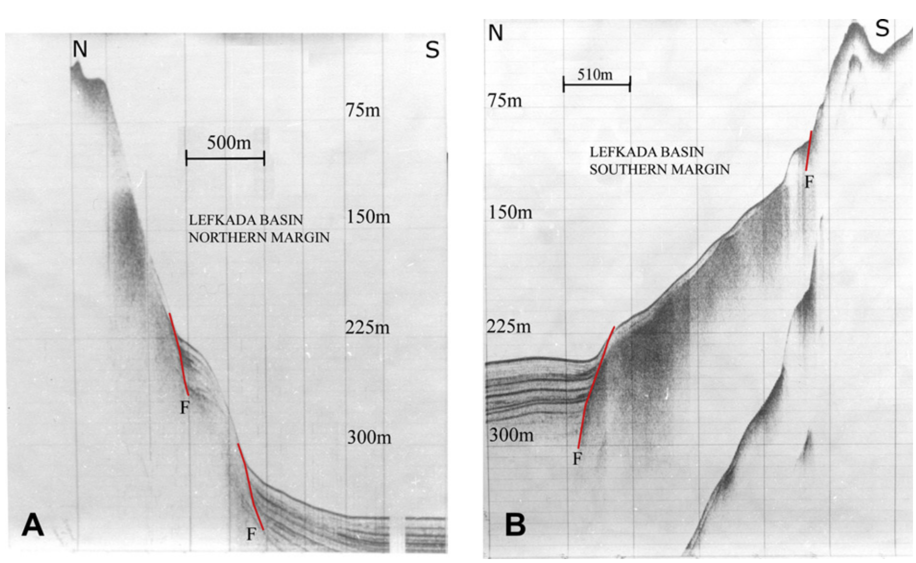


**Fig. 5.** 3.5 kH profiles S8A, B across the Lefkada basin showing the fault controlled margins and the basin fill sedimentary succession. F: Fault. See Fig. 2 for location.

**Table 1**
Palaeo-depths ($P_d$) at selected time windows in the last 125 ka in the Lefkada basin. Also are shown, the Palaeo-seafloor level due to subsidence ($T_{sub}$) and sediment accumulation ($S_{th}$). Fault slip rates of: 1, 2 and 5 mm/year correspond to 0.66, 1.33 and 3.33 subsidence rates based on an uplift to subsidence ratio of 1:2.

| Time (ka) | | $D$ | $P_{sl}$ | $T_{sub}$ | | | $S_{th}$ | | Palaeo-depth (m) $P_d = D - P_{sl} - T_{sub} + S_{th}$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Present-day seafloor level (depth) (m) | Palaeo-sea level (m) based in Fg 3 | Palaeo-seafloor level (m) for slip rates of: | | | Palaeo-seafloor level (m) for sedimentation rates of: | | | | | | | |
| | | | | 2/3 × 1 mm/y | 2/3 × 3 mm/y | 2/3 × 5 mm/y | 1 mm/y | 3 mm/y | | | | | | |
| 8 | Mesolithic/Neolithic Transition | 300 | 20 | 5.3 | 10.6 | 26.6 | 8 | 24 | 282.7 | 277.4 | 261.4 | 298.7 | 293.4 | 277.4 |
| 10 | U. Palaeolithic/Mesolithic Transition | 300 | 50 | 6.6 | 13.3 | 33.3 | 10 | 30 | 253.4 | 246.7 | 226.7 | 273.4 | 266.7 | 246.7 |
| 20 (18–21) | Last Glacial Maximum | 300 | 120 | 13.2 | 26.6 | 66.6 | 20 | 60 | 186.8 | 173.4 | 133.4 | 226.8 | 213.4 | 173.4 |
| 30 | M. Palaeolithic/U. Palaeolithic Transition | 300 | 60 | 19.8 | 39.9 | 99.9 | 30 | 90 | 250.2 | 230.1 | 170.1 | 310.4 | 290.1 | 230.1 |
| 59 | Termination of the First Glacial Maximum | 300 | 80 | 38.9 | 78.5 | 194.7 | 59 | 177 | 240.1 | 200.5 | 84.3 | 358.1 | 318.5 | 202.3 |
| 100 | L. Palaeolithic/M. Palaeolithic Transition | 300 | 20 | 66 | 133 | 333 | 100 | 300 | 314 | 247 | 47 | 514 | 447 | 257 |
| 125 | Tyrrhenian Interglacial | 300 | ca 0 | 83.3 | 250 | 416.6 | 125 | 375 | 351 | 185 | 19 | 601.7 | 435 | 268.4 |

occur at different levels from the predicted level of between −120 and −125 m below the present day according to Lambeck's (1996) curve (Fig. 3). On the Zakynthos shelf, the transgression surface lies at a depth of 85 m (Fig. 6A). In the Killini peninsula shelf it lies at a depth of 110 m (Fig. 6B). On the southern and northern Kefallinia and Zakynthos shelves, the transgression surface is at a depth of 105 m (Fig. 6C). On the shelf bordering the Greek mainland between the Peloponnesus and Aetolo-Akarnania, isotopic stage 2 delta lies at a depth of between 137 and 165 m, (Piper et al., 1990, their Fig. 3, pp: 454). The occurrence of the LGM transgression surface at different depths to the expected one between 120 and 125 m suggests that the shelf is subjected to differential vertical movement which greatly varies in space, ranging from −2.4 m/ka (subsidence) to 1.8 m/ka (uplift). Similar special variability in tectonic movements is observed in a longer time scale in the surrounding coastal zone. The occurrence of the Last Interglacial transgression terrace (Tyrrhenean) at different altitudes to that of the expected altitude of between 4 and 10 m, i.e. in Zakynthos island at 20 m above sea-level (Zelilidis et al., 1998), in Killini at between 20 and 70 m (Kelletat et al., 1976; Kowalczyk and Winter, 1979) and in Varda at between 40 and 60 m (Stamatopoulos et al., 1988; Stamatopoulos and Kontopoulos, 1994), indicate that the bordering land was also subjected to differential vertical movement with estimated uplift rates of between 0.2 and 0.5 m/ka. The complex spatial and temporal variability of the vertical tectonic movements as described above does not permit the inclusion of tectonically driven seafloor movement data from different localities into a single sea-level curve. Therefore, in the reconstruction of the palaeo-shoreline position and configuration shown in Fig. 7, the tectonically driven modification of the seafloor is not included. However, the average shifting of the palaeo-shoreline caused by the vertical tectonic movements, based on the aforementioned uplift and subsidence rates in relation to the sea-level change over the same time period and the shelf gradient, as determined from the seismic profiles, would have been between a few hundred meters and 2 km. Therefore, the palaeo-shoreline position and configuration shown in Fig. 7 would slightly deviate from the exact position and configuration of the palaeo-shoreline of that time.

The study of the palaeo-shoreline position and configuration of the southern Ionian Islands and the Greek mainland between 100 and 8 ka BP, at six key time windows of the human cultural evolution mentioned above, suggests that the shoreline configuration and the size of the present day land-locked sea was continuously changing at the time concerned (Fig. 7). During that time the land-locked sea was bound by a highly indented coastline, with the mainland and the islands so closely integrated, as to give the impression of a continuous landscape (Fig. 7A–E).

For the last 125 ka when the sea level was fluctuating between −20 and −120 m below present (Fig. 7) the island of Lefkada was connected to the mainland (Fig. 7A–E). The Kefallinia, Ithaka and Zakynthos islands, which were larger than at present, were always insular (Fig. 7A–E). When the sea level was between −60 and −80 m below the present one, the shoreline progression substantially narrowed the distance of the islands from the mainland to between 5 and 12 km, the distance from each other to between 5 and 7 km and islets emerged from the sea (Fig. 7C and D). During the Last Glacial Maximum when the sea level was at −120 m the Kefallinia, Ithaka and Zakynthos islands were connected as one large island, separated from the mainland by narrow straits between 5 and 7.5 km long and new islets emerged from the sea (Fig. 7E).

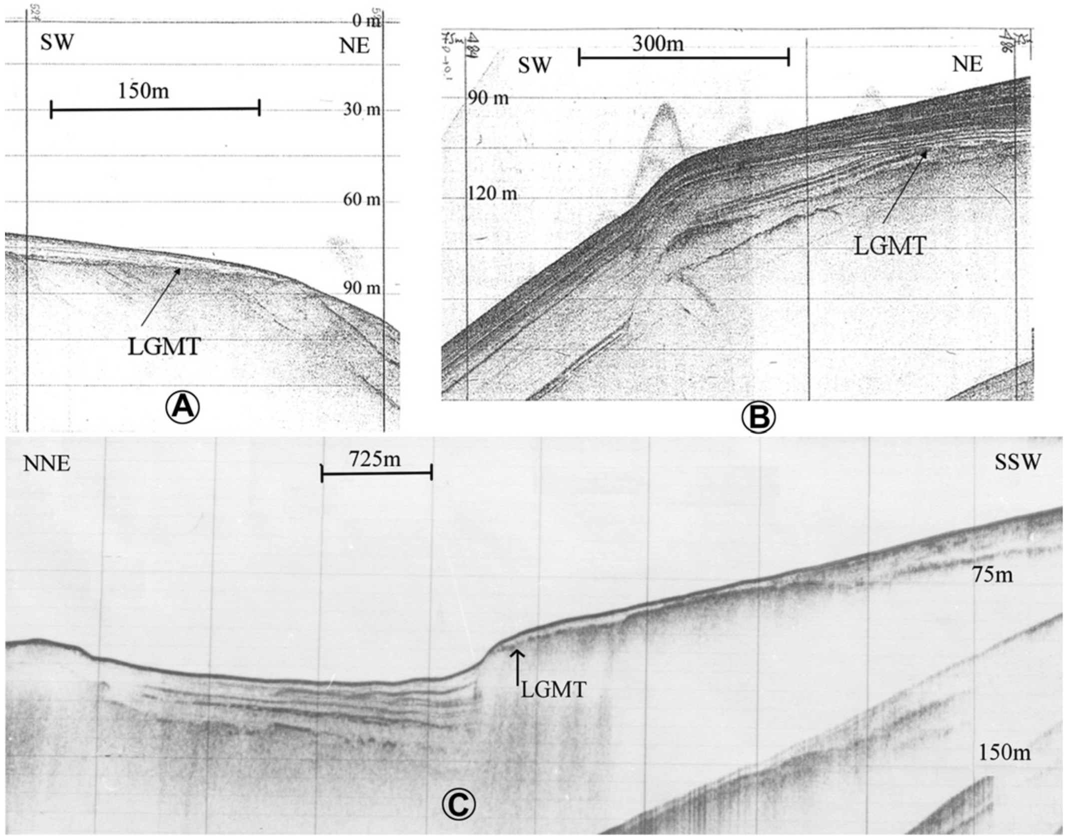


**Fig. 6.** 3.5 kH profiles S10A, S10B and S10C across the Zakynthos, Killini and Kefallinia shelf, respectively, showing the Last Glacial Maximum Transgression surface lying at different depths below present day. See Fig. 2 for location.

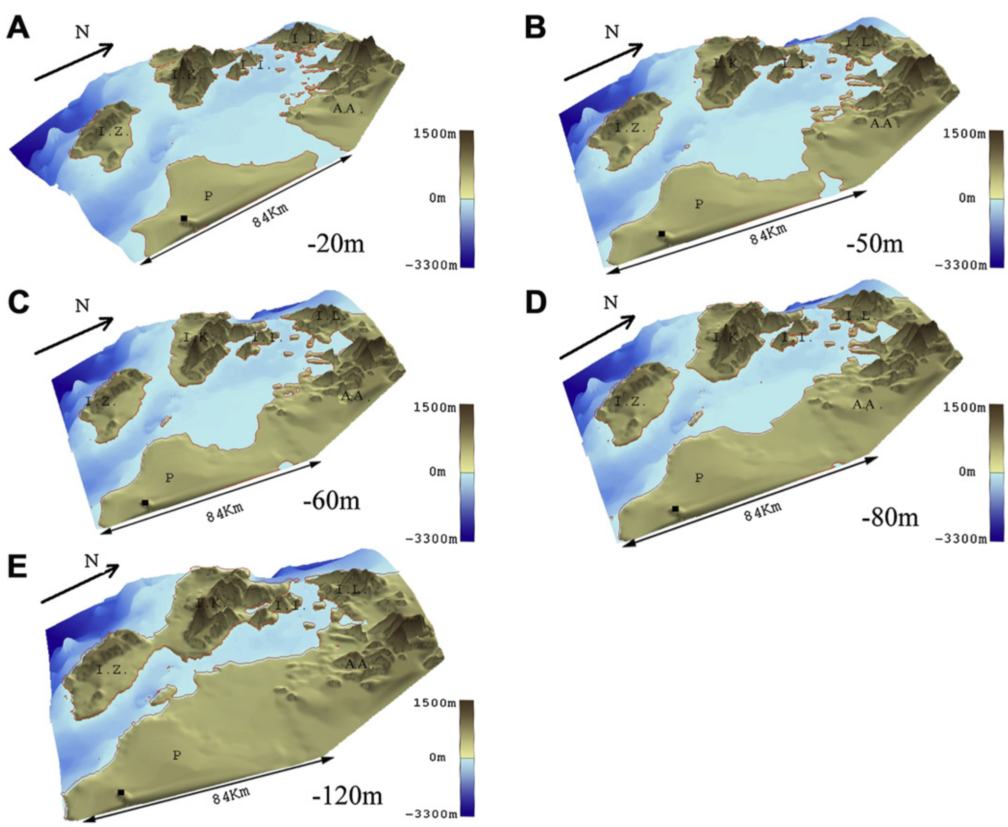


**Fig. 7.** 3-D time–space models of palaeo-shoreline configuration in the southern Ionian Islands at 100, 60, 30, 18, 10 and 8 ka BP when the sea-level was at −20, −80, −60, −120, −50 and −20 m below present, respectively. The perspective views are from a point in Peloponnesos marked by a solid square and from a height of 500 m. P: Peloponnesos, AA: Aetolo-Akarnania, IZ: Zakynthos Island, IK: Kefallinia Island, IL: Lefkada Island.

## 6. Discussion

The presence of Middle and Upper Palaeolithic sites in Kefallinia and Zakynthos, which were insular during this period, suggests that the hunter-gatherers were able to travel to these islands from the Greek mainland by crossing the straits, which were less than 12 km wide. The time-space models of the palaeo-shoreline configuration of the southern Ionian Islands and the western Greek mainland (Fig. 7) show that during the Middle and Upper Palaeolithic periods, access to the islands could have been achieved via two routes. One route was from the southernmost extremity of the present day island of Lefkada, which at that time was a peninsula, and involved two sea crossings of between 5 and 7.5 km with intervening islets (Fig. 8). The other route was from the Greek mainland and involved three crossings with a width of between 5 and 12 km (Fig. 8).

Having in mind that: (i) the sites found on the western Greek mainland are dated at between 98 and 30 ka BP (Runnels et al., 1999; Runnels and van Andel, 2003) and are characterized by Mousterian technology (Runnels et al., 1999; Runnels and van Andel, 2003) produced by the Neanderthals (Mellars, 1996) and (ii) the lithic industry found in the Zakynthos island (Vassilikos Peninsula) resembles that found in Rodaki in Epirus and both are like the Mousterian (Pontinian) in Italy, which is dated between 110 and 35 ka BP (Kuhn, 1995), the most plausible suggestion is that the sea-goers were the Neanderthals. Hints of maritime crossings in the Mediterranean Sea by the Neanderthals are also given by Broodbank (2006). Taking into consideration (i) and (ii) above and, given that seafaring in the south-east Asian Islands and greater Australia started at around between 50 and 40 ka BP (Mellars, 2006; Balter, 2007) it can be suggested that seafaring in the southern Ionian islands started at about the same time or even earlier, by about 60 ka, but the crossing lengths were on a much smaller scale. The extended Neanderthal seafaring activity in the Ionian Islands further supports the view, accepted by many scholars, of the cognitive learning ability of the Neanderthals (Broodbank, 2006).

The presence of undated Upper Palaeolithic industry in Kefallinia, similar to the Aurignacian industry of the Upper Palaeolithic in Epirus (Runnels et al., 1999) and in Elis and Achaia (Chavaillon et al., 1969, 1967; Darlas, 1999, 1995, 1994) suggests that the maritime activity between the mainland and the islands continued throughout the Upper Palaeolithic and was probably carried out by behaviourally modern humans.

Human presence in the Mesolithic period is concentrated along the Greek mainland coastline but is also found on the island of Zakynthos (Runnels and van Andel, 2003). The lithic industry of all the coastal sites is identical and points not only to hunting as the main activity, but also to the repair and maintenance of hunting equipment or, to the building of simple reed-boats (Runnels and van Andel, 2003).

The regional palaeo-shoreline configuration was the major factor that motivated the Middle and Upper Palaeolithic hunter-gatherers to develop seafaring capabilities in order to reach the islands. The configuration of the Greek mainland and Ionian Islands coast, gives the impression of an almost continuous landscape interrupted by short water gaps, which provides the perception of easy accessibility, thus creating ideal maritime "nursery" conditions for experimentational seafaring (Irwin, 1992; Broodbank, 2006). Additional factors that motivated the hunter-gatherers to seafaring were: (i) the short distances between the mainland and the islands involving one-day crossings, (ii) the inter-visibility and the stepping stone islets, which all promised a safe return voyage (Keegan and Diamond, 1987) and (iii) the short fetch.

Recently, the presence in Crete of Acheulean type (sensu lato) lithics in a marine terrace of an estimated age of ca 107 ka BP and in an alluvial fan of an indicative age of ca 130 ka BP, based on the palaeosol pedogenic maturity, motivated Strasse et al. (2011) to suggest that pre-sapiens hominins were able to reach Crete from Greece and Turkey by crossing open bodies of water as far back as ca 107 and 130 ka BP. Similarly, it can be argued in this paper that seafaring could have started in the southern Ionian Islands as early as it started in Crete, at ca 107 to 130 ka BP and probably further back at ca 150–200 ka BP, considering: (i) the presence of Lower Palaeolithic: in four sites in Epirus (Kokkinopilos, Ormos Odysseos, Alonaki and Aghios Thomas peninsula (Fig. 1) with an Acheulean and/or early Mousterian typology lithic industry of an estimated age of between 200 and 150 ka BP (Runnels and van Andel 2003; Tourloukis, 2010) and (ii) the presence of Lower Palaeolithic in Kefallinia island (Nea Skala) (Fig. 1) with an Acheulean lithic industry, which is dated at ca 125 ka BP as it was found in an uplifted marine terrace of assumed Tyrrhenian age (Cubuk, 1976; Tourloukis, 2010).

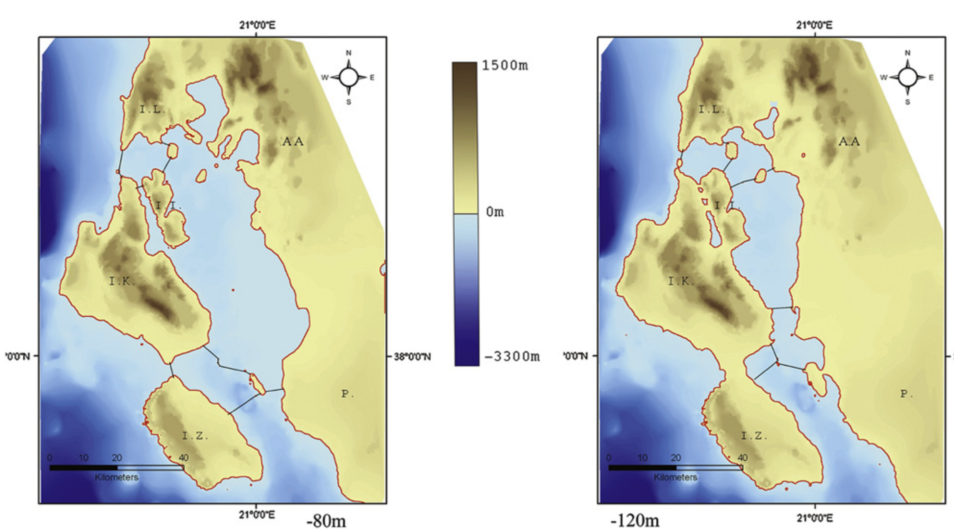


**Fig. 8.** Palaeoshoreline reconstruction when the sea level was at −80 and −120 m showing the most likely used short range route crossings to the islands from Middle Palaeolithic to Mesolithic. P: Peloponnesos, AA: Aetolo-Akarnania, IZ: Zakynthos Island, IK: Kefallinia Island, IL: Lefkada Island.

## 7. Conclusions

Drawing together the evidence set out above, certain general conclusions emerge:

(i) Seafaring activity in the southern Ionian Islands in the Mediterranean Sea started in Middle Palaeolithic. An exact date from the present available data cannot be given, but most likely started some time between 110 and 35 ka BP. However, earlier beginning of seafaring activity as far back as 200 ka BP can not be excluded.
(ii) Seafaring in the southern Ionian Islands started at around the same time as in the south-east Asian Islands and greater Australia (Mellars, 2006; Balter, 2007) and probably much earlier at around 110 ka BP or even further back at 200 ka BP.
(iii) The first voyagers who travelled to the Ionian Islands were the Neanderthal hunter- gatherers, who occupied the Greek mainland at that time, whereas those that travelled to the south-east Asian Islands and greater Australia were biological and behaviourially modern humans. However, pre- Neanderthal hominins seafaring can not be excluded in the case of seafaring in the southern Ionian Islands had started at ca 200 ka BP.
(iv) Seafaring activity was encouraged by the prevailing favourable regional coastal configuration in the Middle and Upper Palaeolithic, which played an important role in the development of seafaring technology and navigation, according to the concepts of 'voyaging nursery' and 'autocatalysis' put forward for island colonization, by Irwin (1992) and Keegan and Diamond (1987), respectively.

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## References

Ammerman, A., 2010. The first Argonauts: towards the study of the earliest seafaring in the Mediterranean. In: Anderson, A., Barrett, J., Boyle, K. (Eds.), The Global Origins and Development of Seafaring. Mc Donald Institute Monographs. University of Cambridge, pp. 81–92.
Bailey, G., 1999. The Palaeolithic archaeology and Palaeogeography of Epirus with particular reference to the Klithi rockshelter. In: Bailey, G.N., Adam, E., Panagopoulou, E., Perlès, C., Zachos, K. (Eds.), The Palaeolithic Archaeology of Greece and Adjacent Areas. Proceedings of the ICOPAG Conference, Ioannina, September 1994. British School at Athens, London, Studies 3, pp. 159–169.
Bailey, G., Papakonstantinou, V., Sturdy, D., 1992. Asprochaliko and Kokkinopilos: TL dating and reinterpretation of Middle Palaeolithic sites in Epirus, northwest Greece. Cambridge Archaeological Journal 2, 136–144.
Balter, M., 2007. In Search of the World's most ancient Mariners. Science 318, 388–389.
Bell, R., McNeill, L., Bull, J., Henstock, J., Collier, R., Leeder, M., 2009. Fault architecture and evolution of the Gulf of Corinth Rift, Central Greece. Basin Research 21, 824–855.
Broodbank, C., 1999. Colonization and configuration in the insular Neolithic of the Aegean. In: Halstead, P. (Ed.), Neolithic Society in Greece. Sheffield Studies in Aegean Archaeology 2. Sheffield Academic Press, pp. 15–41.
Broodbank, C., 2002. Islands, people and seafaring. In: An Island Archaeology of the Early Cyclades. Cambridge University Press, U.K.
Broodbank, C., 2006. The origins and early development of Mediterranean maritime activity. Journal of Mediterranean Archaeology 19 (2), 199–230.
Brooks, M., Ferentinos, G., 1984. Tectonics and sedimentation in the Corinth Gulf and the Zakynthos and Kefallinia Channels, Western Greece. Tectonophysics 101, 25–54.
Chavaillon, J., Chavaillon, N., Hours, F., 1967. Industries Paleolithiques de Elide, Region du Kastron. Bulletin de Correspondance Hellenique 93, 77–151.
Chavaillon, J., Chavaillon, N., Hours, F., 1969. Industries Paleolithiques de Elide, Region d Amalias. Bulletin de Correspondance Hellenique 90, 151–201.
Cherry, J.F., 1981. Pattern and process in the earliest colonization of the Mediterranean Islands. Proceedings of the Prehistoric Society 47, 41–68.
Cherry, J.F., 1984. The initial colonization of the western Mediterranean Islands in the light of island Biogeography and Paleogeography. In: Waldren, P., Chapman, R., Lewthwaite, J., Kennard, R. (Eds.), Early Settlement in the Western Mediterranean Islands and Their Peripheral Areas. The Deya Conference of Prehistory, W BAR-IS 229, Oxford, pp. 7–23.
Cherry, J.F., 1990. The first colonisation of the Mediterranean Islands: a review of recent research. Journal of Mediterranean Archaeology 3 (2), 145–221.
Chronis, G., Piper, D., Anagnostou, C., 1991. Late Quaternary evolution of the Gulf of Patras, Greece. Marine Geology 97, 191–205.
Cubuk, G., 1976. Altpalaolithische Funde von den Mittelmeerterrassesn bei Nea Skala auf Kephallinia (Griechenland). Archaologisches Korrespondenzblatt 6, 175–181.
Darlas, A., 1994. Le paleolithique inferieur et moyen de Grece. L'Anthropologie 98 (2–3), 305–328.
Darlas, A., 1995. The earliest occupation of Europe: The Balkans. In: Roebroeks, W., van Kolfschoten, T. (Eds.), The Earliest Occupation of Europe, Proceedings of the European ScienceFoundation Workshop at Tautavel (France), 1993. University of Leiden, Leiden, pp. 51–57.
Darlas, A., 1999. Palaeolithic research in Western Achaia. In: Bailey, G.N., Adam, E., Panagopoulou, E., Perlès, C., Zachos, K. (Eds.), The Palaeolithic Archaeology of Greece and Adjacent Areas. Proceedings of the ICOPAG Conference, Ioannina, September 1994. British School at Athens, London, Studies 3, pp. 303–310.
Dousougli, A., 1999. Palaeolithic Leukas. In: Bailey, G.N., Adam, E., Panagopoulou, E., Perlès, C., Zachos, K. (Eds.), The Palaeolithic Archaeology of Greece and Adjacent Areas. Proceedings of the ICOPAG Conference, Ioannina, September 1994. British School at Athens, London, Studies 3, pp. 288–292.
Foss, P., 2002. Kephallenia: archaeology and history: the ancient Greek cities. In: Randsborg, K. (Ed.), Acta Archaelogica 73. Blackwell Munksgaard, Copenhagen.
Geraga, M., Tsaila- Monopoli, S., Ioakim, Ch., Papatheodorou, G., Ferentinos, G., 2000. Evolution of Palaeoenviromental changes during the last 18,000 years in the Myrtoon Basin, S.W. Aegean Sea. Palaeogeography–Palaeoclimatology–Palaeoecology 156, 1–17.
Geraga, M., Tsaila- Monopoli, S., Papatheodorou, G., Ferentinos, G., 2005. Short term climate changes in the southern Aegean Sea over the last 48,000 years. Palaeogeography-Palaeoclimatology-Palaeoecology 220, 311–332.
Geraga, M., Mylona, G., Tsaila- Monopoli, S., Papatheodorou, G., Ferentinos, G., 2008. Northeastern Ionian Sea: Palaeogeographic variability over the last 22 ka. Journal of Marine Systems 74, 623–638.
Giresse, P., Buscail, R., Charriere, B., 2003. Late Holocene multi-source material input into the Aegean Sea: depositional and post-depositional processes. Oceanologica Acta 26, 657–672.
Hasiotis, T., Papatheodorou, G., Ferentinos, G., 2005. A high resolution approach in the recent sedimentation processes at the Head of Zakynthos Canyon, Western Greece. Marine Geology 214, 49–73.
Higgs, E., Vita- Finzi, C., 1966. The climate, environment and industries of stone age Greece. Proceedings of the Prehistoric Society 32, 1–29.
Huxtable, J., Cowlett, J., Bailey, G., Carter, P., Papakonstantinou, V., 1992. Thermoluminescence dates and a new analysis of the early Mousterian from Asprochaliko. Current Anthropology 33, 109–113.
Irwin, G., 1992. The Prehistoric Exploration and Colonasation of the Pacific. Cambridge University Press, Cambridge, U.K.
Kavvadias, G., 1984. Palaeolithic Kefallinia. Fitrakis Press, Athens.
Keegan, W., Diamond, J., 1987. In: Schiffer, M. (Ed.), 1987. Advances in Archaeological Methods and Theory, vol. 10. Academic Press, New York, pp. 49–92.
Kelletat, D., Kowalczyk, G., Schröder, B., Winter, K., 1976. A synoptic view on the Neotectonic development of the Peloponesian coastal region. Zeitschrift der Deutschen Geologischen Gesellschaft 127, 447–465.
Kokinou, E., Kamberis, E., Vafidis, A., Monopolis, D., Ananiadis, G., Zelilidis, A., 2005. Deep seismic reflection data from offshore Western Greece: a new crustal model for the Ionian Sea. Journal of Petroleum Geology 28, 185–202.
Kokkalas, S., Xypolias, P., Koukouvelas, I., Doutsos, T., 2006. Post-collisional contractional and extensional deformation in the Aegean region. In: Dilek, Y., Pavlides, S. (Eds.), Post-collisional Tectonics and Magmatism in the Eastern Mediterranean Region. Geological Society of America, Special Papers 409, pp. 97–123.
Kourtessi-Philipaki, G., 1999. The Lower and Middle Palaeolithic in the Ionian Islands: new Finds. In: Bailey, G.N., Adam, E., Panagopoulou, E., Perlès, C., Zachos, K. (Eds.), The Palaeolithic Archaeology of Greece and Adjacent Areas. Proceedings of the ICOPAG Conference, Ioannina, September 1994. British School at Athens, London, Studies 3, pp. 282–287.
Kowalczyk, G., Winter, K., 1979. Die geologische entwicklung der Kyllini Halbinsel in Neogene und Quartar, West Pelopones, Griechenland. Zeitschrift der Deutschen Geologischen Gesellschaft 130, 323–346.
Kuhn, S., 1995. Mousterian Lithic Technology: An Ecological Perspective. Princeton University Press, Princeton.
Lambeck, K., 1996. Sea-level change and shoreline evolution in Aegean Greece since Upper Palaeolithic time. Antiquity 70, 588–610.
Lykousis, V., Sakellariou, D., Moretti, I., Kaberi, H., 2007. Late Quaternary basin evolution of the Gulf of Corinth: sequence stratigraphy, sedimentation, fault–slip and subsidence rates. Tectonophysics 440, 29–51.

Melis, R., Mussi, M., 2002. S. Maria is Acquas, A new pre-Neolithic site Southwestern Sardinia. In: Waldren, W., Ensenyat, J. (Eds.), World Islands in Prehistory, International Insular Investigations. 5th Deia Conference of Prehistory. British Archaeological Reports, International Series 1095. Archaeopress, Oxford, pp. 454–461.
Mellars, P., 1996. The Neanderthals Legacy: An Archaeological Perspective from Western Europe. Princeton University Press, Princeton.
Mellars, P., 2006. Going east: new genetic and archaeological perspectives on modern human colonisation of Eurasia. Science 313, 796–800.
Monopolis, D., Bruneton, A., 1982. Ionian Sea (Western Greece): its structural outline deduced from drilling and geophysical data. Tectonophysics 83, 227–242.
Mussi, M., 2001. Earliest Italy: An Overview of the Italian Palaeolithic and Mesolithic. Springer, pp. 399.
Patton, M., 1997. Islands in Time: Island Sociogeography and Mediterranean Prehistory. Routledge, New York.
Piper, D., Perissoratis, C., 2003. Quaternary Neotectonics of the South Aegean Sea. Marine Geology 198, 259–288.
Piper, D., Stamatopoulos, L., Poulimenos, G., Doutsos, T., Kontopoulos, N., 1990. Quaternary history of the Gulfs of Patras and Corinth, Greece. Zeitschrift fur Geomorphologie 34, 451–458.
Rousakis, G., Karageorgis, A., Conispoliatis, N., Lykousis, V., 2004. Last glacial-Holocene sediment sequences in N. Aegean Basins: structure, accumulation rates and clay mineral distribution. Geo-Marine Letters 24, 97–111.
Runnels, C., 2001. Review of Aegean prehistory IV: the stone age of Greece from the Palaeolithic to the advent of Neolithic. In: Cullen, T. (Ed.), Aegean Prehistory: A Review. American Journal of Archaeology, Suppl. 1, pp. 225–258.
Runnels, C., van Andel, T., 2003. The early stone age of the Nomos of Preveza: landscape and settlement. In: Wiseman, J., Zachos, K. (Eds.), 2003. Landscape Archaeology in Southern Epirus, Greece, vol. 32. Hesperia Supplement, pp. 47–134.
Runnels, C., van Andel, T., Zachos, K., Paschos, P., 1999. Human settlement and landscape in the Preveza Region (Epirus) in Pleistocene and early Holocene. In: Bailey, G.N., Adam, E., Panagopoulou, E., Perlès, C., Zachos, K. (Eds.), The Palaeolithic Archaeology of Greece and Adjacent Areas, Proceedings of the ICOPAG Conference, Ioannina, September 1994. British School at Athens, London, Studies 3, pp. 120–129.
Shacketon, N.J., 1987. Oxygen isotopes, ice volumes and sea level. Quaternary Science Reviews 6, 183–190.
Sordinas, A., 1968. Ph.D. Thesis, Harvard University.
Sordinas, A., 1970. Stone Implements from Northwestern Corfu, Greece, 1970. Memphis State University, Anthropological Research Center. Occasional Papers 4.
Sordinas, A., 2003. The 'Sidarian': maritime Mesolithic non-geometric microliths in western Greece. In: Galanidou, N., Perlès, C. (Eds.), 2003. The Greek Mesolithic: Problems and Perspectives, vol. 10. British School at Athens Studies, London, pp. 89–97.
Stamatopoulos, L., Kontopoulos, N., 1994. Geomorphology and evolution of the region between Lapa and Eleotopos, northwestern Peloponessus, Greece. Il Quaternario 7, 537–554.
Stamatopoulos, L., Voltaggio, M., Kontopoulos, N., Cienque, A., La Rossa, S., 1988. $^{230}Th/^{238}U$ dating of Corals from Tyrrhenian marine deposits nearby Varda (northwestern Peloponessus), Greece. Geografica Fisica e Dinamica Quaternaria 11, 99–103.
Strasse, T., Runnels, C., Wegman, K., Panagopoulou, E., McCoy, F., Digregorio, C., Karkanas, P., Thompson, N., 2011. Palaeolithic sites in southwestern Crete, Greece. Journal of Quaternary Science 26, 553–560.
Tourloukis, V., 2010. The Early and Middle Pleistocene Archaeological Record of Greece. In: Archaeological Studies Leiden University 23. Leiden University Press, Holland.
van Andel, T.H., 1989. Late Quaternary sea-level changes and archaeology. Antiquity 63, 733–745.
Zelilidis, A., Kontopoulos, N., Avramidis, P., Piper, D., 1998. Tectonic and sedimentological evolution of Zankynthos Island, Greece: case study of the transition from compressional to extensional tectonics. Basin Research 10, 393–408.