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The Middle Pleistocene archaeological record of Greece and the role of the Aegean in hominin dispersals: new data and interpretations

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A B S T R A C T

In the debate about hominin dispersals, Greece is expected to have been among the core areas for the peopling of Eurasia, serving as a 'refugium' and source region for (re)colonizations. Yet, its early Pleistocene record is still scarce, forming a conspicuous 'gap' in the early human geography of the Mediterranean. Here we investigate this gap and provide for the first time a synthesis of the Lower Palaeolithic record of Greece. Our study adopts a geoarchaeological approach to explain the current status of the record and argues that the 'absence of evidence' should be understood as the result of the biasing effects of erosional geomorphic processes and not as an indication of a former absence of hominins. In this line, the potential for archaeological preservation and recovery is assessed as a function of landscape dynamics. Climatic seasonality, tectonic activity, high relief and marine inundations have altogether contributed to significant reworking and/or total loss of archaeological sites: in spatial terms, only about 2–5% of the Lower Palaeolithic record of Greece may have survived up to the present. On the other hand, we interpret recent geological data, which show that half of the Aegean Sea would have been subaerially exposed for most of the early Pleistocene. Our results emphasize the potentially central role of the Aegean region in hominin dispersals, both as a biogeographical landbridge and as a highly productive landscape for occupation. This conclusion opens up new prospects for future fieldwork in an area that was hitherto essentially neglected. Finally, in showing how geomorphic processes bias site distribution patterns, the results and methodological perspective developed here can be seen as having implications that are wider than the geographical limits of the Greek Peninsula: they are pertinent to the investigation and interpretation of the early Pleistocene archaeological records in the highly dynamic landscapes of southern Europe – if not in even broader scales.

1. Introduction

The chronology, number and directions of early hominin dispersals between Africa and Eurasia have long been highly contested issues in human origins research (e.g. Dennell, 2010 and references therein). The Greek Peninsula appears to occupy an important biogeographical position in human evolution and the only substantial gap in its contribution of evidence from the Miocene up to the Holocene regards the Early and early Middle Pleistocene. Greece has yielded a rich record of Neogene terrestrial primates (cercopithecids and hominoids; e.g. Koufos, 2009), including key representatives of large-bodied hominids/hominines, such as *Ouranopithecus*, which has been interpreted as a direct link between Miocene apes and australopithecines (Koufos and de Bonis, 2004). In fact, it were such discoveries from Greece (e.g. *Dryopithecus*), which repositioned Europe as the possible source of later hominines that dispersed into Africa in the late Miocene (Begun, 2009). Moreover, the Greek Peninsula has provided significant contributions with regard to Europe's first farmers and the Mesolithic hunters-gatherers in the Holocene (Perles, 2001; Galanidou and Perles, 2003), the late Neanderthals and the Middle-Upper Palaeolithic transition in the Late Pleistocene (Harvati et al., 2003; Panagopoulou et al. 2002–2004; Richards et al., 2008; Stiner et al., 2010); while there is also a small but important data-set from the late Middle Pleistocene (Harvati, 2009; Harvati et al., 2009, 2011).

This early Pleistocene gap cannot be adequately explained in terms of climatically, palaeogeographically or ecologically unfavorable conditions for hominins and/or other large mammals. On the contrary, Greece has been for long expected to yield valuable

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evidence for the earliest occupation of Europe (e.g. Roebroeks, 2001), because (1) it lies within the most probable route facilitating hominin movements between Africa and Europe and vice versa (e.g. Harvati et al., 2009); (2) due to the Mediterranean climate and a highly diverse and mosaic landscape, it is assumed to have sustained refugial areas for floral, faunal – and hence probably also human- populations during periods of climatic stress (e.g. Tzedakis et al., 2002); (3) on current evidence, the Mediterranean part of Europe was peopled earlier than the rest of the continent north of the Alps (Roebroeks, 2001).

In the circum-Mediterranean region, the rich records of the Iberian and Italian peninsulas, the early sites in North Africa and the Levant, and the growing evidence coming from Turkey and, lately, from the northern Balkans as well, altogether furnish a pattern of early Pleistocene human geography in which Greece stands out as a conspicuous lacuna. How are we to explain the absence of Early and paucity of Middle Pleistocene sites in Greece, and how does this apparent 'absence of evidence' fit in the discussion about early hominin dispersals? Insufficient research is certainly an issue, but the relative abundance of Palaeolithic material in certain areas such as Epirus (NW Greece) can no longer be accredited to the lack of investigations elsewhere (Runnels and van Andel, 2003). To resolve the question posed above, we adopt a fieldwork-based, geoarchaeological and geomorphological approach here.

The analysis is carried out at the landscape-scale and it assesses preservation potential in conjunction with archaeological accessibility. In the first section we provide a critical re-appraisal of the evidence for a human presence in Greece during the Lower Palaeolithic period. In the second section we explore the geoclimatic history and structure of a highly dynamic landscape that has acted against the preservation and/or archaeological accessibility of material from the period at stake. In interpreting the results of our research we argue that, in all probability, the scarcity of Early-Middle Pleistocene sites from Greece should be understood as a consequence of the biasing and destructive effects of Quaternary geomorphic processes and not as a real absence of hominins. Most importantly, we emphasize the potentially central role of the broader Aegean region in large-scale biogeographical patterns related to hominin dispersals: for most of the Early and Middle Pleistocene, extended landmasses that would emerge in the Aegean during glacial sea-level lowstands, but also during most interglacials, would facilitate direct connections between mainland Greece (and hence also the northern Balkans) with Southwest Asia via Asia Minor. Therefore, the examination of the Greek record exemplifies how the absence of evidence can often be more apparent than real, thereby confusing interpretations of occupational patterns, and also how large-scale studies of landscape dynamics are able to elevate the status of a region to a crucial biogeographical position. In this respect, both the results and the approach advanced by our study can be seen as having wider implications for the reading of regional records and the practice of fieldwork in human evolution research, at least with regard to areas as dynamic and as crucial as the Mediterranean.

2. The Lower Palaeolithic record of Greece

Unequivocal lithic evidence or human remains dating to the Early and early Middle Pleistocene are so far lacking in Greece and any report or discussion with reference to the Greek 'Lower Palaeolithic' chiefly refers to surface finds. Lithic material that is considered to date to the late Middle Pleistocene is scarce and typically consists of finds that have been chronologically bracketed only in the broadest of terms, with relative dating techniques that are mainly based on the inferred archaic morphology of the artefacts and on usually inadequate stratigraphic correlations. Here we focus only on the most 'secure' material, attributed to the Lower Palaeolithic on the basis of contextual data.

2.1. The palaeoanthropological evidence

An exceptionally well-preserved cranium from the cave of Petralona (Fig. 1) is so far the most solid evidence for a Middle Pleistocene hominin presence in Greece. The specimen lacks reliable provenience data and it cannot be associated with the faunal remains of the cave, whereas the artefactual status of the published lithic material is considered to be doubtful (Harvati et al., 2009). The fossil is now generally assigned to the taxon of *Homo heidelbergensis*, probably representing one of the earliest forms of the Neanderthal lineage in Europe (Harvati, 2009). It was found encrusted with calcite and the most reliable dates are those derived by ESR measurements of the calcite layers, bracketing the age of the skull between about 150 and 250/350 ka (Grün, 1996).

In contrast to the Petralona specimen, there are as yet no radiometric dates for the two crania from the cave of Apidima, southern Peloponnesus. The skulls were found *in situ*, wedged between the cave-walls, but they cannot be securely associated with the faunal and lithic material unearthed from the cave (Harvati and Delson, 1999). A recent multivariate analysis of 'Apidima 2', the better-preserved of the two fossils, showed that it does not present affinities with *H. heidelbergensis* (*s.l.*) or with the Petralona skull in particular, but it is instead better grouped with the Neanderthal samples of the study (Harvati et al., 2011). Geological observations on the setting of the site suggest that the associated sediments were accumulated in the time-span between 400 and 105 ka and probably closer to the later part of this chronological bracket (Harvati et al., 2011).

The only hominin fossil that could potentially (prove to) date to the early Middle Pleistocene is an isolated upper third molar from the Megalopolis basin. The basin preserves a thick sequence of Pliocene and Pleistocene fluvial and lacustrine sediments, which have yielded abundant macro- and micro-faunal material that includes *Hippopotamus antiquus*, *Praemegaceros verticonis*, *Pliomys* aff. *episcopalis*, *Mimomys* aff. *savini* and *Mus* cf. *spretus* (Sickenberg, 1975; Van Vugt et al., 2000). Most of the fossils from the collection, in which the hominin tooth was included, were recovered from secondary deposits (Sickenberg, 1975). Although the exact primary location of each fossil from this assemblage could not be pinpointed, it was considered that the assemblage as a whole derives from the Marathousa Member of the Choremi Formation (see Sickenberg, 1975: pp. 62, 26 for relevant arguments). The most recent biostratigraphic analysis concluded that either the entire Marathousa Member dates to the Late Biharian, or the lower part is of late Early Biharian and the upper part of Late Biharian age (Van Vugt et al., 2000). An ESR date of ca 370 ka from the upper part of the local sequence, the identification of the Matuyama-Brunhes polarity reversal near the base of the section and the aforementioned biochronological data, altogether indicate a time bracket of ca 950–300 ka for the Marathousa Member (Van Vugt et al., 2000; Okuda et al., 2002). In sum, if the hominin tooth derived indeed from deposits of the Marathousa Member, as Sickenberg (1975) argued, it could well date to the early or middle Middle Pleistocene – in which case it would be the oldest hominin fossil in Greece at the moment. Despite this uncontested evidence for the presence of hominins in Megalopolis, systematic archaeological investigations have not been carried out in the basin yet.

2.2. The lithic evidence

Lithic material that has been provisionally and/or tentatively ascribed to the Lower Palaeolithic period involves mainly the

Fig. 1. Map of Greece showing sites discussed and examined in this paper. Archaeological sites: 1) Petrota 2) Doumbia 3) Siatista 4) Palaeokastro 5) Rodia 6) Korissia 7) Alonaki 8) Kokkinopilos 9) Nea Skala 10) Triadon Bay 11) Plakias 12) Gavdos. Sites with human remains: P = Petralona Cave; M = Megalopolis; A = Apidima Cave. Sites with pollen records: TP = Tenaghi Philippon; I = Ioannina; K = Kopais.

northern parts of the mainland but also some of the Ionian and Aegean islands. For all reported cases, the lack of certainty in those ascriptions stems from the following reasons (see Tourloukis, 2010 for a detailed re-evaluation of all published accounts, and references therein):

(1) The material was found on the surface but there is no *demonstrable* association with a geological context, hence any attribution to the Lower Palaeolithic relies mainly or solely on typo-technological considerations. This is the case with the site of Petrota in Thrace; an Acheulean biface found at Palaeokastro, the material from the terraces of the Aliakmon River, Siatista and the site of Doumbia, all of which are located in Macedonia; the site of Triadon Bay in the island of Melos and a site on the island of Gavdos (Fig. 1).
(2) The surface material *can* be more or less associated with a geological context, either because some specimens were retrieved from stratified positions or on the basis of certain geomorphological considerations, yet the association is not strong enough to allow for a solid ascription based on contextual data. This is the case with the site of Alonaki (Epirus) and the sites of Nea Skala and Korissia (Kephallonia and Kerkyra, respectively; Fig. 1).

Recently, Lower Palaeolithic sites were discovered in the area of Plakias, Crete (Strasser et al., 2010). Although most of the material is surface finds and more that one Palaeolithic industry may be represented here, a few artifacts with Acheulean affinities (*sensu lato*) were found in direct association with marine terraces and paleosols. Minimum ages of 72–107 ka were calculated for the terraces and a relative age of more than 110 ka was assigned to the paleosols (Strasser et al., 2011). However, these ages provide only a *terminus ante quem* for the associated artifacts. Since the study of the sites is still in progress, new finds and dates may fill the picture.

There are two more sites that deserve a more detailed examination here, because they have thus far provided the best-documented stratified material. These are the sites of Kokkinopilos and Rodia, located in Epirus and Thessaly respectively, which are also the two provinces yielding the greatest bulk of 'Lower' and Middle Palaeolithic evidence in Greece (Runnels, 1995).

Epirus is the region with the richest Palaeolithic data-set in Greece. The wealth of finds along with the distribution of sites is thought to reflect not only landscape attributes attractive to early hominins, but also geomorphological factors that favor the preservation of archaeological remains (Runnels and van Andel, 2003). Most of the open-air sites in north-west Greece are associated with red sediments, the so-called 'redbeds' of Epirus. Since the 1960's, there has been a long-lasting debate over the age of the deposits, the chronological relationship of the latter with the lithic artefacts, and the potential for recovering material from undisturbed contexts; as the best-studied site, Kokkinopilos has since remained central in this discussion (e.g. Higgs and Vita-Finzi, 1966; Bailey et al., 1992). The claims of Higgs' team for finding artefacts *in situ* (Dakaris et al., 1964) were contested by Bailey and colleagues, who argued that "none of the flint artefacts recovered from Kokkinopilos can be demonstrated to be geologically *in situ*" and that "essentially the same point could be made about the other open-air sites in Epirus" (1992, pp. 142). In 1991, Runnels and van Andel (1993a) discovered an Acheulean handaxe, stratified within non-reworked deposits. Lithic artefacts of non-Levallois morphology were observed in the same layer that contained the handaxe and at other localities of the site. A paleosol that caps the entire sequence was TL-dated to ca 91 ka (Zhou et al., 2000) and, by extrapolating sedimentation rates, the researchers suggested an age of ca 250 ka for the handaxe and the other artefacts.

Our fieldwork in Kokkinopilos aimed at evaluating the contrasting interpretations on the integrity of the site, the arguments for the discovery of stratified Lower Palaeolithic artefacts and the prospects of finding *in situ* lithic material. During the first visit, we found a biface that can be typologically described as an 'amygdaloid à talon' Acheulean handaxe (Fig. 2a); the artefact was lying on reworked deposits of an erosional gully (Tourloukis, 2009). During the second visit, we discovered another biface (or, 'bifacial core'), made on a flake-blank and displaying a flat bifacial retouch (Fig. 2b). The latter was found lying horizontally, embedded within *non-reworked* deposits of the uppermost stratigraphic zone (Fig. 3); gleying of the sediments occurred after the deposition of the artefact and the drab halos that wrap around the specimen confirm its *in situ* position. More artefacts were observed in similar, *in situ* positions at different parts of the site, either protruding from the exposed profiles or unearthed while we were sampling for luminescence dating. Some of those stratified occurrences were found stratigraphically close to the findspot where Runnels and van Andel discovered the handaxe and associated artefacts. Furthermore, we were able to identify stratified artefacts also in other 'redbed sites' of Epirus (Ayia, Morfi and Karvounari) although our fieldwork there was limited and constrained by permit issues.

The results from our investigations at Kokkinopilos suggest that undisturbed sediments occur over large parts of the site. In accordance with Runnels and van Andel (2003), there is ample stratigraphic and sedimentological data pointing to the low-energy depositional environment of a shallow lake, which was formed in a tectonic basin (a 'polje') and at times dried out either locally or entirely. Gleying and mottled bands attest to sedimentation under wet conditions, whilst paleosols and desiccation zones mark depositional breaks and designate subaerially exposed surfaces upon which artefacts (could) have been discarded (Fig. 3). The observed laminations, the fine-grained caliber of the sediments and the fresh condition of the artefacts indicate transportational agents of very low energy and hence minimum transport of the lithics from their original places of discard (cf. Runnels and van Andel, 1993a). Nevertheless, the biface associated with reworked sediments calls for attention: the site is a treeless badland dissected by numerous rills and gullies, and there are many parts where modern infills can be discerned. At the moment, however, what is most important (and implied in our assertion of *in situ* finds) is that, for the undisturbed localities, the dating of the engulfing sediments could provide age-estimates for the associated artefacts (Tourloukis, 2009). In this line, Runnels and van Andel's (1993a) attribution of the handaxe and associated artefacts to the Lower Palaeolithic can be considered at the moment as solid enough from a contextual, stratigraphic perspective. Furthermore, preliminary results from luminescence dating of our samples confirm an age greater than 200–250 ka for the whole sequence below the capping paleosol (Wallinga and Johns, unpublished Optical Dating Report). Specifically, by use of the Post-IR IRSL (pIRIR) method (e.g. Thiel et al., 2011) we were able to obtain minimum age estimates of 207 ka BP for the findspot of our stratified biface (Figs. 2b and 3), which is stratigraphically a few meters below the capping paleosol; as well as a minimum age of 220 ka BP for another sample taken from zone B, stratigraphically close to the findspot of Runnels and van Andel's handaxe.

The tectonically-formed karst basin of Kokkinopilos has acted as a sediment trap, in which *terra rossa* from the surrounding limestone slopes has been redeposited, concealing artefact scatters and thereby providing today a good degree of preservation. Fault activity and uplift changed the drainage from endorheic to

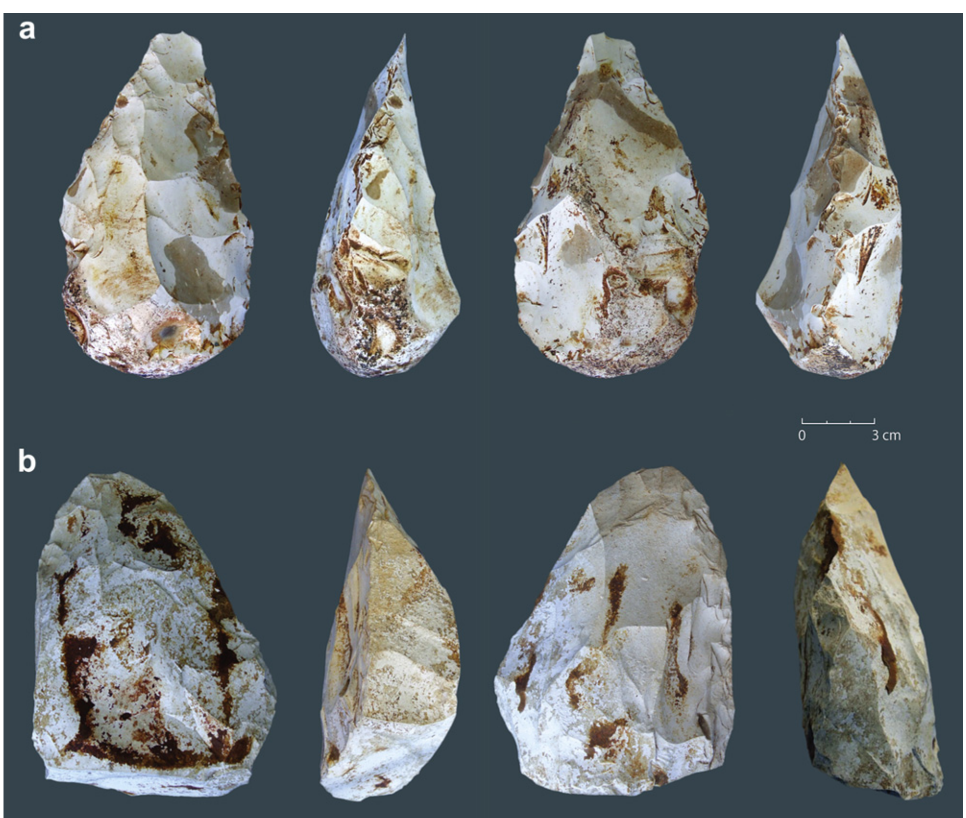

Fig. 2. Bifacial artefacts found recently at Kokkinopilos, Epirus, NW Greece (Tourloukis, 2010). a) Acheulean-type handaxe b) biface or bifacial core.

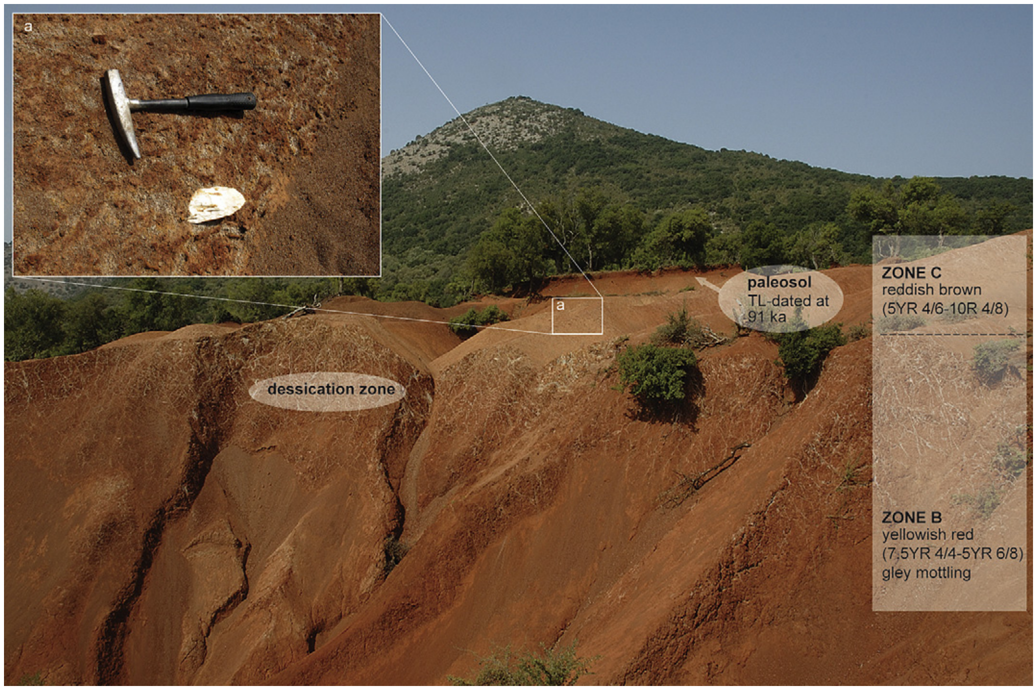

Fig. 3. Exposed profile at Kokkinopilos. The white box indicates the stratigraphic position of the biface of Fig. 2b, shown here in the inset as it was found upon discovery. Note the desiccation band between zones B and C, indicating subaerial conditions and probably a considerable sedimentary hiatus.

exorheic, initiating dissection, gully formation and exposure of long stratigraphic sections. In archaeological terms, the exposure of deep profiles is translated into a fairly good degree of accessibility of artefact-bearing layers. 'Absolute' dating of the uplift and the drainage transition is lacking, but the intense erosion creating the badlands is probably a recent phenomenon that can be attributed to the Late Pleistocene and Holocene (cf. Dakaris et al., 1964). Hence, the archaeological material was buried in a flat-floored, low-energy depression, it remained protected from erosion for a long time-span and it is only relatively recently being uncovered again. As discussed in the next section, geological opportunities that combine sufficient preservation with adequate archaeological accessibility are extremely rare in Greece. In that respect, sites like Kokkinopilos can serve as valuable 'windows of opportunity' and this qualitative characteristic of the small basins of Epirus appears to have been largely ignored, in favor of interpretative schemes that emphasize the attractiveness of the poljes in terms of hominin preferences for the rich lacustrine resources (e.g. Van Andel and Runnels, 2005).

Considering that much of the Lower Palaeolithic evidence in Europe and the Mediterranean is associated with fluvial settings (e.g. Mishra et al., 2007), Thessaly would theoretically be a promising target for early Pleistocene archaeological investigations, as it is the largest lowland area and river catchment in Greece. Yet, as shown below, the geological opportunities here are overall very limited. Nonetheless, Runnels and van Andel (1993b) discovered a Lower Palaeolithic lithic assemblage at site FS 30, in Rodia (NE Thessaly). The material was reported to be associated with a Pleistocene terrace of the Pineios River and includes specimens that were recovered *in situ* from within the terrace deposits. In revisiting Rodia, our aim was to evaluate the claims of Runnels and van Andel, contribute in refining the age-estimates for the archaeological material and assess the potential for finding new sites.

The assemblage ($N = 65$; Fig. 4) is made on quartz and consists of large flakes with large platforms and bulbs of percussion, bifacially-flaked cores and core-choppers, and retouched tools predominated by notched and denticulate specimens often displaying the so-called 'Clactonian notches', while the Levallois technique is absent (cf. Runnels and van Andel, 1993b). The researchers correlated the artefact-yielding sediments with the highest -and hence oldest- fluvial terrace of Thessaly, the 'Hochterrasse', as it is known in Schneider's (1968) work on the Thessalian fluvial stratigraphy (Fig. 5). A U/Th date of ca 210 ka from a capping paleosol (Demitrack, 1986) furnishes a minimum age for the Hochterrasse and it was suggested that the industry from Rodia dates to ca 200–400 ka (Runnels and van Andel, 1993b). In examining the stratigraphic section at FS 30 we were able to establish that the exposed fluvial gravels are correlative to either Schneider's (1968) upper unit of the Hochterrasse or to the upper part of the Rodia Formation (Caputo, 1990; Caputo pers. comm. 2008; Figs. 4 and 5). In either case, the fluvial sediments are in all likelihood older than originally suggested and they probably date to the Early Pleistocene, particularly if we regard them as part of the Rodia Formation. Nonetheless, the fluvial gravels at FS 30 are overlain by a layer of slope-wash sediments (Fig. 4: layer B) and it is not clear to us whether the artefacts collected by Runnels and van Andel (1993b) were retrieved from the primary fluvial deposit or from the secondary, reworked gravels. In the latter case the context of the site cannot provide secure stratigraphic grounds for an ascription to the Lower Palaeolithic.

Due to the extensional tectonics that affected Thessaly (Caputo et al., 1994), exposures of Early and Middle Pleistocene sediments are restricted to small areas that were uplifted and/or did not experience any subsidence. As a result, the exposed Early and Middle Pleistocene deposits today occupy less than 34 km^2, namely 0.8 percent of the basin's total extent. This figure vividly shows how exceptional it is to find stratified Lower Palaeolithic material in Greece's largest fluvial catchment. In those restricted areas where Early-Middle Pleistocene deposits crop out, like in the case of Rodia, the sediments have been dislocated and eroded by tectonic and

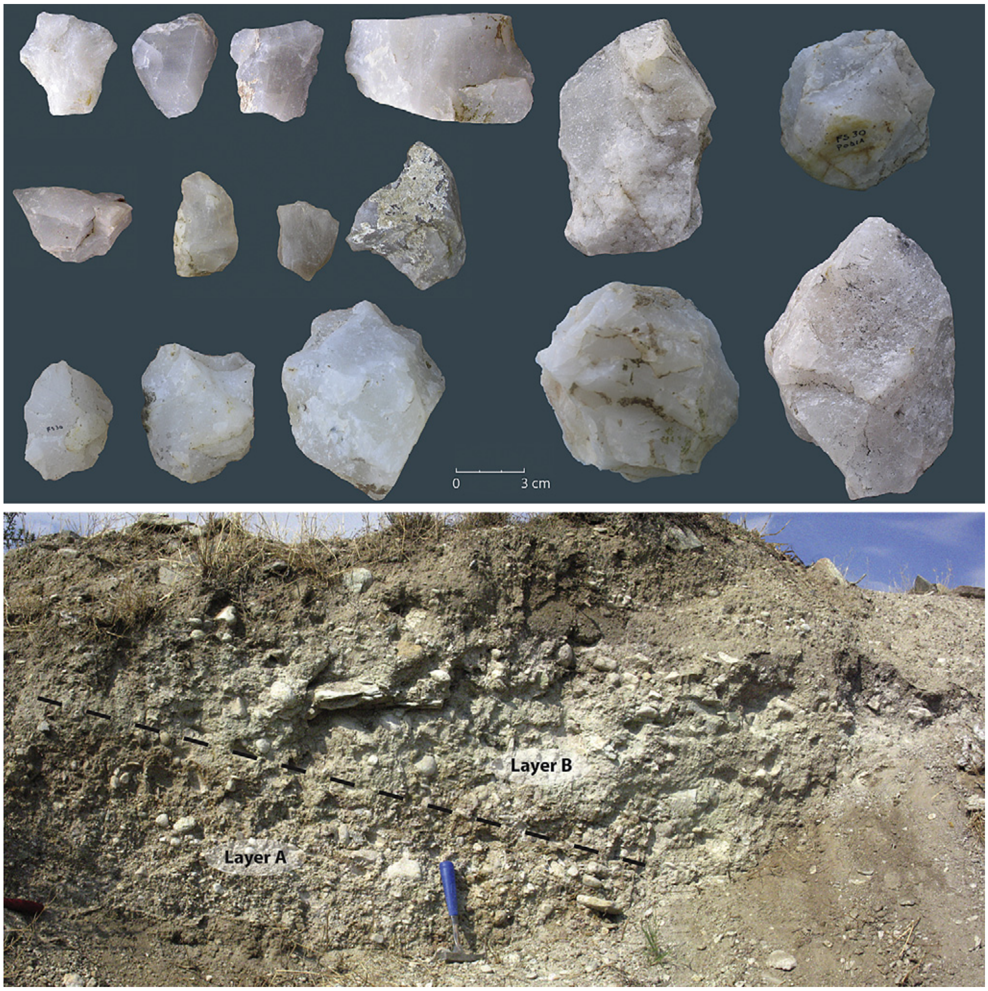

Fig. 4. Artefacts (flakes and cores) and exposed section at site FS30, Rodia, Thessaly, Central Greece. Slope-washed sediments (layer B) overlie fluvial sands and gravels (layer A). The fluvial deposit is correlative either to the upper part of Schneider's (1968) 'Hochterrasse' or to the upper unit of the Rodia Formation (see also Fig. 5).

surface processes; therefore, they occur only as isolated patches that are discontinuous and extremely fragmented in both their horizontal and vertical arrangement.

In conclusion, if we exclude the evidence from Rodia due to the doubts on the context of the site, then the only cultural material, for which an ascription to the Lower Palaeolithic is supported by stratigraphic data, is restricted to the finds from Kokkinopilos and the assemblages from Crete. Nevertheless, the Cretan evidence needs further refinement of the chronological estimates. The fossil remains from Petralona, Megalopolis and possibly that of Apidima demonstrate the presence of humans in Greece during the Middle Pleistocene, probably even before ca 200–300 ka. But overall, on the current evidence the bulk of the Greek Middle Pleistocene record is scanty, ill-dated, mostly surficial and principally lacking an anchor in stratigraphic data. The difficulty in discovering stratified remains emerges as a wider reality that cannot be sufficiently explained as a 'technical issue' of research biases, such as research intensity, designs and objectives.

3. Landscape dynamics and the preservation/accessibility of the early Pleistocene archaeological record

Considering that the nature and completeness of the archaeological record is constrained by the structure and completeness of the geological archive, in this section we explore general trends in the Pleistocene landscape evolution of Greece and the degree to which geomorphic processes have acted against the preservation and/or accessibility of archaeological material. A basic premise in our examination is the treatment of artefacts as another form of clastic material, because their hydromechanic, taphonomic and transportational behavior does not differ from that of geologic clasts. In this vein, we assess current preservation and accessibility of Pleistocene deposits as if they are all potentially artefact-bearing.

3.1. Climate changes

The impact of climatic factors upon the preservation and accessibility of the archaeological record of Greece refers primarily to water-related geomorphic processes: it is principally water flow in the form of surface runoff, alluviation, fluvial incision and aggradation, which is responsible for total destruction of sites, reworking of artefact-bearing deposits and/or burial under thick alluvia. Considering the highly dynamic setting of Greece, which involves a steep relief, omnipresent tectonism and base-level control by sea-level changes, there are valid reasons to suggest that the time-spans of alluvial erosion/aggradation would have been short and episodic, but, importantly, with very brief recurrence intervals (Tourloukis, 2010). In effect, the archaeological record would have been frequently subjected to geomorphic disturbances.

The main climatic parameters inducing landscape instability in Greece are the uneven annual and inter-annual distribution of

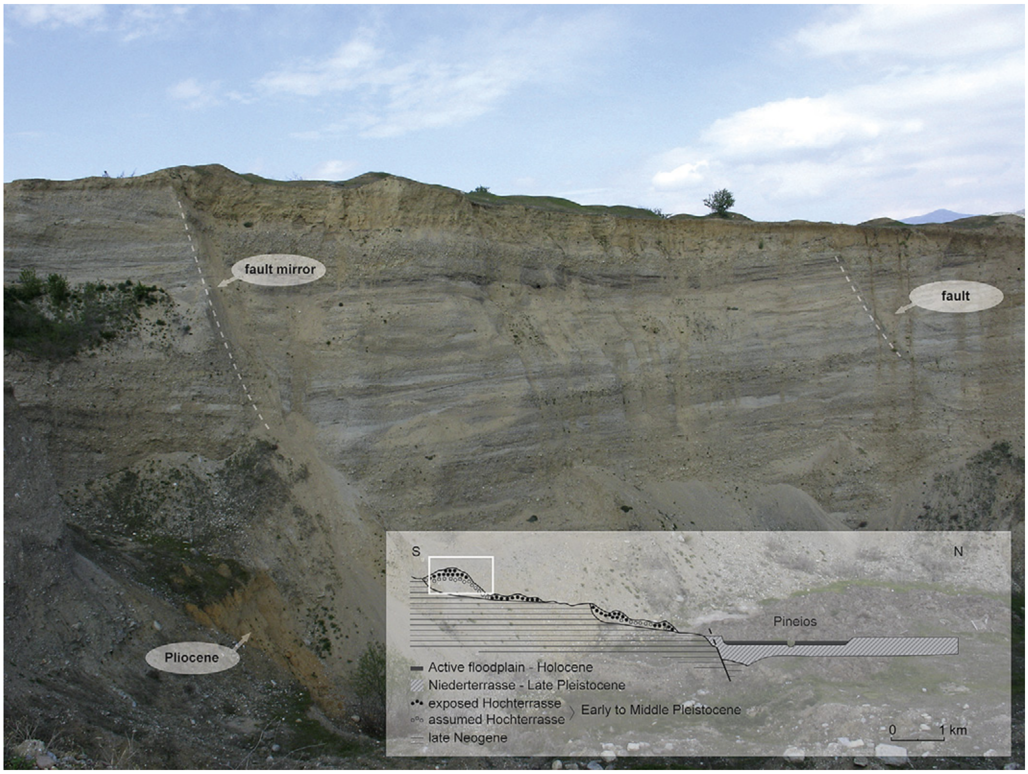

Fig. 5. 'Hochterrasse' fluvial sands and gravels exposed at the area of Rodia, close and correlative to those outcropping at site FS30; note the underlying Pliocene sediments, and the faults, which are responsible for significant dislocations of the fluvial deposits. Inset: schematic cross section of the Thessalian fluvial stratigraphy (modified after Schneider, 1968); the white box indicates the stratigraphic position of the fluvial deposit that is shown in the photograph.

rainfall, the extreme rainfall events, the seasonality of precipitation and the fact that rainy and vegetative seasons are out-of-phase (Kosmas et al., 1999). The dominant influence on erosion and sedimentation is the precipitation input, particularly as a result of extreme events, such as large-scale floods or deluges generating high turbulent surface runoff (Grove and Rackham, 2001). Most of the river basins in Greece are small and drained by steep-land river systems. This configuration, coupled with a markedly seasonal precipitation, results in hydrological regimes with steep hydrographs and seasonal fluvial runoff (Mimikou, 2005). Similar spatial climatic patterns characterized the Last Interglacial (e.g. Tzedakis, 2005) and probably other past interglacials as well (Cheddadi et al., 2005). During cold stages, fluvial regimes were even *more seasonal* (Macklin et al., 1995), as shown also in computational experiments (Leeder et al., 1998). Consequently, any increase in the ephemerality of flow patterns and a decrease in the recurrence interval of high-discharge peaks would increase the frequency of short-lived, high-magnitude flood events and result in fluvial regimes with even steeper hydrographs. In contrast to the river systems of north-west Europe, the drainage basins of Greece display a strong slope-channel coupling, due to their small sizes and steep-land catchments (Macklin et al., 2002). In effect, processes operating in upland reaches quickly affect lower areas downstream. Indeed, evidence from the Middle and Late Pleistocene glacio-fluvial sequence of the Voidomatis River (North Greece) shows a strong coupling between the upland glaciated plateaus and the middle and lower reaches: changes in sediment supply in the uplands (>2000 m) extended their influence below 500 m and down to the coastal zone (Woodward et al., 2008).

Pollen diagrams (Tzedakis, 2005), glacial records (Hughes et al., 2006), glacio-fluvial sequences (Woodward et al., 2008), lacustrine stratigraphies (Okuda et al., 2001), pedogenic data (Woodward et al., 1994), alluvial sequences (Wilkinson and Pope, 2003) and cave records (Karkanas, 2001), all indicate landscape instability prevailing during climatic transitions, mostly those from cold to warm climates (e.g. Karkanas, 2001; Roucoux et al., 2008). Rapid fluctuations, related to the North Atlantic suborbital climatic variability triggered in-phase responses of terrestrial ecosystems in millennial/centennial scales (e.g. Tzedakis et al., 2006; Roucoux et al., 2008). In the Pindos Mountains, glacier behavior was unstable and, due to their small size, glaciers would have been responsive to centennial- *or even decadal-scale* climatic changes (Hughes et al., 2006).

In sum, a number of palaeoenvironmental and geomorphological evidence indicate that terrestrial responses to climatically-induced landscape instability were expressed in the form of brief but high-magnitude extreme events, most notably occurring during Milankovitch-scale climatic transitions but also during oscillations within full glacial/interglacial conditions. Enhanced flood magnitude, increased sediment supply and catchment-wide alluviation alternating with phases of river incision and erosion would appear in an episodic fashion but with short recurrence intervals in millennial, centennial or even decadal time-scales. Unless protected by deep burial soon after discard, archaeological assemblages would be subjected to disturbance, reworking or total destruction every few thousands, hundreds or even tens of years. A high frequency of such erosional episodes may have been largely set by climate-dependent parameters such as those mentioned above, but it is reasonable to envisage the pre-conditioning or reinforcing role of other geomorphic factors and feedback mechanisms. Tectonic activity was certainly among the latter, as it is outlined below.

3.2. *Tectonic activity*

Extensional tectonic movements prevailed in Greece from the late Miocene to the Pliocene and well into the Pleistocene (Jolivet and Brun, 2010). Most of the systems of horsts and grabens, which at present divide the topography into rising and subsiding blocks, were formed from the late Pliocene up to the present (Angelier, 1978). The extensional motions dictated the spatial extent and distribution of the main basins, which are today morphologically defined by major drainage courses, lakes and shallow gulfs. The vast majority of Pleistocene deposits crop out or are buried inside those basins (Fig. 6a; Mountrakis, 1985) and hence the bulk of the relevant archaeological record is associated with this type of geological setting. Subsiding areas have been acting as sedimentary receivers, whereas uplifting blocks served as source areas for weathering and transport (e.g. Bailey et al., 1993). In subsided blocks, sediments and associated artefacts have been locally protected from erosion as long as they remained buried; in this case, preservation potential today is high, but archaeological accessibility is low if sediments are deeply buried. Early and Middle Pleistocene artefact-bearing deposits that were originally accumulated in subsiding/subsided blocks, subsequently buried by younger sediments and at a later stage subjected to uplift, may provide better accessibility if uplift-triggered erosion has exposed them from overlying sediments; but at the same time they may offer little potential for preservation, depending on the time that has elapsed since their subaerial exposure. Therefore, the conditions that ensure a combination of adequate preservation with efficient exposure of artefact-yielding deposits chiefly depend on the *timing of uplift/basin inversion*, and the *duration* and *intensity of erosion* accompanying the uplift: in an exemplary situation, Early and Middle Pleistocene deposits would remain buried in low-gradient basinal settings – thus ensuing a good degree of preservation, until uplift re-exposed them in the Late Pleistocene or Holocene -thus allowing now accessibility to investigations.

The tectono-sedimentary evolution of the main Neogene-Quaternary basins of Greece indicates that such conditions were hardly met, as regards Early and Middle Pleistocene depositional landforms in topographic depressions. According to various lines of evidence from different parts of Greece, significant local and/or regional changes in tectonic activity took place in the early-middle Pleistocene. For instance, there is a change of the hydrographic network in the Thessalian basin (Caputo et al., 1994); a reorganization of stress fields occurs in the Aegean region (e.g. Angelier et al., 1982); whilst uplift is recorded in some of the Peloponnesus basins, including a rapid phase of rifting in the Gulf of Corinth (Rohais et al., 2008). In short, there is a change in the direction of extension during the early-middle Pleistocene, which is thought to be related to a major kinematic transition that affected the tectonic regime of the entire eastern Mediterranean region (Schattner, 2010). We consider this transition as the most recent tectonic paroxysmic phase affecting the Greek peninsula and we see it as one of the main causal factors behind the scarcity of early-middle Pleistocene stratified archaeological remains or their total lack thereof. Many (if not most) parts of the Greek sedimentary basins were raised and inverted already in the early-middle Pleistocene; in effect, Early and Middle Pleistocene sediments (potentially artefact-bearing) were exposed to the erosional effects of surface processes (e.g. alluvial dissection) for time-spans of more than two glacial/interglacial cycles. In those parts of the basins, which from the middle Pleistocene onwards experienced subsidence instead of uplift, Early and Middle Pleistocene sediments may be deeply buried, as it is the case in Thessaly.

The assertion above refers to tectonic controls in a macro-scale perspective. In a smaller-scale perspective, tectonic influences upon the (in)completeness of the geoarchaeological archive relate to agents of deformation, such as earthquakes. These are able of generating vertical and horizontal offsets of the surface, thereby inducing slope destabilization and mass movements ranging from slow downslope creep and debris flows to rapid sliding of large masses (e.g. Koukis et al., 2009). The Greek peninsula and the Aegean is one of the most rapidly deforming areas in the world and

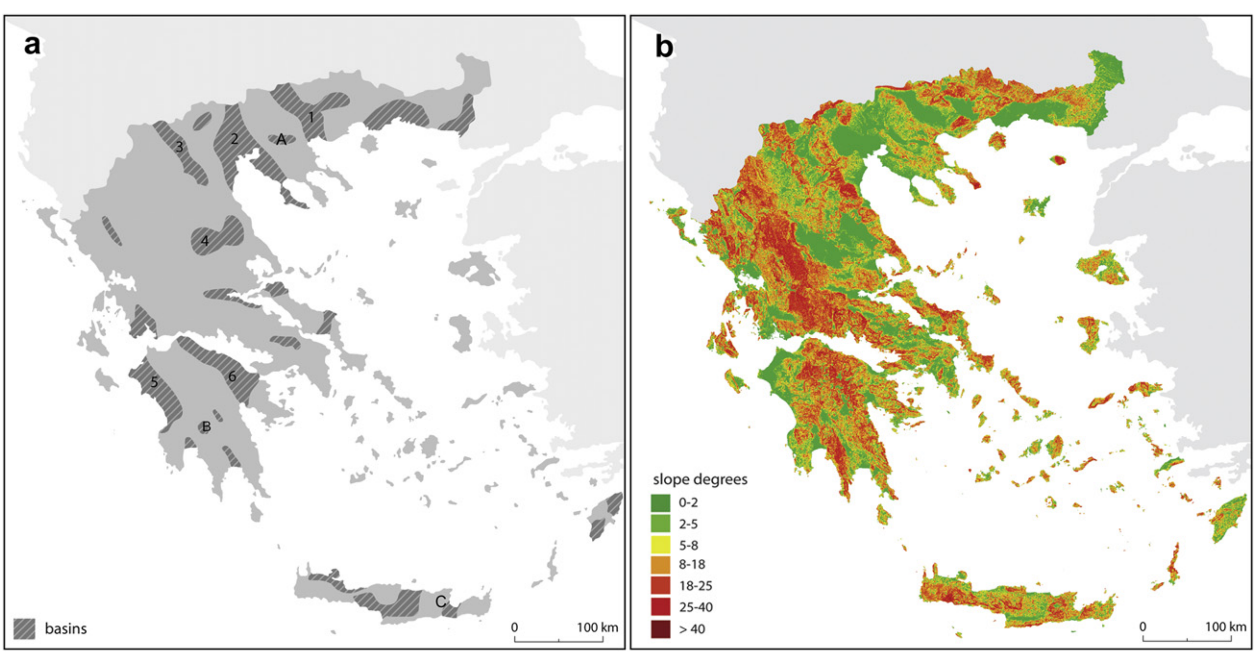

Fig. 6. a) The main Neogene-Quaternary sedimentary basins of Greece, where the bulk of Pleistocene sediments are located (modified after Mountrakis, 1985). 1) Strymonas river basin, 2) Axios river-Thessaloniki basin, 3) the Florina-Vegoritis-Ptolemais basins, 4) the Larissa-Karditsa basins, 5) the Pyrgos-Kyllini basins, 6) the Argos-Korinthos-Xylokastro basins; examples of basins promising for future research: A) Mygdonia basin, B) Megalopolis basin, C) Katharo plateau. b) Slope map of Greece (adapted from Tourloukis, 2010). The map was produced in ArchGIS 9.2 and it is based on 1:250,000 topographic maps with a 20-m contour interval. The bulk of Pleistocene sediments are spread out in the basins shown in (a) and depicted with green color in the slope map. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

seismically the most active region in West Eurasia. Seismicity is undeniably a crucial element of landscape disturbance in Greece: based on a historical record of more than 2500 years, it has been estimated that the mean occurrence frequency of strong earthquakes (>6° in the Richter scale) equals about one every 1.7 years (Papadopoulos and Kijko, 1991, cited in Caputo et al., 2006). Hence, apart from the climatically-induced, short-lived but high-amplitude extreme events emphasized in the previous section (e.g. deluges, floods), we can also envisage tectonically-exerted episodic but catastrophic events, such as slope failures and landsliding, fragmenting the geological record and reworking artefact-bearing deposits.

3.3. *Sea-level changes*

Greece has the longest coastline in the Mediterranean and thus a great component of geomorphological processes is influenced by sea-level changes, either directly, as along the coasts, or indirectly, as in the case of inland alluvial adjustments to base-level changes. It has for long been acknowledged that many Pleistocene sites, which were situated at coastal locations during glacial stages, have been submerged during subsequent interglacial sea-level highstands (e.g. Runnels, 1995). This is the most dramatic manifestation of the role of the 'marine control' in biasing site distribution patterns; yet it was hitherto nearly impossible to quantitatively and qualitatively assess the amplitude and importance of site loss due to marine inundations in the Early and Middle Pleistocene.

The extensional tectonic regime discussed above continued to prevail in the Aegean during the late Pleistocene. The subsidence rates associated with this latter regime during the last 400 kyr have been investigated by means of high-resolution seismic reflection profiles (Lykousis, 2009). Those profiles enabled the identification of successive peak glacial delta prograding sequences, which indicate the positions of glacial sea-level lowstands. Lykousis (2009) estimated the rates of subsidence by comparing the vertical displacement from the topset-to-foreset transitions (i.e. shelf-breaks) of every two successive prograding sequences. The recognition of those palaeo-shelf break delta deposits, together with the derived estimates of subsidence, allowed the reconstruction of the Aegean palaeogeography for the most pronounced glacial periods of the last 400 kyr (Lykousis, 2009; Fig. 7). One first important finding that derives from this study is that the emergence of subaerial surfaces was not restricted only to glacial stages but occurred also during early interglacials, notably those of MIS 9 and 11, and to a lesser extent MIS 7. Whereas marine conditions continued in most of the southern Aegean, *more than half of the present Aegean Sea was subaerially exposed during MIS 8, 9, 10, 11 and 12*. Together with other sedimentological and biostratigraphic data, the absence of prograding sequences deeper than those correlated to MIS 10–12 indicates that the central Aegean would have been a subaerially exposed land even before ca 500 ka (Lykousis, 2009). The lower age-limit of this extensive land-exposure in the Aegean has not been pinpointed. If we consider the mean subsidence rates of MIS 8–10 and 10–12 as indicative (or even minimum) for the early Middle and Early Pleistocene, then this lower age-limit probably reaches back to the Early Pleistocene. Directly to the south of the South Ikaria basin there is a marine corridor between approximately the islands of Naxos and Leros. As shown in Fig. 7, this passage was closed (i.e. became exposed land) for the last time in MIS 8. As a result of the closure of this marine corridor, it is very likely that the sea would not penetrate into the central and northern parts of the Aegean prior to about MIS 10–12 and all major depressions would have turned into lakes. Indeed, Lykousis (2009) reports on sedimentological and mineralogical evidence from commercial boreholes in the northern Aegean that indicate sedimentation under fluvio-lacustrine conditions (i.e. a non-marine setting) throughout the Pliocene and the Early Pleistocene.

At the moment, it is difficult to assess the validity of the details of this reconstruction, mainly due to the coarse resolution and the indirect dating and correlation of seismic stratigraphies. That said, we regard the reconstruction as generally solid enough to allow a first-order interpretation of its archaeological implications. Notably, care must be taken in interpreting the palaeotopography of the Ionian Sea, because there are no seismic reflection profiles taken from the Ionian itself -the closest profile comes from the Corinth Gulf. It is, however, noteworthy that Levallois-Mousterian lithic debitage has been found by diving ca 200 m off the coast of the Ionian island of Kerkyra (Flemming, 1998).

The aerial extent of the subaerial land reconstructed for MIS 10-12 amounts to a total area comparable to the current continental extent of the Greek Peninsula (ca 130,000 km^2). In all probability, the area exposed prior to MIS 10–12 and during the Early Pleistocene would be close to the latter figure. The area of land that emerged during MIS 8 was only slightly less than that of the preceding glacial(s) and only from MIS 6 onwards would there have been a significant difference in emerged aerial exposure. In brief, from an as yet unknown datum-line in the Early Pleistocene until (a cautious) MIS 8 but essentially until MIS 6, extended landmasses (in total, almost equaling what is today continental Greece) were exposed in the Aegean and Ionian Seas during both glacials and interglacials (pre-MIS 10 period), or during only glacial sea-level drops (post-MIS 10 period). In archaeological terms, this means that *half of what would have been* '*the Greek Lower Palaeolithic record*' *is currently underwater*, forever virtually lost.

Besides lakes as large as -and even larger than- the size of Crete, we can envisage the emerged land being dotted with numerous lagoons, moors, ponds, marshes, estuaries, rivers and ephemeral streams. Although continental conditions would have been accentuated during marine regressions, the water bodies were most important in setting the ecological tone of these landscapes, with freshwater, brackish and marine resources located within short distances of each other and alternating during the emergence–submergence cycles. Arguably, a high ecological value is to be attributed to these environments, which periodically combined marine influences with the most beneficial features of terrestrial ecosystems (freshwater lakes, rivers, etc). Exactly such an environmental structure would have constituted the most efficient buffer to the effects of glacial climatic extremes. Discussing the ecological importance of the poljes of Epirus, Runnels and van Andel (2003, p. 77) note that "If the resource potential of an environmental zone is assumed to be roughly equal to its area, most of the time [in their case: over the past 130 kyr] the coastal plains were at best equal in potential to the combined area of all poljes". Assuming the same for the emerged Aegean and Ionian landscapes, their ecological significance becomes immediately obvious. In short, those landscapes would have served as:

(1) Refugial areas during periods of increased climatic stress
(2) Corridors and landbridges for animal, and, most notably, hominin movements
(3) Super-ecotones (cf. Bailey et al., 2008), hence ideal habitats for hominins, and, generally, areas of broader archaeological and palaeoanthropological significance, as potential sources of evidence for biological adaptations and behavioral innovations.

It can be argued that those areas would have been the best places for exploitation by hominin groups arriving in the wider Aegean region. A marine control on sedimentation (e.g. creating extensive coastal flats), along with the influence of the rivers of Asia Minor and Northern Greece debouching thick alluvia, would have

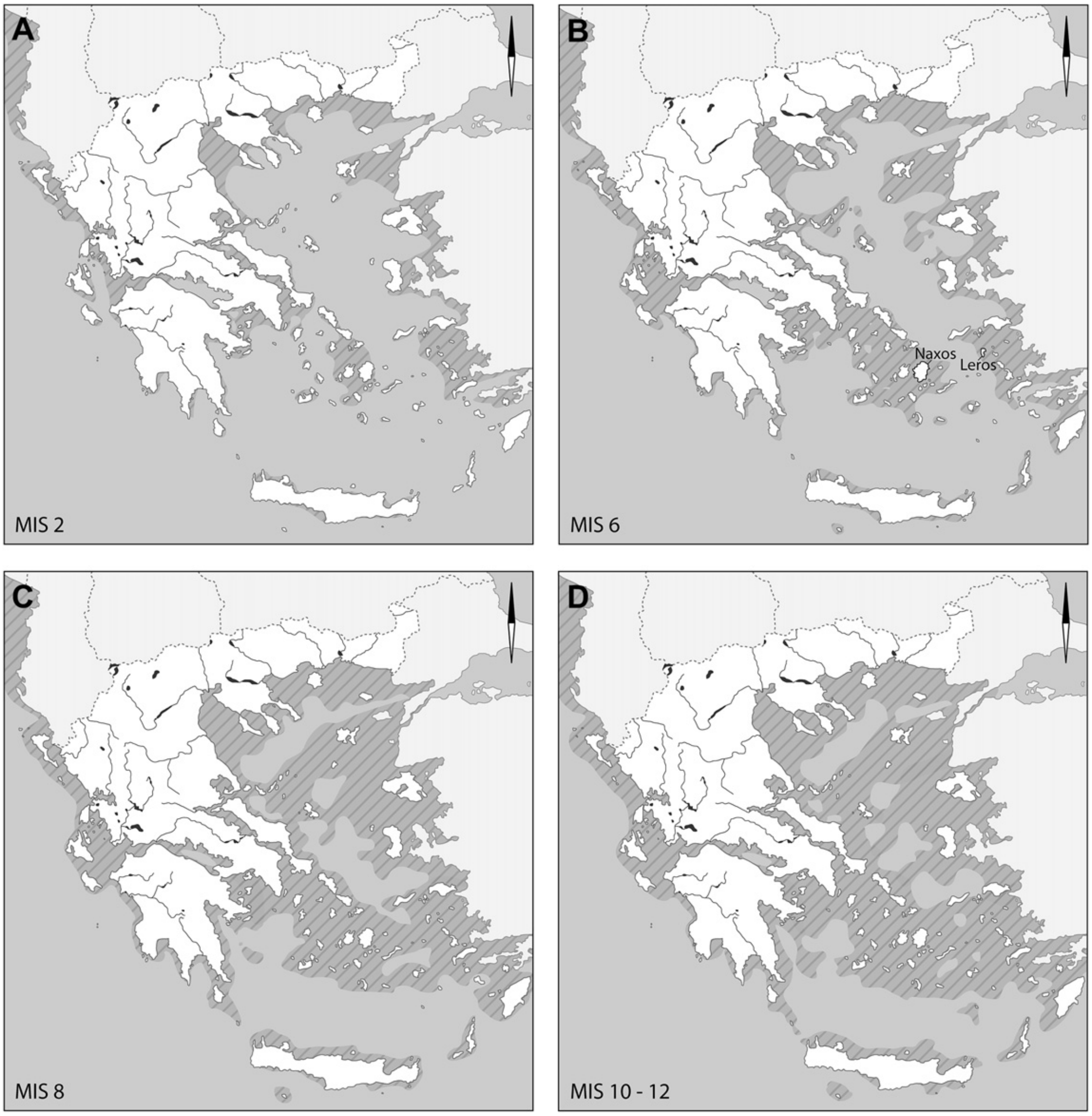

Fig. 7. Palaeogeographic reconstruction of the Aegean and Ionian Seas for selected glacial stages (modified after Lykousis, 2009).

created extended terrains of coastal lowlands, deltaic and lagoonal low-gradient depositional settings and floodplain flatlands. Hence, both the two most important factors for archaeological investigations would be met here: hominin habitat preferences and a high degree of geomorphological preservation potential. In this sense, the fact that the vast majority of this part is now practically inaccessible suggests that we are missing not only half of the Greek record, but most probably *the best half of it*.

3.4. Topography and surface processes

In tectonically active settings such as that of Greece, there are two main landscape types, defined on the basis of the geomorphological controls on landscape-scale erosion rates (Montgomery and Brandon, 2002): (1) low-relief, low-gradient landscapes where erosion rates relate linearly to mean slope or local relief; here, climatic or tectonic controls direct erosion rates through changes in hillslope steepness; (2) high-relief, high-gradient landscapes, where changes in tectonically-driven rock uplift rate influence erosion rates through adjustments in the frequency of slope failure (primarily, landslides). In Greece, extreme erosional episodes such as landslides are the most significant landscape-modifying process (cf. Wainwright, 2009) and are promoted by the rugged relief and high gradients of the terrain (Koukis and Ziourkas, 1991). In many large-scale investigations that link tectonics and surface processes, hillslope erosion is modeled as a function of either elevation or slope (Montgomery and Brandon, 2002 and references therein). In line with directions from this type of research, on the basis of the aforementioned relationships between relief/slope and erosional regimes, and in the absence of models addressing Quaternary erosion at the landscape-scale, we constructed a slope map and we use here slope angle as a surrogate for mean local relief and as a proxy for assessing long-term erosion in Greece (Fig. 6b).

The slope map can be seen as a morphologic measure that provides an immediate visual impression of patterns of surface steepness. The hilly and mountainous parts occupy ca 65% of the country, while shallow gradients at elevations less than 200 m cover the remaining ca 35%, of which "the real plains reach only 25%" (Koukis and Ziourkas, 1991, p. 48). Thus, the areas covered by the first slope class ($0^{\circ}-2^{\circ}$) mainly represent the sedimentary basins and lowland coastal plains of Greece – the "real plains" of Koukis and Ziourkas (1991), which are also the places where the vast majority of Pleistocene sediments have accumulated. This slope class corresponds also to either smaller-scale, inter- and intramontane topographic depressions, or to plateaus: an example of the former type would be the numerous karst and solution basins of Epirus (dolines, poljes), whilst the latter are well exemplified by the plateaus of Macedonia. In all of these settings, deposition has been prevailing over erosion. The second slope class (2°–5°) represents gently inclined slopes and typically shows a clustering mostly at the fringes of and occasionally within the basins. The rest of the slope classes (5° to >40°) refer to (strongly) inclined up to almost vertical slopes, which altogether make up the characteristic rugged landscape of Greece. This is the mountainous realm that epitomizes the effects of surface processes and it can be collectively understood as an assemblage of residual landforms, each in the process of being consumed or transformed by erosion. Most of landslide phenomena occur in these areas (Koukis and Ziourkas, 1991), regulating the long-term erosion rates and the large-scale landscape-modifying processes.

As a working hypothesis, we argue that, with the exception of caves and rockshelters, these latter areas of hilly-to-mountainous terrain have hardly any potential for yielding stratified Lower Palaeolithic evidence; if they do, the material will be either contextless, or associated with a secondary context. Conversely, we expect that it is basically in the low-gradient basins and coastal settings occupying ca 40% of the country where material can be found in a stratified position, associated with either a primary or a secondary context. The basic argument behind this assessment is that low gradients favor the persistence of depositional landforms, whilst high gradients are predominated by erosional ones.

3.5. Evaluating the preservation of the Greek early Pleistocene record

In order to assess taphonomic bias on the spatial extent of the Lower Palaeolithic record, we can consider the total area of Greece as the *potentially initial extent* of that record. To this, we have to add the now-submerged areas of the Aegean[1] and Ionian Seas discussed above, which have a total extent that approximates that of the current mainland. Since those latter areas are now almost entirely inundated, we can consider that only about half of the initial record is theoretically today at the disposal of archaeologists for investigations. Thus, according to the arguments presented above, potential areas for preserving the record are restricted to about 40% (the low-gradient settings) of half (50%) of the initial record, namely some 20% altogether. This twenty percent mainly represents the low-gradient, sedimentary basins, which have been hosting the bulk of Quaternary sediments. However, much of the latter value (the total area of the basins) corresponds to Holocene and Late Pleistocene surficial sediments, since a large part of the Middle and Early Pleistocene deposits lies now at great depths, as it is the case with the stacked alluvial sequence of Thessaly, where exposed Early and Middle Pleistocene sediments occupy only ca 0.8% of the total extent of the basin. Moreover, for another fraction of the basins it is pre-Pleistocene deposits that are exposed on the surface, as for instance in northern Greece (Mountrakis, 1985). Quaternary formations occupy 15.8% of the total area of Greece (Koukis and Ziourkas, 1991) and in a most conservative evaluation Pleistocene sediments would thus cover about 10% of Greece, the rest 5.8% representing Holocene deposits. In effect, Pleistocene sediments cover today a spatial extent which corresponds to 10% of the 50% of the potentially initial extent of the record, namely some 5% of the latter. This assessment is independent of the geoarchaeological/geomorphological appraisal on the spatial coverage of potentially promising areas. If we do consider the geomorphological argument based on relief, then, areas promising for preserving the record would amount to:

10% (=Pleistocene deposits) of the 40% (=low-gradient depressions including pre-Pleistocene and Holocene sediments) of 50% (=current continental extent of Greece) = 2% of the potentially initial extent of the Lower Palaeolithic record.

The premise of an 'initial extent' is not entirely arbitrary, but it is dependent on time: the initial extent of double the size of Greece is best applied to time-periods at around and before ca 400–500 ka, when emerged areas in the Aegean attained their maximum coverage during sea-level lowstands. After MIS 10–12, this 'initial' value would be smaller (viz. the emerged areas were more restricted) but the final outcome of the estimate would not be much different. When considering the geomorphological argument based on relief, the concluding amount is still small, even if we ignore the 'missing Aegean and Ionian areas' and regard the 'initial extent' as equaling that of Greece's current area:

10% (=Pleistocene sediments occurring in sedimentary basins and other types of topographic depressions) of the ca 40% of the area of Greece (=low-gradient settings), = *4% of the 'potentially initial extent of the Lower Palaeolithic record*'.

We believe that possible miscalculations due to the 'roughness' of the assessment would be averaged out, and anticipate that more accurate calculations based on higher-resolution data will probably yield even smaller percentage values. In fact, it can be argued that for both of the above scenarios (pre- and post-500 ka assessments) the above-estimated final amounts could be viewed as maximum evaluations.

4. Discussion

Geomorphologically-informed approaches to the study of early hominin habitats, land use and dispersal patterns are rare but not nonexistent, providing a valuable contribution to human evolution research (e.g. Bailey et al., 1993, 2011). Although the study of taphonomic processes is included in several interdisciplinary investigations (e.g. Domínguez-Rodrigo et al., 2009), the role of landscape dynamics in conditioning the dipolar relation between preservation and archaeological accessibility is only occasionally explicitly addressed (but see e.g. Cohen et al., in press), and it is rarely approached within the spatial and temporal scales of human evolution. In this paper we elaborated on such broad scales, to show how geomorphic processes filter early Pleistocene archaeological patterns, and how the study and interpretation of large-scale landscape dynamics can alter our understanding of the potentiality of a region for yielding evidence. The 'discovery factor', as it is referred to in the work of Bailey et al. (2011), appears to have significantly influenced the quantity and quality of what we find and collect from the modern land-surfaces or geological outcrops of Greece. Evaluating landscape taphonomy is therefore a prerequisite before assessing 'absence of evidence' versus 'evidence of absence' and, in the case of Greece, the most dramatic expression of this assertion relates to the now-submerged landmasses of the Aegean and Ionian Seas: far from just signaling a pessimistic message with regard to how much of evidence has vanished, it also shows that the surviving part of the record may yield extremely important data in the future.

Although the data-set is ever-growing, Lower Palaeolithic evidence from Aegean or Ionian insular sites is still scarce or tenuous. Thus, refraining ourselves from sheer speculation, we only sketchily present here some of the archaeological implications that can be distilled from the new palaeogeographic data -notwithstanding the need for cross-checking and further refinement in the resolution of this data. Despite their preliminary status, the recent results from the

[1] The Turkish coastline is excluded from this account.

Aegean islands of Melos and Gavdos (Chelidonio, 2001; Kopaka and Matzanas, 2009) can be seen as already prefacing such high prospects, whilst the Cretan evidence and the possibility that it attests to a Lower Palaeolithic seafaring (Strasser et al., 2010) has already stirred up intriguing discussions, although in light of the present reconstruction the capability for seafaring is mitigated.

A new model that has recently been proposed for the earliest colonization of Europe identifies Western Eurasia as the central area of dispersals -a 'source region' of continuous human presence that was able to feed migration pulses (Dennell et al., 2010). According to this model, the Acheulean in Europe was introduced from Southwest Asia and *H. heidelbergensis* specimens -such as that from Petralona- represent a primarily West Eurasian taxon. If the Levant and western Turkey were among those core areas of Southwest Asia (Dennell, 2010), the Aegean would most probably *not* have been peripheral. Instead, particularly before and up to the mid-Middle Pleistocene, the terrestrial landmasses in the Ionian and the Aegean could have provided direct connections between the Balkan refugia and Southwest Asia via Asia Minor. In contrast to the Iberian and Italian peninsulas, which remained isolated from their surroundings in the longitudinal axis (e.g. O'Regan, 2008), during the periods of Aegean land emergence the peninsular character and a *cul de sac* status for Greece would have been canceled in terms of the latter axis. It has been argued that in the Afro-Eurasian Pleistocene, the predominant pattern of large-mammal movements was east-west rather than north-south, i.e. between Europe and Asia, rather than Africa (O'Regan et al., 2011). Considering that the 'Out of Asia' palaeoanthropological scenario finds ever-increasing support (e.g. Dennell and Roebroeks, 2005; Dennell et al., 2010), the role of the broader Aegean region needs to be reconsidered, as it is highly probable that it constituted not only an important refugial and source area for (re)colonizations, but also an integral part of east-to-west (and vice versa) dispersal routes within Eurasia. The importance of a '(quasi-)terrestrial Aegean' becomes obvious also in the framework of the 'Out of Africa' paradigm: in almost all of the classic models (e.g. Bar-Yosef and Belfer-Cohen, 2001), the depicted dispersal route from Africa includes the Levantine corridor, which is still considered to have been the most probable route facilitating biogeographical connections between Africa and Eurasia, at least in the latest Pliocene and early Pleistocene (e.g. Turner and O'Regan, 2007); yet, once past the Levant, the illustrated route commonly continues *across mainland Turkey*, either reaching Europe by way of the Bosporus strait, or going through a palaeo-Euphrates passage into the Caucasus -and then moving westwards- as for instance in the latest scenario advanced by Muttoni et al. (2010).

Assuming now that the barrier of the Aegean Sea would not have existed for much of the Early and Middle Pleistocene (practically up to about MIS 8), new dispersal routes can be envisaged. Fig. 8 (black line) illustrates such an example, with a route passing along the southern coasts of Turkey and across the Aegean. This offers a more parsimonious, least-cost direction connecting the Levantine scene with the continental areas of the Mediterranean, which would have provided an alternative to the crossing of Anatolian barriers, such as the Taurus mountain range (cf. Kuhn, 2010). In this example, the route crosses the mainland along the lacustrine setting of the Patras-Corinth Gulf (a miniature of the East African Rift System) and continues through the emerged land of the Ionian and further north along the Dalmatian coasts to meet the Po Valley; large stretches of the latter would have been more persistently exposed since MIS 22, providing for the first time new migration pathways across northern Italy to southern France and Spain in the west (Muttoni et al., 2010). Considering that mountain ranges such as the Carpathians, the Dinarides or the Stara Planina would have acted as important physiographic barriers, impeding intra-Eurasian east-west biogeographical movements, we could also envisage other dispersal pathways, following non-mountainous littoral belts: for instance (Fig. 8, red line), one that trails along the coast of the Black Sea and continues across the northern Aegean region, thereby connecting the central and western Mediterranean with western Eurasia by way of low-relief drainage catchments, instead of crossing the aforementioned transverse anticlinal structures.

The significance of a 'terrestrial-wetland Aegean' is not restricted only to its role as a *biogeographical landbridge*; rather, it

Fig. 8. Schematic palaeogeographic scenario for early Pleistocene glacial stages showing examples of two new routes of hominin dispersals within Eurasia and between Africa and Eurasia that can now be envisaged in light of the data and interpretations discussed in this study. Coastlines are at the −120 m isobath based on the reconstruction of Lambeck and Purcell (2005) for the Last Glacial Maximum, except for the Po Valley-Adriatic Sea, for which the coastlines are after the reconstruction of Muttoni et al. (2010, Fig. 4 and references therein), and the Aegean and Ionian Seas, which are reconstructed for MIS 10–12 after the study of Lykousis (2009). Notwithstanding the depicted arrows, dispersal movements could follow both directions. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

refers also to its hitherto unidentified potential as a *landscape for occupation* by early humans -and in fact, a rather ideal one. If dynamic landscapes create favorable conditions for hominins; and if some hominin taxa were indeed adapted for environmental and long-term habitat disturbance (as e.g. *Homo erectus*; Cachel and Harris, 1998), then a lot can be learned from the Aegean region: to our knowledge, nowhere in southern Europe would there ever have been Pleistocene landscapes as dynamic as those that would periodically emerge between Asia Minor and continental Greece, in what has been -and continues to be- one of the most tectonically active regions in Eurasia.

Today, the available windows into this picture are restricted to insular locations as well as onshore raised beaches, caves, and other settings (e.g. lacustrine/lagoonal) preserved due to uplift. Similarly, the geoarchaeological windows from what we know today as continental Greece are also constrained by the biasing filters of past and present geoclimatic processes, and yet they are capable of filling the Early-Middle Pleistocene gap in the occupational history of the Greek Peninsula. Limited as they may be, we are confident that those small windows are able to shed a disproportionate amount of light to the lifeways and environments of early humans. Moreover, we anticipate that our research will have considerable implications for upcoming investigations in Greece, not only because of its results, but also as a methodological approach that sets novel 'points of departure' for the design and practice of future fieldwork. We can briefly mention three points (cf. Tourloukis, 2010): 1) we have narrowed-down the focus for the search of Lower Palaeolithic material in Greece: future work should target fluvio-lacustrine basins that have been inverted in the late Pleistocene – e.g. the Megalopolis and Mygdonia basins in the mainland, as well as insular basins such as that of Katharo in Crete (Fig. 6); 2) field-strategies should give emphasis to the inspection of exposed profiles, rather than land-surfaces, aiming at stratified material that can be securely dated; 3) localities that have already yielded early Pleistocene paleontological finds should also be given priority, for they indicate areas with promising geoarchaeological opportunities, in the sense defined here with regard to the preservation/accessibility relationship. Finally, both the results and the methodological perspective developed here can be seen as having implications that are wider than the geographical limits of the Greek Peninsula. For example, commenting on the recent Acheulean discoveries from India (Pappu et al., 2011), Dennell (2011) remarks that the intensity of hominin occupation in India appears to have been much lower than previously thought. However, Early Pleistocene deposits in India are overall either scarcely preserved or chiefly inaccessible in most of the main basins or river valleys (Dennell, 2010) – a fact that echoes the main conclusion from our research in Greece: assessments of site distributions and occupation (dis)continuities and densities are likely to be flawed unless the observable patterns have been evaluated against the biasing effects of geomorphic processes.

5. Conclusions

(1) On the current evidence, i.e. the cave of Petralona and possibly Apidima as well; the site of Kokkinopilos; and the new sites from Crete, humans were present in Greece in the late Middle Pleistocene; an earlier presence in the early Middle or Early Pleistocene may be indicated by the human remains in Megalopolis and the lithic material from Rodia, respectively, but the evidence from both sites requires further confirmation of the contextual data.

(2) In spatial terms, based on the Quaternary geological opportunities in Greece, only a meager 2–5% of the early Pleistocene record could have been preserved, and, in this portion, much of the potentially preserved material is likely to occur in a reworked context, whereas material in primary contexts may be lying deeply buried. The fact that geological opportunities are limited and unpropitious for preserving stratified material, particularly in primary contexts, can be explained in terms of landscape dynamics and their spatio-temporal specifics. Quaternary landscape evolution in Greece was primarily controlled by four main driving mechanisms: (i) *tectonic activity*, with rates of vertical and horizontal deformation that are among the highest in the entire Eurasia; (ii) a markedly *seasonal climate*, in which the seasonality of precipitation is the key parameter, being accentuated mostly during glacials, and, in turn, affecting runoff and river flow fluctuations; (iii) *sea-level oscillations* exposing and submerging large areas, at the same time controlling inland patterns of fluvial incision and sedimentation; and, last but not least, as the land-surface manifestations of all of the above, (iv) *slope processes* on a predominantly high-relief terrain, with spatially restricted drainage basins, erodible lithologies, skeletal soils and an effectively strong slope-channel coupling. Rather than being temporally continuous, landscape disturbance occurred in an episodic fashion and in the form of extreme events of short duration but high amplitude and high frequency of recurrence, in time-windows that were pre-conditioned by the combined forces of some (or all) of the four above-mentioned factors. Changes to the threshold conditions at which a disturbance-event became effective could be due to climatic transitions (mostly cold-to-warm ones) at millennial, centennial or decadal scales, and/or due to associated sea-level changes (e.g. affecting base-levels of rivers); if not climate, tectonic movements would have been equally efficient as triggering factors.

(3) A landscape dominated mostly by transient, erosional landforms indicates that the fragmented status of the early Pleistocene archaeological record and the scarcity of stratified occurrences are to be interpreted as the outcome of the biasing and destructive effects of Quaternary geomorphic processes and not as the net result of a real absence of hominins.

(4) In a long-term perspective, the Quaternary tectono-sedimentary evolution of the Greek basins, which host the bulk of the early Pleistocene geoarchaeological archive, largely explains why an advantageous association between high preservation potential and sufficient accessibility appears at present to be the exception rather than the norm. In turn, this elucidates much of the current status of the Greek record not only *per se*, but probably also as compared to those of Italy and Iberia, considering that, in the latter areas, the overwhelming majority of the evidence occurs in fluvial and lacustrine settings (cf. Tourloukis, 2010 and references therein).

(5) Any future assessment of Early and Middle Pleistocene human dispersals and the Lower Palaeolithic of the eastern Mediterranean in general and Greece in particular, for instance with regard to dispersal routes, site distribution patterns, occupation densities or the (dis)continuity of early Palaeolithic human presence, needs to account for the biases imposed by a potentially high-magnitude site loss in the wider Aegean region due to marine inundations. Nevertheless, the reconstruction of extended terrestrial landmasses in the Aegean and the Ionian Sea highlights the potential of those areas for yielding important early Palaeolithic sites and contributing to the debate over the routes, chronology and evolutionary processes associated with the early or earliest dispersals of hominins in Eurasia.

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