University of Southampton

Faculty of Arts and Humanities

Humanities - Department of Archaeology

Hominin movement and occupation spatial patterns in Eastern and North-Eastern Mediterranean during the Lower Palaeolithic: the Aegean perspective

by

Panagiota Tsakanikou

Thesis for the degree of Doctor of Philosophy

May 2020

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Abstract

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This thesis explores possibilities for hominin movement and occupation over the exposed dry land landscapes of the Aegean region during the Early and Middle Pleistocene (focusing more on the Middle Pleistocene ca. 0.8- 0.2 Mya). The point of departure and inspiration is the recent palaeogeographical reconstructions from the study area. Geological evidence reveals the existence of extended terrestrial landscapes, with attractive environments, connecting western Anatolia to Europe via the Greek mainland, during the glacial lowstands of the Middle Pleistocene, and possibly during certain interglacials. These lands are now lost, lying underwater, but, in spatial terms, a completely new spectrum of possibilities opens up for hominins moving across or settling over this part of Eurasia, affecting the wider narrative regarding the early settlements out of Africa. Yet, the research potential of the submerged landscapes of the Aegean has not been fully integrated in the way(s) we study and interpret the Lower Palaeolithic evidence from this region.

The discussion about the early colonisation of Europe has been long focused on the western part of the continent due to the abundance of available evidence. The wider Aegean region was excluded, until recently, as a ‘cul de sac’ that blocked movement and dispersal towards the west, representing a gap in the European Lower Palaeolithic archive, with very little to contribute in terms of material culture or hominin fossil evidence. Advances in palaeogeography and geoarchaeology and exciting new finds urging now for a reconsideration. Could the Aegean exposed lands provide land bridges for movement and favourable niches for occupation, offering perhaps an eastern gateway to Europe during the Early and Middle Pleistocene? In order to answer these questions I drew information from archaeology and palaeoanthropology, palaeozoology and palaeoenvironments, and geology and palaeogeography. These multiple lines of evidence have been synthesised within an affordance-based GIS framework, which centres on

the relationship between the hominins and their 'affording' world. The new methodological scheme developed here led to new hypotheses and scenarios of movement and occupation, predicting areas in the Aegean, onshore and offshore, with increased research potential for the Lower Palaeolithic, based on the level of suitability for the hominin survival, subsistence and dispersal.

The findings of my study suggest that despite the serious methodological challenges imposed by landscape dynamics, temporal limitations and extensive discontinuities in the archaeological record, a cross - and inter - disciplinary approach can help us gain valuable insights into the nature of the past landscapes and land use by hominins. In this respect, the complex topography concept and the concept of affordances constitute the backbone of my approach. The first, by setting out the background against which suitability was built, and the second, by attributing a lived and experienced element into the past landscape.

The contribution of this study is twofold: (a) offers a framing heuristic, to the newly founded discipline of the continental shelf prehistoric research, for testing further ideas on hominin movement and occupation in dynamic environments; and (b) proposes trans-Aegean corridors of opportunity for dispersal and occupation areas, complementing the current Lower Palaeolithic narrative with a potential eastern gateway to Europe.

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Research Thesis: Declaration of Authorship

Print name:	Panagiota Tsakanikou

Title of thesis:	Hominin movement and occupation spatial patterns in Eastern and North-Eastern Mediterranean during the Lower Palaeolithic: the Aegean perspective

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myshelf jointly with others, I have made clear exactly what was done by others and what I have contributed myshelf;
7. None of this work has been published before submission:

Signature:		Date:	06/05/2020

Acknowledgements

I would like to express my deepest gratitude to my main supervisor Dr John McNabb, who has been an inspiring mentor. I would like to thank him for the generous sharing of his knowledge, epxerience and enthousiam, and for believing in me, when I had lost belief in myself. I would also like to thank my second supervisor Dr Helen Farr for pushing my limits further, in the study and understanding of the prehistoric submerged contexts.

This thesis is following the research path opened by Prof Nena Galanidou and Dr Dimitris Sakellariou, who I would like to thank for their valuable insights, advice and collaboration. Particularly Prof N. Galanidou for giving me the opportunity to excavate at the site of Rodafnidia on Lesbos Island during consecutive field-seasons from 2013 to 2018, and for her continuous support, and Dr D. Sakellariou and the Hellenic Centre of Marine Research for making available bathymetric data from the Aegean.

Special thanks are due to my friend and colleague Dr Crystal el Safadi for saving my sanity by helping me to understand GIS applications, and for the enlightening discussions on spatial analyses. I would also like to thank Prof David Wheatley and Prof Fraser Sturt for their constructive comments and feedback during earlier stages of my work.

The Greek Archaeological Committee UK (GACUK) and the University of Southampton have offered financial support throughout my PhD studies. To this end, I would like to express my gratitude to Mrs Matti Egon and the members of the GACUK, especially Dr. Zetta Theodoropoulou-Polychroniadis, Prof Panos Arvanitakis and Prof Irene Lemos for their trust.

This endeavour would not have been successful without the love and support by my two ‘families’. I particularly want to thank the multinational group of friends in the UK: Nikko, Anna, Giorgos, Erato, Julieta, Emilia, Maria, Panos, Helena, Alkyoni, and Christian; all my peers (past and present) at the PGR office and the CAHO Lab.; and my friends from Greece who never gave up on me: Marilou, Roula, ‘Ries’, Mary, Stefanos, Mina, Georgia, Elli, Marianni and Menios.

Finally yet importantly, I cannot thank enough my father, Michalis, my mother, Charis, and my sister, Niki, who have been an infinite source of love, inspiration and support.

Dedication

To my parents,

for helping me to find my way into the unknown

Chapter 1 Introduction

"The rare finds are just enough to be useful"

(Gowlett 1999: 43)

1.1 Background

The Aegean region (fig.1.1) is dominated by the Greek archipelago and by the Greek mainland, which separates the Aegean Sea (to the east) from the Ionian Sea (to the west). The archipelago comprises nearly 6.000 islands and islets, with only 227 being inhabited. Its coastline covers 7.500 km out of the total 16.000 km of the Greek territory's coastline. The topography of the wider area (including the mainland) is diverse and complex, combining coastal plains, lowlands and mountainous areas, and hosts variable environments. The Aegean has been developed as an extensional basin, due to the geotectonic evolution of the wider eastern Mediterranean. Sea-level fluctuations, following the glacial-interglacial oscillations during the Pleistocene and the Holocene, repeatedly changed the paleogeography of the Aegean, at times inundating and at other times exposing the seabed as dry land. The current configuration was established around 9 Kya. Diachronically, human populations occupying or moving across the area must have been drastically affected by the dynamic nature of this landscape - either as a terrestrial landscape or as a seascape - in terms of adaptability and behavioural flexibility (Harff, Bailley and Lüth 2016).

Figure 1.1. Satellite image of the study area. The Aegean archipelago separates W. Anatolia from the Greek mainland. Source: NOAA National Environmental Satellite, Data and Information Service. Environmental Visaulisation Lboratory

The Aegean is a key-geographical location between Africa, Europe and Asia, in an area that has proved to be crucial for the survival and dispersal of populations during the Early and Middle Pleistocene. The wider eastern and north-eastern Mediterranean served as a refugium during the glacial periods, but also as a core area hosting source populations for the repopulation of the northern and western parts of Europe during the interglacials (Dennell, Martinon-Torres and Bermudez de Castro 2011). The palaeofaunal record shows that the Balkans in particular operated as a reception and diffusion area for the expansions towards Europe, providing multiple and multidirectional routes during the Pleistocene for several mammalian species (Kahlke et al., 2011). Recent evidence suggests that Europe may have been reached by hominins at - or slightly prior to - 1 Mya via the Peri-Pontic routes and the Bosporus passage (through Asia Minor), during a faunal westward expansion around 1.3-1.2 Mya (Spassov 2016; Koufos and Kostopoulos 2016). This is in very good agreement with the earliest secure evidence for the presence of hominins in southern Europe from Spain, France and Italy (Garcia et al., 2014; Minchel et al., 2017; Arzarello and Peretto 2010), offering support to the 'Mature Europe' hypothesis (Carbonell et al., 1996).

Taking into consideration that during the Early and Middle Pleistocene (a) the mountains and the water barriers in Caucasus region would have blocked or delayed hominin dispersals into Europe (Kuhn, 2010a), and (b) that climatic and topographic variability within the vast area of Anatolia must have created inhospitable conditions for hominins (Dinçer 2016), it is reasonable to investigate for further evidence in south-eastern Europe along Asia Minor, the Bosporus, the Aegean and the Balkans. Despite the high research potential, the Lower Palaeolithic signal from this part of Eurasia remains surprisingly weak, with sparse archaeological and palaeoanthropological evidence and extensive spatiotemporal discontinuities. Until recently, the focal point in the prevailing scenario for the early colonisation of Europe was the Iberian Peninsula, in the west. However, recent finds from the eastern gateways offer support for the reconsideration of eastern and north-eastern Mediterranean as a central area during the Lower Palaeolithic, instead of a peripheral one (Harvati and Roksandic 2016). The traditional narrative for the early peopling of Europe is being challenged, with implications for (a) the origin of the hominins populating Europe, (b) the routes they followed and (c) the timing of the early dispersal events (long vs short chronology).

Within this framework, the Aegean region, in particular, has been highlighted since the 1990's, with Gowlett (1999: 54) suggesting that: *"… the record [of Greece] is already of real importance in assessing that nature of early colonisation in Europe"*. This concept seems to be the prevailing objective in the Lower Palaeolithic fieldwork undertaken in Greece during the last few decades.

Despite advances and progress witnessed in the Greek Palaeolithic research (Galanidou 2014a) the record has been surprisingly poor. Up to the 1980's, this paucity of evidence was attributed to the limited interest of Greek archaeologists in the Lower Palaeolithic, focusing mainly in later periods (e.g. Bronze Age, Classical times). During the first intensified steps of the Palaeolithic research, there was no story of continuity to be told for the Greek Lower Palaeolithic, with available evidence creating a rather fragmented picture*, "a patch-work of migrations and new settlements followed by long periods of adaptation, interruption and abandonment",* as described by Runnels (1995: 728). Most possibly, this low occurrence of the Lower Palaeolithic evidence could be the result of interpretation bias, posed by landscape dynamics. Active geomorphic processes negatively affected the preservation, availability and visibility of the Lower and Middle Pleistocene archaeological and palaeoanthropological material (Tourloukis 2010). As such, this absence of evidence does not necessarily represent evidence of absence across the Aegean region.

Recent finds from Rodafnidia site on Lesbos Island (Galanidou et al., 2013; 2016) and Marathousa 1 site in Megalopolis basin (Panagopoulou et al., 2015) provide unequivocal evidence for the presence of hominins in the Aegean region around, and possibly prior to, 500-400 Kya. Furthermore, recent ongoing research on submerged landscapes (Lykousis 2009; Sakellariou and Galanidou, 2016; 2017) revealed the existence of extended subaerially exposed landmasses with favourable conditions in the Aegean during the Middle and possibly during the earlier parts of the Pleistocene. During the glacial lowstands, a global sea-level drop by as much as 120-135 m has been documented (Rohling et al., 1998). Due to this regression, continental shelves that were submerged during warmer phases with higher sea levels became gradually exposed and dry, offering inhabitable lands. For the Aegean region in particular, it has been suggested that a large amount of the seabed in the northern and central parts was exposed, not only during the glacial stages of the Middle Pleistocene but possibly also during certain interglacials (MIS 11, 9 and to a lesser entend 7), i.e. without interruption from at least MIS 10-12 (480-350 Kya) until at least MIS 8 (300-250 Kya). The cyclic scheme of exposure and submergence continued after the marine transgression that occurred at some point after MIS 9 (Lykousis 2009: 2043). The occurrence of the continuous terrain throughout the glacial-interglacial cycles of the Middle Pleistocene, a suggestion made by Lykousis a decade ago (2009:2041, 2043), certainly needs further investigation to be fully established. For the purposes of this study, however, it is considered at least a possibility, until proven otherwise.

The potential role of the central and northern Aegean as an attractive land for occupation, a refugium and a dispersal corridor, is being put forward, highlighting the increased research possibilities, due to a set of promising characteristics (fig. 1.2): (a) the spatial coverage of the

Aegean exposed landmass, comparable during the maximum exposure to the extent of continental Greece, (b) the time coverage, during a crucial period in the history of hominin dispersals and the peopling of Europe, and (c) the high ecological value, with rich and variable natural resources facilitating the survival and circulation of populations, throughout the glacial-interglacial oscillations. In a sense, returning to the initial point made by Van Andel and Shackleton (1982), that currently submerged landscapes hold valuable information about early human behaviour i.e. exploitation of resources and mobility. The archaeological implications are enormous, raising questions in relation to the role of the Aegean during the early colonisation of Europe. Was the Aegean a barrier during the Middle (and Early) Pleistocene, or an extended terrestrial landscape with attractive habitats?

The Aegean dry land hypothesis is starting to have an important impact on the archaeological thought beyond the Greek Palaeolithic. In a recent publication entitled *Palaeoanthropology of the Balkans and Anatolia*, *Human evolution and its context* (Harvati and Roksandic 2016) researchers, such as Roksandic (2016), Strait et al. (2016) and Galanidou et al. (2016), recognise and consider the existence of the exposed Aegean landscapes as a dynamic agent in the history of movements during the Early and Middle Pleistocene. Strait et al. (2016:76) refer specifically to the 'Trans-Aegean pathway', as one of the possible dispersal routes during the Middle Pleistocene. Yet, the idea of the Aegean as a traversable terrain or as a land for settlement by hominins is very generic and needs further exploration.

1.2 Research Questions

This thesis has dual aims: (a) to explore more closely the possibilities of movement (routes) and survival (areas of occupation and activity) that the Aegean dry land hypothesis landscape offered to hominins during the Middle – and possibly the Early – Pleistocene, and (b) to develop a methodological approach in order to unlock information kept within the Aegean dynamic context. Based on recent studies (Lykousis 2009; Sakellariou and Galanidou; 2016; 2017), the working hypothesis is that the largest part of the Aegean region (now covered by the northern and central Aegean Sea) was not a barrier during the Middle Pleistocene, and possibly during the Early Pleistocene, but an open terrestrial landscape, a dry land, from at least MIS 10-12 (~480 Kya) until at least MIS 8 (~250 Kya).

From this working hypothesis, two main research questions emerge:

1. Can we suggest possible zones of hominin activity that correspond to exploitation territories – following the 'site region' definition given by Bailey and King (2011:1533) – taking into account: (a) the topographic complexity of the landscape, (b) the suggested

richness of natural resources during the Middle and potentially the Early Pleistocene and (c) the raw material availability (especially of volcanic origin) over the Aegean exposed landscapes?

The 'site region' encompasses the spatial range of activity for hominins, as reconstructed from biological adaptations (locomotion) and behavioural aspects (foraging strategies, transportation of raw material, social structure), suggested to cover a zone of ca 10km during the Lower Palaeolithic.

2. Can we suggest possible corridors of opportunity for hominin dispersal, traversing the Aegean exposed landscapes?

Followed by three sub-questions:

I. Is it possible to identify areas with high potential for the Lower Palaeolithic research over the Aegean?

II. Consequently, can we target specific areas to investigate for the Lower Palaeolithic evidence?

III. To what extent is it possible to observe and conceptualise hominin movement and occupation patterns over the Aegean regional scale?

1.3 Challenges and Objectives

The obvious problem is that the topography and the environments of the now submerged Aegean landscapes are, largely, unknown. Moreover, available information from this region, is characterised by (a) scarce and discontinuous evidence (archaeological, paleoenvironmental and paleogeographical), (b) temporal limitations, with the vast majority of available evidence covering only the last glacial cycle (the last 120 Ka), but not the earlier periods of the Pleistocene before that, and (c) the dynamic character of the tectonically active Aegean landscape. These limitations pose several methodological challenges in the study of hominin movement and occupation across the Aegean palaeolandscape during the Early and Middle Pleistocene. These same limitations should be expected to affect any attempt to model hominin behavioural patterns, with low resolution and accuracy, due to the poor quality of available data. Thus, the investigation and modelling of the hominin presence, activity and mobility over the study area, cannot be accomplished within a strictly archaeological methodological scheme; the challenges exceed the efficiency of the available toolkits.

In the complex topography concept, developed by Bailey and King (2011; King and Bailey 2006) archaeology is coupled with earth sciences, offering a rigorous approach to tackle some of the main challenges in the Aegean region relating to landscape dynamics. This approach provides the theoretical framework and the practical tools to make approximations about the nature of the past landscapes using current topographic evidence. According to the concept, active/dynamic landscapes with their complex topography, helped in the maintenance of mosaic environments in the remote past. This refers to microhabitats with favourable conditions for the survival of early hominins. Indeed, key-Early Palaeolithic localities in Africa and elsewhere (e.g. Ubeidiya and Dmanisi) are found in such dynamic environments, while corridors for dispersal have been bordered by natural barriers generated by tectonics and volcanic activity (Reynolds, Bailey and King, 2011). Work by Bailey and King demonstrate that in landscapes with a long-lasting activity, modern topographic complexity can be used to deduce information about the complexity in the past topography, in both terrestrial and submerged contexts. Surface roughness – measured using present-day elevation and bathymetry – provides a proxy for doing so. The resulting topographic roughness maps, allow the identification of areas with increased research potential: areas with high values of surface roughness in the modern landscape indicate high topographic complexity in the palaeolandscape; in retrospect, preferable areas to hominins for settling in and/or navigate across.

These methodologies have never been tested in the north-eastern Mediterranean. I will be applying the complex topography concept to the Aegean region for the first time, attempting a preliminary identification of areas that could have been attractive to hominins, based on the logic outlined above. Both land and seafloor surface roughness will be recorded, since the palaeolandscape included parts that are now submerged. In the absence of a palaeolandscape reconstruction for the Aegean for the period of interest, the complex topography concept allows us to deal with the palaeolandscape as a whole, creating a unified topographic record by integrating evidence from above and below the sea level. Setting, in a sense, the background against which all available evidence from archaeology, palaeoanthropology and palaeoenvironments can be projected and synthesised to assess further hominin occupation and dispersal.

For the synthesis of evidence, an interdisciplinary approach will be followed, having archaeology and spatial analyses as the two main pillars. Geographical Information Systems (GIS) offer multiple and variable tools to address archaeological questions referring to past activity and develop models. In this study, hominin activity is conceptualised over a wider landscape, in other words at a regional scale of analysis. In this respect, the Aegean dry land is perceived not solely as a natural landscape but rather as a record of the hominin presence and endeavour, following Ingold's 'dwelling perspective' (Ingold 1993: 152). This experiential approach is included in the affordance-based GIS framework developed in this thesis. The concept of affordances humanises the past landscape by establishing links between the hominins and their natural world - offering opportunities for survival, exploitation and dispersal through the availability of various natural resources.

The primary aim here is to delve into the 'hominin factor'. For doing so, direct and indirect evidence and proxy data will be used. Not for producing accurate reconstructions of hominins' lives and behaviours, but rather for testing ideas about how, and to what extent, the occurrence of the exposed lands between W. Anatolia and Europe affected the patterns of the early settlers and navigators in the Aegean region and beyond, during the Early and Middle Pleistocene.

The assessment of the archaeological potential of the Aegean exposed landscapes is a strand of – and an asset to – the newly established discipline of continental shelf prehistoric research (Flemming et al., 2014). The potential of the now submerged landscapes as previously terrestrial environments has not been fully appreciated – not in the Aegean case alone, but globally – and it is only in the last few decades that is starting to become acknowledged (Flemming et al., 2017). The current research agenda in the wider eastern and north-eastern Mediterranean is being re-shaped with a new focus to a previously unexplored area: *"Beyond terra firma, the submerged landscapes of the north-east Mediterranean constitute a new research path that is now opening. Mapping them and exploring their archaeological potential aims to provide a fuller reconstruction of Pleistocene and early Holocene landscapes and their affordances"* (Galanidou 2014a: 5).

This thesis aspires to (a) provide arguments for the redefinition of the biogeographical role of the Aegean during the Early and Middle Pleistocene, as a core area for the study of hominin activity and mobility, (b) provoke the traditional readings of the current Lower Palaeolithic evidence and generate alternative scenarios for the hominin movement and occupation, highlighting the potential of the eastern part of the European continent, and (c) develop new methodological schemes for identifying, recording and interpreting evidence of hominin activity and mobility in broader geographical scales within geodynamic contexts.

1.4 Structure

Chapter 2: This chapter provides an overview of the Lower Palaeolithic research background in Greece, the Balkans and Anatolia. The Greek Lower Palaeolithic record, in particular, is examined within its wider eastern and north-eastern Mediterranean context. Emphasis is given on recent advances and archaeological and palaeoanthropological finds that have an important effect on current interpretations about the biogeographical role of W. Anatolia-E. Europe during the Early and Middle Pleistocene. This is a synthesis of available evidence, rather than a detailed account of sites and finds. Research limitations and biases are discussed in relation to the geodynamic character of the Aegean region.

Chapter 3: The role of the Balkans as a core area for the Plio-Pleistocene dispersal events is highlighted through available faunal evidence. The palaeofaunal records from the wider eastern and north-eastern Mediterranean, with specific reference to the Greek record, are viewed here as an important *corpus* of information from where valuable insights can be extracted on hominin mobility. Available evidence on timing, dispersal routes and environmental conditions are discussed in correlation with early evidence for the hominin presence in the area, concluding in the currently prevailing dispersal scenarios during the Early and Middle Pleistocene.

Chapter 4: This chapter deals with the dynamic nature of the Aegean landscape within the active province of eastern Mediterranean. The geotectonic evolution and the history of the volcanic activity are reviewed, to enable a better consideration of the taphonomic factors that affect preservation and availability of the Early and Middle Pleistocene material. Changes in the Aegean paleogeography and palaeotopography, caused by active geomorphic processes, are identified and discussed using available palaeogeographical reconstructions. The extensive exposed terrain over the northern and central Aegean during the Middle (and possibly during the Early) Pleistocene deserves a closer review for its archaeological implications. New options for the hominin movement and occupation during the LP are opening up over an area that remained until recently unexplored, in this regard.

Chapter 5: This chapter provides a detailed description of the affordance-based GIS methodological framework developed in this thesis and its application in the Aegean context. The new methodological scheme uses GIS applications – spatial analyses (quantitative methods) to gain a better understanding of the lived and experienced space during the remote past (qualitative element), by perceiving affordances as relations between the hominins and their environments. The points on interaction are defined firstly in spatial terms to further indicate levels of suitability, a term used here in a specific way - i.e. areas that would favour more or less hominin survival and activity; thus, identifying/predicting target areas for the future Lower Palaeolithic research. The complex topography concept contributes greatly to the preliminary identification of attractive areas for hominins and consequently, to the definition of the components of suitability. Theoretical concepts, greatly influencing methodological choices are also discussed. The chapter is divided in two sections. The first deals with the palaeolandscape and the second with the hominin factor.

Chapter 6: In this chapter, a case study for the expansion of the new methodological approach is presented. The work on suitability (Ch.5) sets the background to explore other aspects of hominin movement/dispersal in relation to landscape structure: the 'traversability' potential and the navigation potential. The first is addressed through a least-cost pathway analysis between archaeological sites (dated to two different time periods) located on both sides of the Aegean, and the second by a version of the landscape legibility approach (Guiducci and Burke 2016) based on the visibility of salient natural landmarks. Both assessments largely rely on proxy topographic data (modern elevation and bathymetry). Landscape legibility is a new approach that adds significantly to suitability. A third affordance variable is attached to the suitability model: the dispersibility potential for hominins, offered by the natural structure of the Aegean palaeolandscape.

Chapter 7: This chapter provides a synthesis, integrating the results from chapters 5 and 6 into a new hypothesis: the affordance corridors of the Aegean. New areas in the Aegean region (onshore and offshore), with increased research potential, are suggested. These correspond to potential occupation areas and corridors of opportunity for dispersal, as identified through the suitability and visibility models. The archaeological implications emerging from the new hypothesis - regarding the wider narrative for the European Lower Palaeolithic and the biogeographical role of E. Europe - are discussed. The contribution of this thesis in the methodological discourse is reviewed against recent advances in the prehistoric continental shelf research. The chapter concludes with suggestions for future work, highlighting the study of edaphics for its potential to offer insights on past land use in tectonically active contexts - complementing, in this respect, the complex topography concept.

Chapter 8: Concluding remarks.

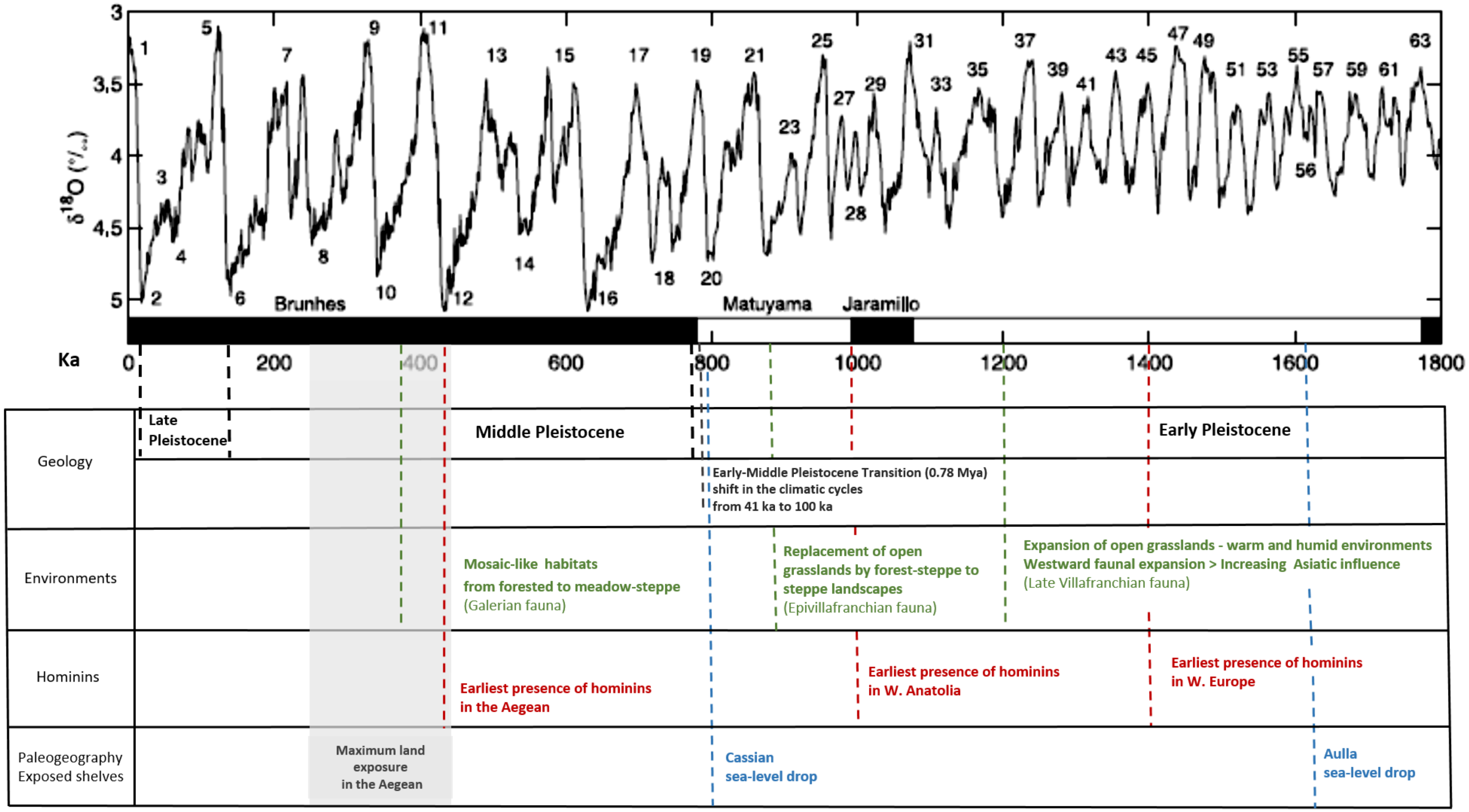


Figure 1.2. Major events placed in the chronological framework of this study. Faunal turnovers and environments (green), hominin first occurrence (red) and major lowstands with subsequent exposure of the continental shelves (blue). The sea-level fluctuations chart (top) adopted from Lisiecki and Raymo (2005). The Middle Pleistocene Transition follows Head and Gibbard (2005) chronology

Chapter 2 The Lower Palaeolithic Archaeology in Greece, Balkans and Anatolia

2.1 Introduction

The investigation and study of the Lower Palaeolithic (LP hereinafter) record from the Balkans - including Greece, and Anatolia (Western Turkey) has intensified during the last few decades, with new evidence starting to fill up some important gaps in the record (for a recent account see Harvati and Roksandic 2016). Yet, the general picture reflects a scarcity of evidence, problematic stratigraphic contexts and dating inaccuracies. The record mainly consists of lithic assemblages (Mode 1 and Mode 2) and fewer skeletal remains. In most cases, the LP material comes from the surface, and the association between the finds and the geological context is not clear. However, there are also some stratified sequences and systematically excavated sites with secure dates, enabling a better consideration of the available archaeological and palaeaonthropological information within the wider Eurasian LP context.

The principal LP research objective is attached to the key geographical location of eastern and north-eastern Mediterranean and consequently generates questions in relation to early hominin dispersal events and the colonisation of Europe during the Early and Middle Pleistocene. Until very recently, this area, including the Aegean region, remained out of the discussion for the early occupation of Europe, representing a hiatus on the LP map (Jöris 2014). The absence of evidence in the eastern part of the continent came in contradiction with the rich Lower and Middle Pleistocene records from the Iberian and the Italian Peninsulas (Garcia et al., 2014; Arzarello and Peretto 2010). Led by the Iberian evidence, the prevailing scenario for the early colonisation of Europe highlights the western part of the continent (Oms et al., 2000; Toro-Moyano et al., 2013). However, current evidence supports the repositioning of the eastern and north-eastern Mediterranean near the centre of developments during the LP, instead of the periphery, offering an alternative scenario, or perhaps a complementary one.

The notion that *"a shift is required in our communal perception of the geography of the region"*, moving away from considering the Aegean and the Black Seas as barriers to hominin movement is now starting to be embedded in archaeological thought (Roksandic 2016: 30). Furthermore, the "*Eurocentric point of view*" in the discussion about the initial colonisation of Europe and the migratory routes, is being challenged (Dinçer 2016: 213). The Balkans are currently viewed as a core demographic area, sustaining populations even during the glacial periods and permitting continuous movement and communication via multiple routes between southeast Europe and southwest Asia throughout the Pleistocene (Roksandic 2016; Dobos and Iovita 2016; Ivanova 2016; Strait 2016), while the perception of Anatolia as a land bridge connecting Asia and Europe in an East to West axis is proving to be oversimplified and needs to be reconsidered. Climatic and topographic variability over this vast area and geographical/natural barriers must have posed serious challenges for early hominins during the Early and Middle Pleistocene (Kuhn 2010a; Dinçer 2016).

The paradox observed here i.e. great expectations for LP evidence – low/weak LP signal, could be a product of research bias (until recently the LP was understudied in this area), geoarchaeological bias (dynamic geomorphic mechanisms affecting negatively the preservation of the LP material) and/or interpretation bias (eastern and north-eastern Mediterranean until recently was perceived as a periphery rather than a core area during the LP); or it could just be the evidence of a sporadic and episodic hominin presence in the area during the Early and early Middle Pleistocene. These are some of the key-questions that current LP research attempts to approach and answer using modern technologies and inter-disciplinary methodologies.

The aim of this chapter is to present the LP evidence from the Balkans, and Anatolia with specific reference to the Greek LP record, under the light of recent advances. In that sense, this is not an exhaustive account of sites and finds, presented elsewhere (for Greece see Tourloukis 2010; Galanidou 2014a); for Anatolia and the Balkans see Harvati and Roksandic 2016; Darlas and Mihailović 2008), but rather a synthesis based on recent discoveries that affect current interpretations, and/or provide some new insight in the way we perceive the role of eastern and north-eastern Mediterranean during the LP.

2.2 The Lower Palaeolithic record of the Balkans and Anatolia.

2.2.1 Anatolia

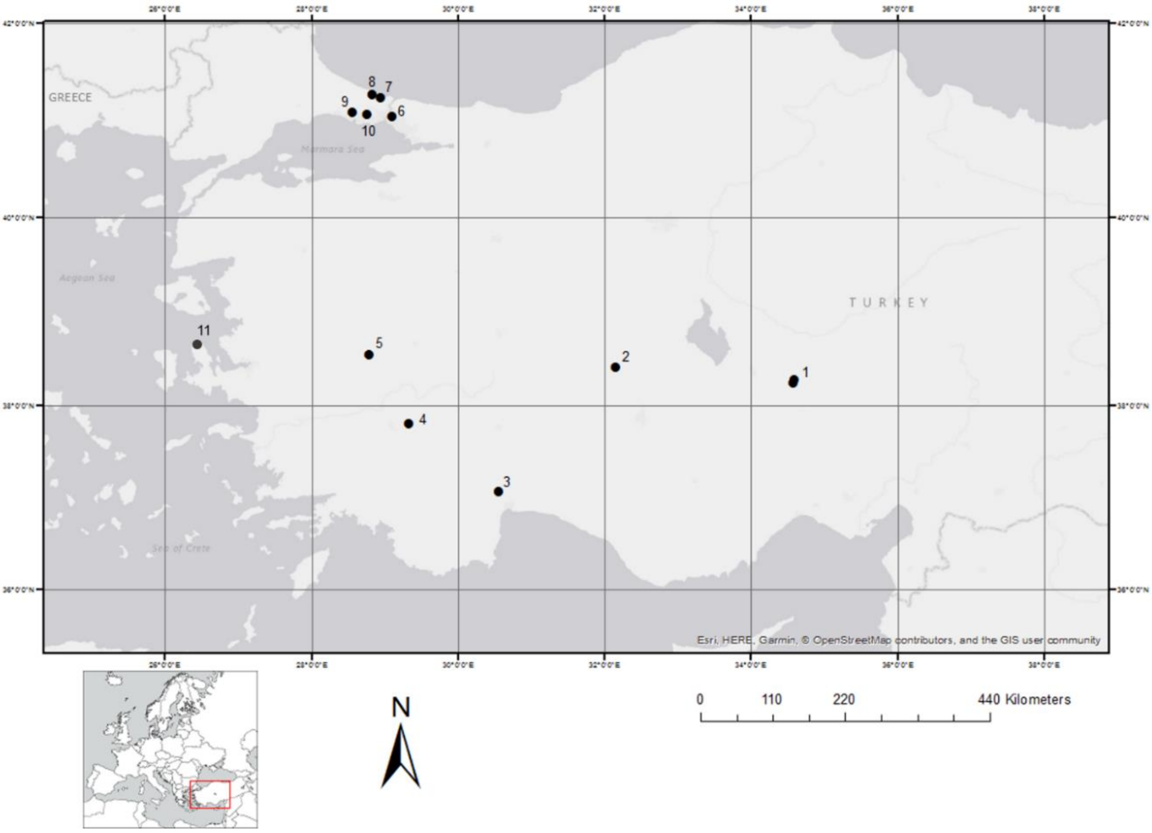


Figure 2.1. Map with archaeological sites in Anatolia mentioned in the text: 1- Göllüdağ and Kaletepe Deresi, 2-Dursunlu, 3-Karain, 4-Kocabaş; 5-Gediz find-spot, 6-Göksu, 7-Gümüşdere, 8-Ağaçli, 9-Eskice Sirti; 10-Yarimburgaz; 11- Kömürburnu. Base map: light grey canvas map, available on ArcGIS online, sources: Esri, DeLorme, HERE, MapmyIndia. Coordinate system: WGS 1984 Web Mercator Auxiliary Sphere; Projection: Mercator Auxiliary Sphere; Datum: WGS 1984; Linear Units: meters. Map produced in ArcGIS 10.6

In geographical terms, Anatolia seems to be the main land bridge directly connecting Asia and Europe. As such, it was expected to bear abundant evidence for the Early and Middle Pleistocene dispersal events. Yet, this is not clearly demonstrated in the archaeological record. Environmental and topographic constrains during the Early and Middle Pleistocene seem to create inhospitable environments for hominins and pose important barriers or delay significantly the movement of population across this area (Kuhn 2010a; Dinçer 2016). Available data show the presence of hominins in Anatolia at various times during the Pleistocene and the use of various stone tool traditions, but the duration of their presence in the area cannot be assessed, due to the extensive spatiotemporal discontinuities. Dinçer (2016:225) argues that the variability observed in the archaeological record, in correlation with paleoenvironmental constraints, possibly reflects various unsuccessful attempts for occupation during the earliest parts of the Pleistocene and until at least the emergence of the Acheulean culture in the area (around 0.8-0.7 Mya).

The LP remains from Anatolia are few and sparsely distributed over this vast area, in such a way that it is very difficult to establish a local chronostratigraphic sequence (Dinçer 2016). This weak LP signal could reflect low population densities and/ or be biased by landscape dynamics - affecting preservation possibilities. It may also relate to research choices, with other areas being more thoroughly studied (e.g. Bosporus-Marmara area, southern Mediterranean coast, Euphrates and Tigris River basins in SE Anatolia) and others being understudied (e.g. central Anatolian Plateau, eastern Anatolia) (Dinçer 2016; Kuhn 2002). Thus, the gaps and concentrations observed in the density of the LP sites and find-spots are not necessarily representative of the original evidence.

There are however, some characteristics observed in the current record: (a) the close association of the LP sites with primary resources of raw material (flint in south-eastern Anatolia and obsidian in central Anatolia) (Dinçer 2016); (b) bifaces (especially handaxes) are very typical and frequent in the Lower Palaeolithic of south-eastern Anatolia (Taşkiran 2018; Dinçer 2016) and (c) the abundance of surface finds attributed to Mode 1 – tradition from the Bosporus - Marmara area (Runnels and Özdoğan 2001; Dinçer 2016). Taşkiran (2018) argues that the distribution and density of Acheulean sites in eastern and south-eastern Anatolia should be considered indicative of the distribution of the Acheulean culture, suggesting several dispersal routes that *Homo erectus* might have followed from Anatolia to the Caucasus. Dinçer (2016: 217) however, emphasises the conspicuous rarity of chopper/chopping tool assemblages from this area, which lies directly in between eastern Africa and Dmanisi – and as such, it would have been expected to bear, as well, evidence from these earlier dispersal events.

According to the Archaeological Settlements of Turkey database (www.tayproject.org), the total number of LP sites in Turkey has increased from 86 to 170 over the last 15 years (Dinçer 2016: 313). Still, only five LP sites have been excavated systematically, including two caves (Yarimburgaz and Karain) and three open air sites (Şehremuz, Kaletepe Deresi 3 and Dursunlu) (fig.2.1). The vast majority of the excavated archaeological material consists of lithics. Faunal remains in association with stone tools have been documented only in Yarimburgaz and Dursunlu (fig.2.1). No hominin skeletal evidence from the LP was known from Anatolia, until the discovery of the Kocabaş skull at Denizli province, attributed to *Homo erectus sensu lato* (fig.2.1).

Secure evidence dated at ca 1 Mya or before, comes from three sites, Kaletepe Deresi 3 (> 1 Mya), Dursunlu (0.99 Mya), Denizli/Kocabaş specimen (1.1-1.3 Mya), and possibly from Gediz River find-bearing terrace (ca.1.24 Ma to ca.1.17 Mya).

2.2.1.1 Bosporus – Marmara

Surface finds from the Bosporus - Marmara area reflect an abundance of choppers and chopping tools e.g. Eskice Sırtı (Runnels and Özdoğan 2001) Yatak, Akçeşme, Kuştepe, and Balıtepe (Dinçer and Slimak 2007) with very few examples of bifaces e.g. the typical late Acheulean from Göksu (Dinçer 2016) (fig.2.1). Those assemblages are usually associated with river terraces, rich in quartz and quartzite pebbles, as good-quality raw material sources are not frequent in this area (ibid 223). This predominance of the Mode 1-tradition has not yet been interpreted convincingly. It could either be the evidence of early hominin dispersal events, as the area lies along the route that connects Anatolia with the southern Balkans and Western Europe, or reflect technical and behavioural adaptations related to the raw material availability (ibid). Given the problematic contexts, one should also consider the possibility that these finds could represent later material.

The Yarimburgaz cave is the only LP excavated site in the Marmara region (Arsebük and Özbaşran 1999) (fig.2.1). It is a large multi-chambered cave, preserving evidence from the Chalcolithic (and later periods) as well as intact Lower Palaeolithic layers (in the lower of the two main chambers). The LP sequence was accumulated in three depositional cycles and contains stone tool artefacts (homogenous industry throughout the different cycles) and paleaofaunal remains (Kuhn 2002; Dinçer 2016). The predominant species in the faunal assemblage is an extinct cave bear (*Ursus deningeri*), suggesting a parallel use of the cave by bears and hominins, with no evidence of interaction between them. Cut marks and other traces of human manipulation and/or carnivore damage are limited but evident on several herbivore remains (in the non-ursus fauna) (Kuhn 2002).

Two main raw materials have been used for the stone tools, flint (predominant), quartz, and quartzite. The assemblage has been attributed to a Mode 1-tradition industry (including core tools and a high frequency of retouched flake tools, dominated by denticulates and sidescrapers, also including abundant flakes, notches and bec/perçoirs) (Kuhn 2002; Dinçer 2016). There is no evidence of bifaces and/or their by-products (Kuhn 2003), and no Levallois production in the Yarimburgaz assemblage. A preference in the raw material according to the tool type has been observed: more than 70 % of the retouched tools and flakes are made of flint, while more than 75% of the core tools are made of quartzite (Dinçer 2016: 223). Similarities have been reported between the Yarimburgaz assemblage and finds from Rodia in Thessaly and Doumbia in Macedonia, Greece (Tourloukis 2010: 41)

The chronology of the LP layers is problematic. Electron spin resonance (ESR) dates on cave-bear teeth range from MIS 6 through Stage 9 (Kuhn 2002) with the most recent Palaeolithic layers deposited during MIS 7d (Dinçer 2016). Analysis of the small mammal fauna demonstrates that the Palaeolithic occupation occurred during a cold phase in the middle of the Middle Pleistocene (Koenigswald et al., 2010). Furthermore, Kuhn et al. (1996) and Kuhn (2010b) and Dinçer (2016: 223) argue in favour of a Middle Palaeolithic chronology for the stone tool assemblage, rather than a LP one, based on the strikingly low number of core tools and the high frequency of retouched flake tools.

2.2.1.2 Aegean region / Asia Minor

Very few surface finds attributed to the LP (three bifaces) were known from the Aegean part of Anatolia, before the beginning of systematic research started only two decades ago (Cilingiroğlu et al., 2016; Dinçer 2016). Geographically it is one of the most promising areas, providing coastal routes from Central Anatolia to the West, but topographically and environmentally it is characterised by high altitude and continental climate. Recent research revealed two of the possibly earliest LP finds in the wider eastern Mediterranean, the Kocabaş skull attributed to *Homo erectus* (Kappleman et al., 2008; Aytek and Harvati 2016) and a single artefact from the Gediz River Lower Pleistocene terrace, with suggested dates over 1 Ma (Maddy et al., 2015) (fig. 2.1). Surface finds from Karaburun peninsula are attributed to the LP on a techno-typological basis (Cilingiroğlu et al., 2016) though no absolute dates are available. They support an early presence of hominins at the westernmost end of Anatolia.

The Kocabaş fossil is a partially preserved hominin skull that was recovered from a travertine block, produced during quarrying activities (Kappleman et al., 2008). The area has been surveyed mainly by geologists interested in the travertine masses in association with the Neogene and Quaternary deposits within the Denizli River basin (Aytek and Harvati 2016). No stone tool artefacts or faunal remains were found in association with the fossil, but Pleistocene fauna has been preserved in the deposits of the Upper Travertine level, from where the block containing the skull possibly originates (Lebatard et al., 2014). The age of the specimen is problematic. The initial ESR dating on the travertine produced a 1.11 ± 0.11 Mya age, thermoluminescence dating gave a much later age at 510–490 Kya, and paleomagnetism suggested an older age of more than 780 Kya for the fossil-bearing sediments (Aytek and Harvati 2016). A recent revision, based on a multidisciplinary study (palaeomagnetic measurements and cosmogenic nuclide concentration), agrees with the initial suggestion of an early age, between 1.3-1.1 Mya (Lebatard et al., 2014).

Taxonomically the specimen was provisionally attributed to *Homo erectus sensu lato*, with suggested similarities to the African and Javan, rather than the Chinese *H. erectus* (Kapplemen et al., 2008). Vialet et al. (2014) based on a comparative analysis (using metric, geomorphic morphometrics and non-metric analysis), argue that the Kocabaş skull demonstrates a mixture of features, with specific traits bringing it closer to the ancient African *H. erectus* and *H. ergaster* (especially the OH9 and Daka specimens), despite the general similarities with the Asian *H. erectus* (e.g. the Zhoukoudian). The suggestion for an early taxonomical positioning (older than 1 Mya) of the Kocabaş fossil within the *H. erectus* evolution is supported by the early geological age of the travertine find-bearing layer. More recently, Aytek and Harvati (2016) repeated the comparative evaluation using geometric morphometrics, due to issues reported with the landmark configuration and taxonomic groupings in the Vialet et al. (2014) study. In the latest examination, the morphology of the supraorbital torus is being taken into account, using a small comparative modern human and fossil sample. Aytek and Harvati (2016) also evaluated the degree of similarity between the Kocabaş specimen and African *H. erectus*, confirming associations with the Asian but not with the African *H. erectus*. Furthermore, they observe affinities with the *Homo heidelbergensis* species (e.g. Ceprano and Arago specimens) (ibid: 87), supporting a younger age for the Kocabaş specimen within the Middle Pleistocene.

A single stone tool artefact was retrieved from Early Pleistocene fluvial sediments, associated with the Gediz palaeoriver (Maddy et al., 2015) (fig.2.1). The authors claim a clear stratigraphic context for the find. An age between ca. 1.24 Mya to ca. 1.17 Mya has been assigned to the find, provided by Ar/Ar and paleomagnetic measurements on the basaltic lava flows that have capped the fluvial deposits throughout the Early Pleistocene sequence. It is a hard hammer flake with a flake removal on its dorsal side, made on quartz. Some broad comparisons are attempted with the Dursunlu assemblage in terms of typological and raw material similarities. However, since this is a single find, our understanding on any technological, behavioural and /or occupation patterns is very limited. The authors emphasise the favourable character of the area dominated by the volcanic landscape and the water resources, and further suggest that the 'occupation level' could potentially be associated with the favourable environmental conditions of MIS 35 interglacial (ibid 74).

Finally, it is worth making a special mention on the biface recently collected from Kömürburnu locality at the northern part of the Karaburun peninsula (Cilingiroğlu et al., 2016) in an area covered by a volcanic outcrop (fig.2.1). The artefact is made on andesite (locally available) by hard hammer percussion and has long S-shaped profiles. The tip and one edge are sharper while the other edge is irregularly shaped. Cores and flakes were also found in association with the handaxe. Two more handaxes had been collected, during the 1960's, from the wider area in Izmir Province, one attributed to the Lower Palaeolithic and the other one to the Middle Palaeolithic. However, the authors consider the Kömürburnu biface is an isolated find, distinctively different from the older discoveries, and believe that it could be seen rather evidence supporting further the presence of hominins in W. Anatolia during the LP, alongside the Acheulean site of Rodafnidia in southern Lesbos (Galanidou et al., 2013; 2016). Hominins would have been able not only to reach the westernmost end of the Anatolian mainland, but to expand to the adjacent Aegean islands through land bridges available during periods of lower sea-levels (glacial maxima), as suggested by available evidence.

2.2.1.3 Central Anatolia

Kaletepe Deresi 3 is an open-air site located in central Anatolia (Cappadocia), in an area dominated by the Göllüdağ obsidian source and the same-named volcano (fig.2.1). The area has been systematically surveyed since 2007 due to the abundance of volcanic raw material. The vast majority of the finds collected and recorded belong to the Middle Palaeolithic, but there are also some important LP artefacts represented by handaxes and other large bifacial tools (Kuhn et al., 2015).

Kaletepe Deresi 3 is the only excavated Acheulean site in Turkey (Slimak et al., 2008). Multiple Lower and Middle Palaeolithic levels have been excavated, producing a total of 6354 artifacts (977 of these coming from the Middle Palaeolithic levels I-II) (Kuhn 2010a; Dinçer 2016: 217-8). The lower levels (IV-VII) yielded an Acheulean assemblage with diagnostic types, such as bifacial and unifacial handaxes and a range of flake cleavers, all made on volcanic materials i.e. obsidian, rhyolite and andesite, locally available in abundance. The Acheulean assemblage from Kaletepe Deresi 3 is consistent with the 'large flake Acheulean' complex - the characteristic production of handaxes and cleavers on large flakes detached from very large prepared cores. It has been suggested that this specific technological trend could be associated with a distinct episode of hominins dispersal from Africa to Eurasia around 750-800 Kya (Kuhn 2010a:435). Kalatepe Deresi 3 represents one of the very few instances - possibly along with Rodafnidia on Lesbos Island in Greece (Galanidou et al., 2013; 2016), where this pattern is observed in temperate Europe and central Asia, otherwise frequently recorded in sites at the northern Rift Valley and southern Asia (Khun 2010a).

The ages of the Acheulean finds are still uncertain. The dating of the rhyolitic bedrock, below the lower levels, by K/Ar provided a 1.1 ± 0.02 Mya age, and recent tephrochronological analysis suggested that the lower levels might be of a Middle or perhaps an Early Pleistocene age (Dinçer 2016).

Dursunlu open-air LP site in south-central Anatolia, is located in a now-deserted and partially flooded lignite quarry (Güleç et al., 2009) (fig.2.1). Abundant faunal remains and stone tools have been discovered within the lignite layers – originally during quarrying activities. The chronology of the find-bearing layers to the Early Pleistocene, between 1.1 Mya and 0.9 Mya, is well established by paleomagnetic dating and paleontological evidence (ibid). Quartz is the basic raw material for the stone tool production (95% of the assemblage). The stone tool assemblage (135 artefacts) has been attributed to a Mode 1 industry (consisting mainly of quartz flakes along with few flint cores and flakes, and a large polyhedron of unidentified volcanic stone), similar to early finds from European sites dated before 780 Kya (e.g. Orce and Atapuerca sites in Spain, Le Vallonet and Lezignan la Cebe in France, Pirro Nord and Notarchirico in Italy, and possibly Marathousa 1 in Greece). However, Kuhn (2010a: 434) notes that *"because the assemblage is small, one cannot exclude the possibility that the absence of bifaces and other indicators of bifacial technology is an artifact of sampling error"*. The fauna is taxonomically diverse, including a wide range of mammalian and avian taxa, indicating open steppic environments beyond the margins of a lake or marsh (Güleç et al., 2009: 14-15). Palaeoenvironmental evidence, in accordance with the faunal evidence, suggest the presence of a large lake in the area. The association between hominins and fauna is not yet clear. Cut marks have been recorded on few animal bones (e.g. on a distal metatarsus of a large bird) but the sample is too small and according to Güleç et al. (2009: 15) it is yet uncertain in what degree hominins had been involved in foraging.

Dinçer (2016: 218-19) emphasises the fact that both sites, Dursunlu and Kaletepe Deresi 3, as well as the find-spots in the Göllüdağ area, are located in high altitude areas (higher that 1000m asl) in central Anatolia, posing some *"serious adaptive challenges"* for the hominins reaching these areas during the Early Pleistocene. In this respect, Kaletepe Desresi 3 is of paramount importance as it preserves evidence for an undisturbed presence of hominins during the Early and Middle Palaeolithic for at least 500 ka, despite the suggested inhospitable conditions due to the high altitude and the continental climate.

2.2.1.4 Southern Anatolia

Similarities have been observed between the LP material from eastern and south-eastern Anatolia. Dinçer (2016: 220) assigns those similarities to the similar high-quality raw material, available in both areas in great abundance. The Karain cave, close to Antalya, is the most extensively studied Palaeolitihc site in Anatolia (fig.2.1). It preserves a long archaeological sequence covering a wide time range from the Palaeolithic to the Roman times, representing the key chronostratigraphic sequence for the Turkish archaeology (Yalçinkaya et al., 1993). The cave is divided into five chambers (A-E). The Lower and Middle Palaeolithic artefacts have been excavated from layers contained in chamber E. The Lower Palaeolithic layers are older than 370–400 ka (Otte et al. 1998a), based on the age of the upper layers of the geological unit (V) bearing them. The LP material consists of a core and flake assemblage (pronounced bulbs of percussion on the flakes and polyhedral cores) with notches and denticulates as main tool types, which have been interpreted as Clactonian by Otte et al. (1998a, b; 1999). However, two bifaces were reported from earlier excavations (Taşkıran 1998) and one more was found recently, possibly predating the 400 Kya assemblage, based on their stratigraphic position (Yalçınkaya et al. 2008; Dinçer 2016). Radiolarite, flint and calcareous stones are used as the main raw materials.

2.2.2 Balkans

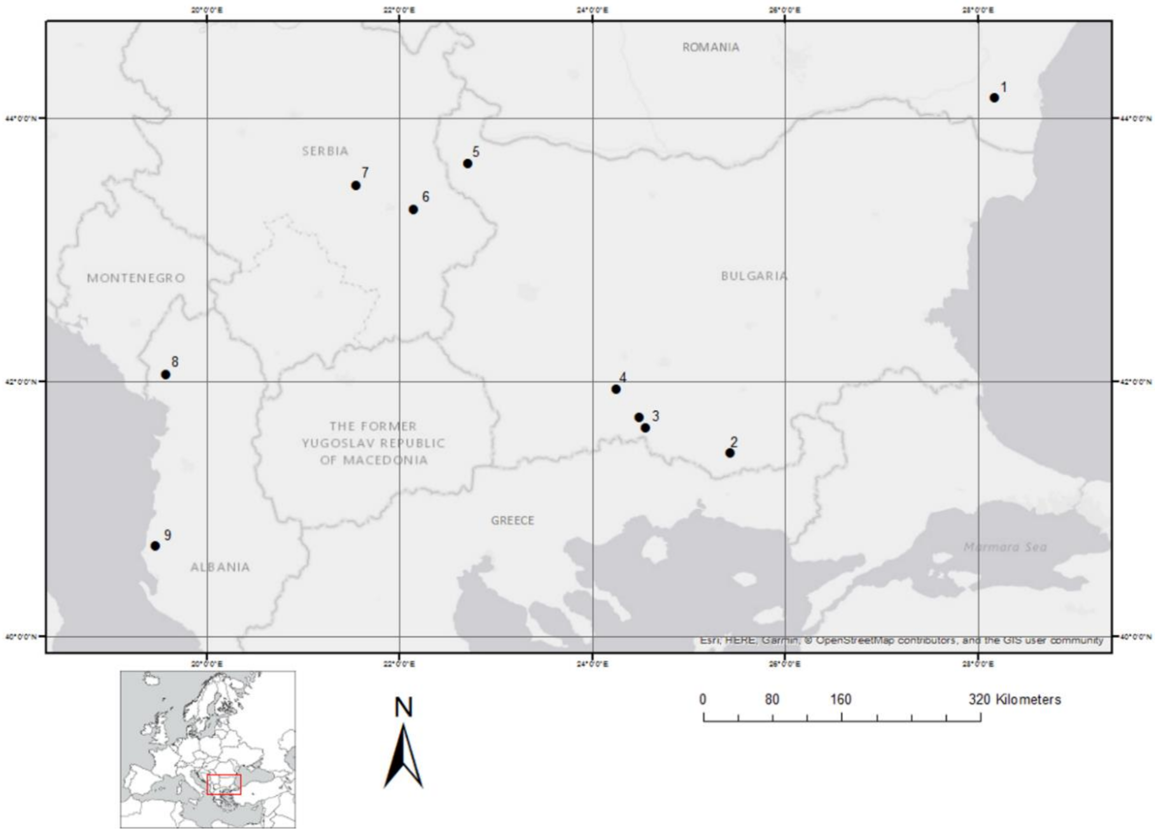


Figure 2.2. Map with archaeological sites from the Balkans discussed in the text: 1- Dealul Guran, 2-Benkovski 3-Shiroka Poljana, 4-Kremenete, 5-Kozarnika, 6-Mala Balanika, 7-Kremenac, 8-Gajtan, 9- Fier province. Geospatial data as in fig. 2.1

The scarcity of the LP evidence from the Balkans is to a great extent a product of the limited research conducted in the area. Projects targeting the Palaeolithic have been launched only during the last few decades, with exciting results. The majority of available evidence has been poorly documented or come from contexts with unclear chronostratigraphy (mostly river terraces). Furthermore, the terminology used in the limited Palaeolithic literature from the Balkans, only recently was synchronised with the commonly accepted LP terminology and became compatible with the European scientific corpus.

Securely attributed evidence to the LP (in terms of stratigraphic contexts and dating) comes from Bulgaria (Kozarnika), Romania (Dealul Guran) and Serbia (Mala Balanika specimen/BH-1). However, possible LP finds have been reported from several areas in Albania, Bulgaria, Romania, Serbia and Croatia, usually collected from the surface and attributed to the LP on the basis of typo-technological characteristics.

2.2.2.1 Bulgaria

Kozarnika cave in Bulgaria provides the earliest secure evidence for the Balkans, before 1 Mya (fig.2.2). The LP artefacts discovered in the lower levels of the cave sequence (units 13-11), have been dated between 1.4 Mya and 0.4 Mya, based on the associated fauna (MNQ 17-MNQ19) and the geological context (Guadelli et al., 2005; Ivanova 2016), with suggestions for an even earlier date at 1.6 Mya (Sirakov et al., 2010). However, the chronology of Kozarnika is subject to discussion (Ivanova 2016).

A long sequence has been preserved with multiple successive archaeological layers, and several facies within each layer, covering the Lower, Middle, and Upper Palaeolithic, as well as the Holocene, providing evidence for a long-term hominin occupation in the area. According to Guadelli and Guadelli (2004) the earliest layers 13-11c have a chronological range between 1.4-0.9 Mya, the layer 11b is dated to 0.8-0.6 Mya and the layer 11a is dated to 0.6-0.4 Mya, based on the faunal composition (microfauna and macrofauna). Preliminary paleomagnetic results demonstrate an unstable signal in the 11c layer that could be translated as a reversal of polarity around 0.78 Mya (Guadelli et al., 2005). The earlier stone tool assemblage (unit 13) belongs to a core and flake industry (Mode 1-tradition) (ibid). Ivanova (2016:199) argues that this assemblage is no older than 1 Mya, based on her observations over the knapping methods and the typology from layers 11-12, demonstrating little change for the period 900-400 Kya. Bifacial tools and artefacts with bifacial retouch – including some ‘atypical’ forms – have been also observed within the LP assemblage (units 11 a,b,c), representing a diagnostic group despite their small numbers (14 specimens) (ibid). This latter group demonstrates distinct differences from biface assemblages found in Europe, Middle East and the Rhodope mountains, according to Ivanova (2016). They are small in size, oval or slightly elongated, shaped by coarse, surface retouch possibly at initial stages of production. The core and flake assemblage may represent an earlier phase within the LP, before the emergence of the ‘atypical’ bifaces group.

Extensive survey has been recently conducted in the Western and Eastern Rhodope Mountains in Bulgaria (Ivanova 2016). Several find-spots in Western Rhodope (Kremenete, Shiroka Polyana) and Eastern Rhodope (Benkovski, Marasi Dere) (fig. 2.2) yielded stone tools that may date to the Middle Pleistocene or even earlier (eastern localities), on the basis of technomorphological characteristics and their geological contexts. The collection from Western Rhodope includes bifaces, choppers, and tools with bifacial retouch. No similarities can be observed between the bifacial forms from Western Rhodope and those found within the LP layers from Kozarnika cave, as mentioned before, but similarities have been reported between the tools from Kremenete and the Middle Pleistocene assemblage from Tsona cave (Caucasus, Georgia) (Ivanova 2016:201-205) The Eastern Rhodope assemblage includes both core tools and bifaces, and unfinished bifaces, as well as some very unique, elongated artefacts (with large tips and with a base part formed by coarse surface retouch).

2.2.2.2 Romania

The first securely dated and systematically excavated LP site in Romania is the Dealul Guran rock shelter (Iovita et al., 2012; Dobos and Iovita 2016) (fig.2.2). Three archaeological layers have been identified, with luminescence dates indicating an MIS 11 chronology for the earlier layers, associated with a Mode 1 stone tool assemblage. Further study on the lithics demonstrated that flint quarrying activities had taken place on site, using the locally available rich raw material resources (flint nodules) (Dobos and Iovita 2016: 171). The researchers argue that the Dealul Guran evidence could be compared to raw material economic strategies as observed in LP sites from Africa (e.g. MNK chert factory site at Olduvai), Israel (the workshop sites of Mountain Pua), and Anatolia (e.g. Kaletepe Deresi 3).

Other evidence attributed to the LP from Romania is poorly documented. This account would include numerous find-spots (about 60 locations) with lithic artefacts from river gravels (Dobos and Iovita 2016: 83-4) and stone tools found in association with Middle Pleistocene faunal remains (e.g. from Sândominic, Gura Dobrogei and Amărăşti) but their anthropogenic character is doubted and the sample is very small (ibid 181). Dobos and Iovita (2016: 181) suggest that it would be more realistic to expect hominins settling in the region after 1 Mya i.e. after the beginning of the loess deposition and the prevalence of open steppic environments, facilitating population movement through this part of the Balkans.

2.2.2.3 Serbia

The hominin mandible from Mala Balanica cave (BH-1) is the first stratified hominin fossil from the Central Balkans securely dated to the Middle Pleistocene, and one of the very few from the wider eastern and north-eastern Mediterranean (Roksandic et al., 2011; Rocksandic 2016) (fig.2.2). The re-examination of the specimen, using combined application of ESR/U-series and infrared/post-infrared luminescence dating, provided a minimum age between 397 and 525 Kya (Rink et al. 2013). Roksandic (2016: 29) emphasises that BH-1 is one of the key-specimens to shape current understanding on the variability observed in the European Middle Pleistocene hominin record. The lack of Neanderthal elements on the morphology of the mandible and the teeth in correlation with the early date of the fossil, is consistent with mosaic traits observed in early members within the Neanderthal evolution, or even indicative of the ancestral character of the specimen, possibly representing one of the paleodemes ancestral to both Neanderthal and non-Neanderthal lineages.

Material attributed to the LP has been collected from Kremenac site near Niš (Šarić 2011) (fig.2.2). The collection consists of twelve specimens, made on pebbles locally available. Unifacial and bifacial choppers, protobifaces, side-scrapers, side-scrapers/end-scrapers and end-scrapers are some of the diagnostic types, recorded by Šarić (2011: 13-14). The author argues in favour of a possible exceptionally early date for the site. He also observes similarities between the Kremenac material and assemblages attributed to the LP from Romania and Bosporus. However, the sample is small, and the context and the provenance of the stone tools do not have secure stratigraphic markers. Surface material has been also reported from several find-spots in the Western Morava valley possibly dated to the LP, but no secure dates are available (Mihailović 2014).

2.2.2.4 Albania

Material attributed to the LP has been reported from the Fier Province, the Baran area and the Gajtan cave in Albania (Runnels et al., 2009; Fistani 1993) (fig.2.2). The Fier province find-spots have been associated with an eroding paleosol dated to ca 100 Kya, providing a *terminus ante quem* for the deposition of the find-bearing layers, according to Runnels et al. (2009). The assemblage is small (thirteen artefacts, including three bifaces) and the attribution to the LP is supported by typo-morphological criteria, as well as the geological context. Choppers and chopping tools have been also reported from the Baran area, associated with river terraces (Fistani 1993). Their attribution to the LP lies mainly on morphological characteristics, lacking secure stratigraphic context. A co-occurrence of a core and chopping tool~~s~~ industry with bifacial tools (characterised as ‘proto-handaxes’ / ‘atypical’) has been documented in the cave of Gajtan (Fistani 1993). The assemblage has been associated with a Middle Pleistocene fauna (Holsteinian stage), but further work is needed to demonstrate the chronological and stratigraphic associations between the stone tools and the faunal remains.

2.2.2.5 Croatia

Few possible LP finds have been reported from Croatia, all coming from uncertain stratigraphic contexts, either being surface collections (e.g. Punikve, Donje Pazarište, and Golubovec) (Karavanić and Janković 2006) or their association with Pleistocene faunal remains needs further examination (e.g. Sandalja I) (Malez 1980). For the time being their attribution to the LP relies on typological and technological criteria.

2.3 The Greek Lower Palaeolithic record

2.3.1 Background and current status of research

Greek LP research is relatively young and Greece was officially added to the European LP map only in the 1960's with two chance finds, discovered by local villagers, the handaxe from Palaiokastro (Epirus, NW Greece; Higgs 1964; Dakaris, Higgs and Hey 1964; Tourloukis 2010) and the *Homo heidelbergensis* cranium from the cave of Petralona (Macedonia, N. Greece; Harvati 2009). Three decades later, in 1994, the *International Conference for the Palaeolithic Research in Greece and Adjacent Areas* (Bailey et al., 1999) brought to the attention of the international archaeological community current LP evidence, highlighting the research potential of the wider area.

The LP research objective, in its essence, remains unchanged even today: searching for evidence linking the Aegean region with the early occupation of Europe. The LP research agenda however, has been reshaped, under the influence of two main factors: (a) the consideration of the geoarchaeological agent for identifying 'windows of opportunity' for the LP research beyond the preservation bias posed by landscape dynamics (Tourloukis 2010; Tourloukis and Karkanas 2012b; Tourloukis 2016) and (b) the exploration of a new area, the now submerged Aegean palaeolandscapes and their affordances as promising targets for the LP research, shifting significantly the research dynamics from the mainland to the sea and the islands (Sakellariou and Galanidou 2016; 2017; Papoulia 2017; Runnels 2014). Sakellariou and Galanidou (2016: 171) in their recent, synthetic overview on the Pleistocene Aegean submerged landscapes, summarise eloquently the developing research agenda and future research objectives: "*Systematic survey and reconstruction of the submerged landscape of the Aegean is expected to reveal new information on the drowned prehistoric archaeology of the region and will presumably bring to light many unknown sites beneath the sea*".

The LP research in Greece has been intensified and advanced methodologically, the last few decades, following the international paradigm. The LP record has been enriched with important new finds and /or new interpretations of older ones (for an overview see Galanidou 2014a). Several surveys and interdisciplinary projects targeting the LP have been conducted, older material attributed to the LP has been re-examined with new methodologies, and two Middle Pleistocene sites (Rodafnidia and Marathousa 1) have been systematically excavated since 2012. In 2015, The *Prehistoric Stones of Greece* open-access dataset was launched (Elephanti, Marshal and Gamble 2010), providing a comprehensive record of available stone tool evidence and a good frame of reference for comparative lithic studies.

Despite the advances and progress outlined above, the Greek LP evidence is scarce with extensive spatiotemporal discontinuities. According to current data, only six sites can be securely attributed to the LP (Rodafnidia, Marathousa 1, Petralona, Apidima, Kokkinopilos and Stelida), covering a chronological range from 0.5 to 0.2 Mya (Galanidou et al., 2013; 2016; Panagopoulou 2015; Harvati 2009; 2016; Harvati et al., 2019; Runnels and van Andel 1993a; Tourloukis and Karkanas 2012b; Carter et al., 2019) (fig.2.3). For the early Middle Pleistocene or the Early Pleistocene there is a gap in the record. The majority of available evidence includes stone tool material (Mode 1 and Mode 2), with only two out of the five localities preserving palaeoanthropological remains (Petralona and Apidima caves).

Figure 2.3. Map with the Lower Palaeolithic sites and find-spots from Greece. Geospatial data as in fig. 2.1

A recent re-examination of Apidima skulls by Harvati et al. (2019), using virtual reconstructions, comparative analyses, and U-series radiometric methods, revealed exciting new finds. The study confirmed the attribution of Apidima 2 to an early representative of a Neanderthal population during the late Middle – early Upper Pleistocene (in accordance with Harvati, Stringer, Karkanas 2011; Harvati 2016), suggesting a new earlier date at 170 Kya. Apidima 1 is older, dated to 210 Kya, while a mixture of primitive and *H. sapiens* features has been identified. The current hypothesis is that Apidima 1 represents an early *H. sapiens* population, the earliest so far known in Europe, as part of an early out of Africa dispersal event. Thus, two different hominin species were present in Apidima during the late Middle Pleistocene: an earlier *H. sapiens* group that possibly was replaced by a later Neanderthal group. However, the partial preservation of Apidima 1 raises some questions, and its attribution to an early *H. sapiens* needs to be further established (Delson 2019). The Petralona skull has been attributed to *H. heidelbergensis*, possibly with African affinities (Harvati 2016), and dated between 150-350 Kya (Grün 1996) representing so far the earliest confirmed presence of hominins in Greek territory. However, another recent re-examination of a single upper molar from Megalopolis basin suggested that the earliest hominin evidence from Greece might be much earlier, if the preliminary attribution of the specimen to the early Middle or even the Early Pleistocene by Harvati (2016) could be further confirmed. Unfortunately, the stratigraphic association between the palaeoanthropological finds from Petralona and Apidima and the faunal remains and stone tool assemblages found in the same sites is yet unclear and needs further investigation.

Lithic finds from Rodia localities in Thessaly and Plakias sites in Crete have been also attributed to the later Middle Pleistocene (ca. 200 Kya) based on absolute dates and stratigraphic associations (Runnels and Van Andel 1993b; Runnels and Van Andel 1999; Strasser et al., 2010; 2011), with the recent addition of Stelida on Naxos Island (Carter et al., 2019) (fig.2.3). However, the exact position of the core and flake industry finds from Rodia, within the fluvial sequences in Larisa basin, remains unclear despite the recent re-examination by Tourloukis and Karkanas (2012b). The *in situ* location of the Acheulean *sensu lato* material within the raised marine terraces from the Plakias area has been questioned as well (Galanidou pers. com. 2018). Galanidou (2014b) suggested that the early component of the Plakias assemblage does not necessarily indicate a Lower Palaeolithic presence, but it could rather be associated with an early *Homo sapiens* presence on the island – in accordance with the available absolute dates, falling within the Middle-Upper Pleistocene transition. The same debate on the *in situ* nature of the finds also surrounded the Kokkinopilos evidence until recently. However, the re-examination of the geological context (Tourloukis, Karkanas and Wallinga 2015), confirmed the existence of undisturbed sediments from where a stratified biface was recovered by Tourloukis and Karkanas

(2012b: 4), who convincingly argue in favour of the geologically *in situ* position of the find (in accordance with Runnels and van Andel 1993a and contra Bailey, Papakonstantinou and Strudy 1992). Luminescence dating (pIRIR) from the find-bearing layers gave minimum ages between 156-206 Kya (Tourloukis et al., 2015).

Stelida site on Naxos Island should be added to this account. Carter et al. (2019) present solid chronostratigraphic evidence for the presence of hominins in the South-Central Aegean basin as early as 200 Kya. Almost 9000 excavated artefacts have been placed in a chronostratigraphic sequence (of eight strata), using infrared stimulated luminescence (IRSL) dating to provide *termimus ante quem* dates for the deposition of each layer (ibid). The lower find-bearing stratum (LU7) was deposited during the MIS7 interglacial (RSL age of 219.9 to 189.3 Kya), assigning the oldest securely dated evidence from Stelida to the transition from the Lower to the Middle Palaeolithic. Despite the unclear/transitional nature of this oldest assemblage, the LP component is supported by the available absolute dates and by artefacts from the surface collection, clearly representing LP technologies (Skarpelis et al., 2017) (see discussion in Ch.7).

With the exception of the securely stratified evidence from Rodafnidia, Marathousa 1 (see below), Kokkinopilos and Stelida, and the potential *in situ* finds from Rodia and Plakias, the LP record mainly includes surface finds and/or artefacts retrieved from secondary depositional contexts, frequently associated with river or marine terraces. Their attribution to the LP is based on typological and technological characteristics, with no reliable geological/chronostratigraphic controls. This is the case of Doumbia, Siatista, Palaiokastro and the Aliakmon localities in Macedonia, the Acheron valley and Agios Thomas Peninsula sites in Epirus, Triadon Bay on Milos Island, Korrisia on Corfu and Nea Skala on Kefallinia, to mention a few (Andreou and Kotsakis 1994; Runnels and van Andel 2003; Chelidonio 2001; Kourtessi-Philippakis 1999) (fig.2.3). Petrota in Thrace, Piros valley locations in NW Peloponnese, Arethousa in Mygdonia basin, could be also included in this part of the record, yielding a possible LP component in their material, which is otherwise Middle Palaeolithic (Ammerman et al., 1999; Darlas 1999; Litsios 2012: 95) (fig.2.3).

Using techno-morphological criteria on surface or disturbed material to make chronological attributions is problematic, as pinpointed by many scholars (Darlas 1999: 306; Dobos and Iovita 2016: 184). The danger of making wrong interpretation and false chronological assessments lies in the fact that certain tool types such as choppers and chopping tools are common over time and they are often found within specific environmental settings such as river terraces, throughout the Pleistocene and the Holocene. Nevertheless, surface material can be very useful as *"a first-order indication"* for the presence or absence of hominins, especially in areas – such as the Aegean – affected by landscape dynamics, as argued by Tourloukis (2010:44).

2.3.2 Absence of evidence or evidence of absence?

Many reasons have been proposed for the scanty and discontinuous character of the Greek LP record. If we go back to the literature of the 1980-1990's the main reasoning encompassed limited field research focused on the Palaeolithic, lack of scientific expertise on this specific field or perhaps the "*relative brevity*" of the Greek Palaeolithic, a period of 0.5 million years versus 2 million years in Africa and Asia (Runnels 1995; Galanidou 2014a). Tourloukis (2010) in his doctoral thesis highlighted the crucial role of the geoarchaeological agent (for an overview see Tourloukis and Karkanas 2012a), suggesting that the Early and Middle Pleistocene archaeological record of Greece is doomed to be incomplete due to the incompleteness of the geological archive. The dynamic landscape of the Greek mainland and the wider Aegean region suffered massive transformations throughout the Quaternary, due to active geomorphic processes (see Ch.4) that apparently affected negatively the preservation, availability/accessibility and visibility of the Lower and Middle Pleistocene archaeological and palaeoanthropological material (Tourloukis 2010; Tourloukis and Karkanas 2012b).

In most cases, as demonstrated in examples from continental Greece (Tourloukis 2010), such material can be found within tectonically controlled basin structures, in topographic depressions that function as sedimentary traps (major drainage systems, lakes, shallow gulfs), either being buried in their deep infill (preserved but not accessible) or cropping out due to later uplift (visible and/or accessible but preservation depends on the time during which the material is being subjected to erosion) (Tourloukis and Karkanas 2012b: 8). This situation has been correlated with the change in the directions of the extensional tectonics during the Early - Middle Pleistocene (see Ch.4), which caused the uplift of basin sediments - bearing Plio-Pleistocene material, and later exposed them into erosional processes for a long period of time (at least over two successive glacial-interglacial cycles), making preservation potential very unlikely in the Greek mainland (ibid). In rare instances, the LP material has been preserved (and is accessible) within secondary (reworked) depositional contexts. Only in cases, when the basin inversion happened during the Later Pleistocene, the chances of the Early-Middle Pleistocene material being better preserved in its primary context and not being lost or transported due to erosion, are higher. Thus, a direct association between the geological and the archaeological record in stratigraphic terms, in most of the cases, is very difficult to make. Apparently, the timing of uplift/basin inversion, and the duration and intensity of erosion accompanying the uplift, are the main parameters affecting the discovery potential of the LP material in the wider Aegean region.

Based on these observations and following a geoarchaeological approach, Tourloukis (2010) developed a tripartite scheme for planning and practicing more effectively future fieldwork in the

Greek territory: (a) target fluvio-lacustrine basins that have been inverted during the Late Pleistocene – higher preservation potential; (b) emphasis should be given in the exposed profiles rather than the ground surface; and (c) further examination of localities yielding early Pleistocene faunal evidence is necessary, possibly representing windows of opportunity for preserved and accessible LP archaeological material as well. This scheme has been evolved into the 'basin model' presented recently (Tourloukis 2016), with applications in tectonically active areas across the Mediterranean, aiming to identify areas with high preservation potential of the LP material and adequate accessibility.

Tourloukis (2010) pinpointed initially the high discovery potential in three areas, Megalopolis basin in Peloponnese, Mygdonia basin in Macedonia and the Katharo plateau in Crete, all meeting the geoarchaeological criteria of the basin model. The first positive result came from Megalopolis basin, an area with increased research possibility, supported also by palaeontological and archaeological evidence (Melentis 1961; Sickenberg 1975; Darlas 2003). The PaGE Project (Palaeoanthropology at the Gates of Europe) started in 2012 - and it is still in progress (Panagopoulou et al., 2015). In 2013 the Marathousa 1 site (MAR-1) was discovered and during the following excavation seasons (2014-2015) a stratified sequence of stone tools (Mode 1) in association with elephant (*Elephas Palaeoloxodon antiquus*) and other faunal remains (carnivores, bovids, cervids, micromammals, turtles and birds) was revealed (Tourloukis and Harvati 2018; Konidaris et al., 2018) (fig.2.4). The MAR-1 is an open-air site currently located in a lignite mine, in an area that was covered by a large lake and river tributaries during the Plio-Pleistocene.

Further study on the elephant bones (cranium and postcranial elements found in close anatomical association possibly representing an individual) and on other mammal remains, revealed human modifications (e.g. cut marks, percussion damage) made by stone tools, indicating carcasses exploitation and butchering activities (Konidaris et al., 2018). A few examples of animal bones modified by stone tools to be further used as bone tools have been recently reported form this site, suggesting that hominin exploitation of animal carcasses was not restricted to meat acquisition and marrow extraction (Tourloukis et al., 2018). The preliminary examination of the stone tools from MAR-1 (ibid), demonstrates the absence of large cutting tools or other Acheulean elements (bifacial debitage), and highlights the 'microlithic' character of the core and flake assemblage (small-sized debitage, retouched tools, a few small and exhausted cores, as well as a large number of debris and retouch products). Large cores and primary flakes are missing, contrary to what it would have been expected for a butchery site – a feature that needs further investigation.

The chronology for the MAR-1 site is well established by ESR dates (0.473 ± 54 Mya and 0.502 ± 13 Mya), Infrared Stimulated Luminescence (post-IR IRSL) (ca. 0.5-0.4 Mya) magnetostratigraphy (0.48-0.42 Mya) all providing dates around 400-500 Kya (Konidaris et al., 2018). This is in good agreement with the depositional history, suggesting that the find-bearing layers within the Marathousa Member in Chroremi formation were deposited during MIS 14 or perhaps during MIS 16 (Tourloukis and Harvati 2018), and with the bioarchronological markers indicated by the Galerian fauna (900-400 Kya) (Kahlke et al., 2011). The MAR-1 site provides secure evidence (i.e. elephant butchering by Middle Pleistocene hominins using a Mode 1 tradition toolkit on a lake environment), to make for the first time direct associations between the Greek LP record and similar exploitation patterns observed at the same period, elsewhere in Europe and eastern Mediterranean, with examples from Israel (Gesher Benot Ya'akov), Spain (Aridos 2), Italy (Nottarchirico), UK (Ebbsfleet), to mention a few (Goren-Imbar et al., 1994; Yravedra et al., 2010; Piperno and Tagliacozzo 2001; Wenban-Smith et al., 2006).

Figure 2.4. Excavation trench in Marathousa 1. Elephant bones in association with Mode 1 stone tools (from Panagopoulou et al., 2015: fig. 4)

2.3.3 The Greek Lower Palaeolithic settings and the spatial pattern observed across the Mediterranean

Indeed, as highlighted by Tourloukis (2016: 310) all the known Greek LP sites, with secure or relatively secure stratigraphic contexts, have been found in tectonically controlled areas with good preservation possibilities – according to the logic outlined above. LP localities are usually associated with fluvial deposits (Rodia, Rodafnidia), lacustrine deposits (MAR-1), ephemeral lakes/polje environments) (Kokkinopilos), coastal settings/marine terraces (Plakias localities), and of course karstic/cave environments (Petralona and Apidima caves).

Surface finds, attributed to the LP have been also found within similar depositional settings i.e. fluvial/alluvial deposits in Macedonia and Peloponnese (e.g. Aliakmon localities, Palaeokastro, Doumbia, Piros Localities), redeposited terra rossa in ephemenral lakes (polje) and coastal plains in Epirus (e.g. Alonaki, Ormos Odysseos, Ayios Thomas), marine terraces in the Aegean and Ionian islands (e.g. Triadon Bay in Milos, Nea Skala in Kefallinia). The proximity of the Greek LP find-spots to water resources has been recorded as a pattern since the 1990's and was interpreted mainly as a preferential association between hominins and specific types of environments, with Runnels (1995:710-711) suggesting that hominin movement and occupation patterns possibly followed the seasonal availability of fresh water in mainland Greece. He further suggested that *"Larger base camps or aggregation sites may exist on the now submerged coastal plains, and early humans probably moved to the interior only in the spring and summer when melting snow filled the lakes and rivers with water"* (ibid).

Evidence across the Mediterranean (see Tourloukis 2016 for specific examples), indicates a wider spatial pattern in the LP locations, found usually (a) in open-air sites, (b) at low elevation areas (below 500m asl) and (c) in association with specific geomorphological contexts i.e. basinal structures of tectonic origin and specific depositional contexts i.e. fluvial, lacustrine, fluvio-lacustrine or coastal. Does this pattern reflect hominins' preference for specific types of habitats during the Lower Palaeolithic (as suggested by Dennell 2010), or is it a product of research and/ or preservation bias (as suggested by Tourloukis 2016)?

River terraces in particular have been a major target for the LP research around the world, as they have proved to be natural archives preserving evidence for hominin presence and activity that can be directly correlated, in some cases, with the environmental, climatic and geochronological records (for a recent review see Chauman et al., 2017); offering valuable insights especially for the earlier periods. Upland areas on the other hand, have been understudied and thought to represent environmental barriers for hominins, due to their mosaic environments and sparsely distributed resources (Hopkinson 2007: 299-302). Indeed, in the archaeological record the presence of hominins in caves and higher elevation areas is starting to be substantial only after 200 Kya (late Middle Pleistocene). However, there are exceptions to this rule as shown by recent data, including Kozarnika cave, Dursunlu and Kaletepe Deresi 3 open-air sites, located in higher elevation areas, all dated before or around 1 Mya, or later cave site examples (Yarimburgaz, Petralona and Mala Balanica) dated to 400-200 Kya.

Ethnography shows that major landscape features such as river networks, mountain chains, coastlines etc. provide natural routes and landscape markers, facilitating navigation especially when exploiting previously unknown landscapes (Kelly 2003; Guiducci and Burke 2016). Early hominins may have had small foraging ranges (Dennell 2007) but they were equipped with cognitive adaptations related to spatial memory and spatial navigation, necessary for foraging in open and wider landscapes, first witnessed within the *Homo erectus* species (Kuhn, Raichlen and Clark., 2016). Examples from eastern Africa and Israel confirm that Early and Middle Pleistocene hominins were able to take advantage of topographic complexity and mosaic environments, in both low and high elevation areas, and develop successful subsistence strategies (e.g. ambush hunting by *H. erectus* in the central Kenya Rift as suggested by Kübler et al., 2015), or exploit efficiently their landscape along with the rest of the faunal community (e.g. Middle Pleistocene seasonal movements of large herbivores and possibly hominins in Carmel area, Israel as recorded by Devès et al., 2014).

Tourloukis (2016: 318) argues that the spatial pattern observed across the Mediterranean in the location of the LP sites, is largely the product of the landscape dynamics that favoured preservation and visibility of the LP material only in specific areas and under specific geomorphic circumstances. Thus, site distributions as recorded today should not be taken at face value, as they do not necessarily represent hominin occupation patterns or habitat preferences, especially in tectonically active areas that have been affected by geomorphic processes (Tourloukis 2016: 319): *"Evidenced throughout the Lower Paleolithic period, the close spatial association of sites with water-bodies is largely the result of geomorphic processes—a fact that tends to be ignored in our reading of site distributional or biogeographical patterns".*

Perhaps, the spatial pattern observed in the LP locations across the Mediterranean is actually the product of preservation and research bias; it may also indicate a preferential association between hominins and specific environments during the LP. It is worth highlighting two points here: (a) the original location, distribution and density of the LP evidence across the Mediterranean has probably been distorted due to landscape dynamics, and in that sense areas that preserve today LP material should not be directly considered as indicative of hominins preference, and (b) current evidence suggest that early hominins were cognitively and behaviourally capable of exploiting a wider range of environmental and topographic settings, perhaps beyond the observed pattern. Large-scale landscape research, taking into consideration the distortion factors associated with the geomorphic processes, may highlight new areas of interest and affect current interpretations about hominin occupation patterns and biogeographical distributions.

2.3.4 Greek Lower Palaeolithic stone tool industries

Two main stone tool traditions (*sensu* Clark 1977:29-31) have been recorded in the Greek LP: Mode 1, the core and flake industries, and Mode 2, with handaxes and artefacts belonging to an

Acheulean technocomplex *sensu lato* (examples fitting the typological criteria but with uncertain chronologies, e.g. Plakias) and *sensu stricto* (examples fitting both the typological and chronological criteria, e.g. Rodafnidia). The raw material used in most cases is local and varies, including: volcanic rocks (e.g. andesites, basalts, rhyolites, trachytes and other lavas), quartz, quartzites and cherts which were widely used (for an overview on sources and raw material economy in the Greek Palaeolithic record see Karkazi 2018).

Until very recently, the vast majority of the material attributed to the LP, either excavated or collected from the surface, was dominated by choppers and flake tools (e.g. scrapers, denticulates, notched implements) with very few handaxe examples from Palaeokastro (Higgs 1964), Kokkinopilos (Runnels and Van Andel 1993a), two localities in Pineios basin (Runnels and Van Andel 1993b), Nea Artaki, Euboea (Sarantea-Micha 1996), and a claim for a biface coming from Megalopolis basin (Lenormant, 1867). During the last decade the sample grew, with two more specimens found in Kokkinopilos (Tourloukis 2009) and a few more bifaces from the Plakias LP localities (Strasser et al., 2010) and Aliakmon find-spots (Harvati et al., 2008) (fig.2.3).

This predominance of Mode 1 was initially interpreted as a reflection of the opportunistic character of the LP and the ephemeral nature of the exploitation sites (Runnels 1995), despite the small available sample. A regional division was also observed with chopper-flake tool industries found in many find-spots in Thessaly (Runnels and van Andel 1993b), while in Epirus the chopper-flake tool tradition co-exists with handaxes and artefacts that may belong to an Acheulean *sensu lato (*e.g. Alonaki site, in Acheron Valley and Ayios Thomas Peninsula-Ormos Vathy in Preveza region, Epirus; Runnels and van Andel 2003: 100-101; Tourloukis 2010: 86). The contemporaneity of distinct lithic industries is well attested throughout Europe and it may be indicative of transitional cultural phases, in the case of the Greek record between the late Lower Palaeolithic (Acheulean *sensu lato*) and the early Middle Palaeolithic (Mousterian) (Gowlett 1999: 54; Runnels 1995: 710); or it could reflect different trends followed by different hominin groups, possibly in order to exploit different types of habitats (e.g. choices related to raw material availability), during the same cultural phase (Gowlett 1999: 47).

The currently excavated open-air site at Rodafnidia on Lesbos Island has been a breakthrough point for the Greek LP research, changing the Mode 1 / Mode 2 equilibrium within the Greek LP record. It is the first major Acheulean site ever discovered in the Aegean, with the density and distribution of the archaeological material being unprecedented, especially when considering the scarcity of such evidence in the wider eastern and north-eastern Mediterranean (Galanidou et al., 2013; 2016). During the first three years of the site's systematic study (2010-2012), thirty Large Cutting Tools (LCTs), characteristic types of a clearly Acheulean assemblage, had been discovered (collected and excavated), tripling the known available sample from the Greek territory - and their numbers are growing as the research is in progress. The examination of the site (including archaeological investigation, survey and post-excavation analyses), reveals a complicated archaeological pattern with at least two different stone tool components: a Lower Palaeolithic associated with an Acheulean technocomplex, and a Middle Palaeolithic associated with the Levallois technology, representing possibly different cultural phases (Galanidou et al., 2016: 128). However, as the research is in progress, and published data include only the finds from the first three excavation and survey seasons (2010-2012), the character of the Levallois component remains unclear. It may equally represent an Acheulean with a prepared core technique (PCT) component (a pattern observed in African LP sites/ESA) or a Middle Palaeolithic assemblage (ibid 132).

The geological and depositional history of the site proves to be tangled, affected by extensive tectonics, volcanic activity and sea-level changes. Geological and stratigraphic analyses permit the reconstruction of a wide hydrological network with smaller and larger rivers and tributaries, flowing through the landscape during the Plio-Pleistocene. The area should be attractive throughout the Pleistocene due to the rich water resources, the raw material availability, and the presence of the geothermal springs (Galanidou et al., 2016). The latter could have acted as a landscape reference and as a landmark for hominins, as well as a micro-refugium during cold phases.

The identification of successive sequences (coarse sediments – glacials/Units 1, 3, fine sediments – interglacials/Unit 2) within the stratigraphy, enables the attribution of the stratified finds to specific environmental settings, following the succession of the climatic cycles (fig. 2.5). Preliminary absolute dates from Unit 2, near the base, suggest that the older sequences were probably deposited during MIS 13, or even earlier (Unit 3), and at least two more depositional episodes have been identified within the overlaying Unit 1, during later periods - MIS 8 and MIS 6 (Galanidou et al., 2016). The working hypothesis is that the LP stone tools recovered from the site, probably originate from layers dated prior to MIS 13. Due to erosion, the archaeological material embedded in these layers was carried away by water, and it was then transported from its original location and redeposited in lower areas across the landscape.

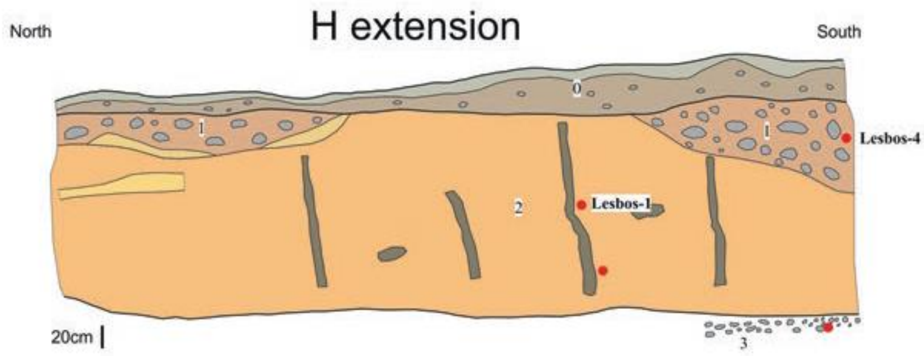


Figure 2.5. Exemplified plan of the stratigraphy of Trench H from Rodafnidia site, showing the succession of the different depositional sequences (Units 0-3). Unit 0: Loose plough soil and Top soil, Unit 1: Conglomarate, Unit 2: Brown sand and Red brown mud with cracks, Unit 3: Conglomerate. Red dots denote the location of the luminescemce dating samples (from Galanidou et al., 2016: fig. 8.9)

The LP component from Rodafnidia, including handaxes and cleavers amongst other types, is consistent with the 'Acheulean package' as recorded from sites in Eurasia and Africa, retaining however "*a strong African flavour*" (Galanidou et al., 2016: 128-132) (fig. 2.6-2.7). Similarities, in terms of technology, have been observed between the Rodafnidia LP collection and finds from Kaletepe Deresi 3 in central Anatolia, Gesher Benot Ya'aqov in Israel and even from certain African assemblages, such as Olduvai Gorge (Galanidou et al., 2016).

The suggestion made by Gowlett (1999: 54) that the "*Acheulean idea was present*" in the Greek record, despite the sparse evidence during the 1990's, has been now transformed into a certainty. The location of Rodafnidia site, at the eastern gates to Europe and the westernmost exodus points from Africa and Asia, makes it a reference point in the discussion about hominin dispersals into Europe during the Pleistocene and the spread of the Acheulean phenomenon north of the Jordanian Rift Valley.

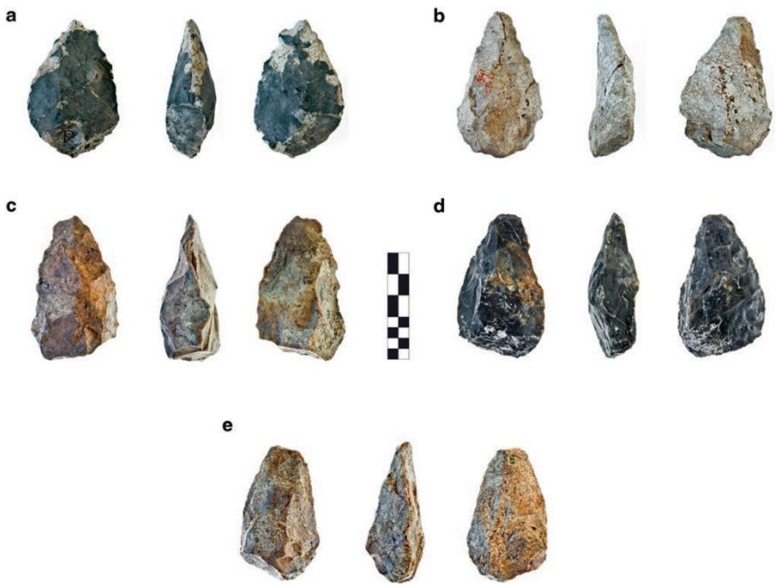


Figure 2.6. Bifaces (handaxes) from Rodafnidia (from Galanidou et al., 2016: fig. 8.10)

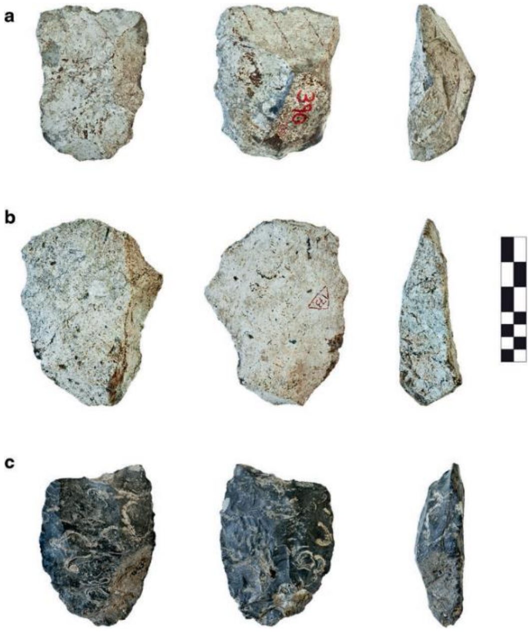


Figure 2.7. Cleaver (a), cleaver flake (b), broken cleaver (c) from Rodafnidia (from Galanidou et al., 2016: fig. 8.12)

2.3.5 New aspects and open questions in the Greek Lower Palaeolithic

Some questions about the Greek LP still remain open, but at the same time some important gaps in the archive are gradually filling up. Archaeological data from Marathousa 1 and Rodafnidia allow further associations with the African, Levantine and the western European stone tool records, regarding exploitation strategies and technological advances during the Middle Pleistocene; while recent finds from the re-examination of older paleoanthropological material extend the time depth of the presence of hominins in the Aegean region, and reveal the diversity in the represented species.

Establishing the hominin presence in the Aegean during the Middle Pleistocene

Until very recently the nature of the Greek LP was unclear. The presence of hominins in the Greek territory was not securely established before the later Middle Pleistocene, and undisputedly from the Upper Pleistocene onwards (Galanidou 2004). While the poor available lithic evidence was interpreted as transitional material from the Lower to the Middle Palaeolithic. In this respect, the area under study was thought to represent a periphery during the Lower Palaeolithic despite its promising geographical location between Africa and Eurasia.

From 2012 onwards, new finds from Marathousa 1 and Rodafnidia leave no doubt that hominins with Mode 1 and Mode 2 stone tool traditions were present in the Aegean region at least as early as 500-400 Kya. Moreover, the re-examination of the hominin molar from Megalopolis basin suggested a potential early Middle or even an Early Pleistocene age, on the basis of morphological characteristics (crown shape), showing similarities with earlier taxa particularly African early

Homo (Harvati 2016). The time frame for the LP research could be stretched back to the early Middle Pleistocene and potentially to the Early Pleistocene, and this would be in good chronological accordance with secure evidence found elsewhere in the southern European Peninsulas and Anatolia for sites over 900 kya (Mincel et al., 2017; Toro Moyano et al., 2013; Arzarello and Peretto 2010; Dinçer 2016). According to current data, it could not be argued with certainty that hominins were present in the Greek territory before the Middle Pleistocene, but such a suggestion is at least now open to future research.

The chronology of the initial peopling of Europe is still a matter of debate. A critical analysis of available radiometric and magnetostratigraphic data from hominin sites in Europe - with reference to the Balkans – by Muttoni et al. (2014; 2013; 2010) concluded that the first occurrence of hominins in Europe took place between the Jaramillo subchron and the Brunhes/Matuyama boundary (0.99- 0.78 Ma); therefore, in between the classic 'long' chronology for earliest peopling of Europe, in the pre-Jaramillo Matuyama (>1 Ma; e.g., Garcia et al. 2014), and the classic 'short' chronology, after the Brunhes/Matuyama boundary in the Middle Pleistocene (<0.78 Ma) (Roebroeks and van Kolfschoten 1994). How the Greek LP record or which parts of it fit into that chronological range needs further investigation.

Establishing the biogeographical role of the Aegean during the Middle Pleistocene

The wider Aegean lies on a central location offering an eastern entry point to Europe from Asia and Africa. The importance of this area, which is clear in geographical terms, is starting now to become more apparent in the paleoanthropological record. The re-examination of the Petralona skull, specifically the reappraisal of the facial morphology using geometric morphometrics, confirmed a closer similarity with the African *Homo heidelbergensis* (Harvati 2016). For the Greek fossil record, these finds suggest, according to Harvati (2016:8), *"contact with Africa at the time of Petralona in the Middle Pleistocene"*. Furthermore, Harvati et al. (2019) recently proposed that the Apidima skulls may indicate the presence of two more hominin species in the same area during the late Middle Pleistocene, including not only Neanderthals but also an early *H. sapiens* population; arguing for the earliest known, so far, *H. sapiens* out of Africa event at about 200 Kya. These recent developments support further, what has been long suspected, that the Aegean region played a crucial biogeographical role during the Middle Pleistocene and perhaps even earlier. Recent palaeogeographical evidence, suggesting that the largest part of the Aegean was subaerially exposed, during certain glacial (and perhaps interglacial) periods of the Middle Pleistocene from ca. 500Kya, possibly even earlier, until at least 250 Kya (Lykousis 2009; Sakellariou and Galanidou 2016; 2017- see Ch.4), reinforces the biogeographical significance of this part of Eurasia. Apparently, several groups, of the same and/or different hominin species could move across or settle in the extended terrestrial Aegean during the Middle and potentially during the Early Pleistocene.

Behavioural diversity, as reflected in the contemporaneity of Mode 1 and Mode 2 stone tool industries, has been observed in the Greek record at ca 400 Kya with a similar pattern occurring also during the late Middle Pleistocene around 200 Kya. The latter, has been considered as indication for the transition from the Early to the Middle Palaeolithic, as mentioned before, but this seems not to be the case for the earlier evidence. The core and flake industry from Marathousa 1 and the Acheulean component from Rodafnidia suggest the presence of hominin groups using different technologies at the same period of time, in different parts of the Aegean. It is not clear whether this overlap in different behavioural patterns signifies variable origins for the populations using different technological traditions; or reflects preferences related to raw material availability and adaptations to different environments; or indicates multiple and perhaps episodic arrivals of hominin groups during the Middle Pleistocene. Unfortunately, the chronostratihraphic discontinuities in the record do not allow us, at this point, to observe any patterns indicative of local technological traditions during the Middle Pleistocene, nor to discuss frequencies and durations of the hominin population in local or regional scales. Further work on the chronology of the sites and comparative studies on lithics are required in order to clarify the nature of the Middle Pleistocene evidence from the Aegean and its potential correlation(s) with isochronous evidence from adjacent areas. As the research in key-sites in the wider Aegean region is in progress, more finds are expected to come to light and add significant information towards this direction.

Chapter 3 Eastern and North-Eastern Mediterranean within the wider frame of the Plio-Pleistocene faunal dispersal events

3.1 Introduction

The paucity of archaeological and palaeoanthropological evidence from eastern and north-eastern Mediterranean (Ch.2) comes in total contrast with the rich palaeofaunal record from the same area for the Plio-Pleistocene (see Kahlke et al., 2011 for an overview). This record may offer direct and indirect information about hominin mobility and activity during a crucial period in the 'Out of Africa' dispersals and the colonisation of Eurasia. Direct information includes possible migration routes and/or evidence for the interaction between hominins and the rest of the animal community. Indirect evidence associates with hominin's biological and behavioural responses to environmental change.

Hominin dispersals are perceived as one facet of the evolutionary history of the terrestrial mammalian fauna of the Plio-Pleistocene (O' Regan et al., 2006: 305). According to the environmentally driven scenario, hominins were part of the Plio-Pleistocene major faunal dispersals from Africa to Eurasia, fuelled by severe environmental change (from ca. 2.5 Mya) (Turner, 1992; Martínez-Navarro, 2010; Palombo 2010; Kahlke et al., 2011). Theoretically, we could identify possible hominin movement patterns and routes, simply by following the Plio-Pleistocene faunal patterns across natural pathways from Africa to Eurasia and vice-versa. However, increasing amount of evidence suggests that hominins did not necessarily disperse out of Africa in concert with other mammalian taxa (Rolland 2013; Palombo 2013). Species respond differently (individualistic response) to ecological change/stress (O' Regan et al., 2011), and the parameters that define dispersal processes in early *Homo* are unique (Spassov 2016: 282). Furthermore, the direct or indirect relationship between climatic fluctuations/environmental changes and bioevents, such as the early hominin dispersals, has not been fully understood yet. Early hominin movements were indeed controlled or conditioned by ecological factors (climate and environments), but were also facilitated by technological developments and cognitive and physical capabilities (McNabb 2005).

Most dispersal scenarios emphasize the importance of the Levantine corridor as the main route for entering Eurasia through the Sinai Peninsula (Derricourt 2005; O' Reigan et al., 2006; Martinez-Navarro 2010; Croitor 2018). This is supported (a) by the dispersal patterns of the Lower

Pleistocene fauna, and (b) by archaeological data, including the earliest hominin site in western Asia (Dmanisi at 1.8 Mya and Ubeidiya at 1.4 Mya), the great density of Lower Palaeolithic sites in SW Asia for the period 1.8-0.8 Mya, and in some cases the continuous / repeated use of the same sites by different hominin groups (e.g. Ubediya, Gesher Benot Ya'aqov) during the Lower-early Middle Pleistocene (Bar-Yosef and Belmaker 2011; Dennell 2003; 2009). Other possibilities, including sea-crossings have been also explored, such as the Gibraltar straits (Gibert et al., 2003), the Sicilian channel (Abatte and Sagri 2011) and the Bab-el- Mandeb straits in the Red Sea (Bailey 2007; 2009). These areas have failed to provide convincing and /or unequivocal evidence for their use as dispersal routes during the Early-Middle Pleistocene (Derricourt 2005; Palombo 2013). However, the potential of the Gibraltar Strait as a dispersal corridor is open to debate (Rolland 2013). It has been argued that at least during short-term optimum climatic and pelagic episodes it would have been feasible for hominins to cross the straits (by swimming or island hopping) and reach Iberia. These would not have been accidental crossings but rather calculated and logistically planned dispersal (s) (as opposed to passive dispersal in sweepstakes events). Still, most possibly it was the Sinai Peninsula that offered an ‘escape’ route from Africa during the Lower Pleistocene, permitting fauna –including hominins – to move within an ecological zone with similar environmental characteristics as their familiar eastern African habitats (green lands and savannahs) (Dennel 2004; Martínez-Navarro 2004).

If we accept the prevailing notion, that the Sinai Peninsula provided the main passage towards Eurasia during the Plio-Pleistocene, we would also expect eastern and north-eastern Mediterranean region to be a core area for the diffusion of populations to western and northern Europe; thus being an important locus in the history of hominin dispersals. Indeed, the strategic position of the Aegean Sea, the Bosporus and western Anatolia, the Balkans and the wider Caucasus region on the map of the Lower and Middle Pleistocene dispersal routes has been widely acknowledged (Straus, 2001; Derricourt, 2005) and is well established, mainly through faunal dispersal and distribution patterns (Koufos and Kostopoulos, 2016; Spassov, 2016).

In this chapter, we will focus on the Balkans, providing arguments for the biogeographical importance of the region during the Plio-Pleistocene, as revealed through the palaeofaunal evidence. Emphasis will be given on the Greek Plio-Pleistocene faunal record and its contribution in the study of the faunal migrations across the wider eastern Mediterranean. Evidence on dispersal patterns, dispersal routes, refugial areas, favourable conditions and habitats will be discussed in correlation with evidence for the hominin presence, concluding in the currently prevailing dispersal scenarios during the Early and Middle Pleistocene.

3.2 The Greek Plio-Pleistocene faunal record: an overview

The Greek Plio-Pleistocene faunal data sets, despite discontinuities, are quite complete, and continuously enriched by ongoing research. The Greek Plio-Pleistocene record provided the core-material for the establishment of a good Plio-Pleistocene mammalian (Villafranchian) biochronology for the wider eastern and north-eastern Mediterranean region. This spatiotemporal framework permits comparisons with other isochronous sites from western Europe and western Asia. Furthermore, it allows palaeoecological and palaeoenvironmental interpretations that enhance our understanding of the archaeological and palaeoanthropological evidence from this region, in relation to wider processes such as the early human dispersal patterns towards Europe.

However, associations between Pleistocene faunal sites and known Lower Palaeolithic sites from Greece cannot easily made. Well-established biochronologies are available from specific parts of Greece i.e. North Greece (Mygdonia basin, Kozani basin) and central Peloponnese (Megalopolis basin) (Kahlke et al., 2011). Furthermore, only in rare instances a co-occurrence of lithic material and/or hominin remains with faunal remains is recorded, and even then there is not necessarily a secure stratigraphic association between them (e.g. Petralona cave, Apidima cave) (Darlas 1995; Harvati, Panagopoulou and Runnels 2009). There are occasions however, when chronological correlations are possible as in the case of Marathousa 1 locality in Megalopolis basin, where a stratified Mode 1 stone tool assemblage was recovered in association with Galerian faunal remains (Panagopoulou et al., 2015; Konidaris et al., 2018). On the one hand, using faunal evidence in making chronological estimations for the archaeological material is certainly not without problems; on the other, the contribution of the faunal evidence in the palaeoenvironmental reconstructions is uncontested, providing information on vegetation/landscape patterns, presence/absence of water resources, and temperature indices.

The analytical presentation of the Greek Plio-Pleistocene faunal record is beyond the scope of this thesis. However, a brief overview will be presented, emphasising associations between the Greek and other European localities that may lead to archaeological, ecological and other affinities. A chronological order will be followed, starting from the Middle Villafranchian (2.6-1.8 Mya) to the Epivillafranchian (1.2-0.9 Mya), following Kahlke et al. (2011) chronologies, up to the Galerian (0.9-0.4 Mya). This wide time period is bordered by major climatic shifts that greatly affected environmental conditions and faunal composition. Variation in the environments caused big changes in the configuration of the landscapes across Eurasia affecting the dispersal patterns.

Table 3.1. Faunal turnovers during the Early and Middle Pleistocene in relation to climate and habitat changes

Faunal Turnover	**Chronology**	**Pleistocene Age**	**Climate**	**Habitats**	**Prevailing species**
Middle Villafranchian	2.6-1.8 Mya	Early Pleistocene (2.58-0.78 Mya)	Initiation of the glacial – interglacial alterations (41ka periodicity) Colder and drier conditions	Gradual deforestation - open and dry environments	Reduction of forest species – abundance of open/wooded species. Decreasing African influence on the Eurasian faunal composition
Late Villafranchian	1.8-1.2 Mya	Early Pleistocene (2.58-0.78 Mya)	Further drop in temperature Steadier climatic alterations	Expansion of open grasslands - warm and humid environments	Open to open/mixed elements Westward faunal expansion. Increasing Asiatic influence on the Eurasian faunal composition
Epivillafranchian	1.2-0.9 Mya	Early Pleistocene (2.58-0.78 Mya)	Climatic instability Glacial conditions in the northern hemisphere Temperate to cool conditions in SE Europe > pronounced differences between glacials-interglacials	Replacement of open grasslands by forest-steppe to steppe landscapes > Variety of habitats Warm and dry & humid and forestial	Absence of purely forest-adapted species -predominance of ungulate forms Presence of semi-aquatic species Increased Asiatic influence on the Eurasian faunal composition
Galerian	0.9-0.4 Mya	Early – Middle Pleistocene Transition around 0.8 Mya Middle Pleistocene (0.78-0.126 Mya)	Change in the periodicity of climatic cycles from 41 Ka to 100 Ka. Increased seasonality and aridity Expansion of the ice-sheets Warm stages – evident Mediterranean influence	Mosaic-like habitats from forested to meadow-steppe Expansion of the mammoth-steppe The Balkans formed a homogenous ecological zone during interglacials	Combination of grazers and thermophilous browsers Establishment of the 'Mediterranean biosystem' with a clear Eurasian character

3.2.1 Middle Villafranchian (MVC) (2.6-1.8 Mya)

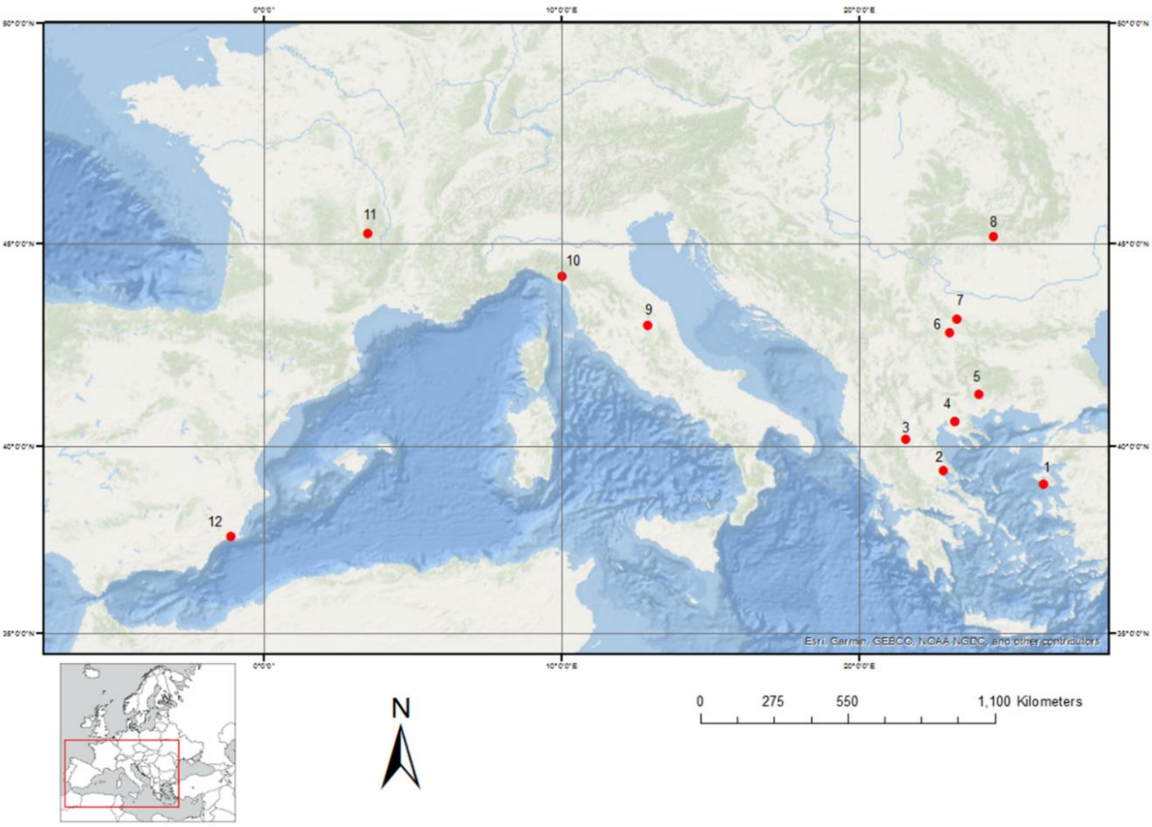


Figure 3.1. Middle Villafranchian key-sites (2.6-1.8 Mya) mentioned in the text (modified after Kahlke et al., 2011). 1-Vatera, 2-Sesklo, 3-Dafnero, 4-Gerakarou and Vassiloudi, 5-Volakas, 6-Slivnitsa, 7-Varshets, 8- Valea Graunceanului, 9-Olivola, 10- Cole Curti, 11-Senèze and Chilhac, 12- Cueva Victoria - El Rincón-1. Base map: Ocean basemap, ArcGIS online, sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors. Coordinate system: WGS 1984 Web Mercator Auxiliary Sphere; Projection: Mercator Auxiliary Sphere; Datum: WGS 1984; Linear Units: meters. Map produced in ArcGIS 10.6

During the period 2.6-1.8 Mya a severe environmental shift towards colder and dryer conditions is documented. This shift is associated with the initiation of the 41ka periodicity in the glacial-interglacial cycle in the northern hemisphere (Zubakov and Borzenkova, 1990). The gradual opening of the landscape – due to cold and aridity – permitted the northward expansion of the African taxa, within a familiar ecological zone. Gradually open grasslands prevailed in Asia Minor and south-eastern Europe, and mosaic-like environments, (i.e. savannah and woodland habitats) across Transcaucasia, the Balkans and beyond, replacing densely forested areas (Kahlke et al., 2011: 1386). Faunas respond to such changes usually by the replacement of old species with new ones, better adapted to new environmental/climatic conditions (faunal turnovers). This turnover is marked by the reduction of the forestial and humid character of the European faunas, and reflects the first major cool event of the northern hemisphere (ca.2.5 Mya) and the beginning of the Artemisia event (steppe- deciduous forest replacement). Apparently, the gradual deforestation had an east to west direction. Middle Villafranchian faunas from Greece and Turkey show open and dry environments, while in south-western Europe this shift is not yet observable at isochronous localities (Kostopoulos and Koufos, 2000: 143-44).

Large mammal assemblages dating to the early Middle Villafranchian are rather rare in the Balkans (Kostopoulos, Vassiliadou, and Koufos 2002: 253-54). The Greek faunal record from the Late Pliocene is quite rich, and includes some of the key-assemblages for the wider eastern Mediterranean (e.g. Gerakarou, Volakas, Dafnero, Sesklo and Vatera - fig.3.1). The Gerakarou locality (N. Greece), for example, is considered to be a pivotal site for Europe as it shows evidence for the 'wolf – event' (ca.1.8 Mya) (Koufos 2014: 453-55). The Greek record clearly demonstrates that species adapted to wooded habitats strongly decrease as they are gradually replaced by open/wooded species (Kostopoulos and Koufos 2000: 143-44). *Equidae* and *Bovidae* become the dominant families indicating open and dry habitats (savannah-like woodland), while *Cervidae* and *Suidae*, forest adapted taxa, become rarer (Athanasiou and Kostopoulos, 2001: 88-89; Koufos 2014: 457; Koufos et al., 2005: 187). Recent statistical analysis from the Slivinitsa key-faunal locality in Bulgaria confirms the environmental shift towards more open landscapes of the forest-steppe mosaic type and a relatively humid climate, being in good agreement with evidence from isochronous faunal sites in Bulgaria (Varshets), and Greece (Dafnero and Volakas) (Spassov 2016).

Despite the general ecological trend outlined above, associations are very difficult to be established due to the local character of the faunas. Kostopoulos and Koufos (2000: 143-44), identify some similarities in terms of preferential habitats and dietary spectra between the Greek, Italian (e.g. Olivola and Colle Curti) and Spanish (e.g. Cueva Victoria) faunas. However, similarities in the landscape character, brings the Greek faunas closer to the Italian rather than the Spanish ones, in terms of habitats, turnover patterns, and large mammal guilds (Kostopoulos et al., 2007: 409).

Vatera locality (Lesbos Island, NE Aegean – fig.3.1) from this period needs a special mention, due to the presence of *Paradolichopithecus arvernensis* (De Vos et al., 2002; Dermitzakis and Drinia, 1999). *Paradolichopithecus* is only known from two other sites, Senèze in France and Valea Graunceanului in Romania (Lyras and Van der Geer, 2007: 11). This primate is considered to rely less on an arboreal way of life, demonstrating characteristics consistent with a highly terrestrial way of locomotion, comparable to early hominins and *Australopithecus,* according to Sondaar et al. (2006). This species probably occupied and exploited similar habitats i.e. forest edges bordering savannahs with humid and warm conditions, resembling African niches. Terrestrial primates such as cercopithecids (*Mesopithecus* sp., *Dolichopithecus ruscinensis* and *Paradolichopithecus arvernensis*) and hominoids (*Ouranopithecus macedoniensis*) are present in the Greek faunal record from the Miocene, the Pliocene and, to a lesser extent, the Pleistocene

(Koufos 2006). *Ouranopithecus* appears to be a key-species sharing derived characteristics with *Australopithecus* and *Homo*, thus probably coming from the same, common ancestor (Koufos and de Bonis, 2004). Tourloukis and Karkanas (2012b:1) note that such discoveries from Greece *"repositioned Europe as the possible source of later hominines that dispersed into Africa in the late Miocene*". Indeed, a recent article by Fuss et al. (2017) presents phylogenetic and chronological evidence placing *Greacopithecus* (only found in Greece and Bulgaria) at the point of divergence between apes and hominins, within our evolutionary history. Thus, *Greacopithecus* might represent the last common ancestor between the two taxa, shifting considerably the research interest from Africa to Europe, and especially the Balkans.

3.2.2 Late Villafranchian (LVC) (1.8-1.2 Mya)

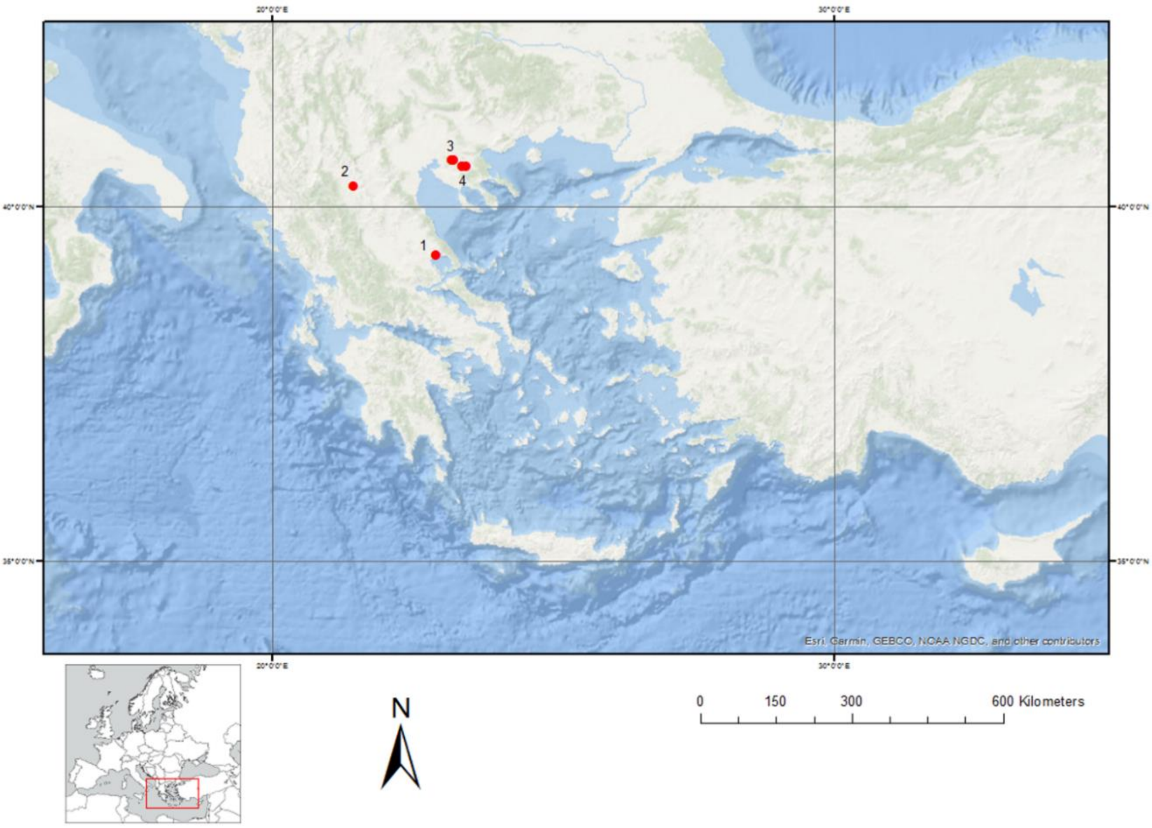


Figure 3.2. Late Villafranchian key-sites (1.8-1.2 Mya) mentioned in the text (modified after Kahkle et al., 2011). 1-Alykes, 2-Libakos, 3-Krimni, 4-Kalamoto. Map produced in ArcMap 10.6. Geospatial data as in fig. 3.1

Species specialised more in open habitats prevail, as the landscape opening progresses and climatic alterations are steadier. Tree savannahs, open grasslands, and extended semi-arid areas are documented in western Transcaucasia, while in south-eastern Europe, open grassy landscapes alternated with mixed forest steppes during milder periods (Kahlke at al., 2001: 1387). The Late Villafranchian fauna has a pronounced Eurasian character, with limited African elements, in comparison to the Middle/Late Villafranchian faunal composition. Around 1.2 Mya new species from Africa and most importantly from Asia are dispersing into western Europe. The Aullan sea-level drop possibly affected the change in the composition of the European biomes (Arribas and Palmqvist 1999). This dispersal event - possibly including hominin species – was facilitated by favourable environmental conditions (warm and humid environments and riverine habitats with zones of riparian vegetation and exposed continental shelves) at the final stage of the Late Villafranchian and the beginning of the Epivillafranchian (Kahlke et al., 2001: 1387). It is worth mentioning that by 1.4 Mya *H. antecessor* is present in the Iberian Peninsula (Toro Moyano et al., 2013; Garcia et al., 2014).

In Greece, two localities mark the begging of the Late Villafranchian both located in N. Greece, Vassiloudi and Gerakarou (fig.3.2). Their age estimation lies between the Olivola (Italy) and Senéze (France) chronology (Koufos and Kostopoulos 1997). No significant environmental change is observed as the open to open/mixed elements constitute 50% of the fauna, (Kostopoulos and Koufos 2000; Kahlke et al., 2011: 1372). The dominance of *Canis* as well as the presence of the hyenid *Pachicrocuta brevirostris* and the felid *Panthera ocrucialnca* in the LVC assemblage is associated with open habitats (grassland) (Koufos, Kostopoulos and Vlachou 2005: 187; Koufos 2014: 457). The predominance of bison and large horse together with hippo and a megacerine cervid, also suggests open landscapes and mild environmental conditions (Kalamoto, Mygdonia basin-fig.3.2) (Kahlke et al., 2011: 1376). A faunal renewal is recorded in the faunal assemblages from Krimni - Mygdonia basin, Libakos - Grevena basin, and Alykes - Thessaly (fig.3.2), consistent with the expansion of open grasslands over this region (Koufos 2014: 457). The last presence of Gazellospira, leptobovines and giraffids is documented in the Balkans, along with the entrance of new species originated from either Africa (*Hippopotamus)* or Asia (*Pontoceros*) (Kahlke et al., 2011: 1376).

3.2.3 Epivillafranchian (1.2-0.9 Mya)

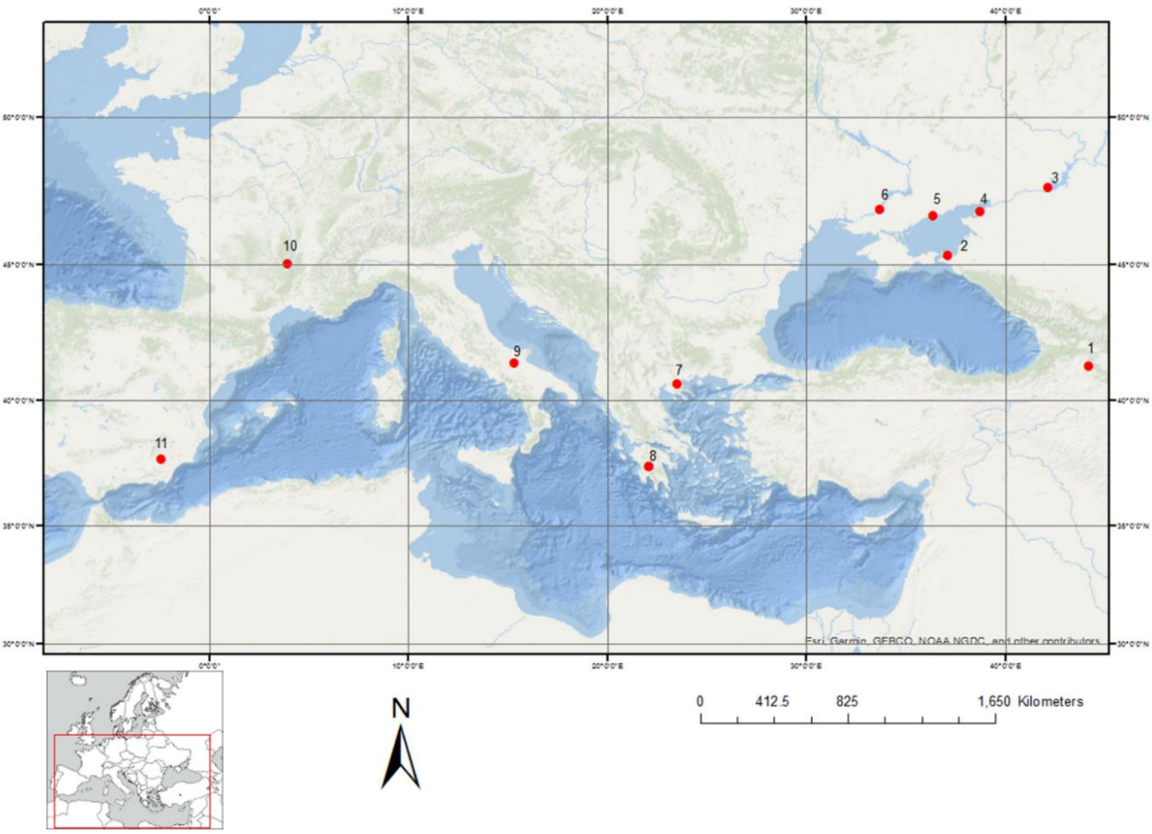


Figure 3.3. Epivillafranchian key-sites (1.2-0.9 Mya) mentioned in the text (modified after Kahlke et al., 2011: 1378). 2-Sinaya Balka, 3-,Sarkel, 4-Port Katon, 5-Nogaisk (Prymorsk), 6-Kairy, 7- Apollonia and Ravin Voulgarakis, 8-Megalopolis, Notice that 1-Dmanisi, 9-Pirro Nord, 10-Sainzelles and 11-Venta Micena are Late Villafrancian localities but similarities have been recorded with specific elements from the Apollonia faunal assemblage. Geospatial data as in fig. 3.1

The Epivillafranchian period is marked by climatic instability and environmental variability across Europe, with phases of pronounced warmth. Around 1.1 Mya (shortly before the Jaramillo event 1.07-0.99 Mya) glacial conditions prevailed in the northern hemisphere affecting even the southern parts of the European continent. This cooling event resulted in more pronounced differences between the glacial and interglacial periods, and the Cassian sea-level drop. In south-eastern Europe, continental climate is recorded, with temperate to cool conditions. Open grasslands were gradually replaced by forest-steppe to steppe landscapes, due to the continuation of aridification (Kahlke et al., 2011: 1378). In western Europe and the Apennine peninsula, new species are recorded, indicating a new environmental niche and the exploitation of a variety of habitats. In Iberia, open landscapes prevailed, but patchy woodland is also recorded during warm phases under the Atlanto-Mediterranean climatic influence and consequent lack of intense cool intervals (ibid 1388). The Epivillfranchian faunas have an intermediate character between the Late Villafranchian and the Galerian faunas (Middle Pleistocene), with specific characteristics developed possibly under warm climatic conditions (ibid).

The EVC large mammal fauna from Apollonia (Mygdonia basin, N. Greece) (fig.3.3) represents the most complete assemblage in south-eastern Europe. The abundance of mammalian fossils from this area allows a close monitoring of the palaeoenvironmental conditions. For the final Early Pleistocene, a diverse habitat with mixed characteristics is suggested. The abundance of bovids and equids indicate savannah grassland with warm and dry climate, while the presence of cervids and suids suggest increased humidity and forestial character (Koufos et al., 1995: 248; Kostopoulos 1997: 873). Pronounced wet conditions at the end of the Villafranchian, and possibly seasonal rainfalls, are also evidenced in the Platanochori Formation fauna (fresh-water mollusks, fish otolithes and hippopotamids), and further attested by the transition of the red beds to lacustrine deposits, within the same geological formation (Koufos et al., 1995: 248)

New elements characterise the EVC faunas, with the replacement of the bovids by several caprine lineages (Kostopoulos and Koufos, 2000). The prevalence of primitive bison and the high frequency of intermediate feeders and grazers (i.e. absence of purely forest-adapted species and the predominance of ungulate forms) are consistent with grassland environments (e.g. *Equus apolloniensis, Pontoceros ambiguous mediterraneus, Soergelia brigittae, Hemitragus orientalis, Praeovibos mediterraneus, Ovis sp., Bison sp., Praemegaceros pliotarandoides,* and *Arvernoceros sp*) (Spassov 2016:288); the presence of semi-aquatic species (hippopotamids) together with the dry elements suggests more mild and moderate conditions, and all together indicate a balanced climate (Kostopoulos, Vassiliadou and Koufos 2002; Kahlke et al., 2011: 1378-79). This diversity in the habitats and environments is also confirmed by the presence of *Canis* and *Pachycrocuta brevirostris*, as well as other carnivorous species (*Megantereon cultridens* and *Lynx issiodorensis*), well adapted in both open and closed environments (Koufos 2014:457-58).

Similarities have been observed between the artiodactyls from Apollonia I and those found in Venta Micena (Spain), Pirro Nord (Italy), and Sainzelles (France) – early Pleistocene archaeological sites (fig.3.3). Moreover, the African sabre-toothed felid *Megatherion whitei* has been recognised in the Appolonia I faunal elements (Martínez-Navarro and Palmqvist, 1996: 869). *Megatherion whitei* marks the Plio-Pleistocene faunal turnover and it is present in archaeological sites such as Venta Micena in Spain and Dmanisi in Georgia in association with early hominins (prior to 1 Mya). This specific felid is thought to be hypercarnivorous, leaving behind large amount of meat for scavengers, such as hyenas and possibly hominins (Martínez-Navarro and Palmqvist 1996; Arribas and Palmqvist, 1999; Martínez-Navarro 2010). From that point of view, the initial out of Africa hominin dispersal has been many times linked with the migration of *Megatherion whitei*, by facilitating the food supply for hominins and providing them a survival strategy. Martínez-Navarro and Palmqvist (1996: 871) support that it would not be a surprise to find *Homo* remains in Mygdonia basin, considering (a) its geographical location in the Balkans, on a possible dispersal route via Bosporus, and (b) the similarities in the faunal evidence with isochronous sites that also bearing early evidence for the presence of hominins in Eurasia. However, it is worth to mention that the ecological relationship between hominins and large carnivores during the Lower Pleistocene is still a debatable subject. It is not quite clear if it was a negative rather than a positive interrelationship between the two. Hominins by nature were poorly adapted to the ecological niche of a sabre-toothed predator (e.g. they would have had very low chances of survival in a densely wooded habitat where a sabre-toothed predator would have performed its ambush hunting; Croitor 2018: 282). The main tension observed in the record, based on the hominin-carnivore density, is that of carnivore avoidance by early hominins, consistent perhaps with higher survival chances (Carotennuto et al., 2016). Still, in several cases, especially in Iberia, hominins and carnivores had been clearly competing for access to the same resources, with the overlapping of tooth marks over cut marks, indicating that in some instances hominins had been more successful at getting to the carcasses first (e.g. in Gran Dolina TD6, Fuente Nueva 3, Barranco León, Vallparadis; Garriga, Martínez and Yraverda 2017). This means that hominins were able to exploit the same meat resources and gain access to them, especially under high trophic pressure, regardless of the carnivore presence and activity in the same area.

Similar fauna, slightly younger (although most of the recorded species need taxonomic revision) has been found in Megalopolis basin (Southern Greece) (fig.3.3). The faunal assemblage, including a large bovine *Praemegaceros sp*., *Hippopotamus antiquus*, *Stephanorhinus sp*. and *Equus cf. aluticus*, suggest that similar environments, as those reflected on the northern Greek faunas, prevailed as far south as the Peloponnese (Kahlke et al., 2011: 1378-79). The Pleistocene fossiliferous sediments in Megalopolis basin have been known since the 1960’s (Melentis, 1961) and numerous palaeontological localities have been exposed during mining operations as the lignite seams have been exploited via open-cast mines (Panagopoulou et al., 2015). During the last two decades, the re-examination of older finds i.e. a hominin molar (Harvati 2016), found accidentally amongst the faunal material, and observations on lithic tools (Darlas 2003) provide arguments for an early human presence/activity in the region.

Most of the localities of the early part of the Epivillafranchian period in the south of eastern Europe are associated with alluvial, deltoid or lagoon deposits (e.g. Sinaya Balka, Nogaisk, Sarkel, Port-Katon, Chishmikioy, Kairy, Tsimbal - fig.3.3), and warm to nearly subtropical conditions (Kahlke et al., 2011: 1380). However, there is a serious contradiction with pollen sequences and small-mammal associations recovered from the same region, showing a significant temperature decrease and increasing aridity (later part of the 1.2-0.9 interval) (ibid).

3.2.4 Galerian - Early Pleistocene to Middle Pleistocene Transition (0.9-0.4 Mya)

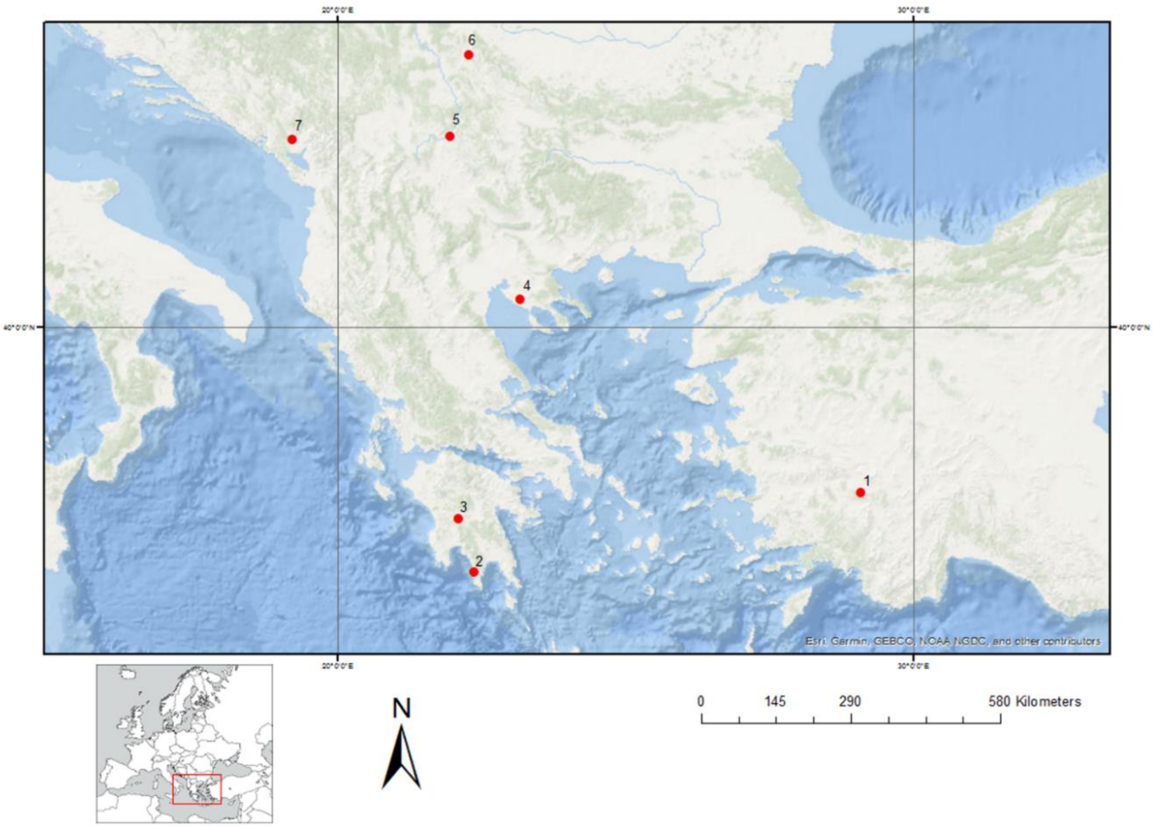


Figure 3.4. Galerian key sites (0.9-0.4 Mya) mentioned in the text (modified after Kahlke et al., 2011: 1381). 1-Denizli, 2-Apidima, 3-Megalopolis –Marathousa, 4-Petralona, 5-Jerinnina, 6-Baranica, 7-Crvena Stijena. Geospatial data as in fig. 3.1

By the end of the Epivillafranchian a major climatic change happened. The periodicity of the climatic cycles advances to 100Kya (from 41 Kya) (Lisiecki and Raymo 2005), marking the Early-Middle Pleistocene Transition (1.2-0.5 Mya) and the initiation of what is popularly conceived of as the 'Ice Age' (Wilson et al., 2000). By ca. 800 Kya this shift has been established, with more or less steady and regular warm and cold intervals. In the northern hemisphere, in northern and middle latitudes, seasonality and aridity increased due to the amplitude of climatic fluctuations. The expansion of the ice-shields is recorded not only in the high-mountain areas but also in the lowland regions during the most extreme phases (Lee et al., 2004). Ice-sheet activity caused big environmental changes, which affected in return massively the European landscape (topography, vegetation, fauna). Apparently, the glacial ice-sheets expansion, dictated the direction of the major dispersal events to follow a north to south axis and vice-versa. During a period of pronounced cold around 0.45 Mya (MIS 12) the steppe-tundra (mammoth steppe), first expands from Central Asia into Europe, west of the Carpathian bow and beyond. However, mammoth faunas did not reach western Europe before MIS 10 (Kahlke et al., 2011: 1388; Koufos, Kostopoulos and Vlachou 2005: 188). In eastern Mediterranean and Transcaucasia similar conditions have been recorded, with varying habitats, from forested (closed) to meadow-steppe (open) environments (Kahlke et al., 2011: 1388). In the warm stages of the early Middle Pleistocene (0.51-0.33 Mya) the influence of the Mediterranean climate is evident. By 0.4Mya (MIS 11), western and eastern Europe formed a homogenous zone with mosaic-like landscapes (open steppe and forest-steppe alternating according to spatiotemporal changes) under the conditions of a fully developed interglacial (Kahlke et al., 2011). The major climatic/environmental shift caused a drastic change in the faunal composition. The Galerian fauna has a clear Eurasian character with no evidence of newcomers. At this stage, the 'Mediterranean biosystem' was established in southern Europe (Koufos, Kostopoulos and Vlachou 2005).

Three localities have yielded faunal evidence from this period: Petralona cave (N. Greece) (Tsoukala 1991), Megalopolis - Marathousa (Peloponnese, S. Greece) and Apidima cave (Peloponnese, S. Greece) (Tsoukala 1999) (fig.3.4). Petralona and Apidima cave assemblages, dated to ≤ 0.4 Mya, have been interpreted as bone accumulations made by bears, hyenas and lions. In both sites, faunal remains have been found with hominin remains and stone tool assemblages, but the association between hominin fossils, faunal remains and material culture evidence is, as yet, not clearly defined (Harvati, Panagopoulou and Runnels 2009). Faunal remains suggest mild conditions under the Mediterranean-influenced interglacial and mosaic-like environments with the presence of permanent water bodies - at least for Apidima (Kahlke et al., 2011: 1382).

The early Middle Pleistocene assemblage from Megalopolis has a diverse character, including *Bison priscus, Bos primigenius, Capreolus sp., Dama sp., Cervus elaphus, Hippopotamus, Sus scrofa, Stephanorhinus kirchbergensis, S. hemitoechus, Palaeoloxodon antiquus* and *Crocuta* (Kahlke et al., 2011: 1382). A balanced combination of grazers and thermophilous browsers is recorded, with the increased presence of pachyderms, and the predominance of open dwellers and intermediate feeders. This is indicative of a range of habitats under temperate climate (*ibid*). Recently, in Marathousa 1 locality, in Megalopolis basin, Galerian faunal remains, including mainly elephant elements (*Elephas Palaaeoloxodon antiquus*) have been excavated in association with stone tools (Mode 1 tradition) (Panagopoulou et al., 2015). According to the excavators, this contextual association and the recent examination of the cut marks on the elephant skeleton (Konidaris et al., 2018) demonstrate animal carcass exploitation and butchery activities by hominins, evidenced for the first time in the Middle Pleistocene record of Greece (see Ch.2).

Isochronous - to the Greek faunas - assemblages from Turkey (Denizli – 0.51-0.33 Mya) and the Balkans (Montenegro - Crvena Stijena Cave V – XXX; Serbia - Jerinnina and Baranica Caves, later Middle Pleistocene - fig.3.4) clearly show that the Balkans during the later Middle Pleistocene, and under interglacial conditions, formed a homogenous ecological zone (Kahlke et al., 2011:

1382). However, both cold and temperate taxa are known from the middle-late Pleistocene of Greece (Koufos, Kostopoulos and Vlachou, 2005: 188)

From the Middle-Late Pleistocene the Mediterranean islands show a completely different faunal pattern. As the insularity progresses due to tectonics and changes in the sea level, special endemic faunas were developed. The evolutionary process known as insular endemism, either 'nanism' or 'gigantism' was the result of the dramatic reduction of the living space and the absence of predators. Insular 'nanism' is observed in elephants and hippos and 'gigantism' in rodents, and has been recorded in several islands in the eastern Mediterranean (e.g. Naxos, Rhodes, Carpathos, Tilos, Crete, Cyprus) (Van der Geer et al., 2014; Koufos, Kostopoulos and Vlachou, 2005: 188). This is in good agreement with the suggestion made by Lykousis (2009) that the gradual submersion of the northern and central 'dry Aegean' did not happen before MIS 9 (i.e. ≤300 Kya) (see section 4.5.4-Ch.4) initiating marine conditions with insular environments – as indicated by palaeogeographical eveidence (subsidence rates and the estimated relative sea-level stand). The modern day archipelagic configuration was fully established by ca. 9 Kya.

3.3 The Balkans' 'hot spot' during the Plio-Pleistocene

The Balkans have proved to be a vital region for the survival and dispersal of several species (flora, fauna and hominis) throughout the Plio-Pleistocene by:

1. Serving as a *refugium* during periods of climatic stress.
2. Being a reception and diffusion area for the dispersals towards Europe.
3. Providing multiple and multidirectional dispersal routes.

The Balkans hold, geographically, a central position on a crossroad connecting Africa, Asia and Europe, representing the *"most probable springboard of hominin colonisation of the European subcontinent"* (Croitor 2018: 283). The abundance of fossil sites, covering a wide chronological, taxonomical and spatial range, and comparative studies of faunal remains confirm that this region provided multiple routes of dispersal throughout the Plio-Pleistocene. Similarities between the Balkan and the western European faunas during the Lower Pleistocene reveal a very strong biogeographic link between the two territories that could indicate a possible route followed by early hominins to, initially, enter western Europe around 1.4Mya (Croitor 2018). The Balkans lie protected (surrounded by the Carpathian Mountains) at the beginning of a potential land bridge leading to the western part of the European continent, possibly via the Pannonian Plain in Central Europe. The susggested landbridge (a) would include low-altitude areas, which seem to be preferentially associated with hominins such as *H. erectus* throughout the early dispersal events (Carotenutto et al., 2016), while (b) the prevailing climatic and vegetation conditions along this geographic corridor during the Plio-Pleistocene, would have favoured dispersal(s) for the Early Pleistocene hominins (and other animals), as shown in the model developed by Leroy, Arpe and Mikolajewicz (2011). In particular, the southern Balkans, including the northern Aegean and parts of the Greek mainland have been highlighted (fig. 3.5). The model is structured upon certain climatic criteria (precipitation and temperature rates) that suggest favourable to optimum climatic and environmental conditions for hominin dispersal (see below - section 3.4.3).

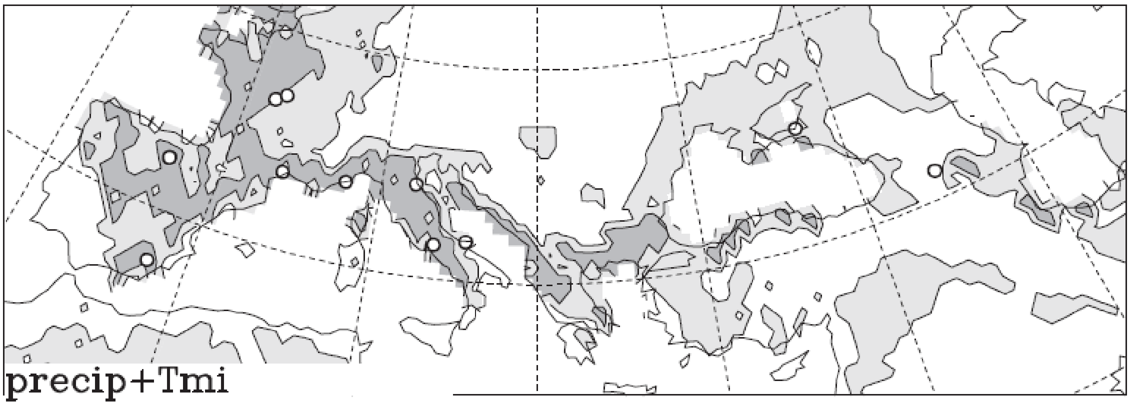


Figure 3.5. Map showing the suggested geographical corridor with climatic and vegetation conditions that would favour hominin dispersal during the Lower Pleistocene (2.56-0.78 Mya) according to the model proposed by Leroy, Arpe and Mikolajewski (2011). Light grey areas: temperature of the coldest month ranges from 0-6ºC or precipitation ranging from 30 to 60 mm/month. Dark grey areas: both the summer precipitation and the minimum temperature criteria suggesting optimum climatic and environmental condition for dispersal are fulfilled (from Leroy, Arpe and Mikolajewicz 2011: fig. 10)

Two routes offered the main gateway from Africa to Eurasia and vice-versa (Muttoni et al., 2010; Spassov 2016; Palombo et al., 2006; Kostopoulos, Vassiliadou, Koufos 2002; Martinez-Navarro, 2010; Kahlke et al., 2011):

1. The Levantine route (via Asia Minor and the Dardanelles).
2. The Black Sea – Balkans route (via the Transcaucasia and the Black Sea - south and/or north of the Carpathians - into northern Mediterranean coasts/ 'Trieste passage').

Both routes lead to the Balkans either as the westernmost-end point for many Asian species, or the gateway to south-western Europe for taxa coming mainly via Asia Minor and/or the Pontic region (fig. 3.6). The Balkans should not be envisioned simply as a transit between Africa, Asia and Europe, but rather as a dispersal centre, receiving mammalian taxa from Africa and Asia, offering a *refugium* and enabling further expansion towards western and northern Europe, and possibly, backwards (Kostopoulos, Vassiliadou and Koufos 2002; Kostopoulos et al., 2007; Kostopoulos and Koulidou 2015). Being part of the refugial zone across the Southern European peninsulas, the Balkans offered favourable conditions (ice-free area, temperate climate) for the survival of fauna, flora and hominin populations, during the unfavourable glacial phases of the Pleistocene (Hewwit 1999; Stewart et al., 2010; Palombo et al., 2006; Dennell, Martinon-Torres, Bermudez de Castro, 2011). The refugial character of the southern European peninsulas is very well attested by palaeoecological evidence (Tzedakis 2004) and phylogeographic studies, suggesting that many extant north populations derived from areas in the south (Koufos and Kostopoulos 2016; Spessov, 2016).

However, differences do occur between the southern European refugia in terms of habitats, environmental conditions and geographical features. In that sense, we should always consider this heterogeneity, instead of presuming common and unified ecological characteristics across the refugial zone. Along those lines, Kostopoulos et al. (2007) identified three distinctive domains, with different functions during migration/dispersal events:

1. 'Reception and diffusion area': the 'Greek arm' of the Balkan Peninsula and within it the Aegean region, served as a reception and diffusion area, mainly for faunal migrations directed from east to west.
2. 'Cul de sac': the Iberian and Italian peninsulas formed the end-points for the most of the Eurasian dispersal events that affected western European faunas.
3. '*Refugium*': Southern Europe is considered to be a refuge area for northern taxa during the Pleistocene climate worsening.

Comparative study of molecular genetic data (DNA sequences) of several animal species by Hewitt (1999) is in good agreement with that differentiation. His study confirmed the locations of the refugial areas during the last glaciation in the southern European Peninsulas, and revealed the recolonization patterns from each of these refugia. As it stands, palaeotopographic parameters affect greatly – either negatively or positively – the diffusion patterns. In this respect, the Balkans seem to offer easier passages to the north and the west. Amongst the southern refugia, the Balkans provided species for north European colonisation and /or recolonisation in nine out of eleven examples while the Pyrenees blocked the expansion from an Iberian *refugium* in four out of eleven cases, and the Alps similarly blocked dispersals from the Italian peninsula in eight out of eleven examples (ibid 104). This conclusion is in good agreement with a recent multivariate cluster analysis of western Eurasian herbivore faunas (Croitor 2018), suggesting that the Italian Peninsula remained in partial biogeographic isolation during the Early Pleistocene due to the dense forestation of the Dinaric Alps, while the Iberian Peninsula represented a biogeographic 'cul de sac' due to isolation by the marine crossing of the Straits of Gibraltar (since the end of the Messinian event). The eastern Mediterranean, including the Balkan Peninsula and the Caucasus region, on the other hand, is highlighted as a region of high biogeographic importance, facilitating movement from western Asia to western and northern Europe within the biological and ecological zone bordered by the Alpine-Himalayan mountain belt.

Dennell, Martinon-Torres and Bermudez de Castro (2011: 1519-20) think of the Pleistocene refugia more like ‘life-boats’ than ‘arks’. They find it quite unlikely, that hominins (and other mammals) would have simply moved/relocated to southern areas during periods of climatic/environmental stress, given that their biological productivity would have dropped as conditions worsened. Instead, they believe that local populations (southern or lowland) had a better chance to survive within the space of those southern refugia. This view is structured upon the demographic theory of ‘source’ and ‘sink’ populations, originally developed by Pulliam (1988) on a theoretical ecological basis. To put it simply, the growth and/or the decline of a population in a specific area, is highly affected by variations in the habitat and the natural surroundings. In a population ‘sink’, the average rate of reproduction is below replacement levels, while in a population ‘source’ the average reproduction rate is above replacement levels. This means that the population within a ‘sink’ will remain viable, and the area populated, only if migrants from other areas, i.e. a population ‘source’, continuously reinforce this locally declining population. In recent studies, researchers are starting to reassess and test the ‘source’ and ‘sink’ population dynamics and envision the Balkan peninsula, in particular, as a core area, hosting source populations (Roksandic, 2016: 29-30; Spassov, 2016: 282) and as a transitional zone for the repopulation of northerly areas during interglacials (Michailovic and Bogicevic, 2016: 150).

3.4 Tracing early hominin movements across Eastern and South-Eastern Europe

Traditionally the initial peopling of Europe (Lower Pleistocene) has been associated with a direct dispersal from Africa at ca. 1.8 Mya through the Levant and the Peri-Pontic pathway (around the Black Sea) (Arribas and Palmqvist 1999; Martínez-Navarro 2010; Palombo 2010). More recently, an alternative scenario has been put forward proposing a dispersal by a secondary nuclei of populations located in the Trans-Caucasus—Asia Minor area through again the Black Sea routes and /or the Balkans (the Trans-Marmara and/or the Trans-Aegean pathway) (Spassov 2016; Strait et al., 2016) (fig. 3.6). This second scenario probably represents a later event within the Lower Pleistocene at ca. 1.3-1.2 Mya. A third scenario (Rolland 2013) proposes the idea that Europe was populated by converging populations originating from two ‘staging-posts’ in western Asia and the Ibero-Morrocan area, thus dispersal(s) happened via two dispersal routes that were used independently and not necessarily during the same periods. The latter scenario is based on the spatiotemporal discontinuities observed in the early presence of hominins in the European continent. Secure dates, prior or around 1 Mya, come from the western part (Iberian sites 1.3-1.4 Mya, French sites ≥ 1 Mya, UK sites 0.9-0.8 Mya) and the eastern part (Levantine Corridor 1.5-0.9 Mya, Transcaucasia 1.8-0.8 Mya). For central Europe, however, much later dates are available (around 0.6 Mya but not prior to 0.85 Mya) - possibly representing an area that was reached later on by populations that were first established at eastern and western Europe.

Abundant faunal evidence from western and south-eastern Europe support the second scenario, weakening the direct African origin and showing clear evidence of an Asiatic fauna - and/or species that might have originated in Africa but had an Asian period of evolution - expanding to the west, around 1.3-1.2 (Koufos and Kostopoulos, 2016: 277; Spassov, 2016: 283); this is in good chronological agreement with early evidence for the hominin presence in Europe prior or around 1 Mya (Jöris 2014), pointing to the 'long chronology' scenario for the initial peopling of Europe. It is worth making a comment here regarding the origins of the hominin populations from the southern Balkans. Recent analyses of palaeoanthropological remains from the wider Aegean region give mixed signals. For the Megalopolis and Petralona specimens, African affinities have been proposed, suggesting a direct link to Africa during the Middle Pleistocene and possibly earlier (Harvati 2016), while the Kocabaş fossil, dated to the early Pleistocene, has been associated with the Asian *Homo erectus* (Aytek and Harvati 2016). However, hominin remains from this part of Eurasia are few, and these results should not be viewed as suggestive of specific patterns, but rather as an indication of the multifaceted nature of the dispersal events during the earlier parts of the Pleistocene.

3.4.1 The Out of Asia Scenario

The Plio-Pleistocene faunal record shows that most of the newly arrived forms in the Balkans originated from Asia and only a small number of taxa had African origins (e.g. Ethiopian species found in Apollonia and Ravin de Voulgarakis-Greece; Kostopoulos, Vassiliadou and Koufos, 2002: 273). Besides, in general, few faunal sites in Eurasia have yielded clear African affinities. Such affinities have been documented in the faunal asemblages from Ubeidiya – Israel, Dmanisi and Akhalkalaki – Georgia, Venta Micena, Fuente-Nueve 3, Baranco Leon – Orce, Spain, Cueva Victoria – Spain, Pirro Nord – Italy, Sainzelles – France (Martínez-Navarro et al., 2010: 210, 218). O' Regan et al., 2011 (1350) emphasise that, in fact, much more movement can be observed between Asia and Europe than Africa and Europe so that the predominant pattern of faunal dispersal in Afro-Eurasian Pliocene and Pleistocene followed an east-west rather than a north-south axis.

More recently, comparative analysis between faunal assemblages from sites bearing evidence of early hominin presence (lithics and/or fossils) in Eurasia (Koufos and Kostopoulos 2016; Spassov 2016) provided further evidence for a pronounced association between early hominin sites in Europe and specific Asiatic faunas. This observation has important implications for our understanding of hominin's dispersal routes and diffusion patterns, the timing of these events, the palaeoenvironmental conditions and preferential habitats. Koufos and Kostopoulos (2016) compared faunal taxa from Dmanisi, Atapuerca and other early hominin sites in western Europe, with the Greek faunal Plio-Pleistocene record, showing a *"preferential association (of hominins) with a particular Asian herbivore assemblage of a specific habitat (i.e., semi-open savannah type ecotonal and mosaic landscapes)"* (Koufos and Kostopoulos 2016: 276) . These assemblages include Asian species (e.g. bisons, caprines-ovibovines, megacerines/deer, wolf-like canids) and species, possibly African in origin but with an Asian period of evolution (e.g. *Megantereon, Panthera* and *Pachycrocuta*). Spassov (2016:286), in agreement with Koufos and Kostopoulos (2016), confirms the association of these faunas (and possibly hominins) with open landscapes and forest-steppe mosaic biotopes or open forests.

These types of habitats are starting to appear in south-eastern Europe and western parts of the continent by 2 Mya, when the aridification trend was initiated after the Meria cooling event (Spassov 2016: 286), and prevailed between 1.3-1.2 Mya. South-East Europe, in particular, was affected by gradual deforestation (as shown in previous sections) and also by the refreshing of the Black Sea that turned into a lake and the temporary closure of the Bosporus that permitted a faunal interchange between Europe and Asia (ibid). During the glacial sea-level low stands and the isolation from the Mediterranean Sea, dry areas over the northern and central part of the Aegean, possibly enabled further the dispersal process (Lykousis 2009; Sakellariou and Galanidou 2016; 2017)

Faunal evidence from Italy and France suggests that at the same period (during the Late Villafrachian/ Epivillafranchian) more wooded areas occurred in this part of Europe in comparison to eastern Mediterranean (Sardella et al., 2018). Probably, this slower pace of the deforestation is the reason behind the recorded delay in the westward expansion of carnivores and herbivores that appear in western European sites almost 500 ka after their first appearance in Dmanisi at ca. 1.8 Mya (e.g. the pan-European expansion of Megantereon happened between 1.4-1.0 Mya while the bison expansion happened between 1.6-1.0 Mya). The retention of more forested habitats in western Europe might have prevented or delayed their expansion (Koufos and Kostopoulos, 2016: 276). The same reasoning could also explain the first delayed appearance of hominins in Europe (at ca. 1.4 Mya in Iberia compared to ca. 1.8 Mya at Dmanisi), given their preferential association with the particular faunas, found in specific habitats (ibid). This is further confirmed by palaeobiogeographic markers (e.g. densely forested Dinaric Alps in relation to the late arrival of hominins in the Italian peninsula; Croitor 2018: 283).

3.4.2 Dispersal events to Eurasia during the Early Pleistocene

Spassov (2016) identified two possible hominin dispersal waves to Europe for the time-period between 2 and 1.2 Mya, through the comparative analysis of palaeofaunal remains found in association with early evidence for the hominin presence in southern Europe and western Asia.

The fisrt event has been linked with the transitional Middle/Late Villafranchian fauna (MNQ18/MNQ17) from sites with suggested hominin evidence dated at ca.2 Mya (Chilhac 3-S. France 2.3 – 1.9, Lézignan-le-Cèbe – S. France 1.57 Mya, Valdarno region - N. Italy 1.95 Mya, Dealul Mijlociu /Valea Graunceanului (Oltet Valley, Romania) 1,9-1.8 Mya, Kermek (Azov sea region, S. Russia) ca. 2 Mya, Bogatyri/Sinyaya Balka and Rodniki 1.6/1.5–1.2 Mya). Populations would have possibly originated directly from Africa and reached Eurasia following the Levantine corridor and then they could disperse further in western Europe via the northern peri-Pontic routes (around the Black Sea) (fig.3.6). The main problem with this scenario is that the supporting archaeological evidence is weak. The nature of the finds (lithics), from the sites mentioned above, as actual cultural remains and/or their chronological attribution to the earlier Early Pleistocene remain highly controversial and in some cases have been openly contested (Spassov 2016: 284). Only the Avoz region localities could be seriously considered for offering solid archaeological evidence securely dated to the Early Pleistocene (Shchelinsky et al., 2010; 2016). With the exception, perhaps, of Pirro Nord (dated between 1.6-1.3 Mya based on biochronology) (Arzarello and Peretto 2010; Arzarello et al., 2015), similar evidence, older than 1.4 Mya, from W. Europe is currently missing. As such, the hypothesised earliest dispersal event at about 2 Mya does not seem to have included hominin species that reached the western parts of the European continent, at least not according to the available archaeological record. Besides, hominin populations could not have been long-lasting at this stage and at this part of Eurasia taking into account the different environmental conditions and habitats compared to their original African ones (Dennell 2003).

The second and more plausible dispersal wave has been associated with the Late Villafranchian / Epivillafranchian faunal turnover, evidenced mainly in southern Europe: Barranco León (Orce, Spain) 1.4-1.2 Mya; Sima del Elefante (Atapuerca, Spain) 1.2-1.1 Mya; Kozarnika (Bulgaria) 1.6-1.4 Mya; Pirro Nord (Italy) 1.7-1.3 Mya; Bogatyri and Rodniki (Taman Peninsula, Azov sea region) 1.6/1.5-1.2 Mya. For the second migration wave, a different process has been hypothesised (Spassov 2016). After a period of local evolution in south-western Asia for some species (including hominins perhaps) coming originally from Africa, the extensive aridification fuelled a further expansion to the west, when suitable habitats (i.e. semi-open savannah type ecotones and mosaic landscapes) prevailed there around 1.3-1.2 Mya. This is correlated with the Late

Villafranchian/Epivillafranchian faunal turnover. Populations then dispersed into western Europe, either following the Black Sea routes, and/or through Asia Minor and the trans-Marmara (Bosporus), and/or the trans-Aegean pathways (fig.3.6). This second wave is considered to have more survival opportunities across the favourable habitats of southern and eastern Europe. Environmental variability must have had an important impact on movement patterns. Highly diverse ecotones, and consequently high variety of food resources, possibly facilitated the presence of hominins in Europe during this phase (Jöris 2014). From 0.9-0.4 Mya onwards the hominin presence seems to be more pronounced and continuous in the southern European peninsulas, while a sporadic presence is recorded in the northern regions mostly during interglacials (Jöris 2014; see also Garcia et al's. (2013) arguments for well-established hominin populations in Europe by 1 Mya).

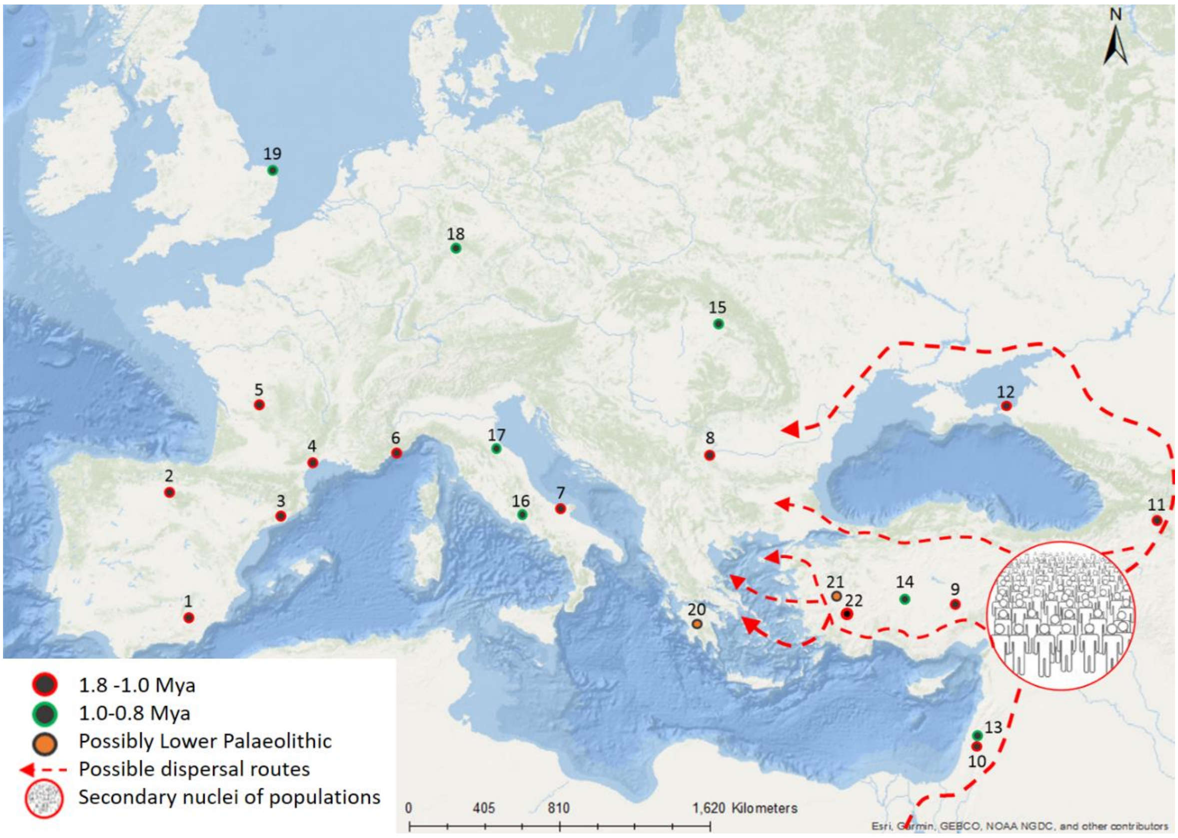


Figure 3.6. Possible dispersal routes via eastern and north-eastern Mediterranean during the Early Pleistocene. The secondary nuclei of populations, associated with the westward migration of Asiatic fauna (ca. 1,2-1,3 Mya), possibly located in the Trans Caucasus - Asia Minor area. Key archaeological/palaeoanthropological sites dated to the Early Pleistocene: 1-Orce, 2- Atapuerca, 3- Vallparadis, 4-Bois de Riquet, 5-Pont de Lavaud, 6-Le Vallonet, 7-Pirro Nord, 8-Kozarnika, 9-Kaletepe Deresi 3, 10-Ubeidiya, 11-Dmanisi, 12-Kermek/Rodniki/Bogatyri, 13-Gesher Benot Ya'aqov, 14-Dursunlu, 15-Korolevo, 16-Arce, Colle Marino, Fontana Liri, 17-Ca' Bellevedere de Montepoggiolo, 18-Untermassfeld, 19-Happisburg, 20-Megalopolis, 21-Gediz find-spot, 22-Kocabaş. Geospatial data as in fig. 3.1

3.4.3 The ecological background of the early long-distence hominin dispersals

The first long-distance hominin dispersal events out of Africa and into Eurasia (and vice-versa), are viewed here as an ecological process, which involves movement of small groups (separated from the native group) into a new area, where they will reproduce and settle (in accordance with the definition provided by Prat 2018: 3). These movements occurred in an opportunistic and nomadic manner, with no predetermination or predefined direction, and possibly they had been conditioned by environmental parameters (environmental change and food availability), as well as demographic parameters (population growth and competition over resources) (Prat 2018; Wren et al., 2014). The early events, included multiple and multidirectional sub-events, some being successful and others unsuccessful - with several turning back episodes, at first occupying adjacent areas with available and viable resources and gradually moving farther (for estimations on distance covered by the early *Homo* dispersals over time see table 1 in Prat 2018). It has been argued that early *Homo* was ecologically sensitive following a more stenobiont biological and ecological strategy (relying on relatively constant environmental conditions compared to other carnivores) therefore, its dispersal had been greatly affected by environmental factors (Croitor 2018: 277). The Alpine-Himalayan mountain belt marked the northernmost limit of the early Eurasian hominin distribution, corresponding to a zone with relatively stable environments during the Early Pleistocene. On the other side of the coin, it has been suggested that early hominins were more versatile rather than specialised animals (Prat 2018). They had the ability to adapt in changing environments with different resources, and this gave them an advantage as they were dispersing into new areas (based on the variability selection hypothesis proposed by Potts 1998). Perhaps hominin versatility in combination with the opportunistic character of their dispersals, might explain why early *Homo* appear to be frequent in occurrence and highly distributed, though in low abundance, in comparison to other Early Pleistocene mammalian species (Rodriguez et al., 2015).

Leroy et al. (2011) identified 42 windows of favourable – to optimum – climatic and vegetation conditions for hominins to disperse during the glacial-interglacial transitions of the Early Pleistocene. Despite their versatility, hominins seem to have low tolerance to climatic variability, as suggested by the clustering of early European sites in areas that fall within narrow ranges of summer precipitation and temperature of the coldest month, according to the model proposed by Leroy et al. (fig.3.5). This indicates quite a particular range of favourable conditions that would have included temperate climate (not too cold – as during the glacials, not to humid – as during the interglacial-glacial interval) and open environments (open woodlands and warm grasslands, as opposed to densely forested landscapes characterising the interglacial – glacial interval). The model aligns with other evidence, presented here and suggesting that the first hominin occupations in the European continent must have had an intermittent nature. Once climatic and vegetation conditions fell out of the narrow, favourable range, hominins are expected not to be able to cope successfully with these changes, at least not before certain biological and cultural adaptations appear in the record (e.g. control of fire). This is perhaps reflected as well in the extensive spatiotemporal gaps found in the archaeological and paleoanthropological archive for the Early Pleistocene. The gradual increase in the presence of hominins and the density of their distribution in western Europe from around 1.2-1.3 Mya onwards has been associated with the specific favourable climate and environmental conditions marking the Late Villafranchian/Epivillafranchian interval.

3.5 Concluding remarks

Faunal evidence from the Early and the Middle Pleistocene (2.6-0.2 Mya), offer valuable insights into environmental and climatic conditions during the early dispersal events, and the interactions between hominins and the rest of the faunal community with their habitats. The dispersing process was largely conditioned by environmental stimuli and controlled by biogeographic and palaeogeographic parameters. The changing landscapes in eastern and north-eastern Mediterranean, with the temporal closure of marine crossings and the exposure of landmasses during the glacial lowstands, is an important element of the palaeogeography that needs to be embedded in the dispersal scenarios for the Early and Middle Pleistocene. In this respect, the Aegean in particular is emerging here as a core area with high potential. The exposed Aegean landscapes, from at least MIS 10-12 (and possibly before) until at least MIS 8, offered dry and inhabitable lands, with riverine and lacustrine environments (Lykousis 2009; Sakellariou and Galanidou 2016; 2017). These lands could be crossed potentially by hominins (along with other fauna) via multiple terrestrial passages connecting western Anatolia with mainland Greece and western Europe, at least during the cold phases (and possibly during certain interglacials MIS 11-9) of the Early and Middle Pleistocene, within a refugial zone with viable resources and optimum conditions for survival and dispersal.

Chapter 4 The Aegean geotectonic evolution and palaeogeography

4.1 Introduction

The Aegean, within the wider Eastern Mediterranean region, has been an active – thus a dynamic – landscape since the Miocene (ca. 24-25 Mya) and throughout the Plio-Quaternary (ca. 5.3 Mya – Present) (Angelier 1978; Le Pichon and Angelier 1979; Taymaz, Jackson and McKenzie 1991). Consequently, it is one of the most rapidly deforming areas of the world (Jackson 1994). This long history of ongoing deformation relates to the complicated tectonics and the intense volcanic activity. The geotectonic characteristics, plate kinematics and faulting processes in this region have been well studied, establishing a relatively good understanding of the mechanisms shaping past and present landscapes in this area. Many different transformation factors (subsidence, uplifting, sedimentation, erosion, sea-level fluctuations) have been active, onshore and offshore, leading to great spatiotemporal variability, fragmentation and heterogeneity. The overall result resembles "*a geotectonic puzzle*" (Mascle and Martin, 1990: 276), dominated by the alternating succession of uplifted and subsiding blocks. The topographic fragmentation is reflected in the morphology of continental Greece, but it is also observed in the Aegean underwater geomorphology, where the morpho-structural characteristics (such as basins, ridges, plateaus, rifts, and troughs) form a setting with bathymetric irregularities (Poulos, 2009; Maley and Johnson, 1971).

The geomorphic processes attached to the geotectonic evolution, have a negative effect on the preservation and availability of the Lower and Middle Pleistocene material over the Aegean region, as discussed thoroughly elsewhere (Tourloukis 2010; Tourloukis and Karkanas 2012b). However, until very recently, the research interest was focused on land, where such processes have visible results i.e. visible geomorphic features, while the offshore strand mainly included extensive research on sea-level changes and coastal palaeogeography (Van Andel and Schackleton 1982; Lambeck, 1996). Whilst sea-level fluctuations have an important impact on the configuration of the palaeolandscape and its changes through time, during the Lower Palaeolithic extensive exposed lands prevailed over the northern and central Aegean. Terrestrial environements occupied the area not only during the glacial periods of the Middle Pleistocene but possibly throughout the glacial-interglacial oscillations, from at least MIS 10-12 to MIS 8-9 (480-250 Kya) without interruption (as proposed by Lykousis 2009 – see section 4.5.4). The palaeocoastline of the extended Aegean coincided with the southern Aegean Volcanic Arc, to the south of the study area. My research interest here focuses on the period(s) when land was exposed at maximum over the Aegean region, and in this respect sea-level fluctuations will not be considered. The northern and central parts of the area now covered by the Aegean Sea are being treated throughout this thesis as a terrestrial landscape for the given period of time.

There are few palaeogeographical reconstructions for the Pleistocene Aegean, and this paucity clearly reflects a biased context. Available information (chronological, stratigraphic, palaeoenvironmental etc.) covers sufficiently the last glacial cycle (about the last 120 Ka), with the majority of evidence referring to the Last Glacial Maximum (LGM hereinafter). For the earlier parts of the Pleistocene, only rough approximations could be made. Lykousis (2009) addressed this, proposing a palaeogeographical reconstruction for the Aegean and Ionian Seas for the last 400 Ka, with serious archaeological implications. Sakellariou and Galanidou (2016; 2017) explored further the Middle and Late Pleistocene submerged landscapes of the Aegean and their affordances. Under the light of these reconstructions, the Aegean region is now emerging as a new arena for Lower Palaeolithic research, possibly holding valuable information for the hominin presence and activity during the Middle (and potentially the Early) Pleistocene.

The focus in this chapter is the archipelagic area between the North Aegean Trough to the North, and the Cretan basin to the South, and the geotectonic evolution of the submerged landscapes under the Aegean Sea; especially the parts that were subaerially exposed during the Middle and possibly during the Early Pleistocene. Along with the geotectonic history, the volcanic activity will be reviewed, focusing on the offshore evidence, and available palaeolandscape reconstructions will be discussed. The distribution of knappable volcanic materials and palaeoenvironmental features – mainly fresh water resources – is of particular interest, due to hominins' preferential association with such features, as documented during the Lower Palaeolithic. The aim here, is to provide a comprehensive background on the evolution of the Aegean palaeolandscape and its affordances, in order to (a) understand the taphonomic control over preservation and accessibility of the archaeological/palaeoanthropological material in the study area, (b) identify potentials and limitations of available reconstructions, and consequently (c) evaluate their contribution in modelling hominin activity and mobility across the Early and Middle Pleistocene Aegean landscapes.

4.2 Geodynamic evolution

In this thesis, the modern Aegean landscape is being treated as a source for deducing information about the nature of the Lower Palaeolithic landscape and its effect on hominins' interactions with their surroundings (following the complex topography concept introduced by King and Bailey

2006, see Ch.5). In this respect, this is a landscape archaeology approach (as defined by Hu 2011: 80). Despite the fact that the Early and Middle Pleistocene landscape represents only one facet in the long history of the geotectonic evolution of the Aegean, understanding the chain of processes that shaped this landscape through time, the nature of its features (e.g. changing and stable elements) and the availability of natural resources (e.g. fresh water) diachronically, is key in order to apply the approach followed here.

Two main factors have been controlling the geotectonic evolution of the Aegean: tectonic extension and magmatism. Both are the products of the convergence between the African and the European continental plates along the Hellenic Trench (South Aegean), causing the gradual removal of the Mesozoic Tethys Ocean (Le Pichon and Angelier 1979; Robertson and Dixon 1984; Robertson and Mountrakis 2006). This ongoing process, started during the Oligo-Miocene (ca. 24-25 Mya), and has been identified as the driving force behind the complicated interaction between the tectonic plates within the wider region i.e. the African, the Eurasian and the Arabian (Taymaz, Yilmaz and Dilek, 2007).

The African plate is subducting (at the currently fast rate of 5 mm a^{-1}) underneath the Hellenic Arc (Southern Aegean Sea) in a NNE-ward direction (Jackson 1994: 265). A continental collision (Arabian-Eurasian plates) in Eastern Turkey and Caucasus – in combination with the aforementioned subduction – forces the Turkish/Anatolian microplate to move SW-ward (McKenzie 1972; Jackson 1994; Taymaz, Jackson and McKenzie 1991; Taymaz, Yilmaz and Dilek, 2007; Dilek, Altunkaynak and Öner 2009) (fig.4.1). The collision of NW Greece with the Apulian block (north of the Kephallonia fault; Mercier et al., 1989) resists the westward motion of Turkey, forcing the Aegean to move SW-wards and override the Mediterranean oceanic crust, causing at the same time continental shortening and thickening along the Ionian Sea and the western parts of mainland Greece (Jackson 1994: 263). The incipient collision with the Lybyan promontory south of Crete should also be added in the main active processes (McKenzie 1978; Sakellariou, Mascle and Lykousis 2013) (fig.4.1). The development of antithetical forces/stresses between the adjoining plates has led to the deformation of the continental and oceanic crust, causing extensive seismicity (expressed with normal, reverse or strike-slip faulting) and volcanic activity across the Aegean and Anatolia (Taymaz, Yilmaz and Dilek 2007).

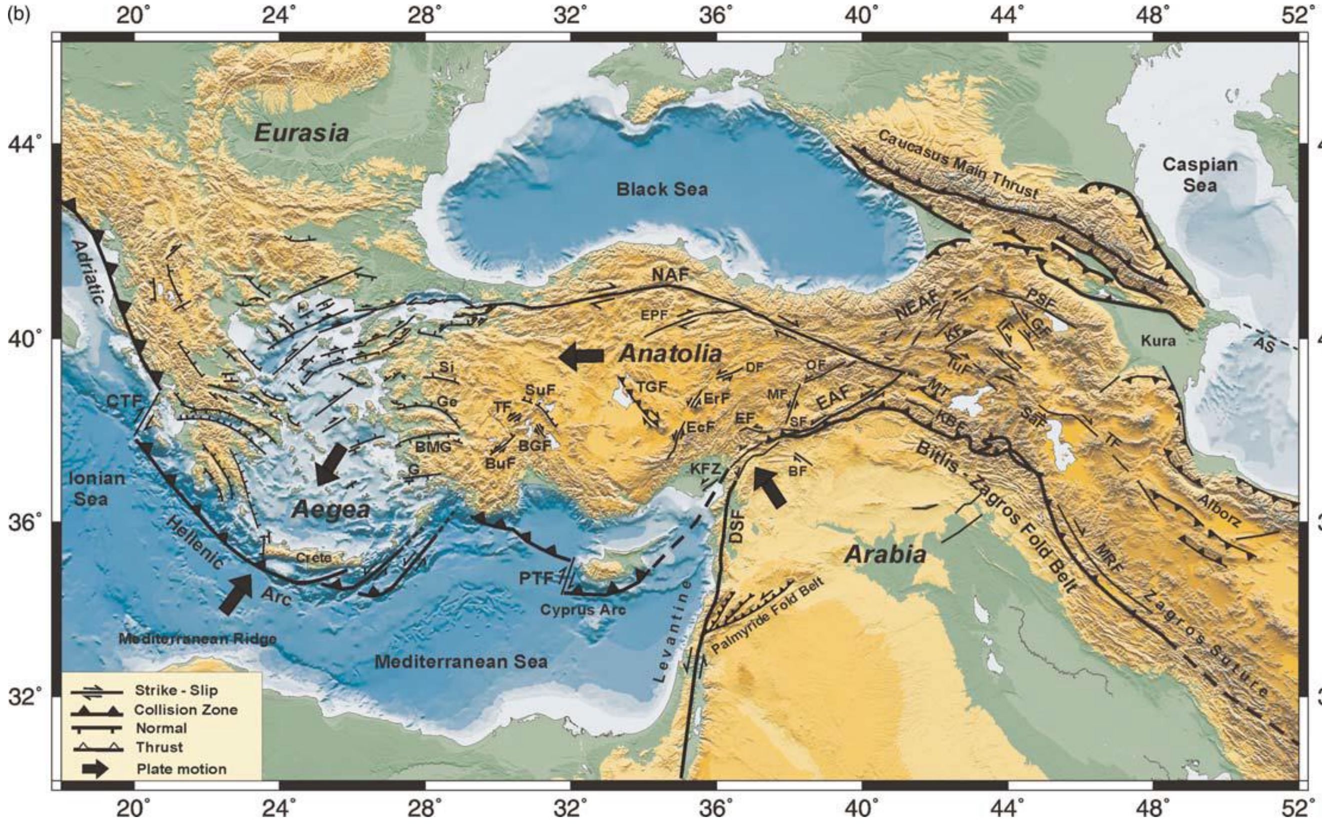


Figure 4.1. Synthetic map with the main tectonic structures in Eastern Mediterranean (from Taymaz Yilmaz and Dilek 2007: fig. 1b). NAF: North Anatolian Fault, EAF: East Anatolian Fault, DSF: Dead Sea Fault, NEAF: North East Anatolian Fault, EPF: Ezinepazari Fault, PTF: Paphos Tranform Fault, CTF: Cephalonia Transform Fault, PSF: Pampak-Sevan Fault, AS: Asheron Sill, GF: Garni Fault, OF: Ovacik Fault, MT: Mus Thrust Zone, TuF: Tutak Fault, TF: Tebriz Fault, KBF: Kavakbas 1 Fault, MRF: Main Recent Fault, KF: Kağizman Fault; IF: Iğdir Fault, BF: Bozova Fault, EF: Elbistan Fault, SaF: Salmas Fault, SuF: Surğu Fault, G: Gokova, BMG: Büyük Menderes Graben, Ge: Gediz Graben, Si: Simay Graben, BuF: Burdur Fault, BGF: Beyşehir Gölü Fault, TF: Tatarli Fault, SuF: Sultandüg Fault, TGF: Tuz Golü Fault, EcF: Ecemis Fault, ErF: Erciyes Fault, DF: Deliler Fault, MF: Malatya Fault, KFZ: Karatas-Osmaniye Fault Zone

The Aegean Sea region experienced subduction-related extension, due to the processes described above, and essentially, it evolved as an extensional back-arc basin (Angelier 1978; Robetrson and Mountrakis 2006: 6; Dilek, Altunkaynak and Öner 2009: 197; Kastens 1991). The extension started as early as ca. 25 Mya (Jackson 1994:242). Based on marine, geological and palaeomagnetic evidence, the Aegean subduction probably started around 13 Mya (Le Pichon and Angelier 1979) or perhaps even earlier around 16 Mya – i.e. at the same time when the Mid-Upper Miocene Ionian Arc started to develop in NW Greece (Mercier et al., 1989). The Aegean Extensional System/Province i.e. the actively deforming part of the Aegean, including Greece, Republic of North Macedonia, Bulgaria, Albania and SW Turkey, extends in an area of approximately 700 x700 km^2 (Jackson 1994: 239). This deforming area is bordered by four major geotectonic structures that are responsible for the present configuration of the region (Sakellariou, Mascle and Lykousis 2013) (fig.4.2):

- The North Aegean Trough (NAT): the westward extension of the North Anatolian Fault system (NAF) into the Aegean Sea. It defines the boundary between the relatively non-deforming Eurasian continent to the north and the deforming Aegean to the south.
- The Hellenic Trench: the southernmost border of the deforming Aegean (i.e. the Aegean extensional province); it is formed by deep, elongated basins aligned along the Hellenic Arc. The North Anatolian Fault system (NAF), and within it the North Aegean Trough (NAT) and the Hellenic Trench in particular, should be highlighted as key-features within the Aegean Extensional System, as they probably relate to the actual mechanisms that drive the extension (Taymaz, Yilmaz and Dilek 2007).
- The Kephallinia Transform Fault (KF): a SSW-NNE trending dextral strike slip fault that marks the boundary between the active (south part) and inactive (north part) zones of the Hellenic Arc.
- The Central Greece Extensional Zone/Central Hellenic Shear Zone: an area of active deformation due to extensional stresses; it works as a diffuse boundary between the Kephallinia fault and the North Anatolian Fault.

Despite the fact that the extensional regime prevails in the Aegean, the tectonic history of the region appears to be much more complicated and polyphase (Angelier 1978: 26). The direction of the stresses affecting the Aegean shifted through time, enhancing the effect of division and fragmentation (uplifted-subsiding blocks). Three successive tensional stress directions have been identified (Mercier et al., 1989: 67): (1) WNW-ESE, (2) NE-SW and (3) N-S, which were active during the Upper Miocene, Pliocene - Lower Pleistocene and Mid Pleistocene-Present day, respectively.

The most recent phase of the geotectonic evolution of the Aegean started during the Pliocene (ca. 5 Mya). During the Plio-Quaternary, extension expressed through large normal faults divided the Aegean into raising and subsiding blocks (Angelier 1978). During the Early Pleistocene, compressional stresses of various directions invaded again (after the Late Miocene compressional phase) the central and northern Aegean. All currently active seismic structures are the products of that latest phase. Between 0.8-0.3 Mya a change in the stress regime has been observed: from NE-SW (south-central Greece) and N-S (Turkey) during the Pliocene-Early Pleistocene, to NNW-SSE (north-central Greece) and NE-SW (western Turkey) from the Middle Pleistocene to the present day (Angelier et al., 1982; Mercier et al., 1989; Duermeiger 2000: 516-17). This shift affected central (continental) Greece and the southern Aegean. The rapid rifting in the Gulf of Corinth and the opening of the Megara basin occurred around the same time (i.e. beginning of the Middle Pleistocene> 0.9/0.8-0.2 Mya) (Duermeiger 2000: 516-17), while the outer Aegean Arc had also been drastically affected by uplifting around 1 Mya (ibid).

In contrast, Western Greece and the Ionian Sea were mainly affected by compressional stresses (folding and thrusting) during the Early Pliocene (Le Pichon and Angelier 1979:19). The compressional features (reverse faults and folds) have a very strong presence in this area reflecting the continuation of the compression regime throughout the Pleistocene and Quaternary – and especially during the earliest Pleistocene (McKenzie 1978: 236; Le Pichon and Angelier 1979: 19). This regime is directly related to the extensive uplift that the western coast of mainland Greece and Ionian Islands have been subjected to (Caputo, Panza and Postpischl 1970; Doutsos, Kontopoulos and Frydas 1987). It is worth mentioning that despite the pronounced compression, the uplift (NE-SW) of the Ionian Islands was accompanied by a similarly directed extension in south-western Greece (van Hinsbergen et al., 2006: 463). From the middle Pliocene onwards (around 3.5 Mya) antithetical extensional stresses (NW–SE to N–S extension east of Apulia and E–W extension in the south) affected the wider SW continental Greece and Ionian Sea, creating curved extensional basin systems, such as the Gulf of Corinth – Saronikos Gulf system and the Gulf of Amvrakikos – Sperchios basin – Gulf of Euboea system (ibid).

During the late Pleistocene and the Holocene an extensional tectonic regime returned in the Aegean and until the present day it remains predominant (Angelier 1978).

4.3 General morphology of the Aegean Sea

The current bathymetry of the Aegean Sea is well described in several detailed studies (Maley and Johnson 1971; Mascle and Martin 1990). As the technology progresses and seismic reflection profiling methods advance, more details have been added, enabling a better understanding of the tectonics and volcanism related to the formation and the nature of underwater structures (Papanikolaou et al., 2002; Sakellariou, Mascle and Lykousis 2013; Nomikou et al., 2013; Sakellariou and Tsampouraki-Kraounaki 2016; 2018). A three-part division (three main areas/domains) for the Aegean has been established (but see Sakellariou and Galanidou 2016 for an alternative division into nine parts) based on current bathymetric characteristics (fig.4.2). However, the boundaries between the domains differ in different studies. Here I follow Maley and Johnson (1971) version:

- The **North Aegean Sea** (NAS): is characterised by the presence of elongated and deep faulted basins, and the high tectonic influence of the westward prolongation of the North Anatolian Fault System (NAF).

- The Central Aegean Sea (CAS): is mainly occupied by the **Cyclades Plateau** (Central Aegean Plateau), a shallow and aseismic platform, bordered on its southern part by the Aegean Volcanic Arc.
- The **South Aegean Sea** (SAS): is the most extended part of the Aegean, where great depths can be found, possibly inactive now. The Cretan Island Arc stands out as a corridor of high relief – remnants of the Alpine orogenic processes/uplift. The southernmost part – where the Hellenic Trench System extends, is directly influenced by the convergence between the African and the Eurasian tectonic plates.

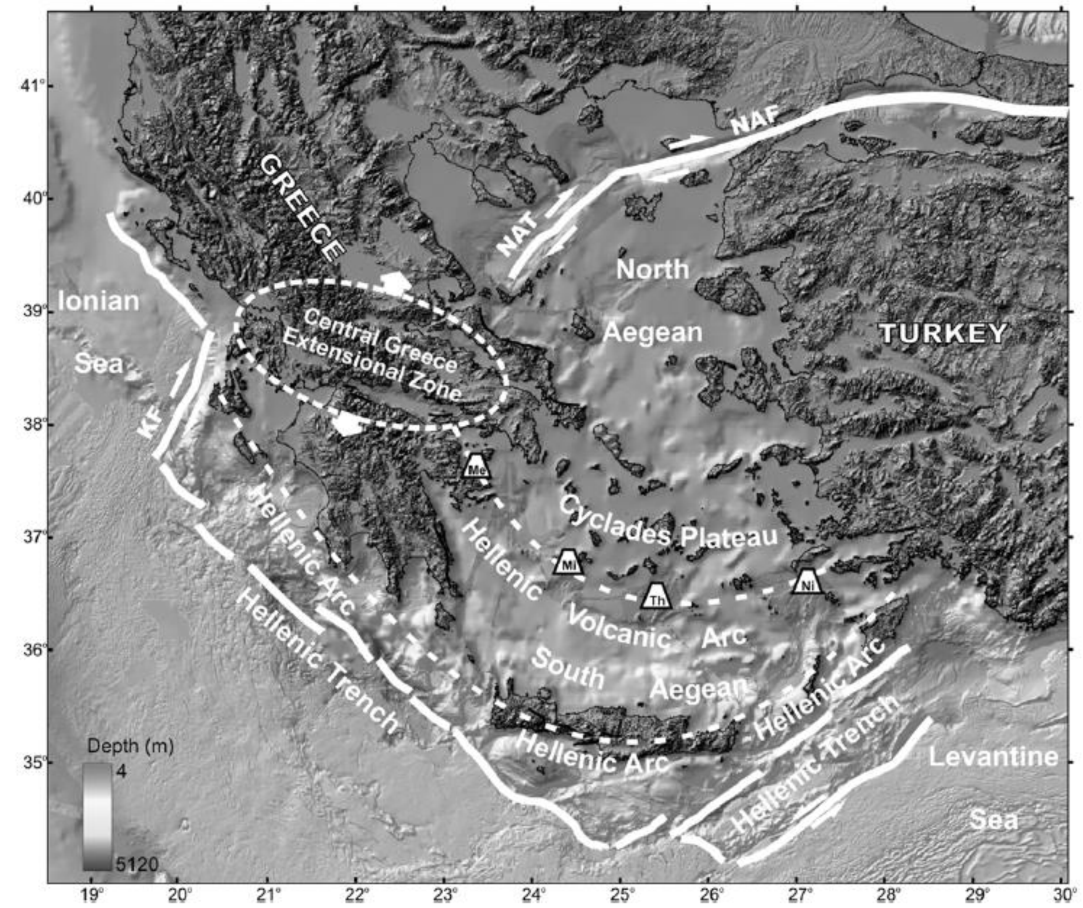


Figure 4.2. Main geotectonic features marking the Aegean boundaries. NAF: North Anatolian Fault; NAT: North Aegean Trough; KF: Kefallinia Fault; The Agean Volcanic Arc: Me: Methana, Mi: Milos, Th: Thera, Ni: Nisyros (from Sakellariou and Galanidou 2016: fig. 3)

4.3.1 The Northern Aegean Sea (NAS)

The Northern Aegean Sea has been shaped by a series of aligned and relatively deep depressions/basins (up to 1600 m). The development of the North Aegean basin started around Miocene (ca. 24-25 Mya) times and some parts of the area experienced uplifting until the Late Miocene-Pliocene (ca. 5 Mya) (Papanikolaou et al., 2002: 466). At this point, the westward prolongation of the North Anatolian Fault started, introducing the neotectonic activity in the North Aegean Sea (ibid). Since the Late Miocene, the wider northern Greece region has been dominated by extensional stresses and consequently subduction (Mountrakis et al., 2006). The directional axis shifted from NE-SW, during the Late Miocene-Early Pliocene, to N-S, during the Early Pleistocene to present (Mercier et al., 1989). During the first phase of that extensional activity, the formation of fault-bounded basins occurred (e.g. Drama, Strymonas, Axios Thessaloniki and Ptolemais) while during the second phase, E-W trending normal faults were activated, leading to the reshaping of the basins developed during the first phase (Mountrakis et al., 2006: 651).

A shallow shelf is observed along the northern margins of the NAS interrupted by a series of NW-SE trending wide gulfs that correspond to tectonically controlled basins (grabens). From west to east: the Gulf of Thermaikos, the Gulf of Orfanou, the basin at the mouth of Nestos River – Prinou basin and the basin below the shelf-margin east of Thasos (Mascle and Martin 1990: 277). Shallow continental platforms surround also the islands of Limnos and Imbros to the East and Sporades to the West (Limnos Plateau and Sporades Plateau).

The **North Aegean Trough** (NAT) is the predominant feature here. It developed along the westward prolongation of the North Anatolian Fault Zone since the early Pliocene (ca. 5 Mya) (Sakellariou, Mascle and Lykousis 2013). It is an elongated formation (NE-SW direction) constituted by a series of three depressions of variable depths (from 1600m to 500m), traversing the central area of the NAS (from East to West/SW: from the Gulf of Imbros to the Sporades basin) and broadening at its western extremity (fig.4.3). This transtentional basin, constitutes of two successive basins / branches, the Athos-Sporades basin (central part of the NAT south of the Chalkidiki Peninsula) with maximum depth of 1476m and the Limnos basin (eastern part that passes between Thasos and Samothrace islands to the north and Limnos and Imbros islands to the south) with maximum depth of 1469m (Androulidakis et al., 2012). This last part extends towards the Marmara Sea. At the westernmost termination of the North Aegean Trough, the **Sporades Basin** is formed, an asymentric basin bounded by three main directions of faults (Mascle and Martin 1990: 280) (fig.4.4). Along the southern branch of the North Anatolian Fault two basins have been developed, the **North and South Skyros Basins** and have been also controlled by the Skyros Trough (NW-SE trending, shallow arcuate trench system) (Maley and Johnson 1971: 116-7; Sakellariou, Mascle and Lykousis 2013) (fig.4.4).

The basinal structures of the North Aegean Trough are persistent topographic features throughout the Pleistocene and the Holocene despite the general trend of subsidence in the Aegean and the extensive sedimentation along the northern Aegean continental shelf (for sedimentation rates see Perissoratis and Mitropoulos 1989; Lykousis, Karageorgis and Chronis 2005). Palaeogeographical reconstructions for the Late Pleistocene (see section 4.5.3) show extended continental shelf and riverine environments, conditions that could be extended to the earlier parts of the Pleistocene. For the period MIS 10-12 (and before) until MIS 8 it has been proposed that the northern part of the Aegean was an exposed landscape and the basins of the North Aegean Trough hosted major water bodies (see section 4.5.4). The abundance of fresh water resources over the extended terrestrial landscape could offer attractive habitats to hominins during the Lower Palaeolithic and/or viable zones for movement (see the northern Aegean affordance corridor in Ch.7).

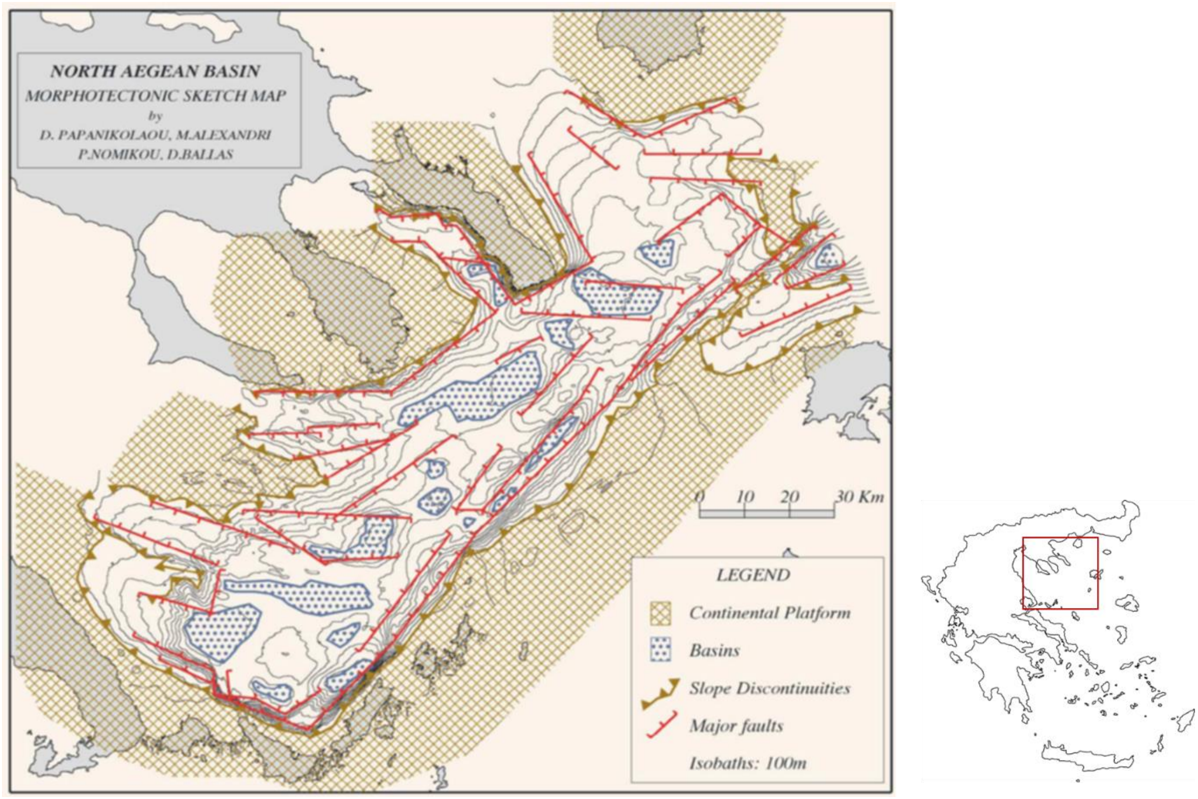


Figure 4.3. Morphotectonic sketch map of the North Aegean Basin (modified fig. 2 from Papanikolaou et al., 2002)

Two more basins on the SE part of the North Aegean Sea, the **Cavo d' Oro** and **Lesbos Basins**, related to the Cavo d'Oro-Lesvos Fault Zone (NE-SW orientation) and being in parallel alignment with the North Aegean Trough (NE-SW orientation) (fig.4.4). Further south, a third, similarly NE-SW trending fault zone separates the **North Ikarian Basin** from the **Mykonos Basin**, marking the south-easternmost border between the North Aegean Sea and the Central Aegean Sea (Maley and Johnson 1971) (fig.4.4). It has been suggested that several strike-slip faults and deep basins bounded by normal faults in northern and central Aegean have been shaped under the influence of the North Anatolian Fault Zone (Taymaz, Jackson and McKenzie 1991; Sakellariou, Mascle and Lykousis 2013).

The **Chios Basin** (depth from 400 m to 1160 m), between Chios and Euboea islands, marks the boundary between the North and the Central Aegean Areas (fig.4.4). It is the place where the water mass exchanges happen between the North Aegean Sea and Central Aegean Sea (Androulidakis et al., 2012: 55).

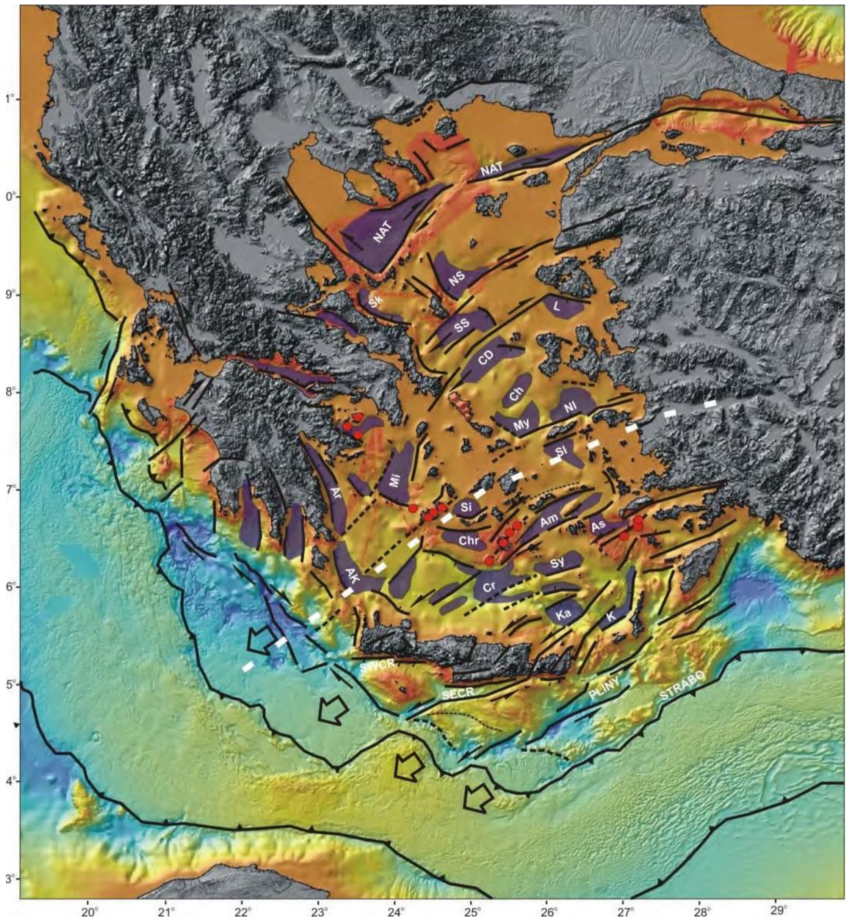


Figure 4.4. The main fault systems and basins/Plio-Quaternary depocentres (in purple) in the Aegean (from Sakellariou, Mascle and Lykousis 2013: fig. 8). The white dashed line marks the Mid-Aegean Lineament. NAT: North Aegean Trough, NS: North Skyros, SS: South Skyros, Sk: Skopelos, L: Lesvos, CD: Cavo d' Oro, My: Mykonos, NI: North Ikaria, Mi: Mirtoon, Ar: Argolikos, Si: Sikinos, Chr: Christiana, Am: Amorgos, Sy: Syrna, Cr: Cretan, Ak: Antikythera, Ka: Kamilonisi, K: Karpathos, SWCR: Southwest Cretan Trough, SECR: Southeast Cretan Trough

4.3.2 The Central Aegean Sea (CAS)

The Central Aegean Sea is the area bordered by the coasts of mainland Greece to the west, the coasts of western Anatolia to the east, the southern margin of the NAS to the north and the **Aegean Volcanic Arc/ Cyclades Arc** to the south. It is a wide and shallow (average depth 200 m) submerged platform, frequently referred to as the **Cycladic Plateau**, which is characteristically aseismic (McKenzie 1972: 139; Maley and Johnson 1971: 114-6) (fig.4.2). However, the area presents structural complexities as it has been fractured by variously oriented normal faults indicating extensional processes (McKenzie 1978; Mascle and Martin 1990; Sakellariou, Mascle and Lykousis 2013).

The Central Aegean Sea could be divided in two domains, each demonstrating distinctive structural characteristics due to analogous tectonic stresses. The Western/Hellenic sector lies along the coast of mainland Greece, including parts of the Cyclades islands (Euboea, Andros and Mikonos to the southwest, and Skyros and Psara to the northeast), and the Eastern/Anatolian sector lies along the Anatolian coast and neighbouring islands.

The western part is a relatively flat area interrupted by three main depressions/basins controlled by normal faults (trending WNW-ESE along the northeastern Euboea and NW-SE south of Skyros) and possibly by strike slip faults (trending NE-SW north of Andros) (Mascle and Martin 1990: 283). The eastern part is dominated by clearer trends expressed in NE-SW trending gulfs, which are basically the offshore extensions of the Neogene grabens of Edremit, Izmir, and Menderes towards the central Aegean (McKanzie 1978: 232; Mascle and Martin 1990: 284). The Lesbos-Psara basin system is the extension of the Izmir graben, the Samos - Ikaria basin relates to the Menderes graben, and two smaller basins (north of Lesvos and east of Skyros) are the westernmost extension of the Edremit graben (ibid). Further south, the Gulf of Bodrum (between Kos and Marmaris peninsula) has an east-west orientation (Mascle and Martin 1990: 268).

One of the major structures within the Central Aegean Sea is the Aegean Volcanic Arc/Cycladic Arc (fig.4.2). It is a marginal structure, developed along the southern boundaries of the Cycladic Plateau (Le Pichon and Angelier, 1979; Papanikolaou et al., 2002) and lies parallel to the Cretan Basin. The Volcanic Arc is vitally related to the subduction of the African Plate underneath the Eurasian (Mountrakis et al., 2006: 651), as it is considered to be the surface expression of that process (Fytikas et al., 1984: 687; Caputo et al., 1970). The melting of the subducting African plate, caused the rising of magma and the consequent formation of active volcanoes along an arc structure (500 km long) in the southern Aegean (Sakellariou and Galanidou 2016). According to Fytikas et al. (1976: 30) it is rather a volcanic belt, with a double-arc structure formed by two arcs: the outer volcanic arc (Crommyonia-Methana-Milos-Santorini-Nysiros) and the inner volcanic arc (Thebes-Achilleion-Likades-Antiparos-western part of Kos). It consists of active volcanoes (i.e. Methana, Milos, Santorini, Nisyros) and fumaroles on the islands of the arc (Maley and Johnson 1971: 113-5), as well as submarine volcanoes (Nomikou et al., 2013).

The stability of the Cycladic Plateau and the distribution of volcanic rocks across the volcanic belt, are two crucial elements of the topography that could have affected the hominin presence and mobility in the area during the Lower Palaeolithic, specifically during the periods when this part of the Aegean was subaerially exposed (see section 4.5.4). An extended zone from the outer volcanic arc, including the Plateau, to the inner arc, could be envisioned as a corridor with areas that escape the effects of tectonics providing some stability, but at the same time containing pockets rich in knappable volcanic rocks that would have been visible and available to hominins during the Lower and Middle Pleistocene (see the 'volcanic route' hypothesis in Ch. 7). This zone corresponds to the Central Aegean Island Bridge proposed to be one of the connecting corridors between western Anatolia and mainland Greece during the Middle and Late Pleistocene, based on its palaeogeographical characteristics (Sakellariou and Galanidou 2016).

4.3.3 The Southern Aegean Sea (SAS)

The Southern Aegean Sea corresponds to the area between the Aegean Volcanic Arc in the north, the Hellenic Trench System in the south, the coasts of south-eastern Peloponnese in the west and the coasts of south-western Anatolia in the east. It is the most extended part of the Aegean, with great depths, quite aseismic and possibly inactive today (Jackson 1994:265-66). Between the Aegean volcanic arc and the island of Crete lies the **Cretan Basin/ Cretan Trough**, formed by a series of separated, elongated flat-floored depression/troughs (Maley and Johnson 1971: 111) (fig.4.2). The Cretan Basin is U-shaped in parallel alignment with the Cretan Island Arc (Peloponnese-Kythira-Crete-Dodecanese). Within the Cretan Basin, some of the deepest parts of the Aegean Sea can be found, with basins getting successively deeper towards the eastern end of the trough (up to 2400m deep) (ibid). This is indicative of dominant tectonic processes on the eastern part of the basin over sedimentary ones on the western part (ibid 113-114). The Cretan Basin developed as a back-arc basin of the Hellenic Arc, since the Late Miocene (Papanikolaou et al., 2002: 466).

The **Cretan Island Arc** and the Southern Aegean Volcanic Arc are both parts of the Hellenic Arc wider structure. The first one corresponds to an outer non-volcanic arc (Epirus, Corfu, Lefkas, Kefallonia, Zakynthos, Peloponnese, Kythira, Crete, Kassos, Karpathos and Phodes) (Duermeijer et al., 2000: 509-10) and the second one to an inner volcanic arc (Methana, Milos, Santorini and Nisyros). Kastens 1991 (27) describes the Hellenic Arc as the remnants of the previously continuous orogenic belt connecting mainland Greece and Western Turkey. This belt was gradually broken with the initiation of the extension regime in the Aegean during the Miocene (ibid).

The Cretan Island arc corresponds to the West and East Cretan Straits proposed by Sakellariou and Galanidou (2016) to be another possible passage between western Anatolia and mainland Greece during the Middle and Late Pleistocene. Despite the fact that throughout the Pleistocene, Crete has been an island surrounded by great depths (since 5.3 Mya), during the low sea-level periods of the Middle and Late Pleistocene the distance between the islands of the Cretan arc was reducing to a few nautical miles (from 2 to 4 nautical miles), due to exposure of the shallow continental shelf. This distance could have been crossed by hominins using maritime means (island-hopping) as early as 130 Kya, as it has been suggested based on the stone tool evidence from Plakias (Strasser et al., 2010; 2011) and Mochlos (Runnels et al., 2014) in Crete. However, the early date for these seafaring attempts has been questioned (uncertainties about the *in situ* location of the lithics), and the hominin species involved in these crossings remains an open issue (pre-*Homo sapiens* or early *Homo sapiens*?; Galanidou 2014b). More evidence is needed to contribute further in the debate about the early seafaring activities in the southern Aegean.

The Hellenic Trench, immediately south of Crete, is a system of deep basins running from the Ionian Sea (Kefallinia island) to the W and SW of the Hellenic peninsula to the Libyan and Levantine seas to the S and SE, including the Pliny and Strabo Trenches (Leite and Mascle 1982: 203; McKenzie 1978: 220; Le Pichon and Angelier 1979; Papanikolaou et al., 2002: 465) (fig.4.2). It is a zone characterised by extreme relief (deep trenches and steep escapements) and has been interpreted as the outcrop of the subduction zone (Kastens 1991). It is considered to be part of the convergence zone between the African and Eurasian plates (Papanikolaou et al., 2002: 465) or a "consuming plate boundary" (Le Pichon and Angelier 1979: 2). It is highly curved (R = 400 km) and partially follows the alignment of the Cretan Island Arc (ibid). McKenzie (1978: 220) in agreement with Le Pichon and Angelier (1979:5) and Leite and Mascle (1982: 203) observed striking differences in terms of tectonics between the western part and the eastern part of the Hellenic Trench that might explain why the southern part of the Aegean moves as a rigid block. Apparently, activity in the eastern part (normal faulting) is consistent with the regime prevailing in the wider western Anatolia while the western part has been controlled by right-handed strike slip faults connecting it with the deformation of north-western Greece (ibid). In the central part, little activity is being observed north of the Arc.

4.4 Volcanic Activity in the Aegean: an overview

The volcanic activity in the Aegean is directly associated with the subduction of the African plate underneath the Eurasian plate, the consequent orogenic processes occurring along the margins of the subduction zone, and the continental extension of the Aegean domain (Fytikas et al., 1984; McKenzie 1978; Jackson 1994). Geochronological, geochemical and radiometric (K/Ar) data show that volcanism within the Aegean migrated over time from the northern part of the region, where it was firstly expressed during the Eocene/Oligocene, towards the south, where the most recent activity (Pliocene to present) has been detected, with an average rate of 10 km/Myr (Nomikou et al., 2013). As such, the original width of the belt effected by volcanism must have been reduced by at least 50% as suggested by Fytikas et al. (1984: 697), so the present-day distribution of erupted materials across the Aegean should be seen as indicative of their original distribution.

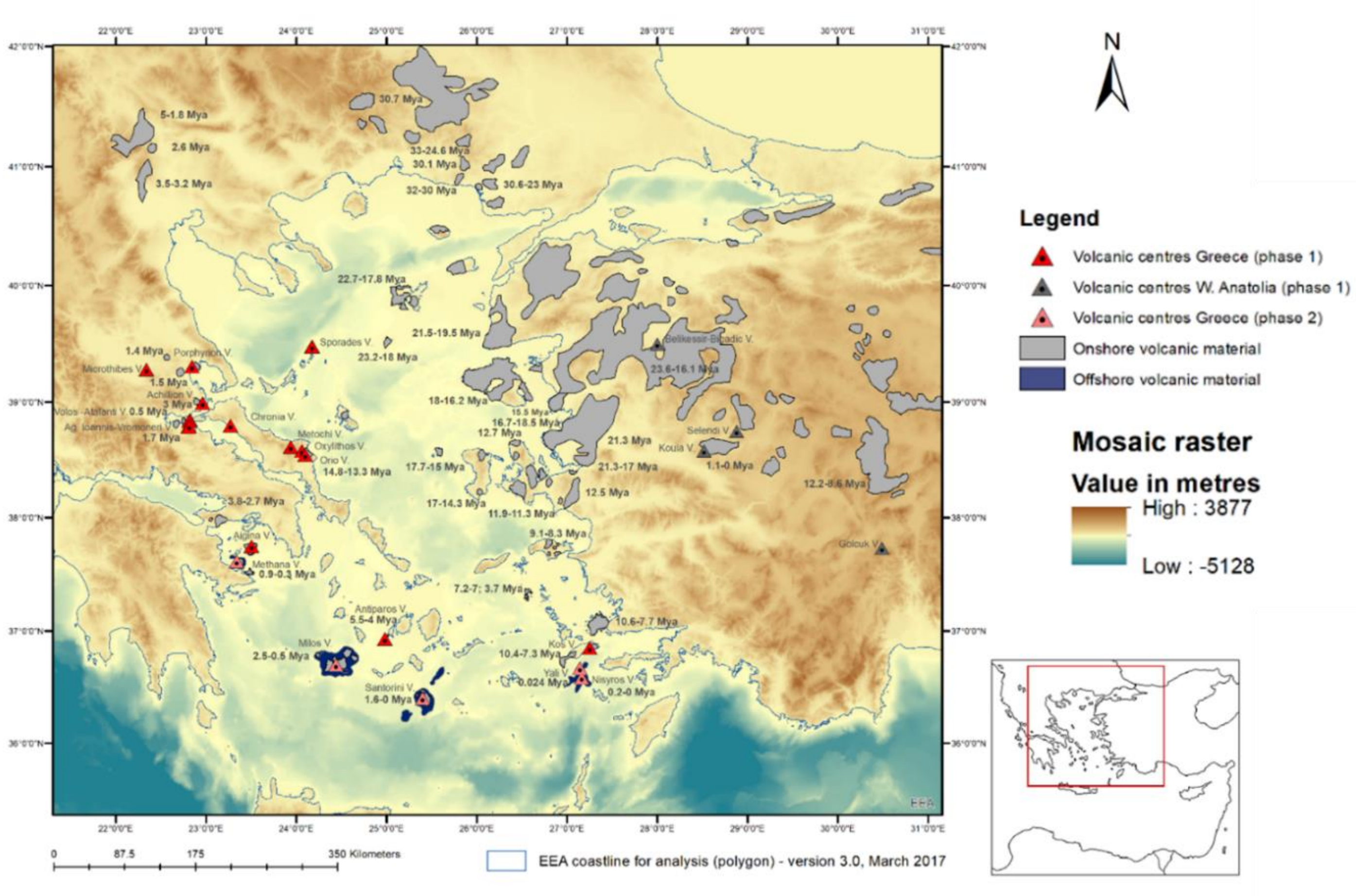


Figure 4.5. Synthetic map with the location of the Oligo-Holocene volcanic centres in the Aegean (sources: Smithsonian Institute/Global Volcanic Programme [http://volcano.si.edu] and the Preliminary List of Pleistocene Volcanoes (Siebert, Simkin and Kimberly 2010: 6). Volcanoes of the World. Univ of California Press.), the distribution of volcanic material (modified after Borsi et al.,1972; Fytikas et al.,1984; Nomikou et al.,2013) and absolute ages of erupted material (after Fytikas et al., 1984).The background mosaic raster combines modern elevation and bathymetry. Terrain data: ASTER Global Digital Elevation Map, version 2 (ASTERGDEM V2) (30m resolution), available at NASA Land Processes Distributed Active Archive Center (LP DAAC). Bathymetric data: Eastern Mediterranean Bathymetric Map (2016) (250m resolution) by courtesy of the Hellenic Centre for Marine Research. Map produced in ArcMap 10.4

Fytikas et al.'s (1976; 1984) work on the Quaternary evolution of volcanic activity in the Aegean region remains until today essential, providing the most complete overview of the distribution, geochemical characteristics and ages (K/Ar) of the erupted materials (fig.4.5). Two distinctive phases of volcanic activity have been documented, each affecting different areas of the Aegean and leaving its own chemical signature. In the northern Aegean the main activity can be detected from the Oligocene (ca. 34-28 Mya) to the Middle Miocene (ca. 13-14 Mya), producing calc-alcaline and shoshonitic intermediate lavas, mainly andesites and dacites, and a smaller abundance of rhyolites, with basalts being almost absent (phase 1). The southern Aegean has been affected by a more recent activity (Pliocene ca. 3.6 Mya - onwards) concentrated along the Aegean Volcanic Arc, producing mainly andesites with minor basalts and rhyolites (phase 2). Mercier et al. (1989:68) proposed the existence of two volcanic arcs being active in the Aegean:

the ‘Pelagonian-Pindinc Arc’ relating to the earlier phase of volcanism in the Aegean (Eocene - Miocene) and the ‘Aegean Arc’ relating to the later/younger, volcanic activity (Pliocene - present).

An intermediate phase (Upper Miocene/ca. 11-5Mya to present) of limited and scattered activity, with variable petrogenetic and geochemical character is evidenced on marginal areas of the Aegean microplate, but not in northern Greece. Fytikas et al. (1984: 293-4), identified four distinctive groups, based on the chemical composition of the erupted materials: (a) sodic alkaline products mainly alkali basalts and hawaiites, detected in the eastern Aegean and western Anatolia (8.3 Mya to 0.5 Mya), (b) highly potassic alkaline lavas of shoshonitic affinity, traced exclusively along marginal areas within the Aegean, with similar products found in Afyon and Isparta, (W. Anatolia), (c) rhyolites formed by crustal anatexis (i.e. crustal melting) during the Miocene/Pliocene boundary, found in Antiparos Island and possibly in Izmir and Afyon regions (W. Anatolia), and (d) small lava outcrops, mainly basaltic andesites in the Volos-Atalanti area (mainland Greece), associated with a volcanic activity occurring between 3.4-0.5 Mya.

Until recently, the younger phase of volcanism (phase 2) had been known only through the study of the onshore and insular outcrops, with the only known submarine volcano being the Kolumbo (NE of Santorini). Nomikou et al. (2013) presented the results of a submarine survey conducted by the Hellenic Centre of Marine Research and the University of Athens, started in the 1980’s and concluded only recently, mapping neotectonic underwater structures. This research, led to the reconnaissance of the Aegean seafloor along the Aegean volcanic arc but also to the discovery of new features such as underwater volcanic rocks and outcrops, either belonging to previously unknown submarine volcanoes (e.g. Pausanias Volcano, W. Saronikos Gulf), or being the submarine prolongation of onshore volcanic activity in the areas of Nisyros, Milos and Santorini. This is the first synthesis of onshore and offshore evidence for the volcanic activity along the Aegean Volcanic Arc (see fig.17 in Nomikou et al., 2013: 143)

The centres of the Volcanic Arc are hosted within specific tectonic environments, i.e. neotectonic grabens (tectonic basins), following in terms of orientation the general geometry of the Hellenic Arc. The tectonic boundary of this structure runs, more or less, along the southern boundary of the Cycladic Plateau. Each volcanic group has its own characteristics in terms of the timing and intensity of activity, and the volume of the erupted material (Nomikou et al., 2013:143). In Aigina, Methana and Milos the volcanic activity has begun since the Late Pliocene (ca. 3.6-2.58 Mya) with onshore and offshore expressions (Pausanias volcano/W. Saronikos) – associated with Late Pliocene-Middle Pleistocene outcrops (fig.4.5); in Santorini, since the Early Pleistocene with an intensive activity (paroxysm) witnessed during the Holocene / 0.0117 Mya-present (onshore and offshore/Kolumbo volcano), while Nisyros represents the youngest group with the highest activity during the Late Pleistocene-Holocene / 0.126 Mya-present (onshore and offshore) – associated with Late Pleistocene-Holocene volcanic outcrops (fig.4.5). Deep and thick (several hundred meters) Plio-Quaternary sedimentary sequences (marine or continental – usually lacustrine) along with volcanic rocks have been deposited within the graben structure along the Volcanic Arc (see for example the area between Kos and Nisyros-below) (ibid 144).

In terms of petrography and geochemical composition, the Arc seems to be relatively homogenous. Andesites and dacites are dominant (as in northern Greece during phase 1), but unlike the first phase of volcanism, basalts and basaltic andesites become very common (about 25% of the overall erupted products), and also a continuous evolution from basalts to rhyolites can be observed (Fytikas et al., 1984: 692). However, variation along the arc occurs in terms of magmatic character and the mode of eruption, relating to variations in the compressional stress (ibid 292-3). The positioning of the volcanic centres of the Arc is relatively high (above the Benioff zone) ranging from 100-160 km at the eastern part (e.g. at Kos and Nisyros) to 100km at the western part (e.g. Soussaki), suggesting that subduction controls magma generation in this area (Dotsika et al., 2009: 19-20).

Volcanic activity and active tectonics are directly linked to the formation and distribution of geothermal systems (thermal and mineral springs and/or geothermal fields) across the wider Aegean (Minissale et al., 1989; Dando 1999; Obetsanof, Koumantakis and Stamataki 2004; Lambrakis and Kallergis 2005; Dotsika et al., 2009; Karastathis et al., 2011; Karakatsanis et al., 2011; Nomikou et al., 2013; Lambrakis, Katsanou and Siavalas 2014). The volcanic activity and heat flow enables fluid movement, while tectonic activity permits the thermal fluids to rise from their reservoirs towards the surface (regional aquifers of neogene sediments such as conglomerates, sandstones and/or alluvial aquifers). Geothermal systems across the Aegean usually associate with three different geotectonic contexts, (a) back-arcs, (b) volcanic arcs and (c) fault systems. However, thermal and/or mineral springs occur also in areas where volcanism is not present, mainly because of the depth and in relation to active fault systems (e.g. W. Greece), and in islands and coastal zones, resulting from the mixing of deep thermal reservoir water with meteoric water.

In north and central Greece, as well as on several islands of north and eastern Aegean, geothermal systems are found in association with back-arc structures (i.e. Aridea, Antemus, Volvi-Langada, Strymon, Nestos-Xanthi and Alexandroupoli basins in north Greece, Samothraki, Limnos, Lesbos, Chios, Ikaria Islands in N-E Aegean, the Gulf of Maliakos, Sperchios basins, north Euboea in central Greece); in the southern Aegean geothermal systems have been evolved along the South Aegean Volcanic Arc (Euboea, Methana, Sousaki, Milos, Serifos, Syros, Paros, Santorini, Ios, Naxos, Syfnos, Kos, Yali, and Nisiros); in Western Peloponnese, where the heat flow is lower, geothermal fields have been developed in relation to fault systems (fault-induced) (Amarantos, Kavassila, Sikies Artas, Antirrio, Kyllini, Kaiafas, Vromoneri).

The great distribution and variety of volcanic rocks across the Aegean during the Pleistocene, including materials frequently used for stone tool knapping during the Lower Palaeolithic, such as rhyolites, andesites and basalts, is another element of the past landscape that needs to be considered in the study of hominin movement and occupation. Furthermore, hydrothermal springs and fields, create attractive micro-environments for hominins (protection during cold phases) and visible landmarks observable from a distance over the open landscape. In the Aegean, we have the example of Rodafnidia site on Lesbos Island, situated very close to the Lisvori hydrothermal springs, with Acheulean handaxes and cleavers made on locally available volcanic rocks and hydrothermal chert (Galanidou et al., 2016). These volcanism-related elements, along with landscape features associated with fresh water resources, will be used as reference points in the spatial analyses in order to explore the distribution of landscape variables favouring hominin survival and activity (see Ch.5).

4.5 Palaeogeographical reconstructions of the Aegean: an overview

Until recently (2009), only reconstructions referring to the last glacial cycle and specifically to the LGM were available for the Aegean palaeogeography. Van Andel and Shackleton (1982) set the pace in the early 1980’s covering the last 20 Ka. The lack of absolute dates on sea-level positions prior to the lowstand of the last glacial cycle, or sea-level markers of glacial-interglacial transitions before the most recent interval, restricted the time depth of the reconstructions. Several methods have been applied, combining multiple datasets, e.g. current bathymetric data, global and local sea-level curves, tectonic data, glacio-isostatic effects, sub bottom seismic reflection profiling, to mention a few.

Advances in technology and especially for mapping and recording the seismic stratigraphy in correlation with the evolution and the texture of the seabed, using modern imaging acoustic methods such as swath bathymetry, has signalled a new era in the exploration of the submerged landscapes in tectonically active areas. In the seismic reflection profiles, the identification of sedimentological/geological sequences typical of the glacial-interglacial transitions (e.g. palaeo delta progradation) are used as markers for the position of the palaeoshorelines, and thus enable the identification of areas that used to be exposed during the glacial lowstands. Geological and sedimentological, lithostratigraphic and biostratigraphic data (acquired by core sampling) add further information, indicating different natural environments (river, lake, marine environments).

Such repeated transitions between fluvio/lacustrine and marine conditions during the Pleistocene have been recorded in several basins over the northern and central Aegean, and further east in the Sea of Marmara, following the global sea-level fluctuations.

Lykousis in 2009 published his reconstruction for the Aegean and Ionian Seas for the last 400 Kya, being the first to break the last glacial time-threshold, and to extend our understanding of the Aegean palaeogeograpgy to the Middle and possibly to the Early Pleistocene. Sakellariou and Galanidou (2016; 2017) refined Lykousis results by integrating morphostructural, geological and hydrological evidence, and highlighted the great relevance of such reconstructions to the archaeological research on early hominin activity and mobility during the Middle and Upper Pleistocene. Foutrakis and Anastasakis (2018a) presented their work on the palaeogeography of the Saronikos Gulf providing evidence for successive glacial lowstands from MIS 2 to MIS 22, the longest geochronological sequence recorded and published so far from the Aegean.

The focus of the underwater research is only now starting to deepen into the past, seeking information about the landscape configuration during the earlier parts of the Pleistocene, with the first attempts being very promising. Up to this point, there is a very good coverage of evidence about the palaeogeographical evolution during the Late Pleistocene over the northern Aegean and parts of the central Aegean, and more specifically the northern Aegean continental shelf and the Cycladic Plateau, with fewer relevant studies for the Ionian palaeogeography (Ferentinos et al., 2012; Zavitsanou et al., 2015) – the latter lies beyond the scope of this thesis. For the Middle Pleistocene there is reliable evidence for the land exposure and the prevailing conditions over the northern Aegean prior to MIS 8, but similarly secure information for the central Aegean is missing, with the exception of the recent study on the Gulf of Saronikos.

4.5.1 First attempts

Van Andel and Shackleton (1982) were the first to attempt a palaeogeographical reconstruction of the Aegean shorelines during the Quaternary (Upper Palaeolithic and Mesolithic). They used recent bathymetric data and general sea-level rise curves. However, they did not take into consideration the glacio-isostatic effects (i.e. deformations on the crust caused by the forming and melting of ice sheets). Their reconstruction for the Upper Palaeolithic revealed the existence of broader coastlines traversed by multiple rivers in northern Greece (Termaikos and Thasos-Samothrace Plains), joining landmasses in Central Aegean (the Cyclades islands joined in a semi-peninsula or the Sporades islands, except Skyros, formed a long peninsula), and islands joined with adjacent main land in the Eastern Aegean and the Ionian Sea (e.g. the eastern Aegean islands were connected to Asia Minor, the Ionian islands to western mainland Greece, and Peloponnese and Euboea were also part of the mainland).

According to the same reconstruction, during the Last Glacial Maximum, modern gulfs had lost their marine connection and had been transformed into brackish and/or fresh water lakes, as the -120 m sea-level drop lies lower than the depths of their sills (Marmara, Saronikos, North and South Evvoikos, Corinthian and the gulfs along the Ionian coast). Van Andel and Schackleton's (1982) work triggered the discussion about the archaeological implications of the exposed landmasses during glacial lowstands, in terms of natural resources availability, exploitation of coastal resources by early humans, and dispersal routes, introducing a new aspect of the Pleistocene Aegean landscape in the Palaeolithic research.

On the same line, Van Andel and Lianos (1984) conducted a research in southern Argolid exploring the Quaternary coastal palaeogeography in relation to the Franchthi cave site (Upper Palaeolithic). Using high-resolution seismic reflection profiling, they manage to identify the position of the LGM lowstand on a sedimentary surface of a former river or coastal plain, now submerged at a depth of -115 to -118m (ibid 40). They were also able to follow the same sequence on land. Their estimation for the LGM sea level – in good agreement with the global average curve – is still a key-work for the LGM Aegean. Their work also demonstrated the contribution of the seismic reflection profiling methods in the research of the Quaternary coastal palaeogeography of the Aegean.

4.5.2 Central Aegean

Lambeck (1995, 1996; 2004; Lambeck and Purcell 2005) worked extensively on sea-level changes during the last glacial cycle (about the last 120 Ka) in the Aegean and the wider Mediterranean. He produced a numerical model for the sea-level changes throughout the last 20 Kya, which remains a point of reference for relative studies in the Aegean Sea (Lambeck 1996) and the wider Mediterranean Sea. He calculated the relative sea-level rise in the Cyclades area and estimated the shoreline displacement based on bathymetric data, interpolated on a 180m grid, from the Upper Palaeolithic to the present, taking into consideration also the isostatic and eustatic contributions to sea-level changes and the tectonic controls. However, he did not incorporate subsidence rates.

Values provided for the Aegean suggest that from ca. 70 Kya up to the start of the LGM (ca. 21.5 Kya) sea-levels fluctuated between -50 to -80 m and from ca. 20 Kya to ca. 16 Kya coastal plains were fully exposed (Lambeck, 1996: 66). In terms of land exposure during the LGM, this study is in good agreement with the earlier work by Van Andel and Shackleton (1982). Lambeck (1996) however, provides some new information about (a) the extent of the exposed landscape, and (b) the pace of the subsequent land fragmentation due to marine transgression. According to Lambeck's (1996: 606) estimations, the Cyclades landmass extended from Andros (in the north) to Ios (in the south) over a distance of 160 km, while the northern Aegean coasts, including the Termaikos Gulf and the Thrace Plain, extended more than 60 km south of the present-day coastline. After ca. 14 Kya the sea-level rise became more rapid resulting in the gradual breaking up of the Cycladic landmass. Around 9 Kya the present configuration of the central Aegean was more or less established with the prior LGM lakes in full marine conditions by that time, and the Marmara being reconnected to the Aegean Sea. The broad and shallow plains between Lemnos and Asia Minor had been exposed during the LGM, blocking the marine connection between the Marmara and the Aegean. The Marmara was transformed into a lake (perhaps even two) until around 9 Kya when the marine reconnection was established.

More recently, Perissoratis and Conispoliatis (2003) worked on the impact of the sea-level fluctuations during the Late Pleistocene and Holocene in the morphology of the Aegean and the Ionian Seas. They produced another predictive model for the last 20 Kya (for three time intervals at 21.5 Kya, 11.5 Kya and 8 Kya) using the global eustatic curve and available local data i.e. sedimentation and subsidence rates, bathymetry and seismic profiles (fig.4.6). Data were corrected for tectonic and isostatic effects, and also the sediment thickness (Late Pleistocene-Holocene) was subtracted (ibid 154). According to their results the sea-level reached its lowest position -120m at ca. 21.5 Kya and started rising at ca. 18 Kya at a rate of 5mm/year; -60m at 11.5 Kya and -15m at 6 Kya. In general, their values are in accordance with Lambeck's (1995, 1996) model (i.e. a sea-level between -115 m and -135m at 18 Kya and between -43m to -45m at 10 Kya). The same areas, as in previous studies, have been identified as subaerially exposed during the LGM low-stand i.e. extended continental shelves with riverine environments and ephemeral lakes in northern Greece, along Asia Minor and, to a lesser extent, along Western Greece, and the Cyclades semi peninsula. However, much more local data (geological and palaeoenvironmental) have been incorporated (especially for the LGM lakes and the Northern coastline) due to the intensification of research on the palaeogeography of the Aegean, noticed after the initial publication of Van Andel and Shackleton (1982) paper.

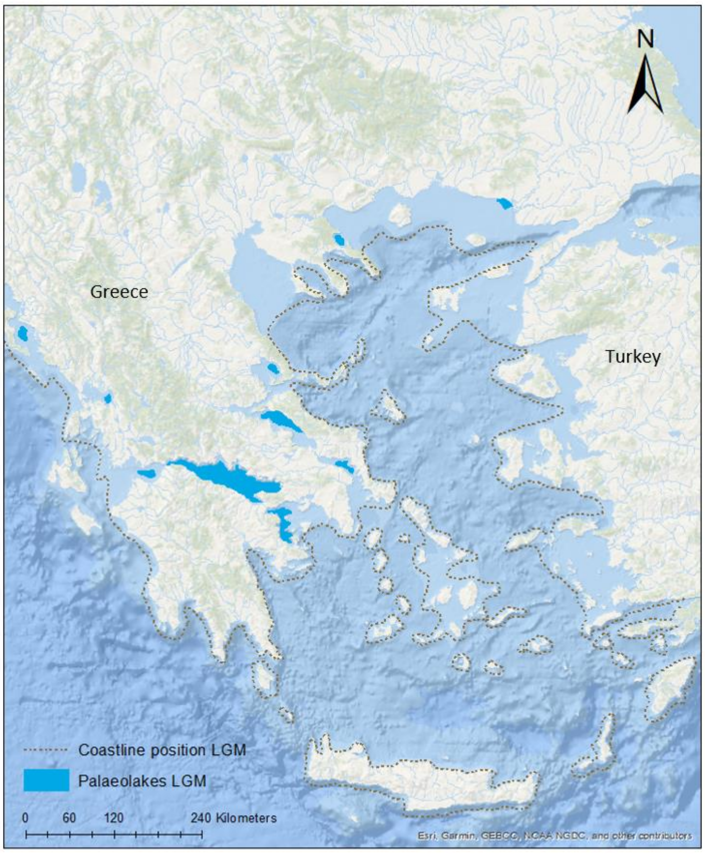


Figure 4.6. Coastline position at lowstand during MIS 2 (ca. 21. 5 Kya) across the Aegean (modified after Perissoratis and Conispoliatis 2003) and location of the LGM lakes (modified after Sakellariou and Galanidou 2016). The background corresponds to the current geographic configuration of the Aegean region. Base map: Ocean Basemap, ArcGIS online, sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors. Coordinate system: WGS 1984 Web Mercator Auxiliary Sphere; Projection: Mercator Auxiliary Sphere; Datum: WGS 1984; Linear Units: meters. Map produced in ArcGIS 10.6

Kapsimalis et al. (2009) examined the Quaternary stratigraphy of the Cyclades shelf and suggested areas of possible archaeological interest, using bathymetric, acoustic (high-resolution seismic reflection profiles) and archaeological evidence. The focus here is the relation between the changing landscape and the development of behavioural adaptations, such as mobility. Through the detailed presentation of the palaeoshoreline displacement and the distribution of slopes in the Cyclades (fig. 4.7), the authors put forward the idea that the lowlands between the modern islands of central Cyclades should be considered as areas of high archaeological potential. These lowlands, now lying underwater, correspond to former plains, hosting attractive habitats for animals and hominins with milder conditions, prevailing even during cold/glacial periods, due to the proximity to the sea. As such, these areas were densely populated, in an extent of 98% of the total available area, according to Kapsimalis et al. (2009: 185). The extent of the Cycladic 'mega-island' has been calculated to be 10.400 km^2 (ibid 187).

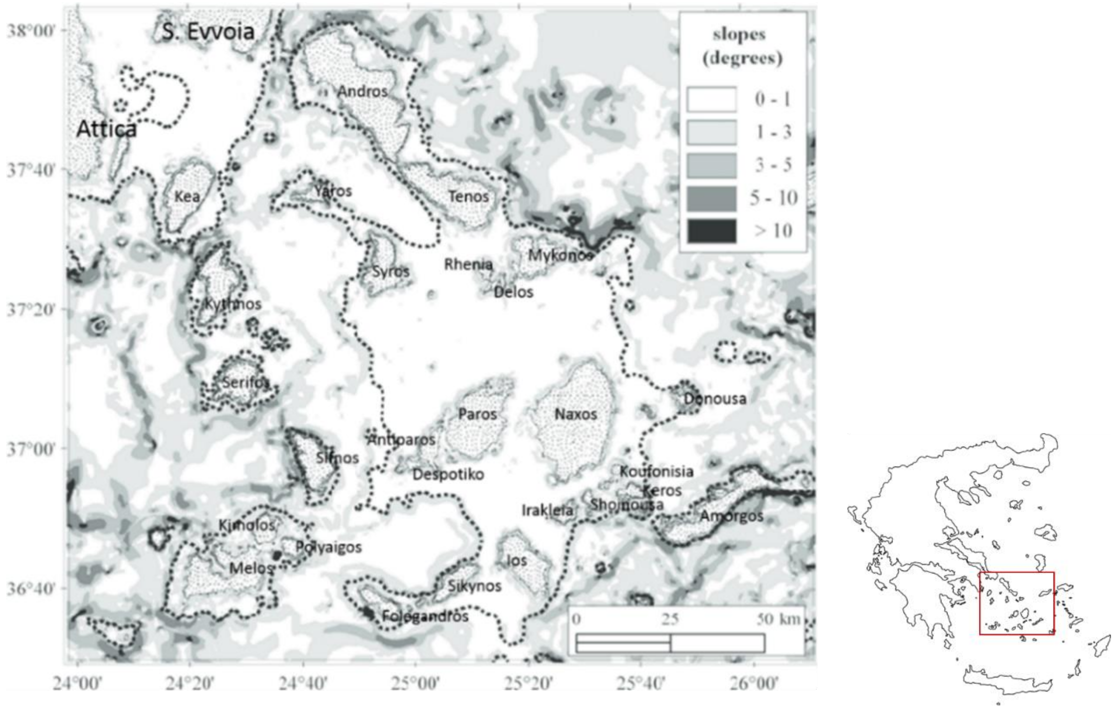


Figure 4.7. Slope distribution at the Cycladic Plateau. The dotted line represents the position of the palaeocoastline during LGM. The area bordered by the dotted line was sub-aerially exposed during the LGM (modified fig. 6 from Kapsimalis et al., 2009)

In all the studies mentioned above, the element of fresh water is being highlighted, either by the occurrence of the LGM lakes or by the presence of exposed landscapes envisioned as habitats with rich water resources. Evidence for the fluvio/lacustrine-marine transitions, subject to glacial-interglacial oscillations, come from basins in the western part of central Aegean, shedding more light on the environmental characteristics of the Pleistocene exposed landscapes. In the modern configuration these basins correspond to marine gulfs but they used to host lacustrine environments during the glacial lowstands, before the last transgression (and before earlier transgressions most possibly), as mentioned earlier. Several LGM lakes have been identified in this area; here we present evidence from the Gulf of Corinth (or Corinthiakos Gulf), the North and the South Euboean Gulfs (or Evvoikos Gulfs).

Three distinctive phases of basin evolution have been identified in the Gulf of Corinth (or the Corinth graben; Lykousis et al., 2007). Four oblique prograding (prodelta) sequences have been identified in the central part of the north margin of the Corinth graben, representing three successive low sea (lake) level stands (OIS 2–3, 6 and 8 — Lowstand System Tracts), indicating continuous subsidence for the last 250 Ka (ibid 48). Lacustrine and fluvial deposits (sands and silts) dated from Late Pliocene to Early Pleistocene (ca. 3.6 to 1.5 Mya) forming the proto-gulf’s sediments that were deposited in continental or fresh to brackish shallow water environment (Ori, 1989). For the period ca.1.5 to 0.7 Mya Gilbert-type fan deltas dominate in the region establishing lagoonal/lacustrine environments (Lykousis et al., 2007). The marine-lake interface has been dated (AMS-dated sediments from new piston cores) at about 13 Kya. During the Late Pleistocene, the Gulf of Corinth experienced repeated transformations between a lake and a marine basin. The new piston cores, coming from the deeper part of the Corinthian Gulf, revealed important information for the initial lacustrine event (ibid 49), enhancing the validity of relevant evidence reported from several places around the Gulf of Corinth (Eratini bay, Alkyonides gulf) and from an onshore coastal borehole (near Aigion harbour).

A subaerially exposed surface (erosional uncomformity) during the last glacial lowstands has been also identified in high-resolution seismic reflection profiles from the North Euboean Gulf (Van Andel and Perissoratis, 2006). On that surface many terraces in different depths have been recorded, corresponding to the fluctuations of the water levels, when the basin was isolated from the Aegean Sea (ibid 157). The existence of a lake during the lowstands has been confirmed by a gravity core (taken in the dipper sector of Euboean Gulf and presented by Sakellariou et al., 2006) showing that a lacustrine section exists below the recent marine deposits.

In the South Euboean Gulf similar conditions have been observed (Perissoratis and Van Andel 1991). Two distinctive units have been recognised (data from shallow and medium –penetration seismic profiles and two cores). The first unit is associated with the post-glacial marine transgression, while the second possibly represents a lake deposit during the lowest sea-level (LGM) (ibid 300). The Pleistocene sediments (found mainly on the west of the gulf) consists of terrestrial conglomerates and lacustrine clays. Sediment was probably supplied by streams, as indicated by the thickening of beds towards river mouths. The researchers believe that the lake existed up to ca. 11 Kya when the rising of the sea level in the Aegean flooded the basin. However, uncertainties remain about the dating of the older sequences, Perissoratis and Van Andel (1991: 301) support *that "the filling of the Southern Evvoikos Gulf did not predate by much the Middle Pleistocene"*.

4.5.3 Northern Aegean Coastline

An extensive alluvial plain (fig.4.8) was present during the Late Pleistocene in the area now occupied by the Thermaikos Gulf, as indicated by high-resolution seismic reflection profiles, thirty-one short sediment cores and nine AMS ^{14}C dates. Lykousis, Karageorgis and Chronis (2005) investigated the sedimentation process and developed a chronostratigraphical framework for this specific area. According to the proposed palaeogeographical reconstruction, during the period ca. 24-18 Kya when the sea level was approximately at -120m, the wider NW Aegean region was subaerially exposed. In the Thermaikos region, an erosional uncomformity, caused by subaerial exposure during the late glacial sea-level fall, was identified (ibid 381). The main feature on that erosional surface is the incised valley of a major river. According to the reconstruction, the Axios, Aliakmon, possibly Pineios and other minor rivers (e.g. Loudias, Gallikos) all connected into a major palaeoriver that flowed into the valley (fig.4.8). The mouth of the river was possibly located very close to the continental slope, directly supplying the Sporades basin. The shoreline during that period occupied an area 10% larger than today (ibid 394).

Perissoratis and Mitropoulos (1989) studied the evolution of the central and eastern part of the northern Aegean shelf, from the end of the Pleistocene until the Pleistocene-Holocene transition (14 -10.5 Kya). They used seismic reflection profiles from the Ierissos-Aleandroupolis shelf, considering two main factors, sea-level changes and sedimentation processes (induced by the rate of ice melting and the input of river sediment, respectively) (ibid 36). During the sea-level lowstand of -120m (16-14Kya), around 5.300km^2 of exposed land was subjected to subaerial weathering and erosion (ibid 44). The exposed shelf between Thasos and Nea Peramos extended about 20-40 km southern of its present location, with Samothraki and Thassos mountains (1225m and 1271m height respectively) standing out on the flat terrain. The area was drained by multiple rivers, the extensions of Nestos and Strymon (major and permanent rivers), and possibly by a number of smaller and ephemeral ones (fig.4.8). Two permanent lakes have been also identified, in the Ierissos and Strymonikos Gulfs (fig.4.8). The first one was connected to the sea as indicated by two channels leading to the coastline, and the second one was supplied by Nestos River. Further south the valley of the Strymonikos Plateau, the two rivers met close to the shore, forming a delta (fig.4.8).

The Gulf of Kavala was also drained by Nestos River, as indicated by the presence of multiple erosional channels and valleys in the seismic profiles, joined into a single channel further south-westward when they connected with the Strymon valley (Perissoratis and Mitropoulos 1989: 45). Core data from the Gulf of Kavala (KB-7) confirmed the existence of that drainage/valley system during the LGM lowstand, showing two different depositional episodes; the upper section corresponds to the postglacial marine transgression and the lower section - a subaerially exposed horizon, with biostratigraphic indicators (calcareous nodules) suggesting a fresh water environment during the LGM (Perissoratis and Van Andel 1988: 58).

The Samothraki Plateau probably was traversed by multiple seasonal rivers and streams (Perissoratis and Van Andel 1988). Between Samothraki and Alexandroupolis no evidence of buried channels has been found, indicating that the Pleistocene Evros, probably flowed east of Samopthraki, forming a delta at this side of the Plateau (see Perissoratis and Mitropoulos 1989: 44) (fig.4.8).

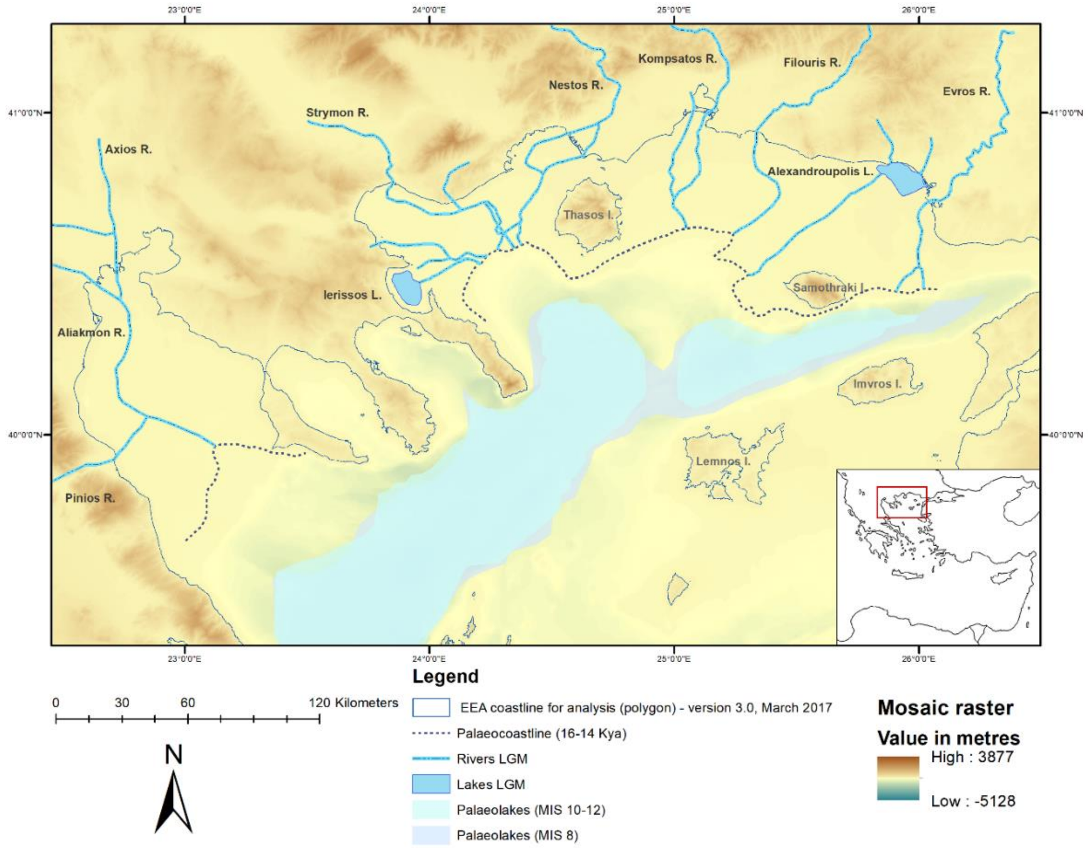


Figure 4.8. The extended northern Aegean shelf during the LGM. The black dotted line represents the coastline ca 14-16 Kya. For the location of the coastline, the palaeolakes and the extension of the palaeorivers, data have been used from Lykousis, Karageorgis and Chronis 2005 (for the Thermaikos Gulf area), and Perissoratis and Mitropoulos 1989 (for the area between the Ierissos L. and Evros R.). Base map: Ocean base map, ArcGIS online, sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors. Coordinate system: WGS 1984 Web Mercator Auxiliary Sphere; Projection: Mercator Auxiliary Sphere; Datum: WGS 1984; Linear Units: meters. Map produced in ArcGIS 10.6

Further to the east, the Marmara Sea was isolated from the Aegean Sea. During MIS 2 (ca. 24 Kya) global sea-level dropped below the -85m Dardanelles sill and the Marmara lost its connection with the global ocean and became a fresh water brackish lake (McHugh et al., 2008: 65). Marine conditions were established again at ca. 12Kya, with the post-glacial marine transgression. The transition from lacustrine to marine environments is marked by a faunal turnover evidenced in sediments acquired from boreholes and cores (McHugh et al., 2008:66; Meric and Algan, 2007). The palaeolake was supplied by rivers and by the Black Sea, which had also lost its marine connection during MIS 2 (Meric and Algan 2007: 128). The cold and dry conditions along with the sparse vegetation (reconstructed by pollen data) enhanced the erosion and sedimentation processes (McHugh et al., 2008). Lagoons, deltas and estuaries were formed on the subaerially exposed coast, indicating a rich landscape in natural resources (Meric and Algan, 2007; Vardar et al., 2014).

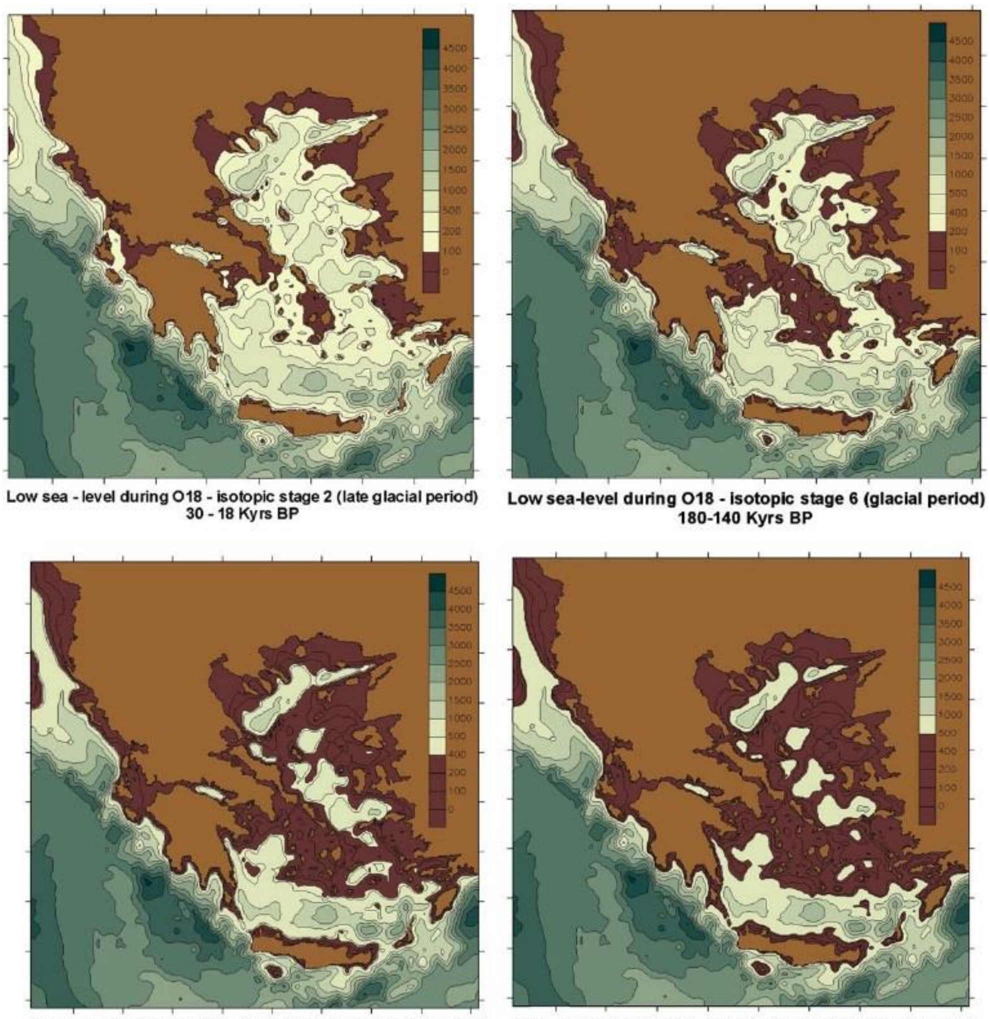
4.5.4 Recent advances (2009 to present)

At least four (and locally five) successive glacial prograding sequences have been identified in different parts of the Aegean by Lykousis (2009) using high-resolution seismic reflection profiles and core data. These palaeo-shelf break glacial delta sediments (LSTs) indicate the position of successive glacial sea-level lowstands and palaeo-shelf edges, with an error margin between 5m for MIS 2, and 10-15m for MIS 6,8, 10 and 12 (ibid 2038-41). The succession of the palaeo-shelf breaks indicates continuous and gradual subsidence of the Aegean margins during the last 400 Ka, a pattern related to the extensional tectonic regime prevailing in the Aegean throughout the Pleistocene (Sakellariou and Galanidou 2016: 158). Subsidence rates have been extracted from the vertical displacement of the topset- to forset transitions of the LST prograding sediment sequences. Lykousis (2009: 2038-41) presented evidence from three areas, as case studies, to demonstrate the method for calculating subsistence rates: the Thermaikos margin (NW Aegean), the margin of the Eastern Cycladic Plateau (central Aegean) and the Northern margin of Gulf of Corinth (see Table 4.1).

Geological data retrieved from the Aegean seabed showed that the largest part (50-60%) of the area now covered by the Aegean sea, used to be a subaerially exposed landmass during MIS 2, 6, 8, and 10-12 glacial stages, as well as during early interglacials MIS 11, 9, and to a lesser extent 7 (ibid 2041) (fig.4.9). The marine transgression did not happen before MIS 9, as suggested by fresh and brackish water sediments showing the prevalence of lake environments in the central-northern Aegean during MIS 8 and prior to MIS 10 (ibid 2041, 2043). Consequently, fluvio-lacustrine conditions would have prevailed in central and northern Aegean throughout the Pliocene and Early Pleistocene, as indicated by geological (absence of deeper and older than 500kya LSTs), sedimentological and biostratigraphic evidence from the north Aegean margin. For the central Aegean, however, there is less evidence. Extensive drainage systems and river deltas, extensions of the Balkans and W. Anatolia riverine systems, must have been supplying the large lakes that formed in the deep exposed basins of the North Aegean Trough and central part of the Aegean respectively, as suggested by the high sedimentation rates. After the first marine intrusion, freshwater, lacustrine and marine resources coexisted on the same landscape throughout the transitions of the climatic cycles of the Middle and Late Pleistocene. It is worth noticing here that the details of the fresh water influx into the area and the interplay between fresh water, brackish and marine environments are very difficult to assess. This would involve the reconstruction of the complete hydrogeological network, too complex and hard to produce (remote past - paucity of evidence, dynamic landscapes - poor preservation of features).

Table 4.1. Summary of subsidence rates over time in the Aegean based on information presented in Lykousis (2009)

Location	Depth of LSTs	Date	MIS	Subsidence Rate	Subsidence over Time
Thermaikos Margin	LST 1 > -116m LST 2> - 226m LST 3> - 375m LST 4> - 520m LST 5> - 680m	c.18 Kya c.146 Kya c.250 Kya c.340 Kya c.425 Kya	MIS 2 MIS 6 MIS 8 MIS 10 MIS12	0.86m ka ^{1} 1.43m ka ^{1} 1.61mka ^{1} 1.88m ka ^{1}	110m subs over the last 128 Ka 149m subs over the last 104 Ka 145m subs over the last 109 Ka 160m subs over the last 85 Ka
				Mean: **1. 385 m ka ^{1}**	***Mean:*** **564m subs over 407 Ka**
Cycladic Plateau	LST 1> - 109m LST 2> - 152m LST 3> - 212m	c. 18Kya c. 146Kya c. 250Kya	MIS 2.2 MIS 6.2 MIS 8.2	0.34m ka ^{1} 0.57m ka ^{1}	42.5m subs over the last 128Ka 60m subs over the last 104 Ka
				Mean: **0.44m ka ^{1}**	***Mean:*** **102.5m subs over 232 Ka**
Gulf of Corinth	LST 1> - 70m LST 2> - 155m LST 3> - 305m	c. 13 Kya c. 120 Kya c. 245 Kya	MIS 2 MIS 6.0-6.1 MIS 8	0.7m ka ^{1} 1.28m ka ^{1}	75m subs over the last 107 Ka 150m subs over the last 117Ka
				Mean: **1.0 ka ^{1}**	***Mean:*** **225m subs over 232 Ka**



Low sea - level during O18 - isotopic stage 2 (late glacial period) 30 - 18 Kyrs BP

Low sea-level during O18 - isotopic stage 6 (glacial period) 180-140 Kyrs BP

Low sea - level during O18 - isotopic sytage 8 (glacial period) 300 - 250 Kyrs BP

Low sea - level during O18 - isotopic stages 12 & 10 (glacial periods) 480 - 350 Kyrs BP

Figure 4.9. The palaeogeographical reconstruction of the Aegean and Ionian Sea over the last 400 Kya, during the glacial stages MIS 2, 6, 8, 10-12, with the maximum land exposure during MIS 10-12 and possibly before, during the Early Pleistocene (from Lykousis 2009: fig. 5)

The extent of the subaerially exposed land during MIS 10-12 (maximum land exposure) has been calculated by Tourloukis and Karkanas (2012b: 9) to be ca. 130.000km^2, comparable to the current extent of continental Greece. It is likely that even before MIS 10-12 (even before ca. 500 Kya), during the Early Pleistocene, and up to MIS 8 - even MIS 6 in some areas - similar conditions would have prevailed. It is worth mentioning that the exposed land during the Late Pleistocene based on the -120m LGM lowstand, is still three to five times less extensive (ca. 41.399 km^2) compared to the estimations for the Early and Middle Pleistocene (Tourloukis 2010:166).

Of course, the reconstruction proposed by Lykousis is not without problems. The suggestion that extended terrestrial environmnets prevailed over the northern and central Aegean without interruption for at least 200 Kya - throughout the glacial-interglacial oscillations from at least MIS 10-12 until at least MIS 8, needs further support. Yet, it is better established, in geological and chronological terms, for the northern Aegean, while information on the pre-MIS 8 conditions in the central Aegean is less robust. However, even if we accept that at the moment the arguments for continuous land exposure in the C. Aegean during the Early and Middle Pleistocene are tenuous, it is still secure to argue that extended lands were indeed exposed across the northern and central Aegean, at least during the glacial lowstands of the same time span.

Furthermore, Tourloukis 2010 (167) emphasised the fact that Lykousis (2009) does not pinpoint the lower age limit for the maximum land exposure in the Aegean. As such, Lykousis' reconstruction could be overruled if the existence of marine deposits older than MIS 10-12 would ever be found – and confirmed as such – in areas that have been reconstructed as dry land. Furthermore, Anastasakis et al. (2006) presented geological evidence (seismic stratigraphy, multichannel seismic reflection profiles and sedimentological data) suggesting that the marine connection between the Myrtoon basin and the central Aegean has been established since the Middle Pliocene, and the Gulf of Corinth connection to the Ionian Sea by the Middle Pleistocene (fig.4.10), contra Lykousis (2009), who suggests that such marine gateways were opened only after the last glacial transgression, around MIS 2 (fig.4.9).

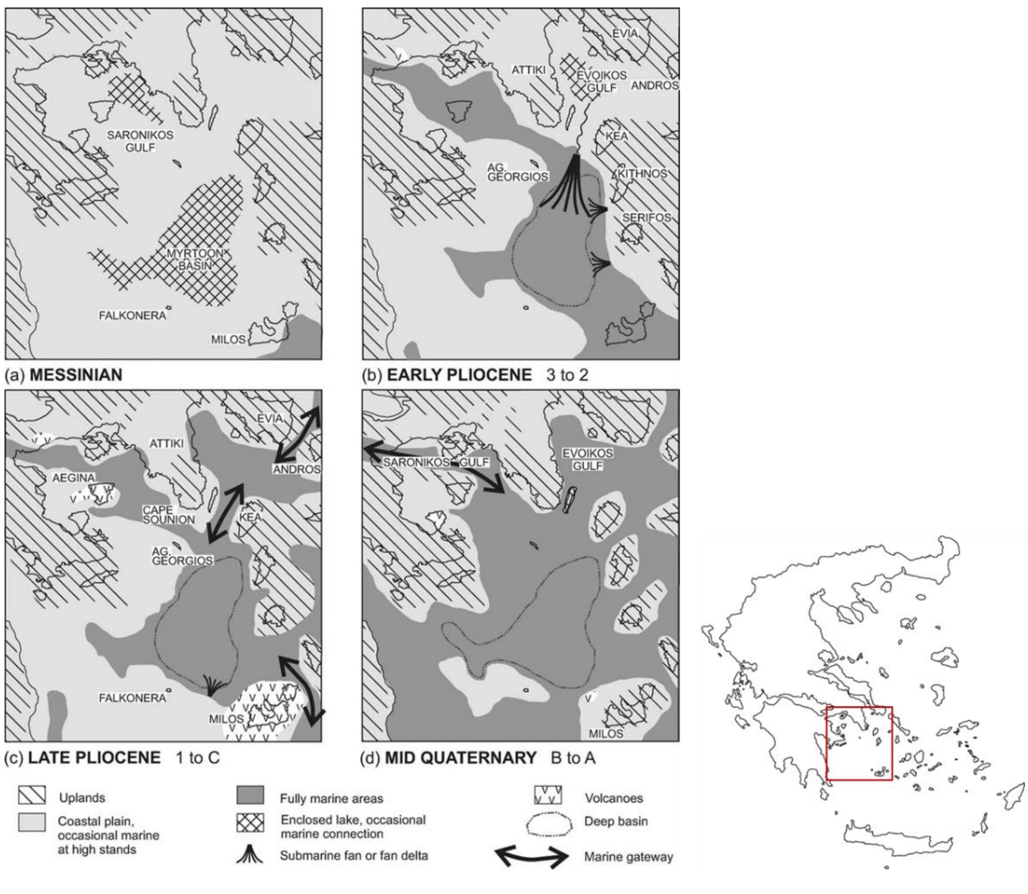


Figure 4.10. Palaeogeographical reconstruction of the Myrtoon Basin, for the Messinian (a), Early Pliocene (b), Late Pliocene (c) and middle Quaternary (d) periods. Notice the marine gateways to Saronikos and Evoikos (c) and the Gulf of Corinth (d) (modified fig. 15 from Anastasakis et al., 2006)

Nevertheless, Lykousis' reconstruction has had a serious impact on the archaeological thought, affecting undoubtedly the shift in the research direction from the Greek mainland to the Aegean Sea. Tourloukis and Karkanas (2012b:11) accepted Lykousis' reconstruction, despite the problematic points, as *"generally solid enough to allow a first-order interpretation of its archaeological implications"*. Founded upon Lykousis' work, Sakellariou and Galanidou (2016; 2017) moved further, integrating evidence on the geology, tectonics, morphology and hydrogeology of the shallow coastal and shelf areas in order to reconstruct the palaeogeography of the Aegean. Taking into account the variable nature of the active morpho-tectonic processes, evolution and configuration of the coastal and submerged landscape, the Aegean has been divided into nine geographical units with discrete geotectonic and morphological characteristics (fig. 4.11). In their synthesis, they emphasise the importance of considering two main factors, when exploring the potential of the Aegean landscapes as terrestrial environments: (a) the contribution of tectonics as the main controlling factor for the evolution of the geographical configuration (past and present), and (b) the high ecological value of the exposed Pleistocene Aegean landscape associated with rich and variable water resources. This study set a frame of reference for assessing land-routes and natural resources available to hominins at different times of the Pleistocene, and allowed the Aegean region to enter the discussion of the early occupation of Europe, via a south-eastern route.

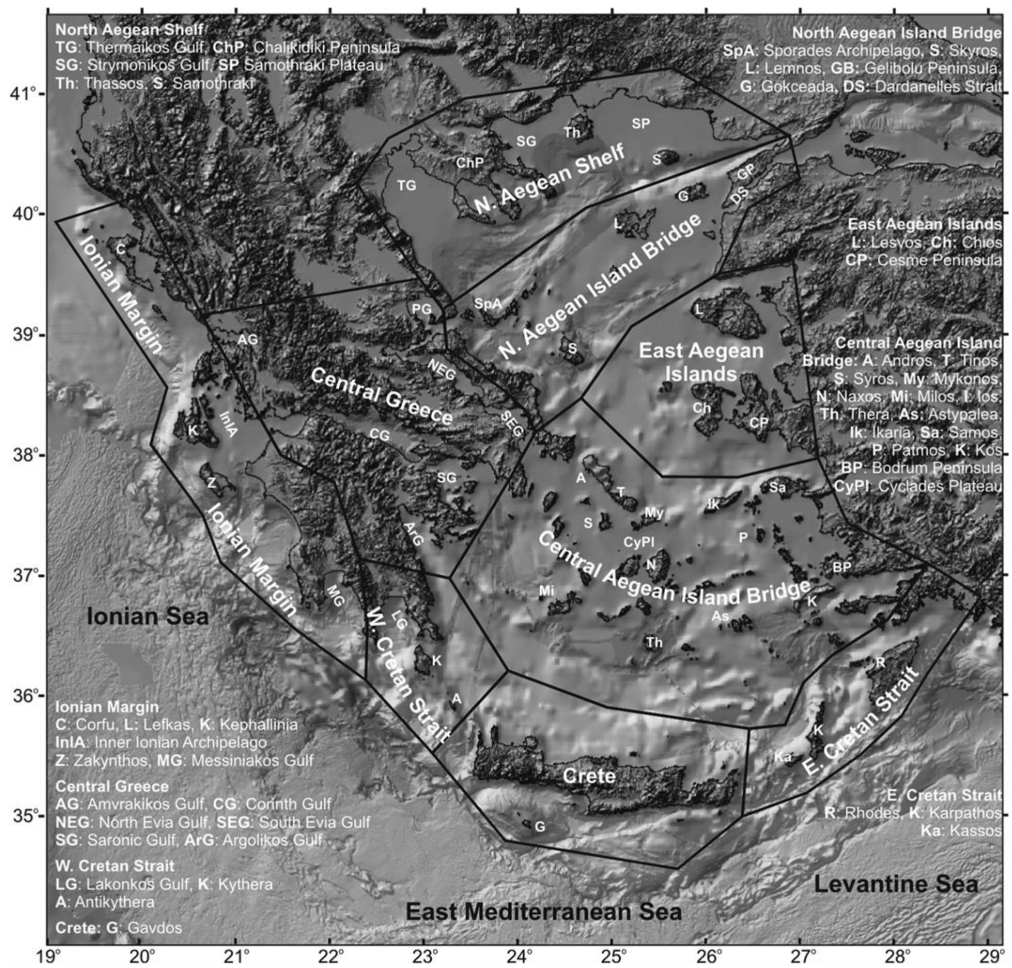


Figure 4.11. The nine geographical units of the Aegean according to Sakellariou and Galanidou (2016; 2017) on a bathy-morphological map of the Aegean (from Sakellariou and Galanidou 2016: fig. 7)

These recent advances triggered new underwater research in the Aegean and Ionian Seas that made available more information about the palaeogeographical evolution of the landscape for archaeological inquiries regarding the hominin presence, activity and mobility over the wider Aegean region.

Zavitsanou et al. (2015) conducted geophysical survey in the Inner Ionian Sea producing a palaeogeographical reconstruction during the Late Pleistocene low sea-level stands. Using a Boomer-type sub-bottom profiler and a dual frequency side scan sonar they managed to identify palaeosea- level indicators such as prograding prodelta clinoforms and submerged marine terraces, in the 152 km of subbottom profiles. The results suggest that the islands of the Inner Ionian Sea were connected to each other and to the adjacent mainland during and prior to the LGM. Thus, the area between the present-day island of Lefkada /western Greek mainland and the islands/islets of the Ionian archipelago formed an exposed terrestrial landscape during the glacial periods of the Late Pleistocene. The archaeological implications have been the focus of the archaeological research conducted on the islands in parallel with the underwater survey highlighting the importance of interdisciplinarity in the exploration of hominins over changing landscapes (Galanidou 2018).

Foutrakis and Anastasakis (2018), more recently, conducted oceanographic research in the Saronikos Gulf, using high-resolution seismic tomography (multibeam echosounders of two different frequencies) for the acquisition of 5000 km of seismic lines. By using the same method as Lykousis (2009) i.e. correlating the topset-to-foreset transition of the vertically and laterally stacked prograding sequences traced in seismic profiles, they managed to identify palaeoshoreline positions during successive glacial lowstands from MIS2 (14 Kya) reaching as far back as MIS22 (866 Kya) (fig. 4.12). This is the longest sequence, chronologically, ever recorded so far. According to their reconstruction, during MIS20-22 most of the Saronikos Gulf was a terrestrial area with lakes formed in Megara and Epidaurus basins (to the western part of the gulf), while in Methana basin another isolated lake was separating the western part from the south-eastern part of the gulf. The outer south-eastern Saronikos was connected to marine environments through a narrow channel, and remained connected throughout the Quaternary. From MIS 16 the Megara and Epidaurus lakes were connected forming a big brackish lake. Extensive exposed lands at the north and lake environments at the west persisted until at least MIS10-12. Until MIS8 NE Saronikos was a fully terrestrial area. From MIS 6 the formation of another brackish lake at the Salamina basin separated NE from NW Saronikos, but no marine connection was established between the N-NW and E-SE parts before MIS 2 - through a narrow strait between Aigina and Salamina. Until MIS 2, Aigina, Methana and Agistri remained part of the exposed terrain and connected to Flesve, Piraeus and Salamina, while Poros was adjoined to Peloponnese. The brackish lake covering the NW –SW part of Saronikos was a persistent feature during MIS 2 (fig 4.12).

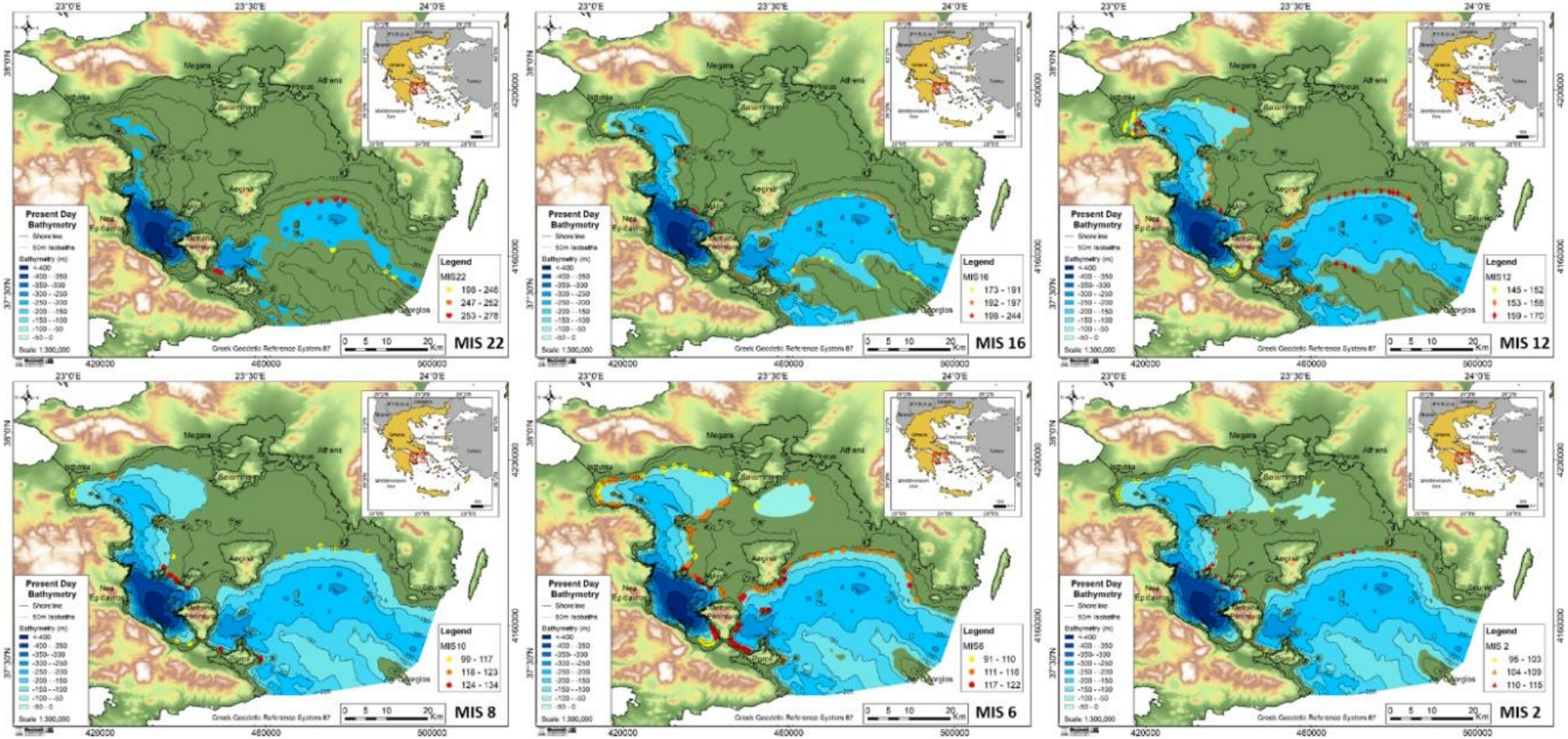


Figure 4.12. The palaeogeographical reconstruction for the Saronikos Gulf by Foutrakis and Anastasakis covers a wide chronological range from 866 Kya to 14Kya. Selected lowstands: MIS22, MIS16, MIS12, MIS8, MIS6 and MIS2 (modified fig.3 from Foutrakis and Anastasakis 2018a)

4.6 Discussing the Archaeological Potential

Available palaeogeographical reconstructions, despite (a) their time limitations, mostly, but not exclusively, restricted to the last glacial cycle, with only two studies referring to the earlier parts of the Pleistocene (with more reliable evidence from the Middle Pleistocene onwards), and (b) their local character (with only few examples covering the whole of the Aegean Sea), provide sufficient evidence to start envisioning the wider Aegean region as an extended terrestrial environment during the Lower Palaeolithic and a potential core for the archaeological investigation.

However, defining areas of possible archaeological interest within the now submerged Pleistocene landscapes is quite difficult and mainly controlled by the ‘discovery factor’ (Tourloukis and Karkanas 2012b:11). The spatiotemporal windows of opportunity are quite random and restricted, due to the dynamic character of the landscape and the active geomorphic processes that set specific limitations on preservation, accessibility and visibility of the Early and Middle Pleistocene material onshore and off, as explained thoroughly by Tourloukis (2010) and Tourloukis and Karkanas (2012b). The same pattern observed in mainland Greece (i.e. the change in the directions of the extensional tectonics during the Early- Middle Pleistocene and the consequent exposure of basin sediments in erosion-see chapter 2) also affected the submerged landscapes of the Aegean. Further erosion should be added, due to successive cycles of exposure following the glacial-interglacial transitions (after MIS 6 until the present), extensive sedimentation (Perissoratis and Conispoliatis 2003; Lykousis, Karageorgis and Chronis 2005) and subsidence (Lykousis 2009). Thus, this part of the record seems to be lost forever or being currently inaccessible (Tourloukis and Karkanas 2012b: 10).

Plio-Pleistocene sediments have been identified in the submarine basins of the Aegean, usually overlaid by thick Quaternary sequences (Mascle and Martin 1990; Sakellariou, Mascle and Lykousis 2013; Lykousis et al., 1995). Sub-bottom seismic reflection profiles demonstrate the existence of such Plio-Quaternary depocenters in (fig. 4.4): Southern Skyros, Cavo d’Oro, the western part of the North Ikarian basin (basement ridge between Ikaria and Mykonos, east of Amorgos and west of Melos), along northeastern Euboea, Southern Ikaria, between Lesvos and Psara (with a possible earlier Miocene component), around Limnos (a thin, 300-400m Miocene-Plio-Quaternary layer) and along the northern margins of the Aegean, (the Gulf of Thermaikos, the Gulf of Orfanou, the basin at the mouth of Nestos River – Prinou basin and the basin below the shelf-margin east of Thasos).

Some interesting cases are observed along the Volcanic Arc (Nomikou et al., 2013). At The westernmost end of the arc in the Western Saronikos Gulf, Plio-Quaternary sediments have been identified within the Epidavros basin (thickness 400m) and the Megara Basin (thickness 500m). Tourloukis has already highlighted the high potential of preservation and visibility for material ≥1 Mya within the Megara basin (2010: 157-9). The whole system has been affected by the volcanic activity of the Pausanias submarine volcano. Evidence from seismic reflectors show that the deposition of the late Pleistocene and Holocene sediments occurred before the volcanic activity (fig.4.13). This may represent a 'sealed' sequence and a unique opportunity for applying absolute dating techniques. Fourtakis and Anastasakis' researches, noted above, (2018a; 2018b) have recognised three main periods of volcanic activity from the Pausanias volcano - at ca. 450 ka (VE3), 200–130 ka (VE2) and ca. 14 ka (VE1) - by correlating the offshore volcanoclastic flows with the chrono-stratigraphically dated sedimentary sequences based on the positions of the palaeoshorlines. Furthermore, they succeeded in establishing correlations with the onshore equivalents from the Methana volcanics on the northern part of the Methana peninsula. This solid chrono-stratigraphic framework, one of the very few in the Aegean region, may be extremely useful for defining areas of possible archaeological interest on- and off-shore.

A similar situation has been identified in the submarine area between the islands of Nisyros, Kos and Telos (i.e. within the volcanic field of Nisyros). The volcanic formations have been found at great depths (680m) within the large graben/tectonic basin, forming a relief of more than 1400m. As demonstrated by the profile in fig. 4.14 (Nomikou et al., 2013: 139), volcanic layers (Late Pleistocene activity) have been deposited over the earlier Plio-Pleistocene sediments. However, given the great depths where these sediments are buried and the thickness of the volcanic layers, access to this promising sequence seems to be impossible.

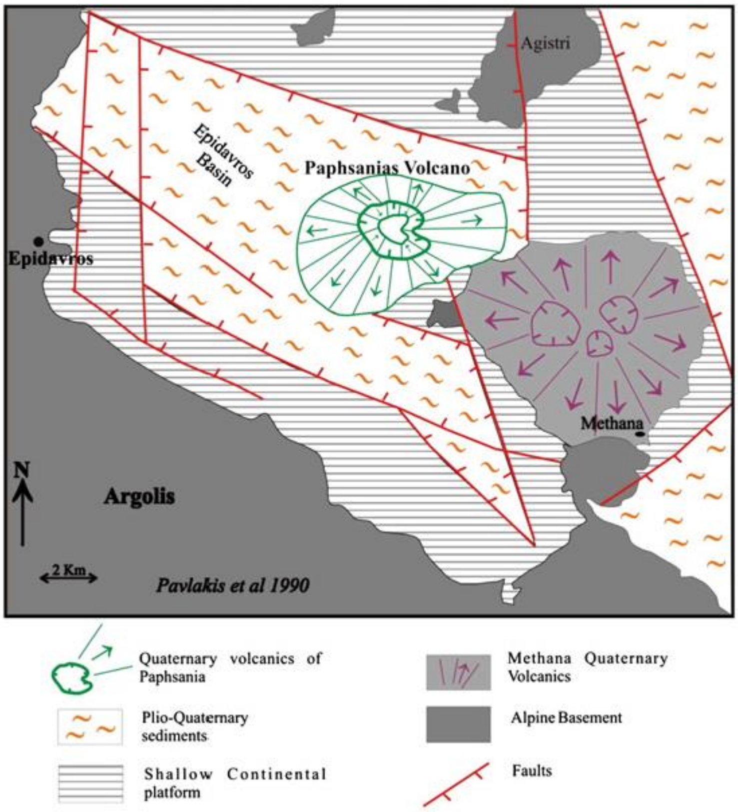


Figure 4.13. Tectonic sketch map of Saronikos Gulf with the location of the Pausanias submarine volcano Plio-Quaternary sediments and volcanic surfaces. Notice the area around the Pausanias volcano covered by volcanic material, overlying the Plio-Quaternary sediments within the Epidavros Basin (from Nomikou et al., 2013: fig. 3a)

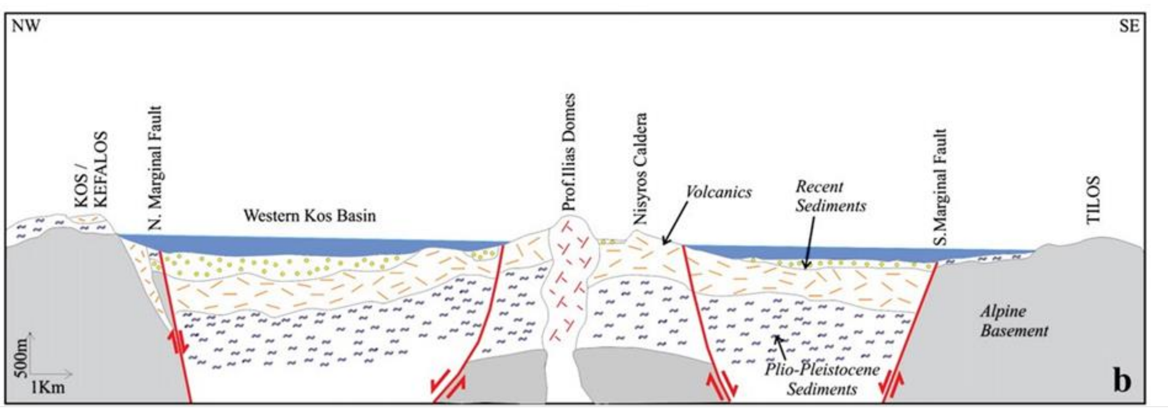


Figure 4.14. Schematic tectonic profile from Kos/Kefalos Peninsula to Tilos. Notice the Plio-Pleistocene sequences 'sealed' by the volcanic layer (from Nomikou et al., 2013: fig.13b)

Tourkoukis and Karkanas (2012b) made some rough calculations about the current preservation potential of the Plio-Pleistocene material (around MIS 10-12 and earlier) taking into consideration, (a) the initial extent of the Early-Middle Pleistocene landscape, including the maximum exposure of the Aegean dry land, (b) taphonomic parameters (Pleistocene sediments occurring in basins/other depressions) and (c) topographic parameters (low-gradient settings), to suggest that only 4% of the initial extent possibly preserves evidence of the Lower Palaeolithic record. Furthermore, if we consider accessibility problems, as demonstrated in the examples above, the discovery and retrieval possibility of the Early and Middle Pleistocene evidence becomes vague. Even so, "*the surviving part of the record may yield extremely important data in the future*" (ibid 11).

4.7 Concluding remarks

Despite the objective difficulties, related to (a) limited chances of retrieving LP material (accessibility and preservation bias), and (b) chronological limitations in the available palaeogeographical reconstructions, the current consensus is that it is worth exploring the archaeological implications emerging from the occurrence of extended lands in the Aegean during the Early and Middle Pleistocene. The recent palaeogeographical reconstruction by Lykousis (2009), the more advanced work by Sakellariou and Galanidou (2016; 2017) and the solid chronostratigraphy from Saronikos reaching as far back as 866 Ka by Foutrakis and Anastasakis (2018a) add significantly to our knowledge about the Aegean palaeolandscape and extend the time range of the research to the early Middle and potentially to the Early Pleistocene - breaking the LGM threshold. The archaeological implications are enormous and need to be assessed due to a set of promising characteristics:

1. Spatial Coverage: the exposed lands of the Aegean were analogous, in terms of spatial coverage during the maximum exposure, to the current extent of the Greek mainland. As such, specific areas may offer windows of opportunity for the LP research.
2. Time coverage: extended terrestrial environments prevailed in the Aegean region during the early out of Africa dispersals and the early peopling of Europe. The now submerged landscapes of the Aegean may hold valuable evidence of an early hominin presence in this area.
3. Ecological value: geological data allow us to envision the exposed lands as attractive habitats, quite rich in natural resources (specifically water supplies and volcanic rocks), offering advanced survival/exploitation and dispersal opportunities to hominins moving across the area or occupying it.

A reconsideration of the wider Aegean region (including eastern and north-eastern Mediterranean) as a possible core area for hominin activity and mobility rather than a periphery during the Lower Palaeolithic is already being put forward (Tourloukis and Karkanas 2012b; Galanidou 2014a; Sakellariou and Galanidou 2016; 2017). However, when attempting to assess the archaeological implications in practical terms, specific challenges emerge:

1. In this assessment, the Aegean is perceived as a terrestrial landscape. However, the environments and the topography of the now submerged landscapes are largely unknown.

2. The dynamic character of the tectonically active Aegean landscape means that the region suffered massive transformations (as explained in this chapter), altering consistently the palaeotopography and palaeogeography throughout the Pleistocene and the Holocene.
3. Available datasets from the Aegean are fragmented due to their scarce and discontinuous nature and due to temporal limitations, with available evidence (archaeological/palaeoanthropological, paleoenvironmental and paleogeographical) covering efficiently only the last glacial cycle (last 120 Ka).

The Aegean is an extremely complex area in terms of geology, hydrology and sedimentation, and reconstructions of deep time can be extremely problematic. Thus, understanding the prehistoric submerged landscape of the Aegean basin, and the potential for preservation that this holds, creates a methodological and interpretational challenge. Available data can still be used to help us explore some aspects, if the appropriate methodologies are employed. Innovative approaches need to be developed in order to overcome successfully the limitations that have been recognised and start conceptualising and modelling hominin presence, activity and mobility over the Aegean palaeolandscape, and ultimately target specific areas over the modern landscape with increased research potential on- and off-shore.

Chapter 5 Theory and Methods

5.1 Setting the methodological framework

5.1.1 Introduction

Available archaeological evidence, bioarchaeological parameters and palaeogeographical indicators as presented in the chapters 2-4, reveal a complex context, with serious limitations on the one hand, and high research potential on the other. This controversy could be summarised under three main points:

1. The potential of the exposed landscapes of the Aegean during the Middle and the Early Pleistocene for hominin dispersal.

Recent work on submerged landscapes reveals the existence of extensive exposed lands during the Middle, and perhaps during the Early, Pleistocene, over the area now covered by the northern and central Aegean Sea (Lykousis 2009; Sakellariou and Galanidou 2016; 2017). Active tectonics and sea-level fluctuations resulted in successive cycles of landscape transformation throughout the Pleistocene; parts of the landscape were uplifted while others were submerged. Newly exposed areas provided (a) pathways for animal and hominin dispersal (via land bridges), as well as (b) attractive niches for occupation (extended exposed lands). Currently submerged landscapes therefore could potentially hold archaeological (artefacts) and palaeontological (faunal) remains from the Pleistocene.

2. The understudied biogeographical role of the Aegean during the Middle and the Early Pleistocene.

The lost lands of the Aegean, a previously unrecognised area for potential hominin dispersal and settlement, lying between western Anatolia and Europe, need to be considered in revised readings of the early hominin evidence in Eurasia, and to be investigated for possible remains of hominin activity and mobility.

3. The negative impact of landscape dynamics on landscape reconstructions.

Deep time reconstructions are difficult and controversial, due to active geomorphic processes shaping the wider eastern Mediterranean since the Miocene. This in turn, poses serious practical limitations in the exploration of hominin behavioural patterns such as mobility and occupation – relating directly to the past configuration of the landscape and its environments.

The current working hypothesis, emerging from the first two points, is that the Aegean was not a barrier during the Middle and perhaps during the Early Pleistocene, but instead it was an open terrestrial landscape, from at least MIS 10-12 (ca. 480kya) until at least MIS 8 (ca. 250kya).

This leads on to the following questions:

1. Can we suggest possible zones of hominin activity (occupation areas) over the Aegean exposed landscapes?

2. Can we suggest possible corridors of opportunity for hominin dispersal, traversing the Aegean exposed landscapes?

Answering the research questions, is an extremely challenging task, lying beyond the effectiveness of fixed methodological tools in archaeology - due to the limitations stressed by the third point. To address it successfully, a new methodological scheme needs to be developed on an interdisciplinary basis, making the best use of available tools for spatial analyses but keeping archaeology as the core element.

5.1.2 Available GIS – based approaches

The research question refers to wider areas and larger, regional/continental scales over which movement is examined, shifting away from the past site-centred studies (Vita-Finzi and Higgs 1970 but see Khun, Raichlen and Clarke 2016, for a reassessment). Geographical Information Systems (hereinafter GIS) offer multiple and variable applications to approach archaeological questions referring to past activity (see Wheatley and Gillings 2002 for an overview), as well as to conceptualise and visualise the palaeolandscapes (Llobera 2001; 2003; Wheatley 2004) and explore several aspects of mobility and landscape use by early populations (Holmes 2007; Field et al., 2007). However, the application of GIS in Palaeolithic archaeology, especially in the earlier periods, has specific limitations relating to the unique nature of the Palaeolithic record itshelf, and the performance of GIS tools in incomplete and/or fragmented datasets, characterising the LP evidence.

There are issues that reoccur in Palaeolithic spatial analysis, and are also encountered in the Aegean LP, such as: (a) the continental scale of analysis – poor accuracy and resolution, (b) the time depth – temporal limitations, (c) the variability in preservation over the study region – coverage bias, which affect the way(s) we understand, model and interpret early human behaviours. Several different concepts and methodological approaches have been explored recently, using GIS applications, to tackle some of these issues in wider prehistoric contexts, such as, affordances (Llobera 1996; Webster 1999; Gillings 2012), accessibility (Garcia 2013), topographic complexity (King and Bailey 2006; Bailey and King 2011), and fuzzy logic (Hamer et al., 2019). The best practice depends, however, on the research question, the availability of data – complete/incomplete datasets, and the selection of appropriate tools to answer the specific research question(s). This is a process of testing methods and GIS tools within Lower Palaeolithic contexts, which represents a relatively new research field. In that sense, experimentation is part of this process. It is in this spirit of experimentation that one should view the methodological approach developed here.

5.1.3 Developing a new approach

The research question raises two main issues: (a) the traversability of the exposed Aegean landscape and (b) the attractiveness of its habitats. To explore this further, first we need to establish a good understanding of the nature of the past landscapes, to then be able to place hominins within their affording environment and make further assessments on behavioural patterns (mobility and settlement). This is the central idea behind the new methodological approach. Two main components need to be factored in: (a) the palaeolandscape and (b) the hominin factor. The palaeolandscape refers to the natural configuration of the past landscape and its affordances, and the hominin factor refers to the hominin response to this (i.e. groups moving across or settling in the palaeolandscape taking advantage of available affordances). Thus, the concept of affordances (*sensu* Chemero 2003) is the binding element, indicating the point(s) of convergence/interaction between hominins and their environments.

In the methodological scheme that will be explained in detail in the following sections, affordances are defined in spatial terms, to reflect survival and exploitation opportunities for hominins. Palaeolandscape features are used as markers for that interaction between hominins and their environments (affording world), and available archaeological and palaeoanthropological material, as a direct evidence of the hominin presence and activity over time and space (agent taking advantage of affordances). Palaeofauna is also included representing, as well, agents (the rest of the animal community) within the affording environment in correlation with hominins. Affordances are measured, recorded and synthesised within a GIS environment.

The scheme is realised in three steps:

> **STEP 1 - Collection of available evidence**: archaeological and palaeoanthropological (Ch.2), palaeofaunal (Ch.3), palaeoenvironmental and palaeogeographical evidence (Ch.4), referring to the Early and Middle Pleistocene, is selected from literature sources and open access data bases. This also includes proxy data.

STEP 2 - Defining affordances: based on available evidence about the palaeolandscape (component 1) and the hominin factor (component 2), firstly, the points of interaction between the two are identified and, secondly, affordance variables are defined.

STEP 3 - Building the GIS framework: adequate tools for spatial analyses, available within the ArcGIS suite, are used in order to process and analyse variables defined in the previous step.

The end-result is a suitability model, indicating areas with high and low affordances i.e. more and less suitable conditions for hominins, favouring their presence (survival opportunities) and activity (exploitation opportunities).

This chapter will provide detailed descriptions of the application of this three-step process to study the potential of the exposed Aegean landscapes for hominin dispersal and settlement during the Middle Pleistocene. Theoretical concepts, greatly influencing methodological choices and practical assessments, will be also discussed. The chapter is divided in two sections. The first deals with the palaeolandscape and the second with the hominin factor.

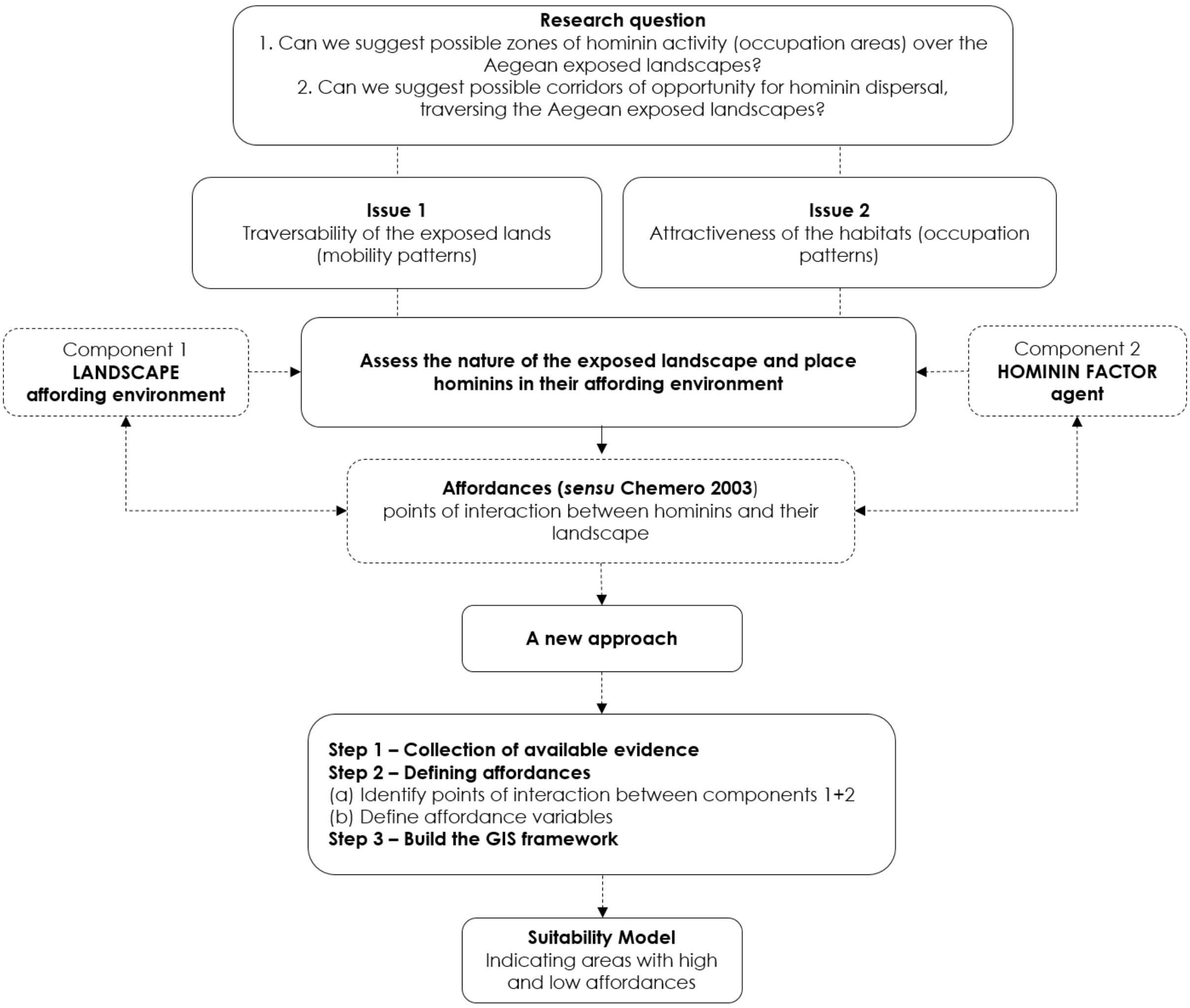


Figure 5.1. A schematic expression of the workflow followed to build the new methodological scheme

5.2 The investigation of the past landscapes

5.2.1 Limitations and potentials in the Aegean context (STEP 1)

As demonstrated elsewhere in this thesis (Ch.4), the production of accurate and detailed reconstructions for the Aegean's deep past becomes extremely difficult due to the geotectonic history of the region and the ongoing geomorphic processes. Reliable reconstructions of palaeogeography, palaeoenvironments and palaeoclimate fall within the time limit of the last glacial period (last 120 Ka). Thus, any attempt to evaluate the ancient landscapes as a whole (including the now submerged parts that used to be exposed in the past) before the LGM, is by default founded upon proxy data. Inevitably, such an investigation is problematic in terms of accuracy and resolution, and therefore limited in approximations and general statements.

The theoretical and practical framework of the complex topography concept developed by King and Bailey (2006; Bailey and King 2011) is used here to investigate the nature of the past landscapes and land use by hominins. The concept is compatible with the inherent limitations in the Aegean context, and helps in addressing them successfully: (a) it is applicable in (and suitable for) tectonically active areas, and (b) uses current topography as a proxy (topographic roughness) to deduce information on the topographic complexity of the past landscape. Topographic roughness is measured using topographic metrics in a GIS environment, to get values of the surface complexity, and ultimately identify areas with high research potential onshore and offshore.

A key concept here is as follows. High topographic complexity, marking territories with favourable (mosaic) environments and natural pathways for movement, would indicate high/higher preference by hominins (documented in the LP record), thus greater likelihood of hominin presence and activity. Since tectonic activity is ongoing in the Aegean, modern topographic complexity will reflect the presence of ancient complexity and in the same places – through the continuous renewal of the features produced by the geotectonic disturbance.

5.2.2 The complex topography concept

A dynamic landscape such as the Aegean, shaped by extensive tectonics and volcanic activity, has a complex topography with pronounced variability and heterogeneities, e.g. fault –bounded basins, uplifted areas, volcanic landscapes (see Ch.4). Seemingly, this topographic fragmentation/complexity in relation to the continuous transformation of the landscape (due to active geomorphic processes) is a negative factor in modelling hominin mobility and settlement. King and Bailey (2006:266) argue however, that complex landscapes actually helped in the maintenance of mosaic environments, variety-rich in natural resources and raw material availability and variability, providing the local conditions for human survival and the development of successful subsistence strategies. Faulting and folding caused by tectonics, create heterogeneous habitats with uplifted-drier areas and lowlands-wetter areas within a relatively small geographic range; disrupted water tables forming local catchments of fresh water supplies; and impose local - larger or smaller -barriers (e.g. lava flows, cliffs and gorges - fig.5.2). Furthermore, active tectonics help in the renewal of these topographic features for as long as the activity persists. Those mosaic environments seem to be attractive to early hominins as shown by available evidence from eastern Africa for the Early Pleistocene (see Reynolds, Bailey and King 2011 for an overview).

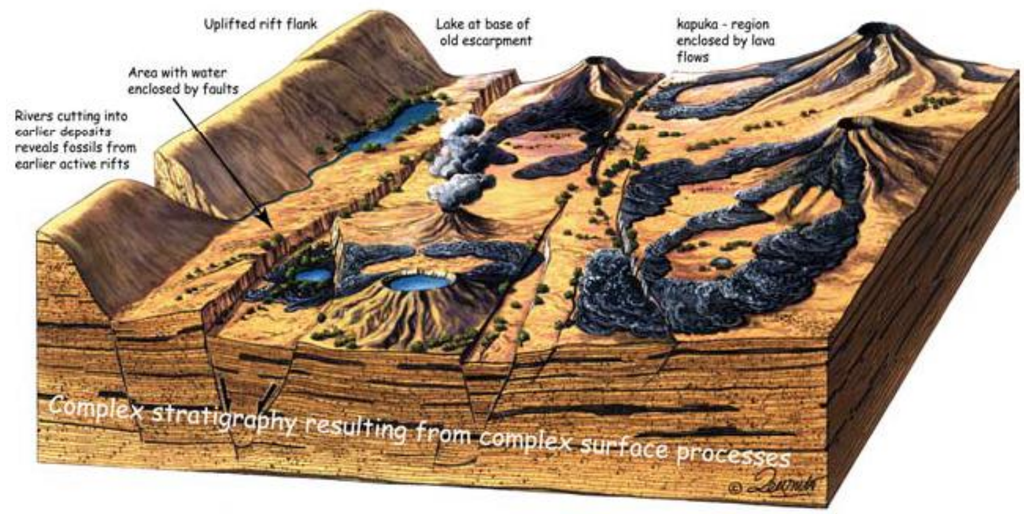


Figure 5.2. Model of a complex landscape (from King and Bailey 2006: fig. 2)

Bailey and King (2011: 1534) note "*We have hypothesised that the creation and maintenance of complex topography by active tectonics afforded opportunities to an intelligent but unspecialized predator to monitor animal resources, out compete other carnivores, and find protection from predators and safety for vulnerable young, thereby creating powerful selection pressures in favour of the human evolutionary trajectory*". Reynolds, Bailey and King (2011:21) emphasise that complex topography may also indicate mobility patterns by determining possible routes. Pronounced landscape features generated by tectonic and volcanic activity, such as lava flows, ridges and water barriers, must have created natural routes followed by dispersing population during the major events of the Early Pleistocene. Winder et al. (2013) go a bit further with the 'Scrambler Man' hypothesis, suggesting that anatomical features associated with bipedalism and the modern way of locomotion developed as hominins were engaging with complex landforms – challenging previous hypothesis associating the development of bipedal locomotion and modern body form with the opening of the landscape and the prevalence of savannah environments during the Early Pleistocene.

Recently, Kübler et al. (2015; 2016; 2019) and Devès et al. (2014; 2015), following and extending the research path opened by Bailey and King, have used a combination of the complex topography concept and edaphics in their approach. Edaphics rely on the chemical analyses of current soils. The regolith (i.e. soils and subsoils) provides the mineral nutrients necessary for the healthy growth of herbivores, especially young animals, through the plant foods that they eat, particularly soluble phosphates but other critical trace elements as well (e.g. selenium, cobalt, copper or potassium, Devès et al., 2014:142-4). Such nutrients are incorporated in the soil formation through the bedrock. Rich soils, promote lush vegetation, which is preferentially targeted by herbivores for grazing. Linking the current edaphic potential of a location with the chemistry of the underlying geology allows us to make generalized statements on the soil composition in the past, if the parent material (bedrock or sediment) is unchanged. Thus, by tracing these elements over modern landscapes, we gain insights into animal movements between areas of suitable grazing in the past. This in turn helps us to identify strategically advantageous locations over the landscape (e.g. good grazing, hunting opportunities) and reconstruct possible movement patterns between such locations (e.g. seasonal movements). However, as pointed out by Devès et al. (2015:210) the role of complex topography and edaphics for better understanding the hominin land use and exploitation strategies has received very limited attention in archaeological studies.

Kübler et al. (2015; 2016) presented evidence from the Kenya Rift, suggesting the initiation of ambush hunting at the Acheulean site of Olorgesailie, possibly favoured by the topographic complexity. Devès et al. (2014; 2015) reconstructed seasonal movement of large herbivores during the Middle Pleistocene, in relation to hominin exploitation strategies, and possible movement patterns in the Carmel area in Israel. These methodologies in combination help us to appreciate the impact of landscape dynamics and soil factors on hominins, and the wider animal community, regarding landscape exploitation.

Table 5.1. The complex topography concept and the study of edaphics use modern data to assess the nature of the past landscapes and the ways hominins and other animals used and exploited their environments

	Complex topography	Edaphics
Present	Measurement of irregularities on surface morphology in tectonically active environments (surface roughness)	Chemical analyses of modern soils to trace specific nutrients responsible for the healthy growth of herbivores
	Use of modern topography as a proxy to identify topographic complexity in the past	Identify strategic *loci* over the modern landscape corresponding to areas suitable for grazing in the past
↓	Topographically complex settings hosted mosaic environments with rich natural resources	Reconstructions of seasonal movements of prey animals
Past	Attractive areas for animals and early humans	Hominin movement patterns
	Possible occupation/exploitation areas and natural pathways	Possible routes for movement and dispersal

The complex topography concept in Lower Palaeolithic archaeology has been developed under the influence of the tectonic geomorphology, where proxy methods, such as topographic (surface) roughness, are used to measure surface irregularities (King and Bailey 2006). However, roughness maps are different from the topographic relief or the slope maps. Topographic roughness may occur in both high and low elevation areas, within variable topographic environments (e.g. steeper or shallower slopes) and in many different forms (e.g. as major fault scarps and deeply incised gorges hundreds of metres high, as minor fault scarps metres high, or as eroded boulder fields of lava; Bailey and King 2011: 1537). Within the complex topography concept, topographic roughness is used as a *“measure of tectonically active environments”* and as *“a proxy indication of the areas most favourable to human settlement and the most obvious pathways for dispersal”* (King and Bailey 2006: 279). In other words, the study of the modern dynamic landscapes can reveal useful information about the topographic complexity of the past landscapes. By using current elevation and bathymetric data to record the topographic roughness of the present surface in dynamic settings, we can identify areas of topographic complexity in the past, using high values of roughness as a proxy. The recorded features, reflections as they are of the past landscape’s configuration, may still offer rough approximations and/or indications for the nature of the past environments and their affordances, i.e. areas with high research potential.

The idea of the complex topography and its affordances was developed during the 1990’s, through fieldwork in Epirus (NW Greece), examining the location of Middle Palaeolithic sites on a complex topographic setting, in relation to the seasonal movement of prey animals (Bailey, King and Sturdy 1993). It has further been tested in Lower Palaeolithic contexts in eastern Africa (along the African Rift) and the Red Sea, in areas with abundant Lower Palaeolithic evidence, primarily in terrestrial settings (King and Bailey 2006; Bailey and King 2011; Bailey, Reynolds and King 2011). The application of the concept to submerged landscapes, using current bathymetry, has, so far, only been attempted in the southern Red Sea – Farasan Islands (Bailey and King 2011; Meredith-

Williams et al., 2014), enabling the identification of some elements of a complex topography *"with localised barriers and basins that would be very familiar to human populations adapted to conditions in the African Rift"* (Bailey and King 2011: 1550). These results however, promising as they might be, should be treated with caution due to the poor resolution of data. Nevertheless, the methodology works sufficiently in dynamic submerged contexts, permitting at least a preliminary recognition of topographic features that may reflect the topographic complexity and the mosaic nature of the past landscapes.

In order to overcome inherent limitations in the available material from the Aegean (section 5.2.1), the complex topography concept framework is applied, testing for the first time this particular approach in the north-eastern Mediterranean. The same practices developed for measuring topographic roughness in terrestrial environments, are used here to record, as well, the Aegean seabed surface irregularities (following Bailey and King 2011). In this way, estimations can be made about the topographic complexity of the Aegean exposed palaeolandscapes as a whole, including areas that may now be submerged but used to be exposed during the Middle Pleistocene - and perhaps even earlier. Underwater surface roughness recording has been attempted so far only once, in the Red Sea, as just mentioned. The new application in the Aegean region will cover a wider area (continental scale of analysis as opposed to the local scale tried before), and will provide a frame of reference for making further comparisons between different geographic regions with similar characteristics, in order to enhance the method in practical terms, and test the new interpretations in archaeological terms.

It is worth remembering at this point that the current land surface and the seafloor of the Aegean region do not correspond directly to the palaeolandscape surface. Raising a crucial question: what surface roughness is it going to be measured then? As it has been explained in chapter 4, local tectonism, erosion, sedimentation and subsidence have been continuously transforming the landscape, 'contaminating' the original palaeotopography of the Middle Pleistocene by creating new features and/or eliminating others. Obviously, these processes have different effect on landscape formation, over time and space, causing great diversity. Sedimentation is one of the high-impact factors controlling topographic configuration, clearly demonstrated along the Aegean continental shelves (especially in the northern and eastern Aegean due to extensive river discharge), as well as on the offshore formation. The evidence from the post LGM transgression-Later Pleistocene sedimentation suggests a great variability over the study area (for specific rates see Aksu, Yaşar, Mudie 1995; Piper and Perissoratis 2003; Lykousis et al., 1995; Perissoratis and Mitropoulos 1989). The thickness of the most recent sedimentary sequences, from different parts of the Aegean, ranges from 2m in the S. Ikaria basin, N. Sporades or the N. Aegean Trough (sedimentation rate of 0.08m kyr^{-1}), to several meters of thickness in Corinthiakos Gulf (40m), Patraikos Gulf (30m), Ierissos – Alexandroupoli Shelf (20m) or Kusandasi bay delta (35m) (sedimentation rates ≥ 1.8m kyr^{-1}), indicating that the rates of sedimentation vary over the Aegean region during the Later Pleistocene- Holocene (Perissoratis and Conispoliatis 2003). The same level of variability should be expected for the pre-LGM activity, as shown in examples from the southern Aegean (Piper and Perissoratis 2003: 263), let alone the diachronic action of tectonism, subsidence and erosion. Consequently, modern landscape topographic roughness cannot be expected to preserve absolutely the past surface irregularities, or to put it differently, past surface roughness is not accurately manifested on the present day surface. Measurements of modern topographic roughness on-and off-shore can only provide approximations for the surface structure in the deep past, with more reliable results deriving from areas where the main landscape features persist in time or remain relatively stable. In the landscape modelling described in the next section, the effect of the various geomorphic processes has not been calculated – this goes beyond the objectives of this study. The aim here is not to create an accurate reconstruction of the palaeolandscape but to identify patterns of complexity in the past topography, using modern surface roughness, in order to establish a wider framework for studying hominin activity over the Aegean dynamic landscapes.

5.2.3 Measuring and recording topographic roughness in the Aegean region

5.2.3.1 Topographic metrics

Topographic, or surface, roughness is a geomorphological variable, which has been used widely in earth and planetary sciences (Grohmann et al., 2010:1200) to deduce information about current and past formation processes. It is a measure of surface irregularities, expressing the variability of a natural surface at a given scale. In the complex topography concept, as stressed in the previous section, topographic roughness is used as a proxy to identify potentially favourable areas to hominins (occupation areas and natural pathways for movement), by measuring topographic irregularities found in tectonically active environments.

The GIS tool kit offers many different ways for measuring and visualising topographic roughness. Three different methods are tested here: Topographic Position Index (hereinafter TPI), Deviation of Mean Elevation (hereinafter DEV) and Slope Analysis (hereinafter SL). All are topographic metrics, measuring the topographic position of a central point in relation to its surroundings, in a predetermined radius; put another way, these are three different ways of measuring the differences in elevation between a central point and its neighbouring points in a given neighbourhood. This concept is based on the topographic prominence idea as expressed by Lliobera (2001: 1007): *"Topographic Prominence is here described as a function of height* *differential between an individual and his/her surroundings as apprehended from the individual's point of view. More precisely, it is defined as the percentage of locations that lie below the individual's location (terrain altitude plus individual's height) within a certain radius. Such a definition contrasts with other possible ones that could be based on visual aspects of the terrain (e.g. how visible and its shape). The definition provided is, on purpose, a relative one i.e. prominence is defined in relation to a radius".*

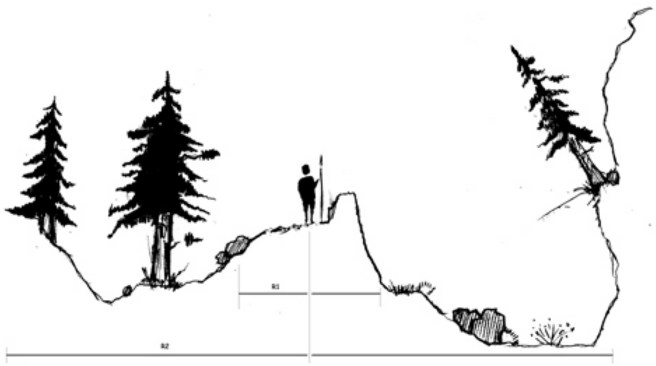


Figure 5.3. Graphic demonstration of the topographic prominence of an individual in a given topographic setting, at different scales (from Llobera 2001: fig. 1)

TPI: Measures the difference between the elevation at the central point (i.e. the cell elevation value, z_0) and the average elevation (ž) around it within a predetermined radius (Gallant and Wilson 2000):

$$TPI = z_0 - \check{z} \quad (1)$$

In other words, the topographic position of each cell in the raster is identified with respect to its local neighbourhood, thus its relative position (Weiss 2001; Jenness 2006). The index is useful to identify landscape patterns and boundaries that may relate with geomorphic processes, soil characteristics, rock types, vegetation. The index is also applicable to bathymetric data (Bathymetric Position Index/BPI) (Verfaillie et al., 2007)

DEV: Measures the topographic position of a central point (z_0) using TPI and the standard deviation of the elevation (SD) (Gallant and Wilson 2000):

$$DEV = \frac{z_0 - \bar{z}}{SD} \quad (2)$$

$$SD = \sqrt{\frac{1}{n_R - 1} \sum_{i=1} (z_i - \bar{z})^2}. \quad (3)$$

In other words, it measures the topographic position as a fraction of local relief normalised to local surface roughness (De Reu et al., 2013:42).

SL: Calculates the maximum rate of change of the surface in the horizontal (dz/dx) and vertical (dz/dy) directions, from every cell of the raster within an eight-cell neighbourhood (around the central cell each time). The maximum change in elevation over the distance between the cell and its eight neighbours identifies the steepest downhill descent from the cell. The basic algorithm used to calculate the slope is from Burrough and McDonell (1998: 190):

$$\text{slope\_radians} = \text{ATAN}\left(\sqrt{[dz/dx]^2 + [dz/dy]^2}\right) \quad (4)$$

a	b	c
d	e	f
g	h	i

The rate of change in the x direction for cell e is calculated with the following algorithm:

$$[dz/dx] = ((c + 2f + i) - (a + 2d + g)) / (8 * \text{x\_cellsize}) \quad (5)$$

The rate of change in the y direction for cell e is calculated with the following algorithm:

$$[dz/dy] = ((g + 2h + i) - (a + 2b + c)) / (8 * \text{y\_cellsize}) \quad (6)$$

5.2.3.2 Topographic roughness on modern elevation and bathymetry from the Aegean region

Maps of surface roughness are produced here by testing the three topographic metrics, mentioned above, on modern elevation and bathymetry from the Aegean. The study area, includes, from east to west, the Aegean coasts of Turkey (W. Anatolia), the area now covered by the northern and central Aegean Sea and the Greek mainland (fig. 5.4). Topographic roughness for the study area has been calculated and recorded using the ArcMap software, a facet of the ArcGIS desktop suite (ESRI), versions 10.4 – 10.7 and specifically the Spatial Analyst toolkit (under the spatial analyst licence). Terrain data was modelled using the ASTER Global Digital Elevation Map, version 2 (ASTERGDEM V2) (30m resolution), available at NASA Land Processes Distributed Active Archive Centre (LP DAAC), and bathymetric data was modelled using the Eastern Mediterranean Bathymetric Map (2016) (250m resolution) by courtesy of the Hellenic Centre for Marine Research (now available at the EMODnet Bathymetry - https://www.emodnet-bathymetry.eu/). The spatial reference used throughout the analysis is the WGS84 geographic coordinate system, with linear units in metres, and all data are projected in the Web Mercator Auxiliary Sphere projection system (compatible with available online data). The Digital Elevation Map (DEM) and the bathymetry raster have been combined into a new raster (mosaic raster thereinafter) using the mosaic to new raster tool (data management) (fig.5.4). This new mosaic raster provides the basic grid for calculating topographic roughness and applying further spatial analyses as it unifies into one topographic record elevation and bathymetric data from the study area.

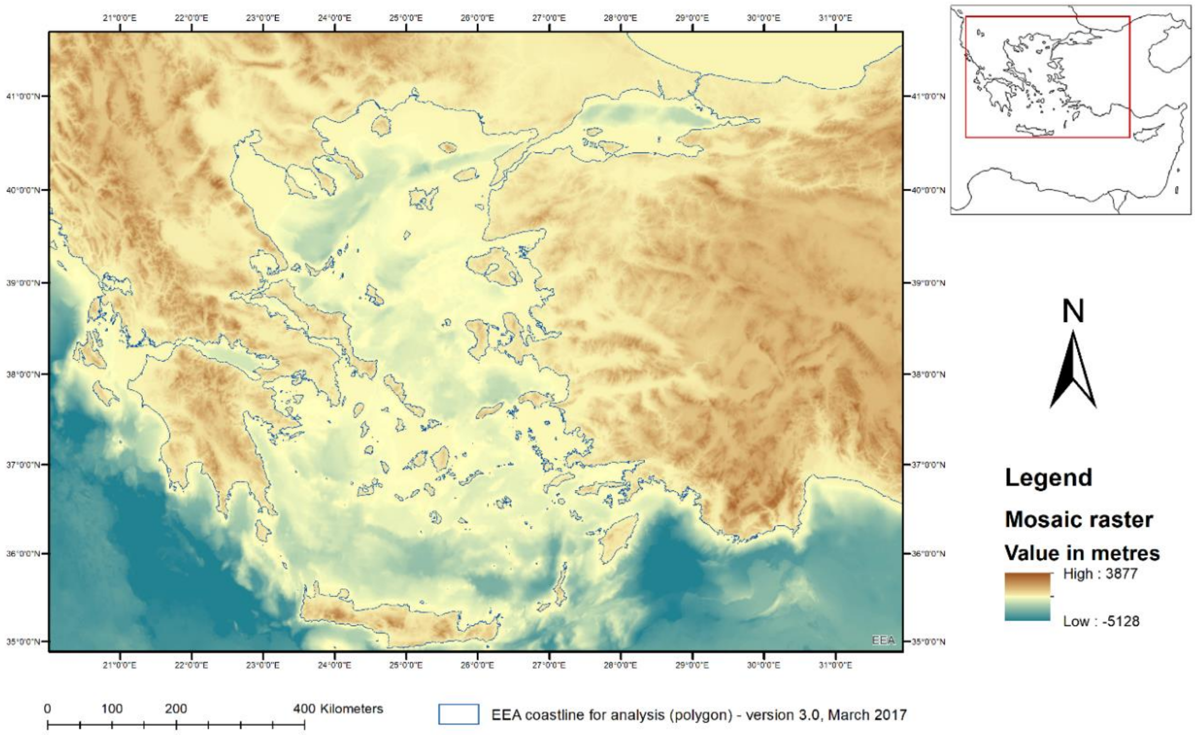


Figure 5.4. The Mosaic raster, combining elevation and bathymetry from the study area. The blue line corresponds to the present-day coastline. Terrain data: ASTER Global Digital Elevation Map, version 2 (ASTERGDEM V2) (30m resolution), available at NASA Land Processes Distributed Active Archive Center (LP DAAC). Bathymetric data: Eastern Mediterranean Bathymetric Map (2016) (250m resolution) by courtesy of the Hellenic Centre for Marine Research. Coastline: European Environmental Agency (EEA), available in ArcGIS online. Coordinate system: WGS 1984 Web Mercator Auxiliary Sphere; Projection: Mercator Auxiliary Sphere; Datum: WGS 1984; Linear Units: meters. Map produced in ArcGIS 10.6

The TPI, for the study area, is calculated from modern elevation and bathymetry grids, using the formula developed by Arthur Crawford of ESRI (Weiss 2001, Jenness 2006). Three new elevation rasters are produced, using as input the mosaic raster (modern elevation and bathymetry combined) (Spatial Analyst>Neighborhood> Focal statistics):

- Mean elevation: calculates the mean (average value) of the cells in the neighbourhood.
- Minimum elevation: calculates the minimum (smallest value) of the cells in the neighbourhood.
- Maximum elevation: calculates the maximum (largest value) of the cells in the neighbourhood.

The following expression is then entered in the raster calculator (Spatial analyst> Map algebra> Raster calculator):

(“radius in meters” – “minDEM”) / (“maxDEM” – “minDEM”)

The “radius in meters” represents the mean (smoothed) elevation raster, the “minDEM” represents the minimum elevation raster, and the “maxDEM” represents the maximum elevation raster.

The output raster provides an index (classes of values) expressing topographic roughness. Positive TPI values indicate that the central point is located higher than its average surroundings, while negative values indicate a position lower than the average. Values near zero represent either flat terrain (slope is near zero), or areas of constant slope (slope significantly greater than zero) (fig.5.5).

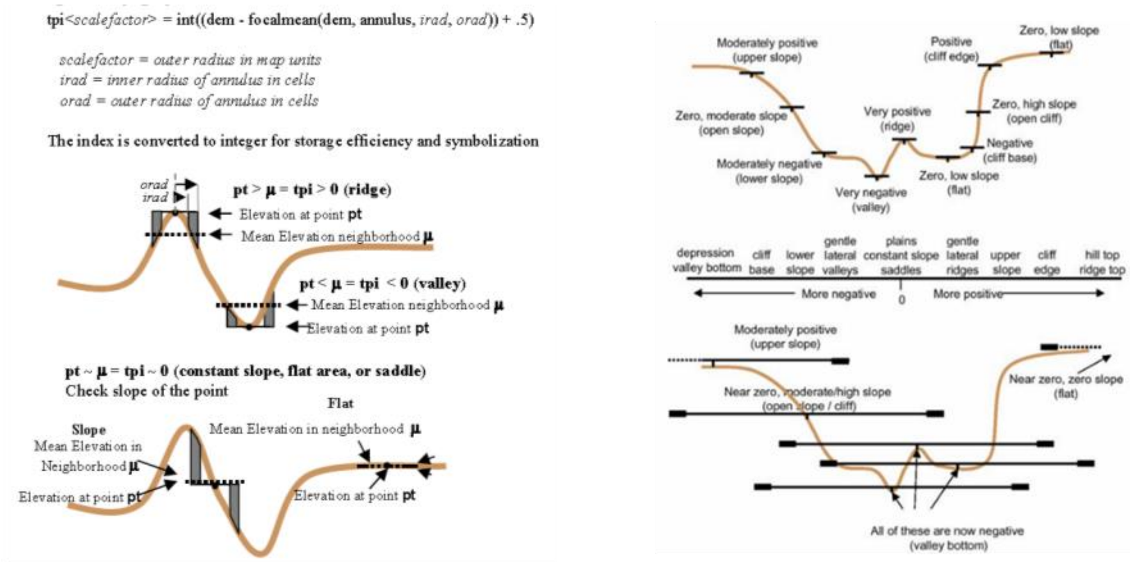


Figure 5.5. Examples of TPI calculations for given locations on a landscape (left) and in different scales (right). Bigger radii reveal larger landscape features (from Weiss 2001: figs 2a, 3a)

The DEVis calculated using modern elevation and bathymetry grids, as before. The mosaic raster is the input in the focal statistics tool to produce two new elevation rasters (Spatial Analyst>Neighborhood> Focal statistics):

- Range elevation: calculates the range (difference between largest and smallest value) of the cells in the neighbourhood.
- Mean elevation: calculates the mean (average value) of the cells in the neighbourhood (the same as before).

The following expression is entered in the raster calculator (Spatial analyst> Map algebra> Raster calculator):

(“meanDEM” – “DEM”) / “rangeDEM”

The “meanDEM” represents the mean elevation raster, the “rangeDEM” represents the raster containing range of elevation values and “DEM” represents the mosaic raster.

The output raster provides classes of values. As in the TPI, positive values indicate that the central point is situated higher than its surroundings (neighbourhood) and negative values indicate that the central point is situated lower. The output values are usually between +1 and -1 and values outside this range usually indicate anomalies within the DEM.

For the Slope analysis, the slope tool is used in the spatial analyst toolkit (Spatial analyst>Slope). Slope values are calculated from the mosaic raster (input). The output raster shows the rate of change in elevation in classes of values; the lower the slope value the flatter the terrain, the higher the slope value the steeper the terrain.

For the TPI and DEV three different radii have been tested: 1km, 3km and 10km, representing different scales within the exploitation range (10km) suggested for the Lower Palaeolithic (Feblot-Augustins 1999; Bailey and King 2011: 1533) (fig. 5.7).

For the classification of the TPI values into morphological classes, two different ways of classification have been used:

(a) The Natural breaks (Jenks) which is the default classification in ArcMAP.

(b) The Weiss (2001) classification (fig.5.6 – right). The landscape is classified into discrete slope position classes using standard deviation of TPI. The degree to which the central point (cell) is higher or lower than its surroundings (in a predetermined radius), plus the slope of the cell (at the central point), is used to classify the cell into a slope position. If it is significantly higher than its surroundings, then it possibly lies on or near the top of a hill or a ridge, if it is significantly lower than its surroundings, then it possibly lies at or near the bottom of a valley (Jenness 2006: 6). However, the characterisation of landscape features may vary according to the scale over which they have been studied. The Weiss classification takes into consideration the variability of elevation values within the predetermined radius, enabling a better visualisation of the topographic complexity in different scales. Larger scales reveal larger landscape features while with smaller scales a more detailed local topography emerges (fig. 5.5).

Landscape classification (Weiss 2001)	**Breakpoints of classes**
Valleys / Depressions	<-1 STDEV
Lower Slope	>= -1,0 STDEV, < 0,5 STDEV
Flat	>= -0,5 STDEV =< 0,5 STDEV Slope <= 5 degrees
Mild Slope	> 0,5 STDEV, <0,5 STDEV Slope> 5 degrees
Upper Slope	> 0,5 STDEV =<1 STDEV
Ridge/Hilltop/Canyon edge	>+1 STDEV
0= mean value/mean elevation of the neighbourhood cells 0,5= half of the standard deviation/STDEV	

5.2.3.3 Identifying the optimum metric for the topographic roughness in the Aegean region

By testing the three metrics for recording surface roughness in the Aegean region, in different radii, a series of observations can be made. When comparing the results from the topographic position index, deviation of mean elevation and slope analysis, two main points deserve further attention:

1. TPI is a more effective metric for measuring surface roughness in the Aegean context, considering (a) the dynamic nature of the landscape – creating a topography of great differences in height, with extreme landscape features (from high mountains to deep depressions), (b) the extent of the study area and the regional scale of analysis. De Reu et al. (2013), showed in their example from NW Belgium, in a topographically complex area, that DEV allows a more accurate recognition of landscape features in subtle topographies at local scales. TPI failed to record details of the local topography, especially over smother terrain. In the Aegean case, however, TPI performed well within the scale of analysis, which is not local but regional, and managed to highlight the main elements of the topography, which is the main aim, at least at this stage of the study (fig. 5.6). Given the spatial extent of the study area, the focus is not on the minor elements of local topographies but the identification of wider patterns over much bigger areas. Therefore, TPI is selected as a more appropriate metric for the Aegean in comparison to DEV. Furthermore, TPI captured efficiently surface roughness even in low elevation areas that SL analysis identified as flat terrain (fig. 5.8). This is extremely important, since topographic roughness refers to surface irregularities found in both high and low elevation areas.
2. The importance of the radius (R) size. Large R-values mainly reveal major landscape units, while smaller values highlight smaller features, such as minor valleys and ridges, as shown in relevant studies (De Reu et al., 2013: 42; Llobera, Fábrega-Álvarez, Parcero-Oubiña 2011; Jenness 2006). As such, the R-size each time, depends on the research question and the scale of analysis (regional scales = larger radii). In the Aegean context, three different radii have been tested (fig. 5.7). The 10km radius offers a general view of surface roughness, which is limiting since it would not allow a further focus on specific territories within the study area. The 1km radius makes the identification of any pattern improbable, and indicates that radii ≤ 1km are most probably not compatible with the scale of analysis in the Aegean case. The 3km radius enables the identification of prominent elements, without excluding pronounced features of the local topography, and also complies with the spatial range of exploitation territories for the Lower Palaeolithic groups, as mentioned before (fig. 5.7). Therefore, the 3km radius has been selected here as the most

appropriate radius for measuring surface roughness in the Aegean context for the purposes of this specific research.

Through these comparisons, the Topographic Position Index (TPI) in a 3km radius has been selected as the most effective topographic metric, capturing regional and local features, onshore and offshore.

The Weiss classification system, with the discrete landform types, provides a visually comprehensive expression of this. Areas with high values of topographic roughness can be identified and used further as a proxy indicator for territories favourable to hominins, according to the complex topography concept.

It is worth mentioning that currently the locations of the known Greek LP (and LP-attributed) sites and find-spots, over the Aegean (including the Greek mainland) appear to be randomly distributed with respect to topographic (surface) roughness, as shown by a one-sample Kolmogorov-Smirnov test (see Appendix B - I). Yet, the difference between the observed value (0.209852) and the critical value (0.205050), which determines the result (random or non-random distribution), is very small. Therefore, what the test suggests, should not be taken at face value, especially if we also consider that the number of the recorded LP locations (n=42) is quite small in relation to the spatial extent of the examined area, causing perhaps a sampling error. Furthermore, the association between hominins and topographically complex settings is undisputable, and it has been very well established in the African and the Eurasian LP records. Many different reasons could explain why this pattern is not statistically detectible on the current archaeological data from the Aegean: (a) it could be correlated with the preservation bias posed by landscape dynamics – the original distribution of LP sites is not reflected in the present-day data coverage, an important part is missing; (b) the use of proxy data to measure surface roughness – this offers an approximation of the past topographic complexity, not an accurate reconstruction; and (c) the paucity of secure LP evidence from this particular part of Eurasia – but the research is ongoing and new finds are anticipated. Thus, it cannot be argued, at this point, that there is definitely a non-causative association between the distribution of the Aegean LP sites and topographic roughness.

The complex topography concept, therefore, remains a structural element in this methodological approach for identifying topographic settings favouring hominin settlement and/or features dictating natural pathways for movement.

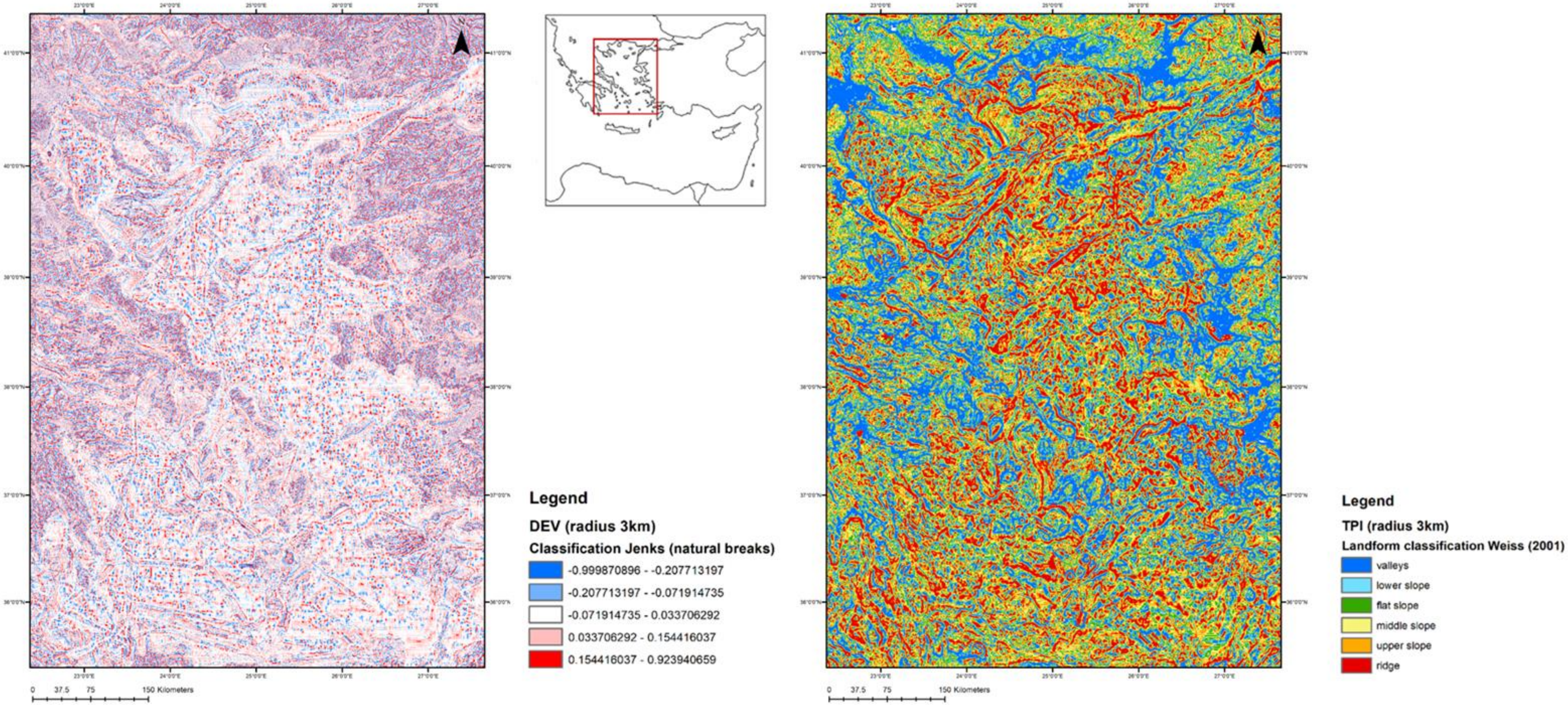


Figure 5.6. DEV (Jenks classification – natural breaks) (left) and TPI (Weiss classification) (right) applied on a 3 km radius. Geospatial data as in fig 5.4

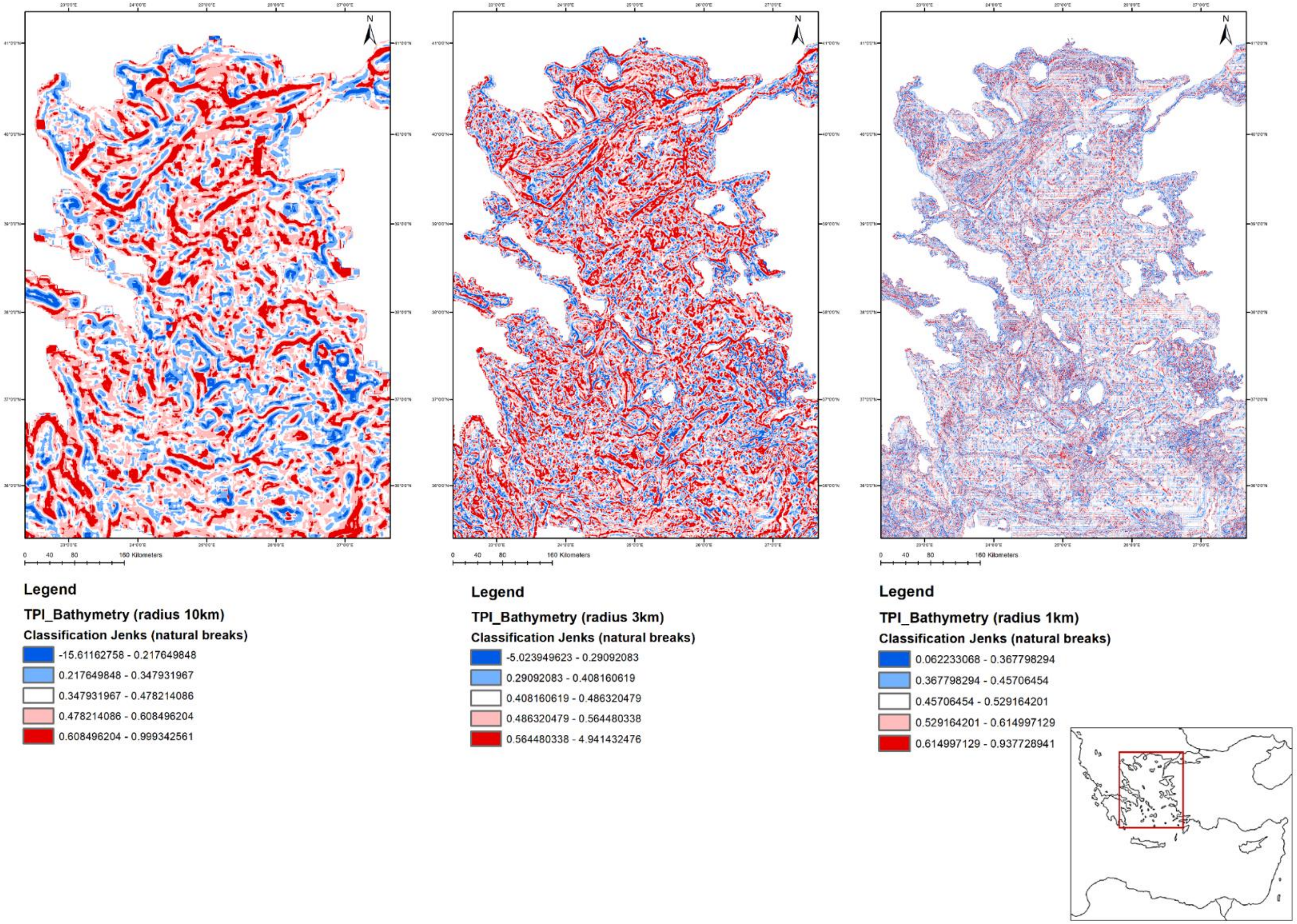
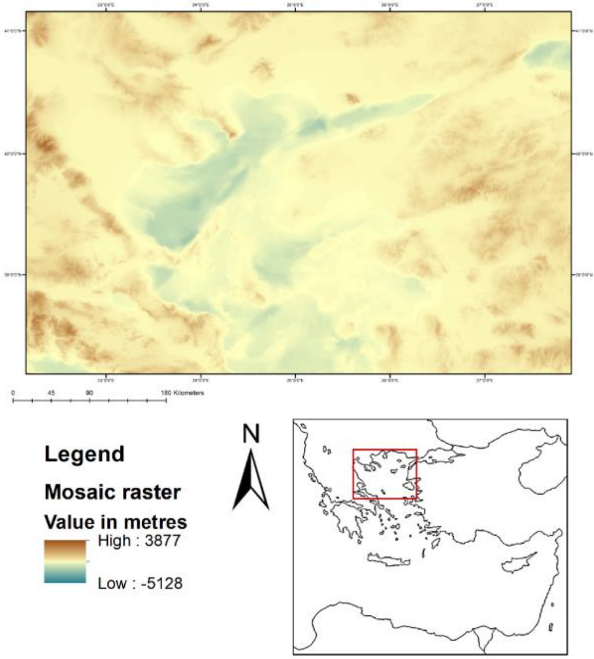


Figure 5.7. TPI applied on the Aegean bathymetry in three different radii (from left to right: 10km, 3km and 1km). Geospatial data as in fig. 5.4



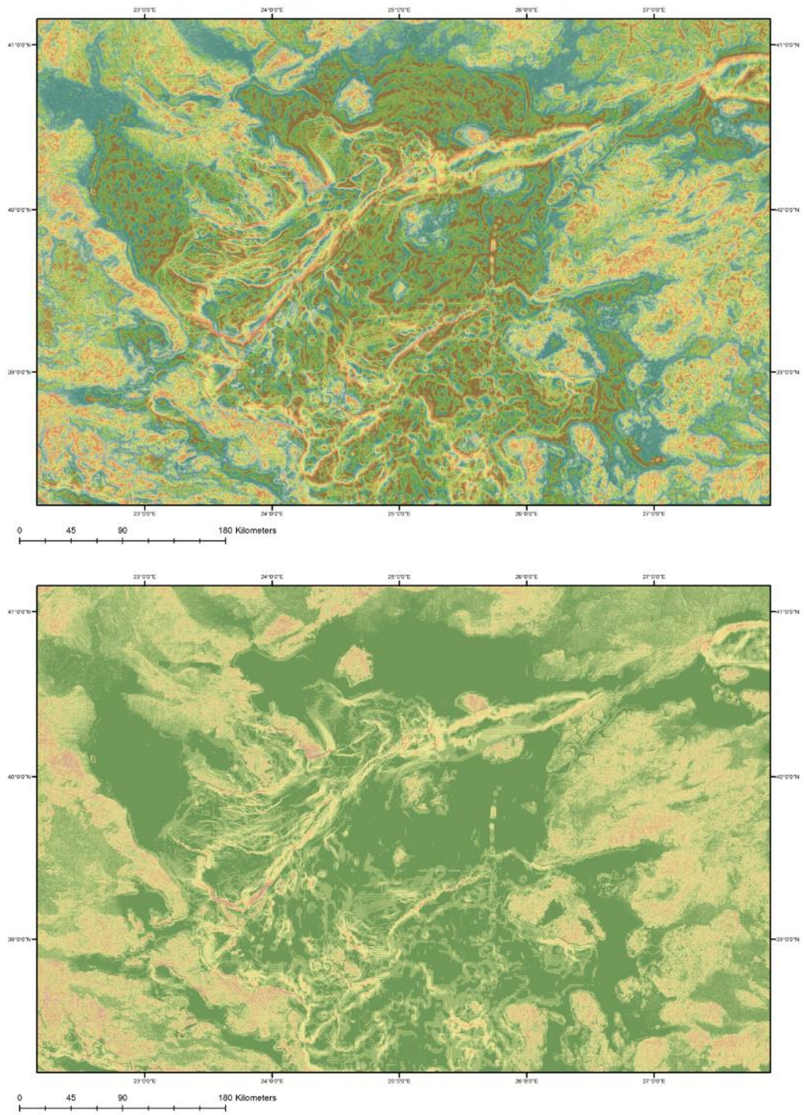


Figure 5.8. SL (bottom right) and TPI overlaying SL (top right) over the same area in the northern Aegean (left– Mosaic raster). Notice that TPI captures surface roughness more efficiently in relation to SL Geospatial data as in fig. 5.4

5.2.4 Examining topographic roughness against other landscape variables: identifying points of interaction between the hominins and the landscape (STEP 2a)

The index of surface roughness for the Aegean highlights several specific areas as possible targets for further study. However, given that this work is based on modern elevation and bathymetry in a dynamic setting, where subsidence, uplifting, sedimentation and erosion are taking place, what criteria should be followed to identify targets with the highest Palaeolithic research potential?

This concern led the preliminary identification of areas with high values of topographic complexity to be focused on parts of the Aegean where, (a) the main landscape features persist in time despite the action of the geomorphic processes and where, (b) abundant and variable natural resources suggesting favourable environments for hominins have been documented through proxy data.

Two areas meet these criteria: at the northern Aegean, along the continental shelf and the basinal structures of the North Aegean Trough (NAT), and at the south-central Aegean, over the Cycladic Plateau and along the Aegean Volcanic Arc.

In the northern Aegean, basinal structures have dominated the topography since the Pliocene (Sakellariou, Mascle and Kykousis 2013; Sakellariou and Tsampouraki-Kraounaki 2018), and palaeogeographical reconstructions for the LGM suggest rich water resources, and extended continental shelf with riverine environments - conditions that could possibly be extended to the earlier parts of the Pleistocene (Lykousis, Karageorgis and Chronis 2005; Perissoratis and Mitropoulos 1989) (fig 4.8-Ch.4). In fig 5.8, we can observe areas with high values of topographic roughness (red) around the margins of the North Aegean Trough basins, over the plateau between Thasos and Samothraki Islands and across the palaeo-Axios valley (modern Thermaikos Gulf), all being parts of the extended continental shelf of the northern Aegean during periods of maximum land exposure in the Early and Middle Pleistocene (see also fig 4.8-Ch.4). In the central Aegean, the Cycladic Plateau is a relatively stable area (McKenzie 1972: 139), marking the southernmost border for the Aegean dry land (from at least MIS 10-12 until at least MIS 8) (Lykousis 2009). A variability of resources (marine, coastal and continental) should be envisioned along the transitional environment between the dry land and the open/deep sea (to the south), including a remarkable distribution of knappable volcanic rocks, due to the extensive volcanic activity (Nomikou et al., 2013; Fytikas et al., 1984). The map in fig 5.7 (3km/middle) shows high values of topographic roughness along the outer and the inner volcanic arcs and the in-between area including the Cycladic Plateau and the Saronikos Gulf. This corridor is spotted with volcanic outcrops (now lying above and below the sea level) that would have been visible and available for exploitation along the palaeocoastline and its immediate continental zone to the north, throughout the Pleistocene (fig 4.5-Ch4).

Two points of potential interaction between the palaeolandscape and hominins emerge from this juxtaposition (topographic roughness-landscape variables), regarding the manipulation/use/exploitation of (a) water resources and (b) knappable volcanic rocks.

5.3 The investigation of the hominin factor in the Aegean

5.3.1 Limitations and Potentials (STEP 1)

To investigate the hominin factor in the Aegean region, direct and indirect information is drawn from a variety of available sources (published scientific literature and open access datasets).

Direct evidence, which is the primary focus, refers to cultural remains (stone tools-archaeology) and physical remains (skeletal remains-palaeoanthropology), indicating the presence and activity of hominins in specific locations, over the study area during the Lower Palaeolithic. As shown in chapter 2, direct evidence for the hominin presence in the Aegean region, and indeed in the wider eastern and north-eastern Mediterranean, before 200 Kya, is still poor despite the exciting recent finds. Dating inaccuracies, fragmented stratigraphies and extensive spatiotemporal discontinuities, disrupt the hominin signal.

Indirect evidence includes information from secondary sources. The faunal record (Ch.3) has proved to be an important resource in reconstructing dispersal patterns, identifying potential routes and considering palaeoenvironmental stimuli, while ethnographic studies on modern hunter-gatherers offer useful insights into hominin exploitation and mobility ranges and navigation capacity.

Direct and indirect evidence together, inform not only the physical, but also the cognitive aspect of the interaction between hominins and their affording world. The latter refers to inner mechanisms and processes involved in movement and settlement patterns, e.g. environmental knowledge and learning process to select optimum resources, or decision-making when entering unknown environments during dispersal, which are not detectable in the archaeological record. The experiential, or phenomenological approach, offers another way, an interpretive tool rather, to investigate how people in the past perceived and experienced their world and interacted with their natural environments. The concept of affordances, discussed in the next section, is central in the experiential approach and its application in the deep past, and the keystone in the methodological structure built here.

5.3.2 Humanising the past landscapes: the concept of affordances

Affordances are part of the act of perceiving the world (Chemero 2003: 186). As a theoretical concept, affordances emerged within the fields of ecological psychology and existential philosophy that deal with matters of perception (agents, agencies and intellectual mechanisms), among others. The concept of affordances entered the sphere of archaeology through landscape phenomenology (Ingold 1992; Tilley 1994), greatly influenced by Gibson's work on visual (direct) perception (Gibson 1979). According to the Gibsonian view affordances are resources that the environment offers to an animal that has the abilities to perceive and use them. Organisms, Gibson argued, perceive the messages that are encoded within their environment by engaging with it through their senses (Gillings 2012: 604). The phenomenological approach, places experience, through sensorial engagement, at the centre of the process of understanding our world and our place within it. Though the senses are perhaps the primary factor to enable perception directly, cognitive and behavioural parameters are also involved to cover the full spectrum of the affording world. Past knowledge, memory and learning – especially within a social context – regulate abilities and adjust behaviours that in return affect the way we perceive the world and engage with it (Hopkinson 2007: 24-5; Knappet 2005: 58). Thus, the *"knowledge in the head"* is essential to fully realise the potential of the *"information in the world"* and take advantage of it (Norman 1998: 54-80).

The experiential/sensorial approach, putting forward the idea of the lived and experienced space, humanises the past landscape. It does not see it as a lifeless vacuum but rather as an archive of human activity in the past (the 'dwelling perspective' proposed by Ingold 1993: 152). The key-question here concerns the possibility of applying the insightful experiential approach in deep time and in the investigation of the past landscapes that have been lost i.e. their prehistoric nature is not directly accessible to us (e.g. submerged landscapes) (Sturt 2006). Not for producing a recoconstruction of the past lives, but rather for gaining a better understanding of apsects of the hominin-landscape interaction. Moreover, if we can actually apply this approach in theory, what methodologies can help us to do so in practical terms?

Spatial technologies have been used widely within landscape archaeology to answer questions in relation to distribution of materials, movement patterns, networks etc. using quantifiable evidence (Holmes 2007; Field et al., 2007; Carotenuto et al., 2016). In the experiential approach however, we deal with qualitative data and as such, there is no objective way to perceive them, let alone quantify and record them with spatial analyses tools. Gillings (2012) addresses the uncomfortable situation between the GIS practitioners that seek to explore past landscapes through the experiential aspect and the theorists of phenomenology. The main point in this discourse is, how is it possible to use qualitative data within a quantitative framework? I think the answer lies in the definition of affordances and the way the GIS framework is structured for this specific purpose (in agreement with Gillings 2012).

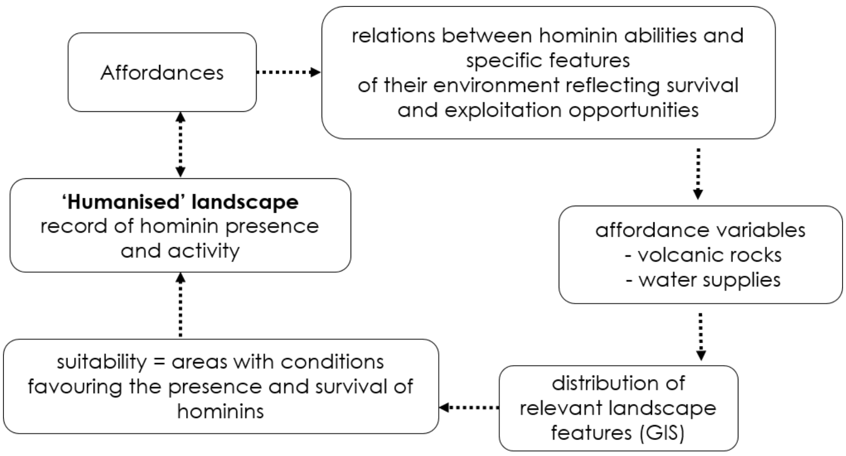
Affordances, as a concept, is not static. There is an ongoing debate, within ecological psychology, about the nature of affordances, their dependence/independence upon the presence of ~~the~~ animals, and the bi-directional effects between the development of abilities/behaviours in animals and perceiving of affordances (for an overview see Chemero 2003). The common ground in all existing theories is the animal-environment mutuality i.e. affordances are animal-relative properties of the environment, qualities shared between the two (Gillings 2012: 605). Chemero identified two main schools of thought, the selectionist view and the dispositional view (for a detailed discussion see Chemero 2003: 182-4). The selectionists (e.g. Reed 1996) place a direct link between the understanding of affordances by an organism and its evolution by natural selection. The animal evolves the ability to perceive specific resources with desirable characteristics. This relates to the selection pressure caused to an organism by the availability/non availability of resources that ultimately affects the organism's behavioural adjustments. Affordances, however, will be there even if animals are not. According to the dispositional view (e.g. Turvey 1992), on the other hand, affordances are dispositional properties of the environment that manifest only under specific circumstances. The properties of the environment need to be coupled by abilities (or effectivities) of animals in order for the affordances to be actualised, or as Chemero (2003: 183) explains it *"the affordance "being eatable" is a property of objects in the environment only if there are animals that are capable of eating"*. Thus, the presence of animals is essential for the affordances to be activated and manifest.

Chemero (2003:185-92) offered an alternative definition of affordances as relations between particular features of animals and particular features of whole situations in their environments. In perceiving affordances, animals are perceiving relations, and these relations may change when environmental situations change and/or when the abilities of the animals change – the latter in relation to experience and learning. In other words, affordances are not inherent in the environmental situations alone nor in the organism's abilities alone, but rather they are inherent in their combination (ibid 187). As such, affordances exist even when no local animals are around to perceive and use them, but in order for the relation to be fulfilled, the organism, as a potential perceiver, is a main element in the equation – a position between the selectionst and the dispositional views.

Chemero's definition of affordances is crucial for applying the experiential approach in the investigation of the past landscapes using a GIS-based framework. The relational theory about affordances proposes another direction, shifting away from the sterile qualitative vs quantitative opposition. As relations, affordances (a) retain the environment-animal mutuality, which is essential for any experiential study and (b) they are real entities and as such, they can be defined and thus explored further using GIS technologies.

5.3.2.1 Defining affordances (STEP 2b)

Building on the previous section, in the suitability model presented in the following section, affordances are perceived as relations between hominin's abilities and specific features of their environments that reflect exploitation and survival opportunities (*STEP 2*). Two affordance variables are being investigated in spatial terms: (a) volcanic rocks – that as knappable material represent exploitation possibilities and (b) water resources – representing survival possibilities (the two points of interaction identified in the previous step 2a – section 5.2.4). GIS applications enable the recording and mapping of landscape features associated with these affordance variables; features that would have been encountered in the past landscapes and would have been available to hominins, and recognised as usuable by them, - offering exploitation and survival opportunities. The end product (suitability model – see below) indicates areas with higher and lower suitability i.e. areas favouring more (higher values of suitability) or less (lower values of suitability) hominin survival and activity. By attributing this 'lived' and 'experienced' element to the past landscape, I conclude in – and return to – the 'humanised' notion of the palaeolandscape (as a record and testimony of human activity in the past) which is inherent in the concept of affordances, as explained earlier:



Information about the hominin factor along with the work on topographic complexity formulate the background upon which the concept of affordances will be employed within the GIS framework.

5.3.2.2 Suitability Model (STEP 3)

If we accept the hypothesis that the central and northern Aegean was a traversable terrain during the Lower Palaeolithic, would it provide viable, in terms of resources, zones for movement and patches for occupation? I have attempted to assess this by using the concept of suitability, derived from land-use analysis – through the development of predictive models for identifying the most appropriate spatial pattern of suitability according to specific parameters (for an overview see Malczewski 2004). In the model developed here, suitability refers to conditions favouring hominin presence, survival, and activity, based on the distribution of *landscape features* corresponding to water resources and volcanic material. The selection of the variables is not random, but founded upon, (a) observations on topographic complexity (as already stated - step 2a) and, (b) a preferential association with hominins, reflecting exploitation and survival opportunities, as documented in the existing literature.

LP evidence is frequently documented near, or in association with, water resources (palaoelakes, palaeoriver beds etc. - see section 2.3.3-Ch.2), with very recent examples from the Aegean (Marathousa 1 is located at the margins of a palaeolake, and Rodafnidia, Lesbos, in a river's flood plain). The use of volcanic rocks, as a raw material for stone tools, is also very common in LP assemblages from E. Africa, Israel and central Anatolia, with Rodafnidia demonstrating some very characteristic new examples (section 2.3.4-Ch.2). Furthermore, the presence of hominins in volcanic landscapes fits perfectly with the complex topography concept. Another strong asset is that pronounced landscape/physiographic features, associated with these variables, such as rivers, lakes, volcanoes and hydrothermal springs, could have operated as landmarks for hominins entering and moving across unknown landscapes, as shown by ethnographic studies on modern hunter-gatherers (Kelly 2003; Guiducci and Burke 2016; see next chapter).

The process followed for the creation of the suitability model involves three basic steps:

1. Creation of multiple zones around the selected landscape features.
2. Attribution of a value of suitability on each of the zones according to a classification system - with low values representing low suitability and high values high suitability.
3. Adding the reclassified variables (rasters) and creating the suitability surface.

Three zones (0-10km, 10-30km and >30km) were created around specific landscape features such as volcanic centres, palaeolakes, palaeorivers, springs etc., corresponding to the variables. These features are perceived as anchors (*sensu* Golledge 2003) over the landscape and are used as reference points in the spatial analysis. Due to limited evidence on palaeoenvironmental variables from the Aegean during the Lower and Middle Pleistocene, the LGM evidence has been used as a proxy for the earlier parts of the Pleistocene.

The anchor-features refer to natural elements exploitable by hominins and the three zones around them reflect an exploitability range. Within the suitability model, a classification system has been developed, ranging from 0 to 3, with 0 indicating the least suitable areas, where exploitation possibilities/opportunities would have been minimal or highly reduced, and 3 the most suitable areas, where exploitation would have been optimum based on the vicinity to the anchor-feature(s) – the source for suitability (=exploitation and survival opportunities). As the distance from the reference point increases, the suitability decreases. The cells included in the first zone, 0-10 km around the reference point(s), are attributed the value 3 corresponding to areas expected to be the most favourable. The 10km radius is selected here as indicative of an exploitation territory during the Lower Palaeolithic, following the 'site region' definition given by Bailey and King (2011: 1533). The second zone (10-30km) is attributed the value 2, and the third zone (>30km) the value 1. The actual reference points have been attributed the value 0 (representing in the case of the palaeolakes, for example, the area covered by water). With one exception. In the case of the volcanic rocks' distribution, the area/polygon corresponding to the raw material coverage is attributed the value 3, because it represents itshelf one of the suitability variables; in other words, the area covered by volcanic material represents a highly suitable area because of the presence of volcanic rocks – potential raw material for stone tools.

Each of the reclassified variables represents a layer, building up the suitability model. The model ultimately defines possibilities through a range of values (more to less suitable) rather than probabilities (absolute values of suitable and not suitable areas) – which as an approach is more consistent with the fragmented nature of available data from the Aegean region and the use of proxy data. The aim here is to define particular areas, where favourable conditions are indicated by the presence or absence of the selected variables. In that sense, increasing the weight of one variable over the others cannot increase nor decrease the suitability value for a given area. This is why the weighted overlay or the weighted sum – other tools within the ArcGIS for determining landscape suitability– have not been selected for this particular model.

Step 1 – Preparation of data that will build the variables of suitability (collecting, georeferencing> spatial analyst; digitizing > editor toolkit). Point, polyline and polygon shapefiles have been created containing spatial information on (a) water resources: LGM rivers (northern Aegean) (Lykousis, Karageorgis and Chronis 2005; Perissoratis and Mitropoulos 1989) (see fig.4.8-Ch.4); LGM lakes (Perissoratis and Conispoliatis, 2003); MIS 10-12 water bodies (Lykousis 2009); thermal and karstic springs (Minissale et al., 1989; Lambrakis and Kallergis 2005; Lambrakis, Katsanou and Siavalas 2014; Karastathis et al., 2011; Karakatsanis et al., 2011; Dotsika et al., 2009; Obetsanof, Koumantakis, Stamataki 2004); (b) Pleistocene volcanoes (the location of the Oligo-Holocene volcanic centres in the Aegean obtained by the Smithsonian Institute/Global Volcanic Programme [http://volcano.si.edu] and the Preliminary List of Pleistocene Volcanoes; Siebert, Simkin and Kimberly 2010: 6); (c) distribution of volcanic rocks onshore (Borsi et al., 1972; Fytikas et al., 1984) and offshore (Nomikou et al., 2013) (see fig.4.5 -chapter 4).

Points, lines and polygons are converted into rasters (conversion tools> from polygon/polyline/point > polygon/polyline/point to raster).

Step 2 – Euclidean distance (spatial analyst>distance>Euclidean distance). New raster maps are created for each of the aforementioned variables.

Step 3 – Reclassify. The input Euclidean distance rasters need to be reclassified according to the classification system of suitability described before. New break values are set (classify>break values) representing the new classes, which will be attributed new values.

Break Values (in meters)	Original values	New Values
0	1	0
10.000	2	3
30.000	3	2
>30.000	4	1

The break values correspond to the buffer zones/radii around the landscape features; original values = before the reclassification; new values= attributed according to the new classification system on suitability, 0=least suitable and 3=most suitable.

Step 4 – Raster calculator (spatial analyst tools> map algebra> raster calculator). The produced reclassified rasters are added using the raster calculator tool

The output raster (Model 1 – fig.5.9) indicates suitability through a range of values, from the most suitable (red) to the least suitable (blue); in other words, it indicates more and less suitable areas based on the availability and distribution of landscape features associated with the affordance variables: water resources and volcanic rocks.

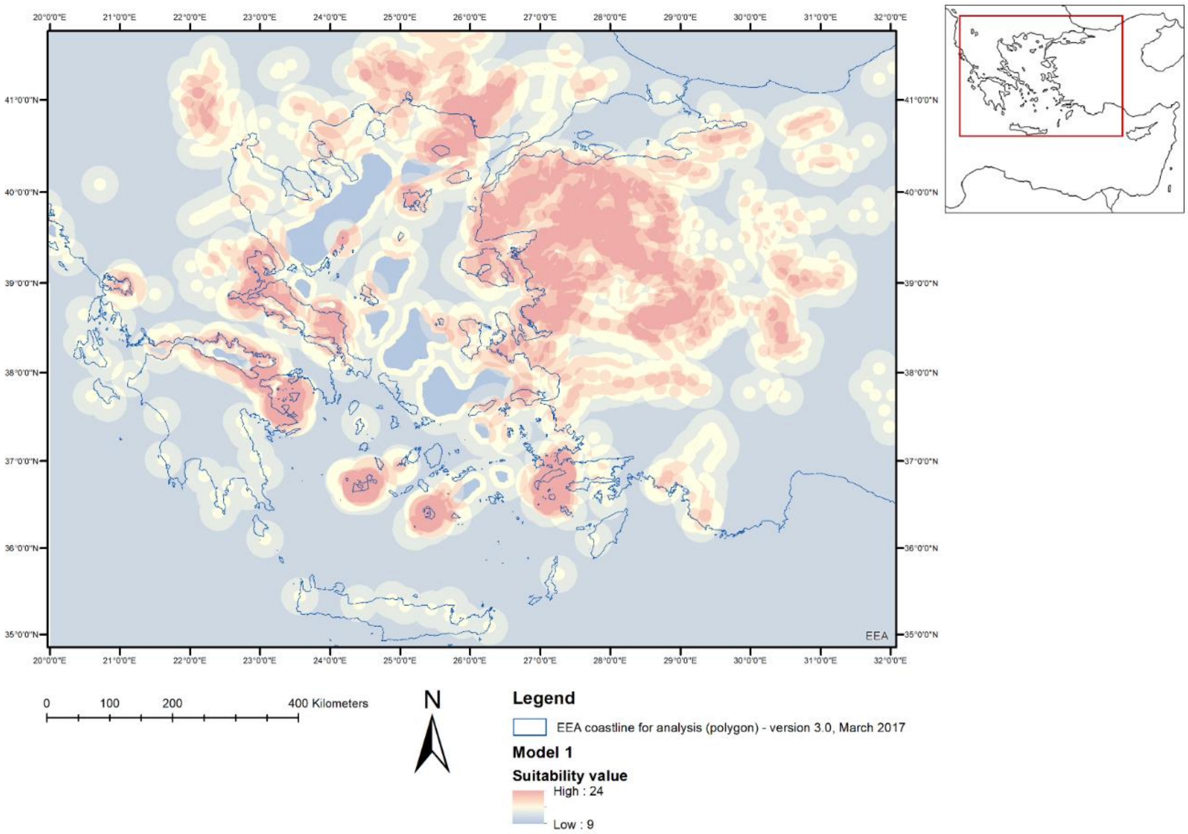


Figure 5.9. Suitability Model 1 (Plio-Pleistocene) - fresh water resources, distribution of volcanic rocks and location of volcanoes. Coordinate system and projection as in fig. 5.4

Following the same logic, two more rasters have been produced: Model 2, which includes Model 1 plus the topographic roughness and Model 3, which includes Model 2 plus the slope analysis.

For Model 2 (fig.5.10), the TPI (3km) raster from before (section 5.2.3) is used again here after being reclassified following the suitability classification system (values ranging from 0 to 3). *This raster represents the optimum way to measure landscape roughness in the Aegean context for the purposes of this particular study, in order to provide a proxy indication for the topographic complexity of the past landscape (as explained in section 5.2.3.3)*. Areas with higher roughness are considered to be more suitable than areas with low roughness, following the complex topography concept.

Spatial analyst tools> map algebra> raster calculator: “Model_1” + “TPI_3000”

For the Model 3 (fig.5.11), the mosaic slope raster (see least-cost pathway section Ch.6) is used after being reclassified following the suitability classification system (values ranging from 0 to 3). Lower slope areas are considered to be more suitable than higher slope areas.

Spatial analyst tools> map algebra> raster calculator: “Model_2” + “slope”

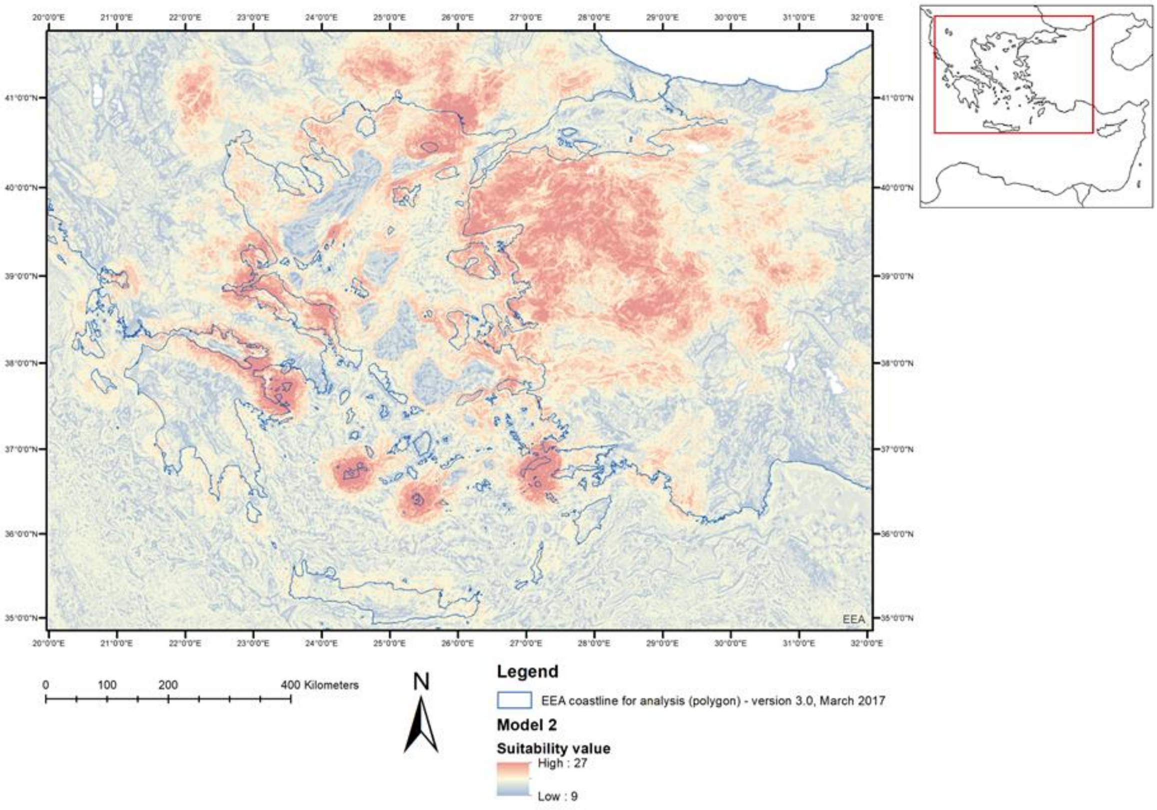


Figure 5.10. Suitability Model 2 (Plio-Pleistocene) – water resources, distribution of volcanic rocks, location of volcanoes and topographic roughness. Geospatial data as in fig.5.4

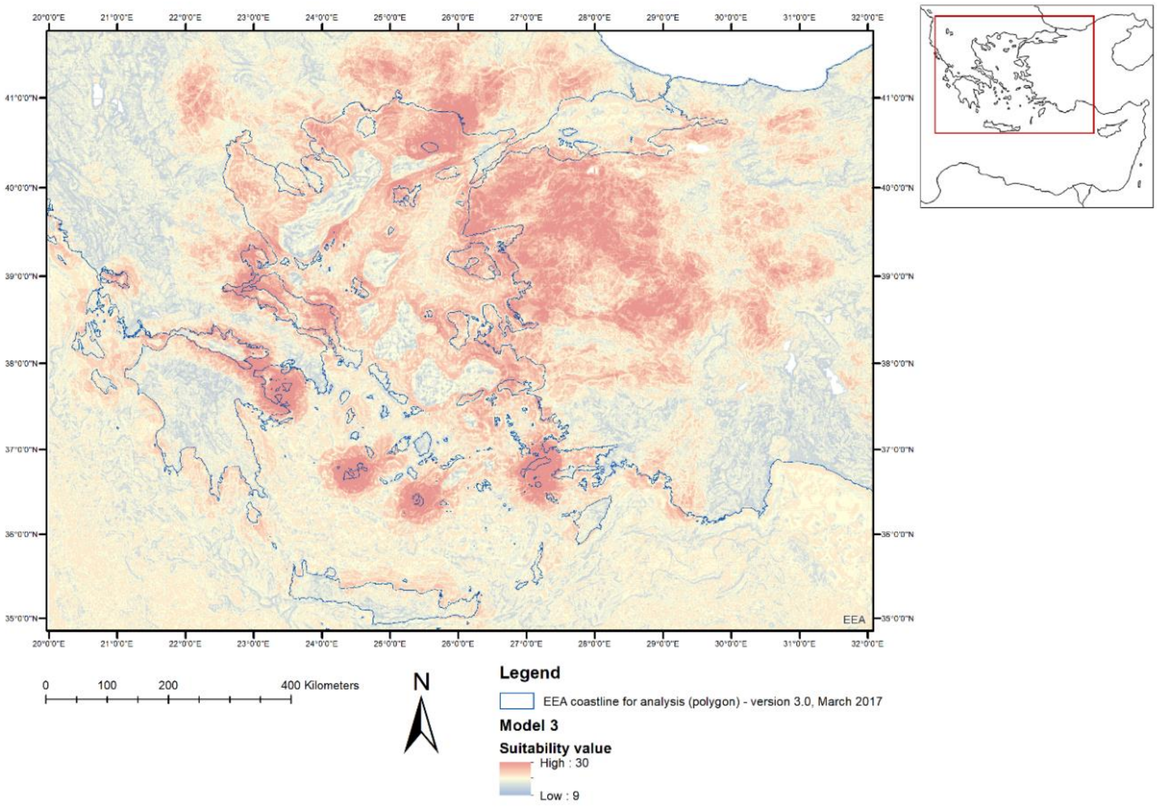


Figure 5.11. Suitability Model 3 (Plio-Pleistocene) – water resources, distribution of volcanic rocks, location of volcanoes, topographic roughness and slope. Geospatial data as in fig. 5.4

These models however, cover a very wide chronological range (from the Pliocene to the Late Pleistocene) and offer a generic view on potential suitable areas across the Aegean palaeolandscape. A further chronological refinement has been attempted with the incorporation of archaeological LP sites (with available absolute dates) and palaeofaunal localities, from the study area, dated within the Early and Middle Pleistocene.

A tripartite scheme, with three time intervals, has been developed: ≥ 0.9 Mya, 0.9-0.4 Mya and 0.4-0.2 Mya (Table 5.2), founded upon chronological evidence from four different datasets:

1. Faunal evidence: Middle Villafranchian (2.6-1.8 Mya), Late Villafranchian (1.8-1.2 Mya), Epivillafranchian (1.2-0.9 Mya), Galerian (0.9-0.4 Mya) and Galerian/post-Galerian (0.4-0.2 Mya) (Kahlke et al., 2011).
2. Archaeological evidence: Lower Pleistocene (2.58 – 0.78 Mya), Middle Pleistocene (0.78-0.12 Mya) (Head and Gibbard 2005).
3. Absolute ages on the volcanic material distributions (Fytikas et al., 1984; Esroy and Palmer 2013) (see synthetic map – fig.4.5-Ch.4).
4. Palaeogeographical evidence: the presence of the water bodies in the northern and central Aegean during the two phases of the maximum land exposure: ≥ MIS 10-12 and MIS10-12 – MIS 8 (Lykousis 2009).

The uppermost limit of the first interval coincides, more or less, with the Early-Middle Pleistocene transition, a time-threshold with pronounced changes in climate and environments, the faunal turnover from the Epivillafranchian to the Galerian (see Ch.3) and the emergence of *H. heidelbergensis* in Europe, with a more stable presence of hominins in the continent thereafter. The uppermost limit of the last interval corresponds to the end of the Middle Pleistocene and the beginning of the Late Pleistocene, when the first evidence for the Middle Palaeolithic starts to be substantially coherent in the Greek archaeological record - e.g. earliest appearance of Levallois technology during MIS 6/MIS 7 (Tourlroukis 2010:17), marking the end of the Lower Palaeolithic. During the first two intervals, the hypothesised Aegean dry land covers most of the central and northern Aegean, at its maximum extent, with the southernmost border laying along the Aegean Volcanic Arc, and, by the last stages of the third interval, the first marine transgression occurred, signalling the gradual fragmentation of the Aegean extended terrain and the subsequent establishment of brackish (at the initial stages), coastal and marine conditions (finalised around 9 Kya).

The spatial reference for the location of the archaeological and palaeoanthropological sites (x and y coordinates) is obtained by the Prehistoric Stones of Greece database and by the TAY (Archaeological Settlements of Turkey) project database; for the palaeofaunal sites, spatial information is from NOW (Fossil Mammal Database, University of Helsinki) and PBDB (The Palaeobiology Database), as well as from relevant literature (Ch.3). All databases are open-access.

The same process, as in the previous models, is followed: creation of three-zones 10km, 30km and > 30 Km around the new reference points (archaeological, palaeoanthropological and palaeofaunal sites), classification and assignment of suitability values (from 0 to 3, with 0 corresponding to least suitable and 3 to most suitable areas), before incorporating this temporal attribute into the suitability modelling (using the raster calculator tool as before). Three new rasters have been produced, corresponding to the three time intervals, using new information - as categorised in the table above - and the variables that have been already modelled (fresh water resources, volcanic rock distribution, location of Plio-Pleistocene volcanoes, landscape roughness and slope) (fig. 5.12-5.14)

Table 5.2. The three time intervals and information on archaeology, palaeoanthropology, palaeoenvironments and palaeogeography included in each time interval

Time Intervals	**Archaeological (A) and /or palaeoanthropological (P) sites**	**Faunal sites**	**Volcanic Material**	**Aegean Water Bodies**
≥ 0.9 Mya	Denizli (1.3 Mya?) (A) Kocabaş (>1 Mya?) (P) Megalopolis (Early /early Middle Pleistocene?) (P)	**Middle Villafranchian** (Dafnero, Volakas, Sesclo, Vatera, Gerakarou, Vassiloudi, Gülyazi) **Late Villafranchian** (Krimni, Libakos, Alykes, Kalamoto) **Epivillafranchian** (Apolonia, Ravine of Voulgarakis, Megalopolis-Marathousa)	Excluding Nisyros and Yali (activity started around 0.2 Mya)	≥MIS 10-12
0.9-0.4 Mya	Marathousa 1 (~ 0.5-0.4 Mya) (A) Rodafnidia (0.476-0.164 Mya) (A)	**Gallerian** (Megalopolis, Apidima, Petralona, Denizli)	Excluding Nisyros and Yali (activity started around 0.2 Mya)	≥MIS 10-12
0.4-0.2 Mya	Rodafnidia (0.476-0.164 Mya) (A) Rodia FS-30 (~0.21 Mya) (A) Kokkinopilos (~0.2-0.25 Mya) (A) Plakias (≥0.14 Mya) (A) Yarimburgaz (~0.3 Mya) (A) Karain (≥0.3 Mya) (A) Petralona (0.15-0.25/0.35 Mya) (P) Apidima (> 0.2-0.17 Mya) (P)	**Galerian/post-Galerian (Late Pleistocene)** (Megalopolis, Apidima, Petralona, Manastirec, Denizli)	Including Yali and Nisyros volanoes and volcanic material	MIS10-12 – MIS 8

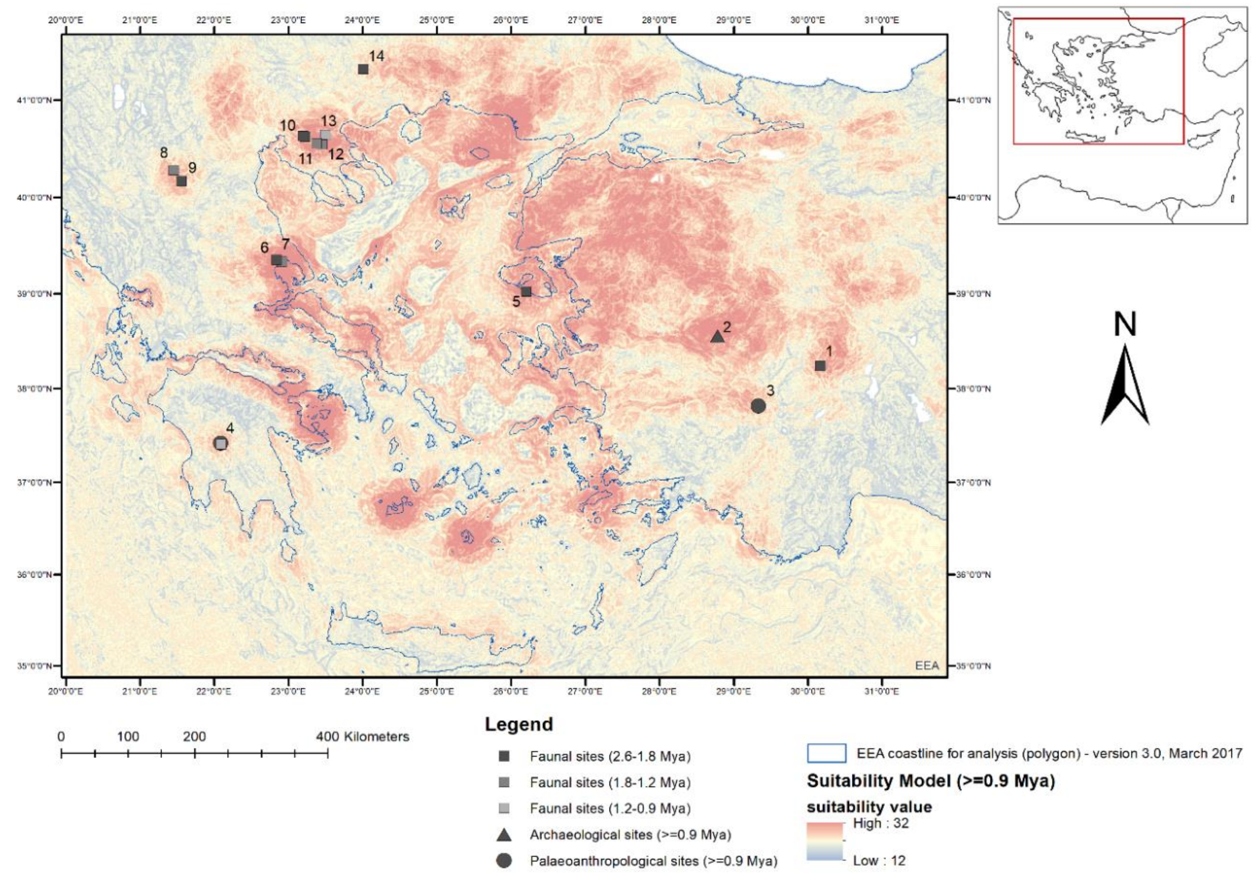


Figure 5.12. Suitability (affordances, topographic roughness, slope) for the interval ≥ 0.9 Mya. Archaeological sites: 2-Gediz find spot (~1.2 Mya?); Palaeoanthropological sites: 3-Kocabaş (> 1 Mya?); 4-Megalopolis (Early-early Middle Pleistocene?). Faunal sites: 1-Gülyazi (Middle Villafranchian); 5-Vatera (Middle Villafranchian); 14-Volakas (Middle Villafranchian); 11-Krimni, Kalamoto (Late Villafranchian); 10-Gerakarou, Vasiloudi (Middle Villafranchian); 12-Ranvin Voulgarakis (Epivillafranchian); 13-Apollonia (Epivillafranchian); 8-Livakkos (Late Villafranchian); 9-Dafnero (Middle Villafranchian); 6-Alykes (Late Villafranchian); 7-Sesklo (Middle Villafrapnchian); 4-Megalopolis (Epivillafranchian). The blue outline corresponds to the modern coastline. Geospatial data as in fig. 5.4

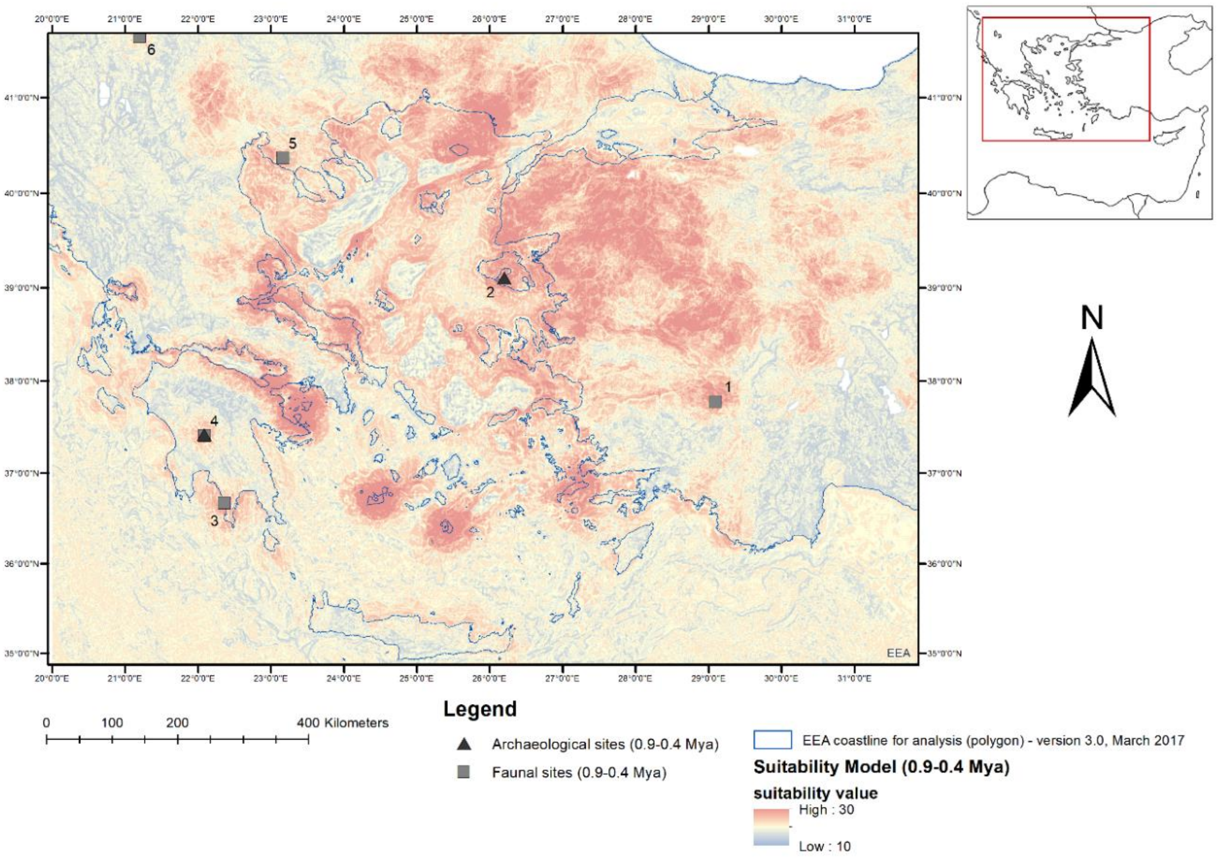


Figure 5.13. Suitability (affordances, topographic roughness, slope) for the interval 0.9-0.4 Mya. Archaeological sites: 2-Rodafnidia (0.475-0.164 Mya); 4-Marathousa 1 (0.5-0.4 Mya). Faunal sites – Galerian: 1-Denizli; 5-Petralona; 6-Manastirec; 3-Apidinma, 4-Megalopolis. The blue outline corresponds to the modern coastline. Geospatial data as in fig. 5.4

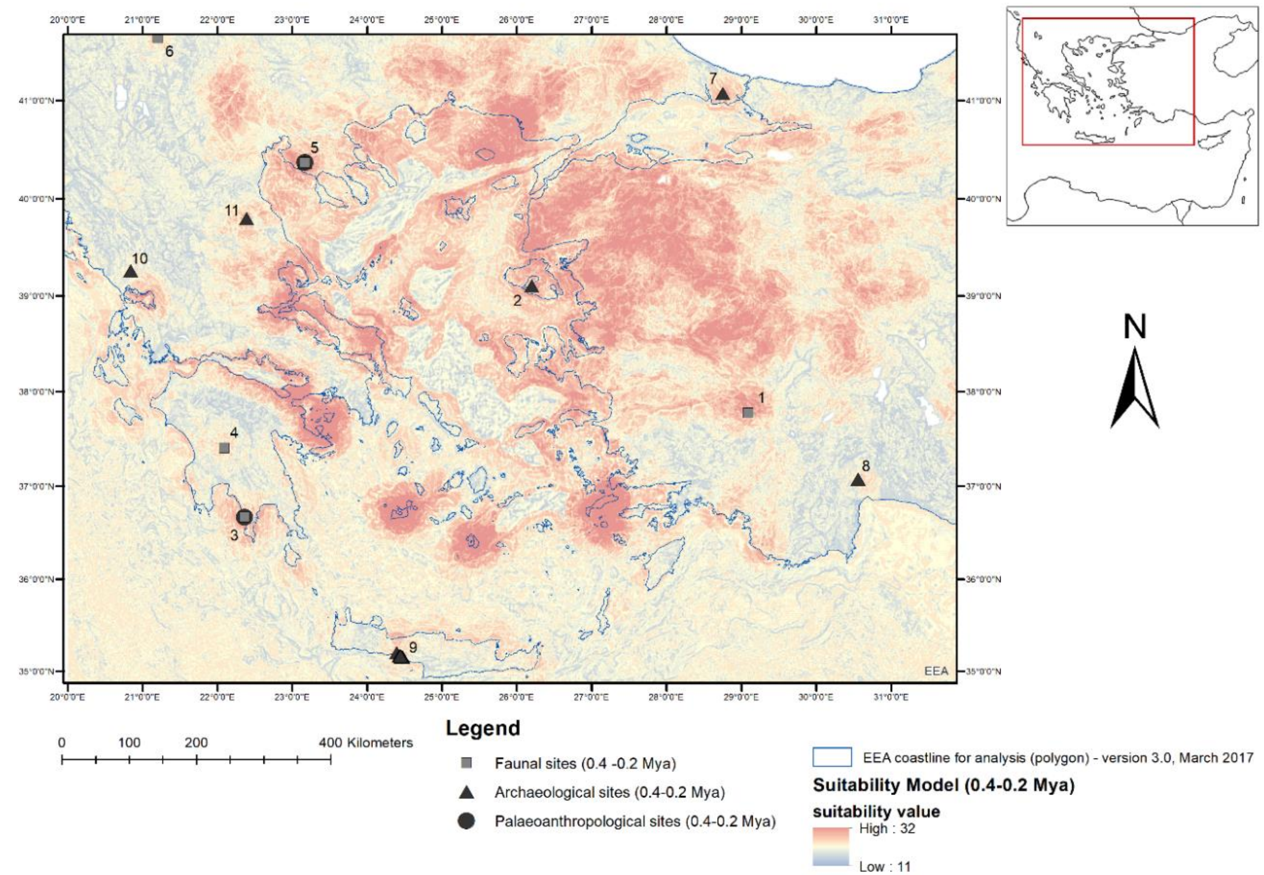


Figure 5.14. Suitability (affordances, topographic roughness, slope) for the interval 0.4-0.2 Mya. Archaeological sites: 7- Yarimburgaz (~0.3 Mya); 8-Karain (≥0.3 Mya?); 11-Rodia FS30 (~0.2 Mya); 10-Kokkinopilos (0.2-0.25 Mya); 2-Rodafnidia (0.475-0.164 Mya); 9-Plakias localities (≥0.130 Mya). Faunal sites – Galerian/post-Galerian: 8-Denizli; 6-Manasteric; 4-Megalopolis; 3-Apidima, 5-Petralona. Palaeoanthropological sites: 5-Petralona; 3-Apidima. The blue outline corresponds to the modern coastline. Geospatial data as in fig.5.4

5.3.2.2.1 The distribution of the Aegean LP sites and find-spots in regards to suitability: a one sample Kolmogorov-Smirnov statistical test

If we display the locations of the known LP sites (including find-spots) from the Aegean region in relation to suitability (fig. 5.12-5.14), it seems that the current distribution is affected by suitability i.e. LP sites tend to occur in areas where the model has assigned high/higher values of suitability. To acquire more objective results about this observed pattern, the distribution of the LP sites is analysed statistically through a one-sample Kolmogorov-Smirnov test, against the suitability index (see Appendix B - II). The test will help us to understand if the LP sites are preferentially distributed on particular values of suitability, by testing two opposing hypotheses:

The null hypothesis (H_0) supports that the distribution of the LP sites is random in regards to the distribution of the suitability values, while the alternative hypothesis (H_1) supports a non-random pattern.

In this case, the test showed (see Appendix B - II) that the observed value (0.29147) exceeds the critical value (0.209852), and so the null hypothesis can be rejected, confirming the alternative hypothesis (H_1) that the locations of the LP sites are non-randomly distributed with respect to suitability.

The results from this one-sample Kolmogorov-Smirnov test must be treated with caution. The test suggests that there is a very small probability (less than 5%) that the observed pattern is the product of chance. This adds significantly to the predictive effectiveness of the methodological framework developed here. However, the predictions need to be tested by fieldwork. Moreover, one needs to keep in mind (a) that the LP investigation in the Aegean is ongoing and (b) that the suitability model itshelf is a work in progress. In other words, the addition of new archaeological data – new LP locations, and the refinement in the methodological scheme – by adding new variables of suitability, would impose alterations in the population (suitability) and the sample values (LP locations). Thus, this causative association between the location of the LP sites and suitability, suggested by the test, should not be taken as a fact but needs to be a matter of continuous re-examination statistically, as the LP research in the Aegean advances.

5.4 Concluding remarks

These models may be initial, but they permit at least the opening of the discussion on suitable areas, with conditions favouring the presence and survival of hominins across the Aegean dry land during the Early and Middle Pleistocene. The quality of such modelling depends largely on the accuracy and resolution of available data. It has been emphasised (Ch.2, Ch.4) that the datasets from the Aegean are problematic due to preservation and discovery bias (landscape dynamics), temporal limitations and spatiotemporal discontinuities. Despite drawbacks and resolution issues, the three time intervals developed here, offer a solid basis for observing changes in suitability of the Aegean palaeolandscape, over time and space. From interval 1 to interval 2, some differences can be noted over the northern Aegean, with a reduction of suitability over the Chalkidiki Peninsula and W. Macedonia during the second interval. In the third interval, suitability increases across the southern Aegean, in parallel with the Aegean volcanic arcs, and in the central Aegean in relation to the changing water bodies. The model also identifies highly suitable areas throughout the three intervals: (a) in northern Aegean, across the northern Aegean continental shelf, and (b) in south-central Aegean, along the southern Aegean Volcanic Arc.

New hypotheses and scenarios can be articulated, proposing potential dispersal routes and occupation/activity areas over the Aegean region during the Early, and more confidently during the Middle Pleistocene (see Ch.7 – Discussion).

The affordance-based methodological approach explained in this chapter (for a scematic outline see fig. 5.15), manages to humanise the past landscape, by adding a purely qualitative element in the equation: the lived and experienced space – drawn from the phenomenological narrative in the study of past landscapes. The method has been designed in such a way so it can be expanded, by adding more parameters signifying new affordance variables, as we will see in the next chapter. Yet, always contributing to the enrichment of the central idea: understanding the palaeolandscape and the place of hominins within their affording world. The aim is, by no means, to provide an accurate reconstruction of the deep past, but rather to offer a framing heuristic for testing ideas and perceptions of how people in the past experienced their natural world and interacted with their landscape in order to develop revised interpretations of the fragmented available evidence and plan the future research accordingly.

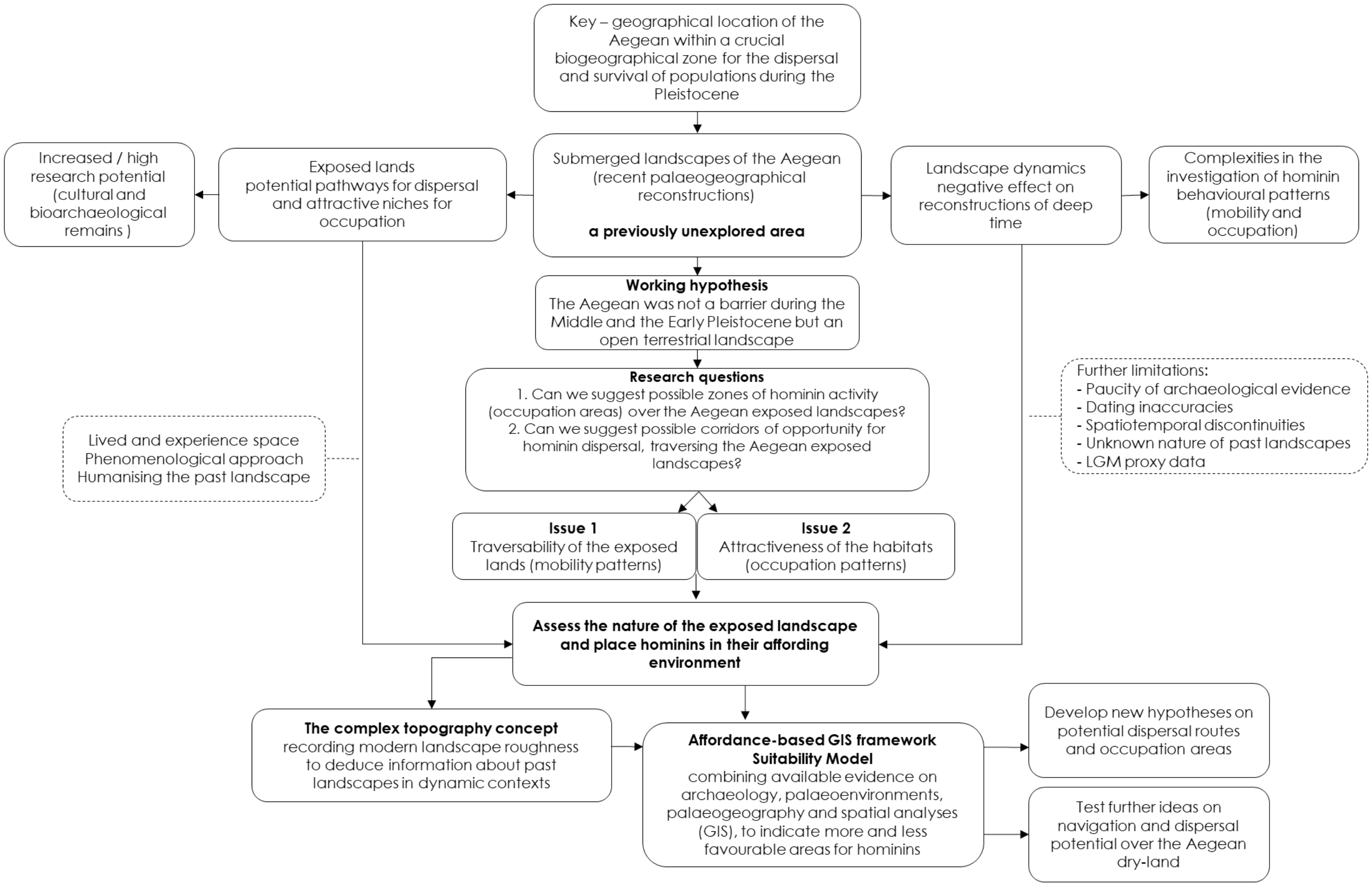


Figure 5.15. A schematic outline of the new methodological scheme

Chapter 6 Adding more affordance variables: the dispersal potential for hominins over the Aegean palaeolandscape

6.1 Introduction

The work on suitability (Ch.5) is fundamental to explore further possibilities of hominin movement: how easy/difficult, or even possible/impossible was it to traverse the Aegean dry land and to navigate across the exposed terrain? Palaeotopographic – palaeogeographical parameters are involved, as landscape structure affects navigation and orientation in humans. However, in the absence of palaeolandscape reconstructions before the Late Pleistocene, modern elevation and bathymetry can provide proxies for the past topographic configuration.

To test (confirm or reject) the traversability hypothesis, a least-cost path approach (GIS) is applied, in order to create scenarios about potential trans-Aegean connections between archaeological sites with cultural and chronological similarities from mainland Greece and western Anatolia. To test the navigability potential of the Aegean terrain – directly relating to the dispersal potential for hominins (or dispersibility after Wren et al., 2014) – a landscape legibility approach is developed, greatly influenced by the method developed by Guiducci and Burke (2016). Navigability, in this specific context, refers to terrestrial and not marine environments. It encompasses the potential of successful navigation for hominins i.e. to accurately locate their position, and plan and follow a route, based on the structure of the Aegean terrain. Topographic prominence and viewshed analysis (GIS) enable the identification of salient landmarks – natural features that could have facilitated wayfinding and orientation for hominins. Cognitive aspects in relation to navigation, such as spatial memory and environmental knowledge, are also considered in this assessment.

This chapter provides a case study for the expansion of the methodological approach. Two more strands can be added to complex topography and affordance based GIS in chapter 5 –

- suitability: high values of traversability (ease to transverse)
- navigability: high values of navigability of terrain (ease to navigate) would indicate highly suitable areas as well.
- Perhaps, a third affordance variable could be attached: the dispersal potential for hominins, offered by the palaeolandscape structure.

Specific territories over the Aegean are highlighted as potential foci for the future LP research, due to certain, or due to a set of certain, characteristics: being easier to traverse (smoother topography), or having a better order of salient features (ease of navigation), or hosting favourable environments (high suitability), or all of the above.

6.2 Finding the way into the unknown: mental maps and navigation over the palaeolandscape

6.2.1 Dispersal processes in the LP: tackling the 'how' of the hominin movement

The long-distance dispersal events of the Lower and Middle Pleistocene are viewed here as the cumulative effect of smaller local-scale mobility events based on exploratory visits and occupation of immediately adjacent areas with viable resources (see section 3.4.3-Ch.3).

The nature of these dispersals is influenced by numerous parameters, which could be grouped into two main categories, external and internal. External parameters ('pull' and 'push' factors) refer to environments (e.g. topography, environmental change, food supply) and demography (e.g. population growth and competition over resources with other predators and perhaps intra-group competition as population increases). Internal parameters refer to the innate abilities of hominins to navigate over the landscape associated with spatial memory and wayfinding (Kuhn, Raichlen, Clark 2016; Guiducci and Burke 2016). The interplay between the external and internal factors determines movement patterns and mobility - "*the sum of small-scaled movements tracked across larger geographical scales*" as defined by Kuhn, Raichlen and Clark (2016: 86).

Relevant studies usually address questions about the 'when' and 'where' of hominin movement taking into consideration spatiotemporal evidence for the hominin presence (Jöris 2014; Croitor 2018; Prat 2018). However, the 'how' of the early dispersal events is not as straightforward a question; the answers lies largely within the internal parameters that control the hominin movement - cognitive abilities and behavioural traits – that are not directly visible in the archaeological record:

1. How a dispersing population is advancing over time and space?
2. How a group of individuals, equipped with motion and navigation capacities, find their way over a landscape?
3. What mechanisms are activated when entering an unknown environment and determine where to move within that environment?

4. How is spatial information communicated effectively over time and space in inter-and intra-group level?

A range of resources, from mathematical models to theoretical concepts - drawn from ecology or ethnography, has been employed by archaeology to tackle some of the issues raised above. Equation based models (or EBM) and computer stimulations (agent-based models or ABM) have been developed to calculate population growth rates and the speed of diffusion in order to provide estimations on how early the wave (of the dispersing population) should be expected to reach a given location. The Reaction-Diffusion models (EBM), based on the wave of advance equation (Fisher 1937), have been widely applied in the early Prehistory to monitor the spread of phenomena, such as the global dispersal of *Homo sapiens* or the expansion of the Neolithic culture, but with no relevant examples for the LP (for an overview see Steele 2009). These models depend largely on the external parameters that control the dispersal process (i.e. environments and demography). The same could be argued for most of the available computer stimulations for the early out of Africa dispersals (Nikitas and Nikita 2005; Carotenutto et al., 2016; Romanowska 2013; Hughes 2007; Holmes 2007). The agents (dispersing population) here have the ability to interact with their environment (contrary to the EBMs), but again external factors – such as paleoclimate, the nature of the landscape or the presence/ absence of specific fauna – determine the mode of dispersal, the timing and the routes. The model developed by Wren et al. (2014) is an exception, as it implemnets not only external but also internal parameters (cognitive ability of the dispersing population) (see below section 6.2.3).

Beyond, or complementary to, models and stimulations, Kuhn, Raichlen and Clark (2016) suggested that the reconstruction of past movement paths may offer a meaningful way to explore further the internal parameters and how hominin groups moved and dispersed. In this approach, skeletal biology (motion and navigation capacity through biomechanics and physiology) is coupled with archaeology (dispersal events through the distribution and location of remains), following the 'movement ecology paradigm'. The link between the ability to move and navigate over a landscape, and the evidence of that capacity over time and space, is the 'movement path' i.e. *"the pattern of movement on the landscape"* (ibid 88). Hominins' movement paths can leave traces archaeologically detectable, usually lithic material. Valuable information has been inferred from the distribution of stone tool assemblages, and the displacement of raw material, about movement patterns and exploitation territories during the Lower Palaeolithic (Potts 1984; Feblot-Augustins 1999; Harmand, 2009; Toth and Schick 2009; Mgeladze et al., 2011). The reconstruction of past movement paths, or the incorporation of their remnants in our reconstructions, may inform further the current understandings on how hominin movement patterns formed, and how hominins exploited their environments and socially interacted with each other.

Ethnographic studies on modern hunter-gatherer dispersing groups may also provide some very useful insights, especially regarding the dispersing mechanisms and the transmission of spatial information, which could be applied to some extent, in earlier phases of prehistory. Not by extrapolating modern traits and patterns to the deep past, but rather by creating models in order to test hypotheses for early Prehistory (see discussion in Kelly 1995: 333-344). These studies highlight the importance of the natural elements of the landscape in shaping spatial memory and promoting navigation through wayfinding – i.e. *"the ability to determine a route, learn it, and retrace it or reverse it from memory"*, as defined by Golledge (2003:25). A significant contribution towards this direction is the concept of landscape legibility as discussed and employed by Guiducci and Burke (2016). The combination of topographic prominence and viewshed analyses has proved to be a successful new tool to quantify and record structural and perceptual salience. Furthermore, it offers a frame of reference for testing new ideas on the navigability of the terrain and understanding better the relationship between the natural structure of the landscape and the hominin behaviour regarding movement and dispersal. This latter aspect will be further explored in the following sections, referring specifically to navigation over and across the exposed landscapes of the Aegean and the dispersibility potential for the Early and Middle Pleistocene hominins.

6.2.2 Spatial memory and landscape learning

Navigation, as a cognitive function, is possibly housed within the hippocampus in the limbic system (medial temporal lobe), a structural element of the brain strongly linked to learning and long-term memory, which are prerequisites for successful navigation (Kuhn, Raichlen and Clark 2016: 89-90; Huth 2013:25). The association between the evolution of the hominin brain and the evolution of the navigation capacity is not understood yet. However, there is evidence suggesting a gradual increase of hippocampus size across human evolution (Conroy and Smith 2007: 7). Moreover, big-brain hominins such as *H. erectus* are starting to exploit open environments over larger ranges, having navigation capacities similar to anatomically modern humans (Kuhn, Raichlen and Clark 2016). This new behaviour, introduced around 2 Mya, could be associated with a structural change in the brain affecting spatial memory, perhaps hippocampus increase. Spatial memory encompasses the ways our surroundings are visually captured and cognitively processed and stored into mental maps, which is a crucial operation for navigation. This cognitive shift possibly enabled the long-distance dispersals (early 'Out of Africa' events) resulting in the expansion of the geographical range of hominins and the widening of the resource spectrum available to them. A second remarkable shift in spatial ability within the human evolutionary history documented around 400 Kya, and associated with the exploitation of more hostile environments (Hopkinson 2007) and the systematic hunting of large mammals (Villa and Lenoir, 2009; Speth 2012). Both of these shifts happened within the early *Homo* span i.e. in a pre-anatomically modern human cognitive context.

Humans have been successful in finding their way over the landscape by learning spatial characteristics, using only information perceived and memorised while travelling (Kelly 2003; Golledge 2003). Environmental cues (e.g. physical structures) rather than shelf-based cues are used as reference points/ anchors (*sensu* Golledge 2003:35) to process spatial information in order to orient themshelves, locate and remember their position over the landscape (Guiducci and Burke 2016: 134). In that sense, physical landmarks have a key-role for organising spatial information within a wider area, either as individual, usually visually prominent points over the landscape or as central, strategic points around which other environmental features are hierarchically structured (Golledge 2003: 35-37). The trait of representing our surrounding world in an allocentric (in relation to external features), rather than an egocentric (in relation to ourshelves), way is shared with great apes (Boesch and Boesch 1984; Menzel 1973) potentially indicating an ancestral condition, possibly also present in earlier hominins.

If we imagine the mental maps in early humans/hominins as a geodatabase consisting of multiple layers of information, landmark identification is the first layer placing the reference points/anchors onto the internal map. The establishment of spatial connections between locations and places is the second layer, called 'frame of reference'. Concepts of distance, proximity and direction are developed in relation to the points of reference, helping further orientation and shelf-location. This stored, spatial information is by no means complete or absolutely accurate. Nevertheless, the frames of reference enable a structured, generic knowledge of the world ('schemata') and help us to memorise features in context (Golledge 2003: 27-29). This is possible due to the ability developed in the course of human evolution to make transferable generalisations about features rather than places in order to locate objects in space (Guiducci and Burke 2016: 134). Early humans and great apes shared the same spatial reference frames, until the emergence of culture and language that influenced the formation of those frames in humans (Gentner 2007).

In a Lower Palaeolithic context, with no artificial elements such as monuments, we could envision that natural structures of the landscape would have been used as landmarks (e.g. water bodies, volcanoes), and environmental schemata (based on major physiographic features such as river valleys, coastlines, mountain ranges etc.) would have been applied to successfully navigate into a new area - setting the primary 'layers' for the creation of the mental map. Most importantly, these maps would have been recalled by spatial memory not only when returning to the same area or retracing the way back to the starting point but also when entering similar environments (see below transferable environmental knowledge).

Spatial memory is built upon the everyday interaction with the environment over which one is moving (Kelly 2003: 49-50). Information about the surrounding world is being physically acquired through experience and the senses, and stored in memory. The accumulation of this information, over time, generates knowledge. Environmental knowledge refers to the nature of landscape features, their spatial and physical characteristics and their carrying capacities; but also, in a more advanced level, to the viability and reliability of the available resources and the biogeographical barriers marking unfavourable territories. In modern hunter-gatherers, knowledge of the landscape has been thought to be almost as important for successful exploitation as the knowledge of hunting and trapping (Nelson 1986: 184). Ethnographic examples demonstrate that orientation skills have been facilitated by the sharing of that environmental knowledge through social interaction within a group over generations (Rockman 2003:5-8). Such information sharing reveals a high level of familiarity with the landscape, which takes at least one generation to be developed in modern hunter-gatherers.

However, in cases where groups enter a previously unknown area (initial colonisation) for the first time, one should assume a lack of that collective social memory. *"In these circumstances people might very well develop cognitive maps over vast areas but with only a few prominent landmarks and several major paths defined by geography – rivers most notably"* (Kelly 2003: 50). In that case, navigation is highly reliant on the generalised 'schemata', stored in spatial memory, extrapolating environmental information from an old area to a new one, since the region-specific knowledge has not yet been acquired. Environmental knowledge, as spatial memory, is transferrable (ibid 18-19). This means that navigators are able to use information from an area visited before into a new one, in order to spot favourable resources and avoid unfavourable habitats, based on the recollection of similar characteristics –as those that they had come across before. If we assume similar navigation capacities between modern humans and earlier hominins (from *H. erectus* onwards), in a hypothetical scenario, an eastern African hominin would have been able to identify a volcanic landscape out of Africa, possibly expecting specific qualities in terms of resources (e.g. knappable volcanic rocks, thermal fields and springs/ microrefugia) by making spatial connections. Specific topographic features commonly found in volcanic settings, such as the one the hominin was familiar with, would have activated the recalling mechanism – information stored in cognitive maps, including the recognition of the value of choosing or favouring complex topography.

Ethnographic studies show that the topography of a landscape plays an important role in the learning process (Kelly 2003: 49-50). The presence of topographic relief with pronounced, distinctive features (as opposed to flat and monotonous terrains) is easier to memorise and also to navigate, connecting the local topography to larger topographic schemes saved in spatial memory. However, at the other end of the spectrum, areas with high topographic relief are difficult to traverse requiring higher effort, thus higher energetic costs and more time of travelling. In that sense, the exposed Aegean terrain, due to its complex relief and topographic variability, must have provided a balanced combination between pronounced topographic elements (memorable features used perhaps as landmarks for orientation) and more easily navigable terrains, corresponding to already recognisable environmental schemata – components of the cognitive maps.

Modern humans store in mental maps not just elements of their surrounding world, but also our relationship and interaction with the space (yet another 'layer') and our perceptions about the space attributing specific meanings (more 'layers'), *"constructing and transforming the abstract space to the theatre of our lives"* (David and Lourandos 1999: 107). This is the point when the natural landscape enters the cultural and social sphere, and becomes social and cultural landscape. How far back in human evolution, could this way of space perception be expanded, and moreover documented? In a cultural landscape, there is material manifestation of the interaction between the individuals and the various components of that landscape. In that sense, Lower Palaeolithic hominins making stone tools from a natural component of their landscape (raw material), using them to exploit available resources of that same environment, and discarding or moving them around within the spatial range of their activity, could be also considered to create cultural landscapes. In this regard, the Aegean exposed landscapes are perceived here as a lived and experienced space, where Lower and Middle Pleistocene navigators left their traces as they were moving across or settling in the area (Ch.5-5.3.2.1). As such, the now submerged Aegean landscapes could be viewed as a testimony of the hominin activity, or at least what it might have been preserved of it (Ingold 1993: 152).

6.2.3 Cognition and dispersibility

If we hypothesise similar landscape learning mechanisms as modern hunter-gatherers, we could expect Early and Middle Pleistocene hominins to have gradually occupied adjacent areas with familiar environments. Thus, the level of landscape learning required or needed to be acquired would have been low, or at least the need to learn about new environments would be lower as one moved from more familiar, gradually, to less familiar environments. Leading to the reasonable assumption that the pace of dispersal, in this case, would have been quick, and the dispersal itshelf would have been successful. However, in the dispersal(s) of hominins, the success and the progress of the event(s) are relative to the nature of the affording environment (heterogeneous/homogenous resources) and the cognitive capacity of the dispersing population. There is an interplay: (a) between resources distribution and dispersibility, and (b) between necessary adaptations to perceive and exploit successfully available resources and dispersibility.

Interestingly, the agent-based model of Wren et al. (2014) suggest that in long-distance dispersals, such as the initial out of Africa events, as cognitive complexity and environmental heterogeneity increase, dispersibility decreases. It appears, paradoxically, that cognitively advanced hominins (at the range of *H. erectus*), with high levels of environmental foresight, had a reduced dispersibility within heterogeneous resource landscapes. Foresight, in the model of Wren et al., refers to the ability of the agents to successfully identify and exploit preferential resources, and it is conditioned by natural selection. High foresight is a cognitive adaptation required for the exploitation of heterogeneous environments. Within less heterogeneous environments, one should expect agents with lower foresight. According to the model, agents with advanced foresight would select the nearest optimum location in terms of resources, as they could predict that the area around it would be worse. As such, they would not move beyond the immediate resource cluster, at least not until the exhaustion of the resources (low dispersibility). On the other hand, the model shows that agents with low foresight tend to move randomly over the landscape and may encounter, by chance, new areas with higher resources (higher dispersibility). Thus, for a successful and viable long-distance dispersal, a balance is required between exploration (beyond the local optima) and resource maximization (local optima) (Wren et al., 2014: 76). Less heterogeneous environments, requiring low foresight (i.e. low level of environmental awareness and consequently increased probability of exploratory behaviour) must have had facilitated hominins to disperse quicker over larger scales.

Perhaps the paradox observed here (advanced cognition – low dispersibility within heterogenous environments) could also be associated with high energetic expenditures required for advanced cognitive functions. The spatial memory mechanism relies on metabolically expensive neural tissue (Aiello and Weller 1995; Isler and van Schaik 2009). Results from Wren et al.'s (2014:71) study suggest that this energetic cost would only be paid within specific environments that actually required it. This is in good agreement with Grove's (2013) model examining how the evolution of spatial memory may affect the foraging behaviour of 'ignorant' and 'prescient' foragers in environments with densely distributed resources. The model suggests that the evolution of spatial memory in the 'prescient' forager, through natural selection, would not make him/her more efficient (recalling the resource locations) than the 'ignorant' forager who may have had encountered resources by chance. In other words, when the result of the two foraging behaviours ('ignorant' vs 'prescient') is equivalent, but the functional/operational cost is higher in the ‘prescient’ brain in comparison to the ‘ignorant’ one, evolution will favour ignorance as the most economical solution.

Based on these studies, one should expect a slow dispersal over the Early and Middle Pleistocene Aegean landscapes. Palaeoenvironmental and palaeotopographic proxies indicate environmental heterogeneity and high terrain complexity. Furthermore, the agents moving across the Aegean terrain and exploiting available resources would belong either to *Homo erectus* or *Homo heidelbergensis*, which are cognitively advanced hominins.

6.3 Least – cost paths over the Aegean dry land

6.3.1 Points to consider in planning least-cost path analysis

Least-cost route analysis is undertaken to explore the potential of the Aegean exposed landscapes as a traversable terrain, and test recently made suggestions about possible trans-Aegean passages (land bridge) between western Anatolia and Europe via the Greek mainland, during the Early and Middle Pleistocene (Tourloukis and Karkanas 2012b; Strait 2016).

The application of least-cost route analysis has been gradually increasing in archaeology, providing a useful tool to explore movement patterns, exploitation ranges and dispersal processes (Herzog 2014). However, examples for the Lower Palaeolithic in particular, refer only to the Later Pleistocene (Field et al., 2007; Anderson and Gillam 2000). This last observation is consistent with limited evidence on palaeogeography and palaeoenvironments for the earlier periods, which is crucial for such modelling.

For the Aegean assessment, proxy information is deduced from the present-day topography (elevation and bathymetry) in the absence of detailed palaeolandscape reconstruction for the Early and Middle Pleistocene. It is assumed, for modelling purposes, that hominin groups would have taken easier routes, requiring the least effort (cost) to cross the landscape - at least the easiest routes within challenging complex landscapes, such as the Aegean. Effort here is relevant to, and determined by, the topographic configuration, based on the general assumption (Tobler 1993) that smoother terrain is easier to traverse than complex terrain. Obviously, slope is only one factor, out of many, that affect biogeographical processes such as movement and dispersal. Still, it permits approximations about time of travelling and energetic costs of movement across a specific surface, and ultimately calculatios of the least-cost way of traversing the landscape from point A (origin) to point B (destination). This is not to imply, however, that dispersing hominins over the Aegean terrain had a predetermined course; on the contrary, as it has been highlighted before, these early events had an opportunistic character with no predefined destination.

Consequently, the concept of given origins and destinations is used here only for the sake of modelling, and does not correspond to the actual dispersing mechanisms of the Early and Middle Pleistocene hominins.

Palaeolandscape features that could have acted as barriers, blocking or disrupting movement, are taken into consideration. This includes: (a) the major water bodies hosted within the basinal structures of the northern and central Aegean during MIS 10-12 and MIS 8 (as indicated by geological evidence - see Ch.4), and (b) the southernmost border of the Aegean dry land, corresponding to two different positions (MIS 10-12 and MIS 8) of the changing palaeocoastline (until the first marine intrusion during MIS8 - see Ch4). Sea-level fluctuations are excluded, as explained elsewhere (Ch.5), because the Lower and Middle Pleistocene Aegean is perceived as a continuous terrain until MIS 8, on the basis of available palaeogeographical reconstructions (Lykousis 2009; Sakellariou and Galanidou 2016; 2017).

River plains, are another interesting physiographic feature, which could have acted either as a barrier for movement, or as a natural corridor facilitating dispersal. In the suitability model, rivers are generally considered as a positive feature (Ch.5). However, for exploring mobility, more detail is required about the characteristics of such features (e.g. length of the river, width, water discharge etc.) in order to determine their role (positive or negative). Rich evidence from the northern part of the Aegean, suggests extended river systems across the continental shelf during the LGM (Ch.4). A cautious projection of similar conditions to the earlier Pleistocene could be made perhaps, at least for the terrestrial part. However, for the now submerged part of the continental shelf, which used to be exposed during the Middle Pleistocene, reliable geological evidence is missing. It is very possible that the LGM rivers extended further to the south, to connect with the palaeoelakes formed within the basins of the North Aegean Trough. Still, without well-founded reconstructions for the complete palaeoriver systems, during the Early and Middle Pleistocene, including on- and off-shore geological evidence, this element cannot be included in the least-cost path analyses.

6.3.2 Least-cost path analysis

The least-cost path travels from a source location (origin) to a destination, guaranteeing that this is the cheapest i.e. the most cost-effective route to traverse the landscape, in relation to a cost surface (friction surface).

Three tools from the spatial analyst toolkit (cost distance tools) ArcGIS are used:

1. Cost surface: produces a cost raster, identifying the cost of traveling through each cell.
2. Cost distance: calculates the least accumulative cost distance for each cell to the nearest source over a cost surface. It requires a source location dataset and a cost raster as inputs.
3. Cost path: produces an output raster that records the least-cost path (or paths) from selected locations to the closest source cell defined within the accumulative cost surface, in terms of cost distance. The produced path is one cell wide.

Step 1. Cost Surface

The cost surface corresponds to a raster where the value of each cell represents a cost of traversing the specific landscape. We could imagine the cost surface (or friction surface) as an underlying grid that tells us how costly it is to move from cell to cell. Thus, each cell is giving us a coefficient which is then multiplied against distance. What represents a cost can be determined each time according to the research questions(s) and the examined variables. Usually cost refers to time (how long it takes to go from point A to point B) or energetic cost (how easy/difficult it is, in terms of energy expenditure, to traverse a terrain from point A to point B).

What is of interest here, is to get a general idea of cost-effective possibilities to cross the Aegean, based on the modern landscape structure, and assuming a continuous terrain over the northern and central parts.

To do so, a cost surface has been created, representing time of travel, i.e. the time it takes to cross each grid cell to walk from point A to point B. Velocity is the indicator we are seeking – a measure of distance per time. Tobler's hiking function (Tobler 1993), using empirical data from Imhof (1950), predicts human walking speed based on slope. The speed is affected by topography; smoother terrain permits fastest walking, while complex terrain reduces walking speed. Palaeogeographical features, representing natural barriers to movement, have been included in this modelling.

The hiking function is expressed as:

$W = 6 * exp\ \{-3.5 * abs\ (S + 0.05)\}$ (7)

Where:

W = walking velocity (km / hr)

S = slope of the terrain (dh/dx)

The hiking function, as expressed by Tobler, suggests that speed is fastest on gentle downslopes and predicts maximum speed at -2.86° (-5%) slope.

In order to use the hiking function in a given landscape, first the slope of that terrain needs to be calculated and then converted to walking velocity. After that, the minimum time path from an origin cell to all other cells of our grid can be computed.

Slope is calculated in percentage (from the mosaic raster) using the Spatial Analyst tool > Slope. The percentage slope formula is:

$slope_{perc} = 100 \cdot dh / dx$ (8)

Where dh stands for terrain elevation and dx for horizontal length.

However, notice that in Tobler's function: S is not the same as $slope_{perc}$ ($S \neq slope_{perc}$) but S corresponds to dh / dx (S = dh / dx).

To get the dh / dx value, the raster of the $slope_{perc}$ is divided by 100 (raster calculator). The new slope dh / dx raster is then used to calculate velocity. In the raster calculator the expression of the hiking function is entered, where S = *slope dh / dx raster*.

The output raster is that of the velocity in km/hr (velocity_km_hr raster). But the original question refers to the amount of time taken to traverse the landscape, thus the ratio km/hr needs to be inverted, to produce the hours per km raster from the velocity raster. To do so the following formula is implemented in the raster calculator:

1.0/velocity_km_hr

The 1.0 forces the raster calculator to use floating numbers instead of limiting it to integers only.

The output raster is now in hours per km, however the coordinate system of the mosaic raster (DEM and bathymetric data), from where slope has been calculated, uses meters as the linear unit. This is solved by dividing the hours per km raster by 1000. The final output raster corresponds to a friction surface with values in hours per meter.

From this final time-of-travel raster (hr per meters), specific areas need to be excluded, corresponding to palaeolandscape features, which would have acted as natural barriers to hominin movement. To do so, first these areas need to be determined. Information from available palaeogeographical reconstructions (Lykousis 2009) is used to produce two new rasters with the areas covered by major water bodies in the northern and central Aegean during MIS 10-12 and during MIS 8 respectively. In order to determine no data for the cells corresponding to water coverage, the Is Null tool is used. Two *is_null* rasters are produced, using as inputs the *water_ bodies* rasters. In the *is_null* rasters, 0 represents no data cells (water coverage), and 1 all the other cells (the area around the water bodies). To include these no data areas in the hours per meter raster, i.e. to exclude water coverage areas, the following expression is entered in the raster calculator:

Con (*is_null* raster, *hr_m* raster)

This conditional evaluation is performed for both rasters - excluding the water barriers (*is_null*) - produced before. The output rasters correspond to two cost surfaces, the first correspond to time of travel over the landscape (hours per meter) excluding the MIS10-12 water bodies, and the second to time of travel (hours per meter) excluding the MIS 8 water bodies.

Step 2 – Cost distance ('spatial analyst'> 'distance'> 'cost distance')

The cost distance tool requires two inputs: a cost surface raster and at least one source feature (origin); it produces two new rasters: a cost distance raster and a back-link raster.

In the cost distance raster, a cost-accumulated surface has been created from the cost surface raster (first input), where each cell represents the minimum accumulation of cost from an origin (second input) (Llobera, Fábrega-Álvarez, Parcero-Oubiña 2011: 844). As such, the cost distance raster identifies the accumulative cost for each cell to return to the closest source location (origin). The back-link raster defines the direction, or identify the next neighbouring cell along the least accumulative cost path, from a cell to reach its least-cost source.

In our case, the cost surface represents time of travelling (during two time periods *hr_m_MIS10_12* and *hr_m_MIS8* rasters), based on topography. Over the accumulated cost surface, the vertical changes in topography do not actually represent changes in height (elevation and bathymetry) but changes in the cost accumulated from the origin. Ridges represent locations where the accumulation of cost is locally maximum, while valleys and/or channel-like features represent areas where the accumulation of cost is locally minimum. In other words, it would be more costly (i.e. it would take more time) to walk across hills than walking across valleys. Movement over the accumulated cost surface, from an origin to a destination, follows the least-cost direction i.e. cells with the minimum accumulation of cost.

As mentioned before, the cost distance tool needs a second input, features representing the source location (origin), the point from where the path starts. In this model, three locations of known LP archaeological sites at the eastern part of the study area have been set as separate origins; from north to south: Yarimburgaz cave site (Bosporus) – origin1, Rodafnidia open-air site

(Lesbos Island) – origin 2 and Karain cave site (SW Anatolia) – origin 3. Yarimburgaz and Karain chronologies fall within MIS 8, while Rodafnidia is older falling within, or even before, MIS 10-12. As such, for calculating the cost distance having Yarimburgaz and Rodia as origins, the *hr_m_MIS8* raster will be used as the cost surface because it represents travel time considering natural barriers during MIS 8; similarly, for calculating the cost distance having Rodafnidia as origin, the *hr_m_MIS10_12* raster will be used as the cost surface because it represent travel time considering natural barriers during MIS 10-12.

Three different sets of rasters are created: *cost_distance_origin1* and *back_link_origin1*, *cost_distance_origin2* and *back_link_origin2* and *cost_distance_origin3* and *back_link_origin3*.

Step 3 – Cost path ('spatial analyst'> 'distance'> 'cost path')

In order to create a least-cost path, a cost distance raster and at least one destination are required (as inputs).

Each of the eastern origins (set in the previous step) has a specific destination, corresponding to isochronous archaeological locations, at the western part of the study area (mainland Greece): Rodia (FS30) open-air site (Thessaly) – destination 1, and Marathousa 1 open-air site (Megalopolis basin) – destination 2. Ultimately three pairs of origins-destinations are created: Yarimburdaz – Rodia (FS30), Karain – Rodia (FS30) and Rodafnidia – Marathousa 1. The spatial reference for the location of the archaeological sites (x and y coordinates) is obtained by the Prehistoric Stones of Greece database and the TAY (Archaeological Settlements of Turkey) project database, both open-access.

Three least-cost paths have been produced using the cost distance rasters (from the previous step) and the destinations:

<u>Least-cost path 1</u>: Yarimburgaz to Rodia FS30 (input raster> cost_distance_origin1, input feature> destination 1) (fig.6.1).

<u>Least-cost path 2</u>: Karain to Rodia FS30 (input raster> cost_distance_origin2, input feature> destination 1) (fig. 6.1).

<u>Least-cost path 3</u>: Rodafnidia to Marathousa 1 (input raster> cost_distance_origin3, input feature> destination 2) (fig. 6.1).

The east-to west direction should not be taken literally as indicative of the direction of movement/dispersal. This is only happening for modelling purposes. By setting points of departure and points of destination on both sides of the Aegean, the model is forced to calculate changes in cost accumulation over the northern and central Aegean, an area that may now be submerged but used to be an exposed terrain from at least MIS 10-12 until at least MIS 8, connecting western Anatolia with the Greek mainland.

The selection of the origin and destination locations is not random but made on the basis of observed similarities between the sites of each pair: (a) chronological associations i.e. securely dated evidence (archaeological and/or palaeoanthropological) indicating the presence of hominins in the Aegean region during the Middle Pleistocene, and (b) similarities in the material culture evidence i.e. technological and typological affinities in the stone tool assemblages. It is worth mentioning that due to the fragmented nature of available records and the extensive spatiotemporal discontinuities, it has not been always easy (or even possible) to draw strict and detailed links, but whenever such associations are present, they are taken into consideration.

The lower levels of Yarimburgaz cave (Arsebük and Özbaşaran 1999) and find-bearing layers from Rodia (Runnels and Van Andel 1993b) are dated within MIS 8, as are specific levels from Karain cave (Otte et al. 1995). Similarities have been reported in stone tools from Yarimburgaz and Rodia regarding the prevailing raw material (quartz) and the core and flake technology (Tourloukis 2010: 41). Rodafnidia (Galanidou et al., 2013; 2016) and Marathousa 1 (Panagopoulou et al., 2015) have been securely dated to the Middle Pleistocene, around, or prior to, 400-500 Kya. However, the stone tool assemblages demonstrate distinctive differences in their technology and typology, with Marathousa 1 following the Mode 1-tradition, while in Rodafnidia an Acheulean industry with possible African affinities, Mode 2, is present. Nevertheless, hominin groups, even with different traditions, were present at roughly the same time (within MIS 12 perhaps even earlier), in different areas of the Aegean.

To reiterate, the produced least-cost paths (fig. 6.1) should not be interpreted as specific dispersal routes followed by hominins nor as suggestive of specific movement patterns, but only as an indication that the concept of the Aegean as a traversable terrain during the Middle and possibly during the Early Pleistocene could be a viable hypothesis.

It would have been at least precarious to claim otherwise, in the absence of palaeolandscape reconstruction covering the earlier Pleistocene, the lack of coherent evidence on palaeoenvironments and the sparse archaeological evidence. Moreover, the least-cost route analyses, described here, are only a first step towards the development of arguments supporting this hypothesis. Other archaeological examples, as well as more variables, both palaeoenvironmental (e.g. climatic evidence) and biological (e.g. energy/calorific costs) could be incorporated in the model, to further inform aspects relating to hominin mobility *per se* (e.g.

energetic costs to move across a landscape along a proposed route), and hominin mobility patterns (e.g. flexibility and/or adaptability in relation to environmental and climatic variability).

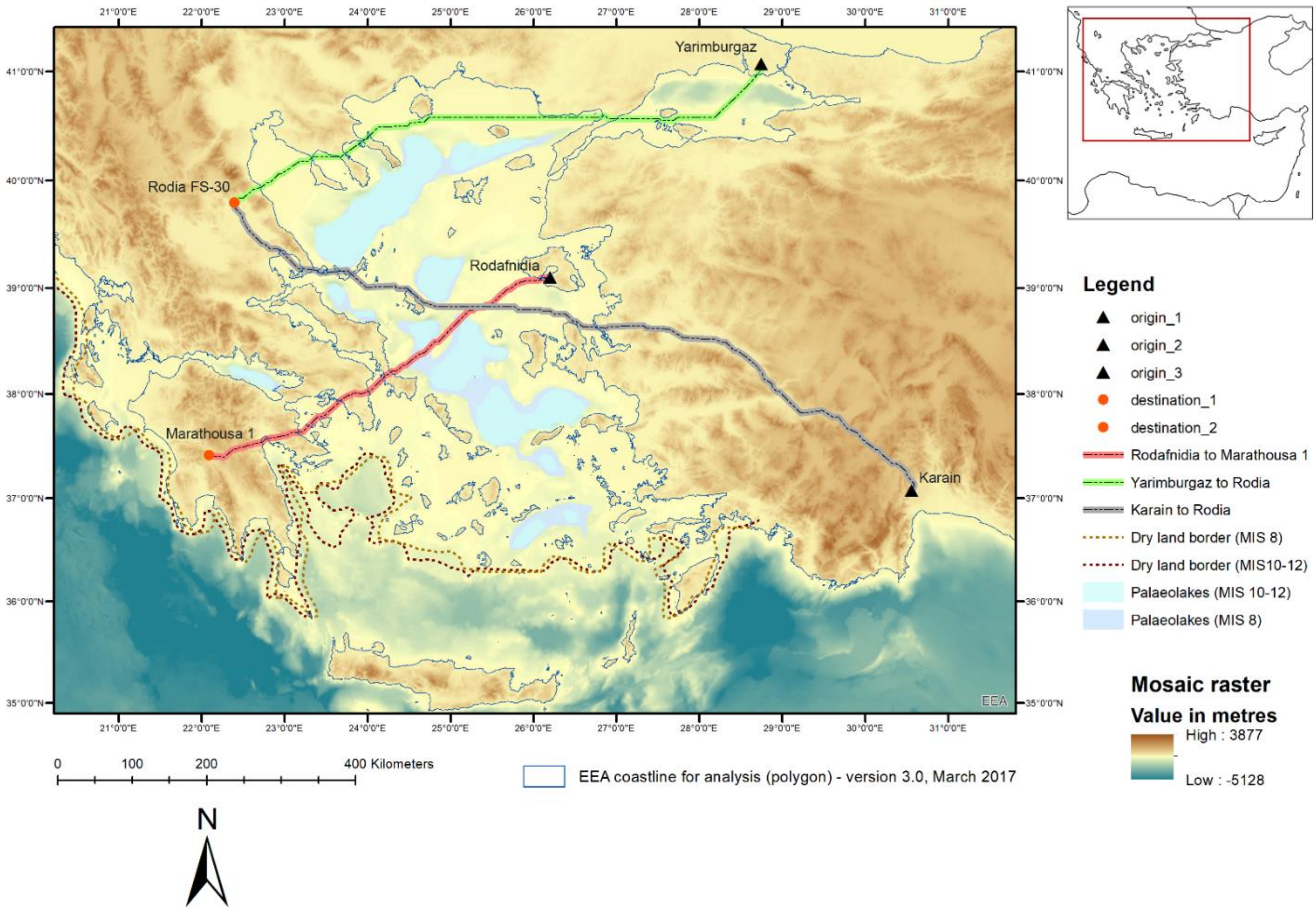


Figure 6.1. Least-cost paths for MIS 10-12 and MIS 8. Palaeoenvironmental and palaeogeoraphic features considered as barriers to hominin movement are depicted: the Aegean water bodies and the palaeocostline of the Aegean dry land. The blue line corresponds to the modern coastline (source: European Environmental Agency (EEA), available in ArcGIS online). Terrain data: ASTER Global Digital Elevation Map, version 2 (ASTERGDEM V2) (30m resolution), available at NASA Land Processes Distributed Active Archive Center (LP DAAC). Bathymetric data: Eastern Mediterranean Bathymetric Map (2016) (250m resolution) by courtesy of the Hellenic Centre for Marine Research. Coordinate system: WGS 1984 Web Mercator Auxiliary Sphere; Projection: Mercator Auxiliary Sphere; Datum: WGS 1984; Linear Units: meters. Map produced in ArcGIS 10.6

6.4 Navigability of the Aegean terrain

6.4.1 Landscape legibility

The (cognitive and biological) ability to navigate over the landscape is key for dispersal and for the development of successful subsistence strategies. However, the navigation process, as shown before, is not determined only by cognitive and biological parameters, it is also highly controlled by the natural configuration of the landscape itshelf (fig. 6.2). Spatial memory and environmental knowledge, which are prerequisites for successful navigation, are shaped and ultimately fixed upon structural elements of the natural environment, the 'anchors' as defined by Golledge (2003:35). These are salient features that have been used as reference points (a) for orientation over the landscape or (b) for navigation, dictating natural pathways (structural salience); usually, due to their visual prominence (perceptual salience) but also due to the attributed sociocultural values (semantic salience), later on in the course of human evolution.

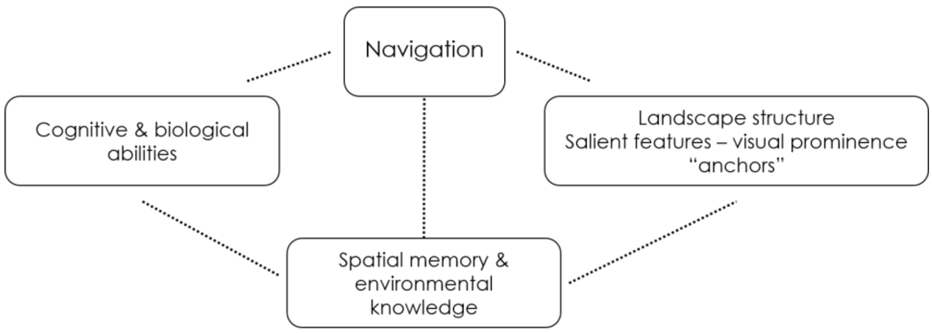


Figure 6.2. Schematic expression of the relation between the factors affecting the navigation process

In the study of the past landscapes, many different ways to quantify and record salience have been attempted using GIS applications. The most frequently applied methods are either measuring topographic prominence based on the relative elevation within a predetermined radius (e.g. Llobera 2001, 2003- see Ch.5) or using viewshed analyses to assess the visual prominence of specific elements in the landscape (Llobera et al. 2010; Lake and Woodman 2003; Wheatley and Gillings 2000). Salient landmarks, by definition, attract visual attention due to certain characteristics or due to a combination of visually attractive cues (e.g. shape, size, configuration, colour, visual prominence), which can be either natural or artificial, depending on the context. Visibility (areas in the landscape visible from a certain point) and inter-visibility analyses (areas with overlapping views), especially within cultural contexts, where archaeological remains exist, help us to explore structural, perceptual or semantic salience, to answer for example questions regarding the placement of monuments and sites (preferential locations) and the sociocultural/behavioural aspects behind these choices (e.g. Rášová 2014; Wright, MacEachern, Lee 2014). However, in natural contexts, as is the case of the Aegean exposed landscapes, things become more complex, since salience only relies on the structural elements of the landscape itshelf, i.e. on the identification of natural features that could have operated as landmarks.

Recently Guiducci and Burke (2016) introduced the Legibility Index, a new approach to assess the navigation potential of a palaeolandscape, combining structural and perceptual salience, by recording topographic and visual prominence. Legibility, as defined by Golledge (2003: 34-6), refers to the way(s) the spatial structure of the landscape affects wayfinding and the navigation process. In a well-ordered landscape, a navigator would encounter natural features organised into a coherent scheme e.g. clusters or an easily perceived hierarchical order (spatial coherence – first dimension of legibility), in such a way that the movement would be guided by this natural structure (ease of navigation – second dimension of legibility). Humans, of course, also create landmarks, which are not necessarily reflected in the physical configuration, by attributing symbolic values to the landscape (sociocultural dimension of legibility). This latter aspect, is very difficult, if not impossible, to be detected in the deep past. The legibility index, is a quantitative metric that captures the first two dimensions of legibility (spatial coherence and ease of navigation), based on the idea that topographic complexity and the level of visibility of salient features across smaller or larger spatial scales, determine how well or poorly ordered is the landscape; in other words, how easy or difficult it is to be navigated. The index is applicable both at local and regional scales.

The process developed by Guiducci and Burke (2016) could be summarised into 3 main steps:

1. Topographic prominence is measured using the Topographic Position Index in order to identify the prominent landscape features, which could have acted as landmarks for orientation and navigation, within a 25km radius. The selected test radius is compatible with long-distance visual perception in humans and falls within the typical exploitation range (residential move distances) documented in modern hunter-gatherers.
2. Viewsheds and fuzzy viewsheds are produced for each potential landmark (identified in the first step) to estimate the visual salience of the prominent features, i.e. to establish how well these features could be seen by navigators across the landscape. First, binary viewsheds (visible/not visible) based on elevation are produced for each landmark, assuming reciprocal visibility to and from. In a second stage, fuzzy viewsheds are calculated, again for each landmark. This measure creates a target-sensitive viewshed, producing a range of visibility values (rather than absolute values-

visible/ not visible), taking into consideration: (a) the size of the target i.e. the area of each landmark, and (b) the gradual falling-off the visibility relative to the increasing distance between the viewer and the viewing point. As the distance between the viewer and the target (viewing point) increases, the visual clarity decreases but the maximum viewing distance is determined by the size of the target itshelf, as shown by Ogburn (2006). Smaller landmarks can be seen well within smaller spatial ranges, while bigger landmarks are clearly visible within larger spatial ranges. A simplified example would be that a mountain chain can be seen or at least clearly identified from a great distance of tens of kilometres, while a boulder would not have been visible within the same scale. This relational situation between visibility, distance (between the viewer and the target) and size (of the target) determines the level of impact (low/high) that each landmark would have in facilitating or obstructing orientation and navigation within a given space.

3. In the final step, cumulative viewsheds are produced for each set (the binary and the fuzzy viewsheds) and multiplied to produce the legibility index. This is key in order to assess the overlapping visual ranges to or from different points in the landscape. If the overlapping between areas with prominent landmarks is high, this means that this part of the landscape has a good coverage and adjacent landmarks would have been visible to navigators, guiding their way smoothly. If the overlapping is low, we should expect that the way-finding in this part of the landscape would be interrupted by the lack of continuous visual cues leading their movement. The produced index shows not only how many landmarks are visible from any point in the spatial extent, but also how well they could be seen.

The case study presented by Guiducci and Burke (2016) refers to an Upper Palaeolithic context in northern Iberia, examining the relation between the location of known archaeological sites and the legibility of the landscape. The authors conclude that there seems to be a preferential association, with the Aurignacian sites located in the immediate vicinity (< 2km) of cells with high values of legibility; an assumption supported also by statistical analyses. However, this approach needs further testing to better understand the effect of landscape structure in hominin movement and dispersal patterns.

6.4.2 Calculating legibility for the Aegean dry land

Is it possible to identify such prominent landmarks across the Aegean dry land using topographic and visual prominence? And furthermore, make assessments about the navigability of the Pleistocene Aegean exposed lands using the current geographical configuration?

In order to provide some initial answers, a simpler process will be followed but keeping the main elements of the Guiducci and Burke method – topographic prominence and viewshed analyses. Fuzzy viewshed will not be included. This is due to the extent of the study area and the scale of the study; it would be computationally extremely expensive and time consuming. *Furthermore, this work corresponds to a preliminary assessment, aiming to evaluate the potential of the legibility approach in the Aegean context rather than producing detailed and high-resolution results.* The latter is by default improbable, because of the undermining lack of resolution in the palaeolandscape analysis - proxy data from modern topography are used to suggest the structure of the Middle Pleistocene landscape.

Step 1. Topographic prominence

Structural salience is deduced from modern elevation and bathymetry, using the Topographic Position Index, a topographic metric already tested in the Aegean context (see Ch.5 - 5.3.2.). The same process as in section 5.2.3.2 is followed but here the size of the neighbourhood is increased to 20km. This is done in order to identify salient features (a) within the range of visual perception in humans, which is 25km as stated by Guiducci and Burke (2016), and (b) within the suggested range of typical residential move distances travelled by LP hominins. Bailey and King (2011) propose a 10km radius, based on evidence for the Lower Palaeolithic, while ethnographic data on modern hunter-gatherers presented by Kelly (1995: 112-115) suggest a great diversity in exploitation ranges; a rough average would indicate a range between 20km and 70km per residential move, but this is quite generic, and it is used here only as an approximation.

The cut-off value for salience is set to ≥0.75. I tested higher cut-off values of topographic roughness (≥0.80 and ≥0.90 - see fig.6.3), but salient features cannot be visually distinguished. The 0.75 limit has been set in order to have sufficient spatial evidence on topographic prominence to further explore landscape structure.

In order to select (from the *TPI_20km raster*) only the cells with values ≥ 0.75, corresponding to prominent topographic features, the following expression is entered into the raster calculator:

Con (PTI_20km raster >=0.75)

The new raster (*salience_20km*) is reclassified (spatial analyst> reclassify) in order to assign no data in the area around the salient features. In the reclassified raster (*salience_20km_recl*) the old value 1 (area around the salient features) becomes no data, and the old value 1 (salient features) remains 1. From the reclassified raster, salient features can be isolated into discrete features (Conversion Tools > From Raster > Raster to Polygon). The new feature class (*salience_20km_poly*) includes polygons that correspond to each salient feature (fig. 6.4).

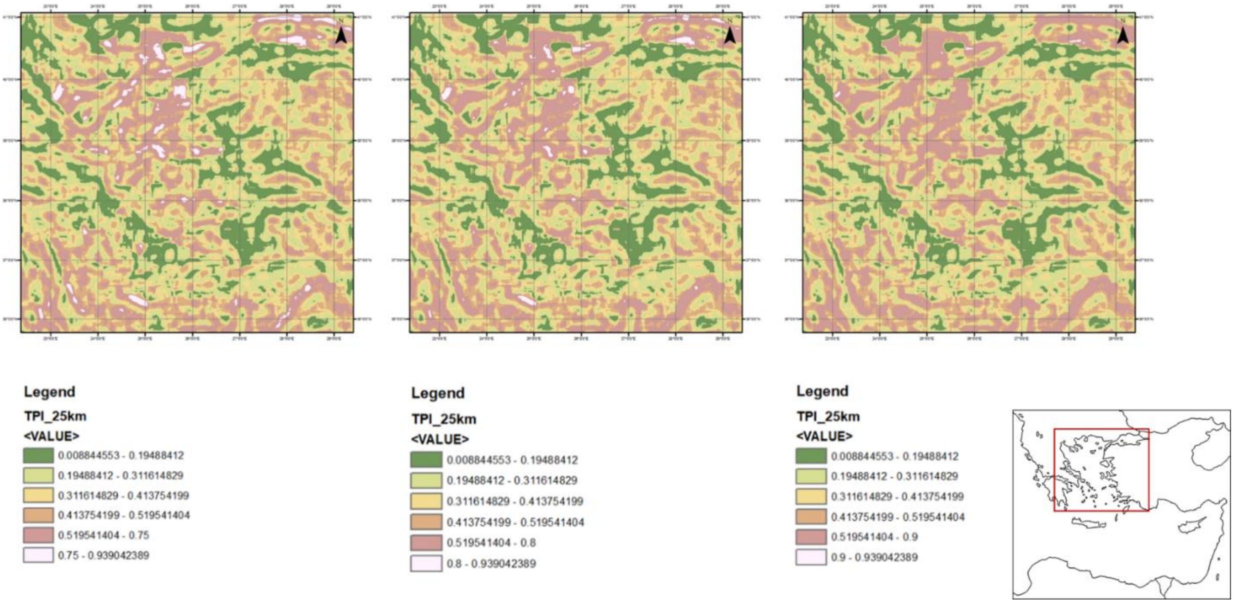


Figure 6.3. Cut-off values for salience (light pink areas), from left to right: 0.75, 0.8 and 0.9. Salient features cannot be distinguished with cut-off values over 0.9 (left). The topographic Position Index applied on the mosaic raster (elevation and bathymetry). Geospatial data as in fig. 6.1

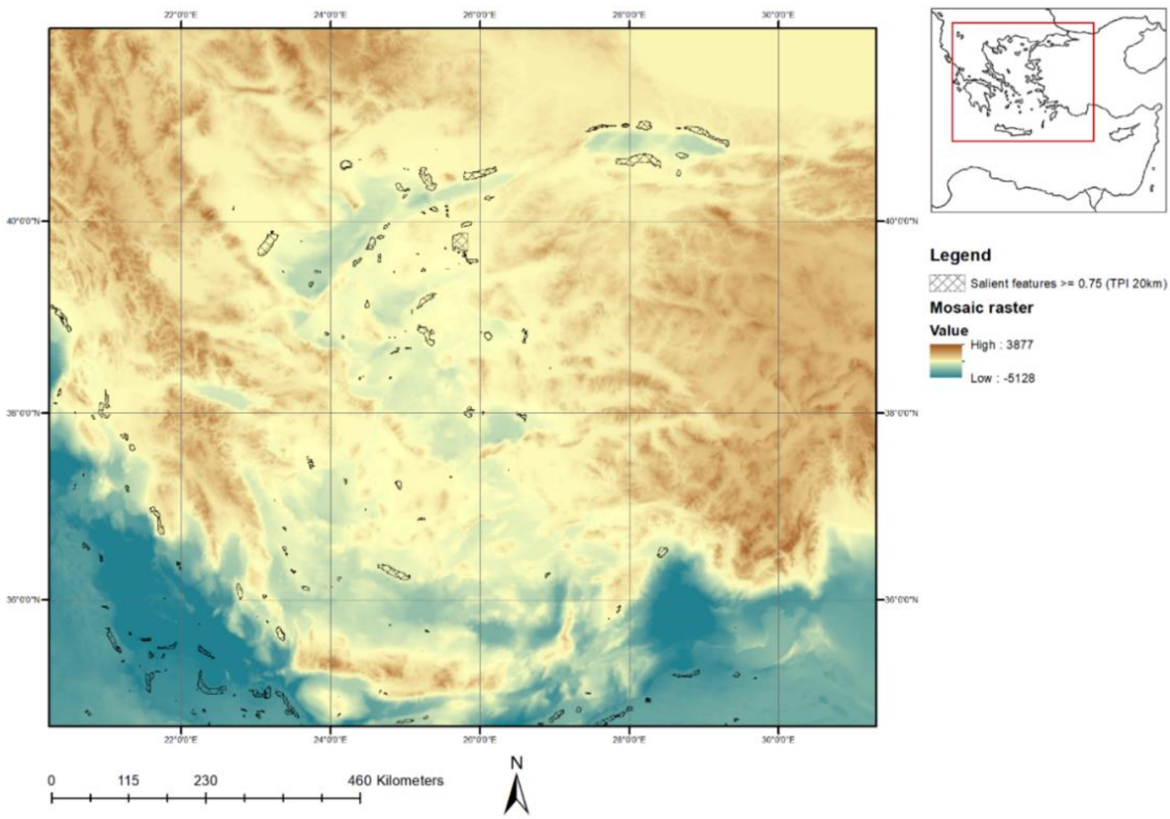


Figure 6.4. Salient features (cut-off value ≥ 0.75) indicated by the hashed polygons. The base map corresponds to the mosaic raster (elevation and bathymetry). Geospatial data as in fig. 6.1

Step 2. Visibility analysis

The features that have been identified to be topographically prominent over the Aegean terrain will be now used as inputs to run the visibility analysis. What is to be examined here is what areas of the landscape would be visible from the salient features, and in turn from where over the landscape the salient features would have been visible, assuming reciprocal visibility to and from viewpoints (salient features). The latter is a general assumption, which is not without problems in terms of accuracy of results, as it has been stressed in several studies (Wheatley and Gillings 2002:210-112; Guiducci and Burke 2016: 135). An effective way of enforcing reciprocity in vision is by defining specific parameters in visibility analysis according to the topographic characteristics of the study area (see for example Zamora (2011) setting OFFSETA and OFFSETB to be equal and inversing the viewing angle). However, that level of detail found in local studies, cannot be reached in the Aegean case. Given that this is a preliminary assessment of possible visibility applied on a regional scale, and based exclusively on proxy topographic data, a coarse-grained model should be expected.

For this model, a bare surface is presumed. Of cource, in natural landscapes (such as the Aegean dry land), with no artificial elements, visbility is affected by several environmental variables such as vegetation cover and lighting conditions, to mention a few (Ogburn 2006: 406-7). However, such evidence is not available for the Aegean during the Early and Middle Pleistocene and, even it if it was, it would not be applicable on the vast spatiotemporal scales investigated here. A finer spatial and temporal resolution is required for more accurate results.

The viewshed tool from ArcGIS is selected for the visibility analysis. The tool creates a raster recording the number of times each area can be seen from the input observer locations (source cell or viewpoint). This value is recorded in the VALUE item in the table of the output raster. The operation is raster-based and requires a surface elevation matrix. Viewshed calculates for each cell in the raster, a straight line of sight between the viewpoint and every other cell within the elevation model. The main determinant of the viewshed is elevation: if on the straight line between the viewer (source cell) and the observing point (target cell) occur cells with height greater than the height of the three-dimensional line (the angle of the line of sight) at the source cell, then visibility to the target cell is blocked (negative results). If the height of the cells occurring on the straight line between the source cell and the target cell do not exceed the height of the three-dimensional line at the source cell, then visibility to the target cell is unhindered (positive results). The output is a binary raster, coding with value 0 all cells with no line of sight with the view-point, and with value 1 all cells that have a direct line of sight with the view-point.

Unfortunately, the viewshed tool in ArcGIS would not accept polygons as inputs, only points or lines could represent viewpoints. Converting our ‘salient’ polygons (*salience_20km_poly*) into points could be a solution, but the point feature class would include thousands of points, and to run viewsheds from each point it would be overwhelmingly time-consuming, considering the extent of the study area, and quite expensive in terms of data storage. To overcome this drawback, a criterion has been set: to select only the highest points within the salient features (within each 'salient' polygon), and use those as viewpoints for the visibility analysis.

This is easily done with the zonal statistics tool, which calculates statistics on values of a raster within the zones defined by another dataset (spatial analyst>zonal> zonal statistics). A zone is all the cells in a raster that have the same value, whether or not they are contiguous. The input zone layer is the 'salient' polygons (*salience_20km_poly*) that defines the shape, values, and locations of the zones. The ID field in the zone input is specified to define the zones. The input value raster is the mosaic raster (elevation and bathymetry combined) that contains the input values used in calculating the output statistic for each zone. For statistics type, 'maximum' is selected, to assign the highest value in each zone to all cells in that zone. Ignore No Data is checked.

To determine which cells in the mosaic raster correspond to the highest elevation found within each polygon in the output raster (*max_elevation*), the following expression is entered in the raster calculator:

Con ("mosaic_raster"== "max_elevation", "mosaic_raster")

Which states that if a cell in the *mosaic_raster* is equal to the corresponding cell in the *max_elevation* raster, then set the cell value of the output raster to what is in the *mosaic_raster*. If the cell value in the mosaic raster is not equal to the value in *max_elevation*, it is set to no data in the output raster.

The output raster (*cell_loc*) shows the cells that correspond to the highest points within every salient feature. Those cells can easily be converted into points (Conversion Tools > From Raster > Raster to Point). The resulted *cell_loc_point* feature class can now be used as input to run viewshed - with the highest points corresponding to the viewpoints (fig. 6.5).

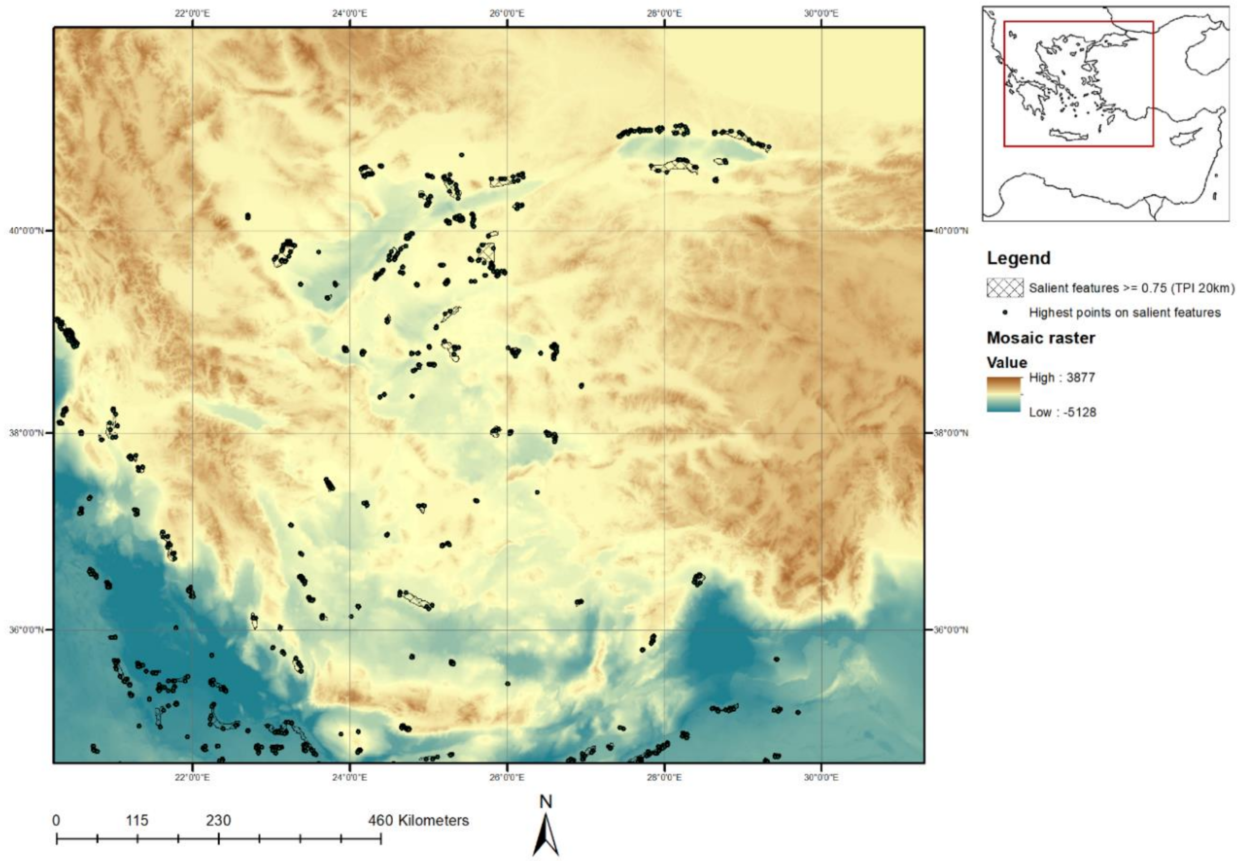


Figure 6.5. Highest points on salient features. The base map corresponds to the mosaic raster (elevation and bathymetry). Geospatial data as in fig. 6.1

Before running the viewshed tool some very basic controls need to be added in order to limit the region of the raster that will be included in the visibility computations. Three controls are defined:

- The height of the navigator. This is specified via the OFFSETB parameter, which indicates a vertical distance in surface units to be added to the z-value of each cell as it is considered for visibility. OFFESET B is added as a new field in the attribute table of the cell_loc_point shapefile, and it is set to equal 1.70m, an average height for a Middle Pleistocene hominin such as *Homo heidelbergensis* (Carretero et al., 2012).
- The extent of the observation area around each salient viewpoint. The RADIUS1 and RADIUS2 parameters, limit the observation within specific areas around the viewpoints. Cells beyond the RADIUS2 observation distance are excluded from the analysis. Cells closer than the RADIUS1 search distance are not visible in the output raster but can still block the visibility of cells between RADIUS1 and RADIUS2. The default RADIUS1 distance is zero. The default RADIUS2 distance is infinity. Here, RADIUS2 is set to 25km, which equals the long-visual perception range in humans (Guiducci and Burke 2016: 135); and RADIUS1 is set to 4km, after which, visual clarity starts to drop-off significantly (Ogburn 2006). The produced viewsheds will then concentrate on the area from 4km up to 25km

around the salient features. The interest here lies in the visibility from the landscape towards the prominent features, and not that much for what would have been visible from the actual features; this is relative to the position of the navigator on the landscape, and not on the landmarks. Thus, the immediate area around the salient features, indicated by the 4km radius, is excluded. It is assumed that the visual clarity within the 4km radius would have been good, so it would be interesting to explore from where over the landscape, within the 25km range of the long visual perception, the landmarks would have been visible by the navigator, before entering that optimum-clarity zone of the 4km. This choice is also consistent with the regional scale of analysis. Completely different choices would have been made for examining visibility at local scales.

To minimise the time/memory requirements of such computation, the visibility analysis is applied separately to the geographic sections of the Aegean, following the nine-part division proposed by Sakellariou and Galanidou (2016; 2017), founded upon discrete morphological and geotectonic characteristics. One more section has been added, the Bosporus section (BOSP), based on the direction of the main fault systems around the Marmara region (Rockwell et al., 2009). Each section is represented by a polygon feature. What it needs to be specified next is how many viewpoints (higher cells within the salient features) are included within each geographic section. The Clip tool is used to extract the viewpoints (from the *cell_loc_pont* shapefile) that overlie with each of the polygons representing the Aegean sections and the Bosporus. Ten new point shapefiles are created, each including the viewpoints within any of the geographic sections (fig. 6.6).

The viewshed tool runs for each geographic section separately – but not for each viewpoint within the section. The total number of viewpoints found within each section is the input feature class for each calculation. For example, for the North Aegean Shelf (NAS) section the input raster (the surface over which visibility will be computed) is the *mosaic_raster* and the input feature class is the *NAS_clip* (viewpoints within the NAS geographic section). What is generated here is a summary theme of the visibility characteristics of the group of viewpoints included in the NAS section (fig. 6.8); otherwise called multiple viewshed theme (Wheatley and Gillings 2002: 207-209). In the output raster, value 1 represents cells visible from any of the viewpoints within NAS while 0 represents areas that are not visible from any of the viewpoints.

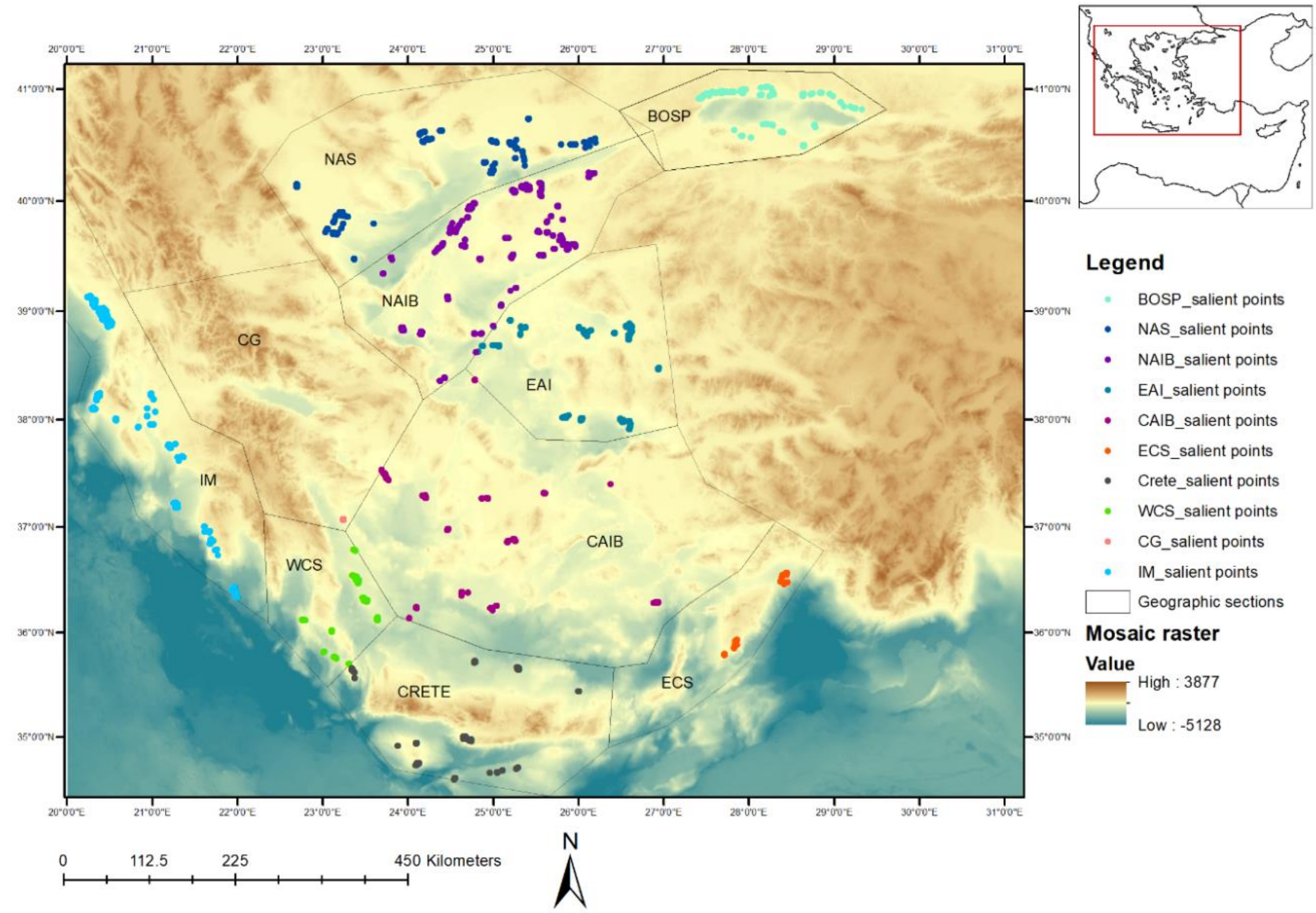


Figure 6.6. Highest points on salient features within each of the nine geographic units of the Aegean and the Bosporus new section. The Aegean division into nine parts follows Sakellariou and Galanidou (2016). The base map corresponds to the mosaic raster (elevation and bathymetry). Geospatial data as in fig. 6.1

When running the viewshed tool an anomaly has been observed: many viewpoints are marginal, laying at the border between two geographic sections. This means that part of the 25km observation radius (RADIUS2) may fall into the adjacent geographic section. As such, the cells of RADIUS2 falling out of the examined polygon (beyond the processing extent), are not included in the viewshed computation for the specific section. To avoid this, buffers of 25km have been created for the viewpoints within each section, e.g. *the NAS_buff25* shapefile corresponds to the 25km buffer zones around every viewpoint included in the NAS section. These buffer shapefiles are selected, through environments, to indicate the processing extent for each viewshed computation (fig. 6.7).

Multiple viewshed themes are calculated for eight out of the nine geographic sections of the Aegean and for the Bosporus section. Crete is excluded from this model since the area lies beyond the suggested southernmost border of the Aegean dry land, representing insular environments during the Middle Pleistocene (Lykousis 2009; Sakellariou and Galanidou 2016; 2017).

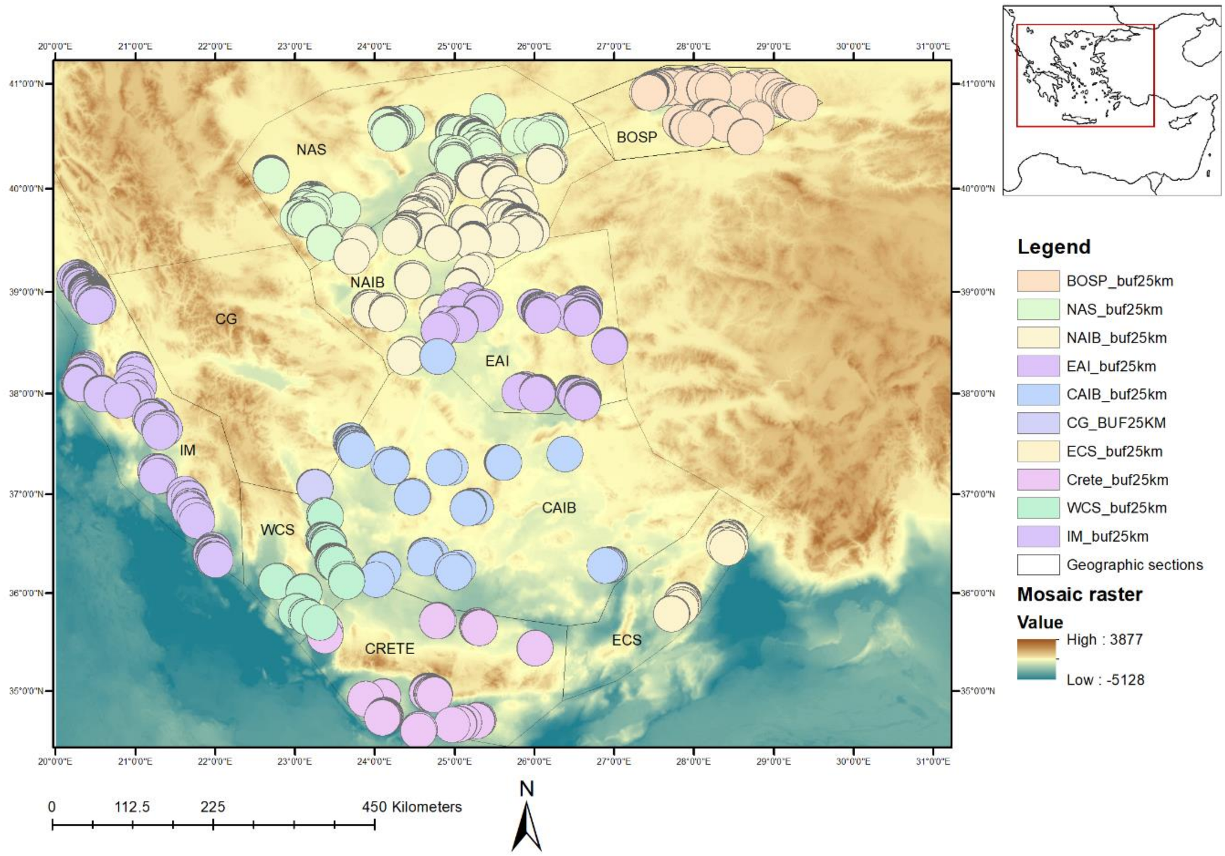


Figure 6.7. Buffers (25km) around the highest points on salient features within each of the nine geographic units of the Aegean and the new section of Bosporus. Notice the overlapping ranges of long-visual perception within the NAS, NAIB, EAI and IM sections. Remarkable overlapping is observed also between adjacent geographic units: NAS and NAIB, and NAIB and EAI. The division of the Aegean follows Sakellariou and Galanidou (2016). The base map corresponds to the mosaic raster (elevation and bathymetry). Geospatial data as in fig. 6.1

These summary viewsheds (fig. 6.10-6.13) permit some preliminary observations about the order of the structural elements of the landscape. Areas from where all salient features would have been visible (within the examined geographic section), would indicate a well-ordered terrain, an indication that the landscape structure would have had a positive impact in orientation and navigation across this particular area.

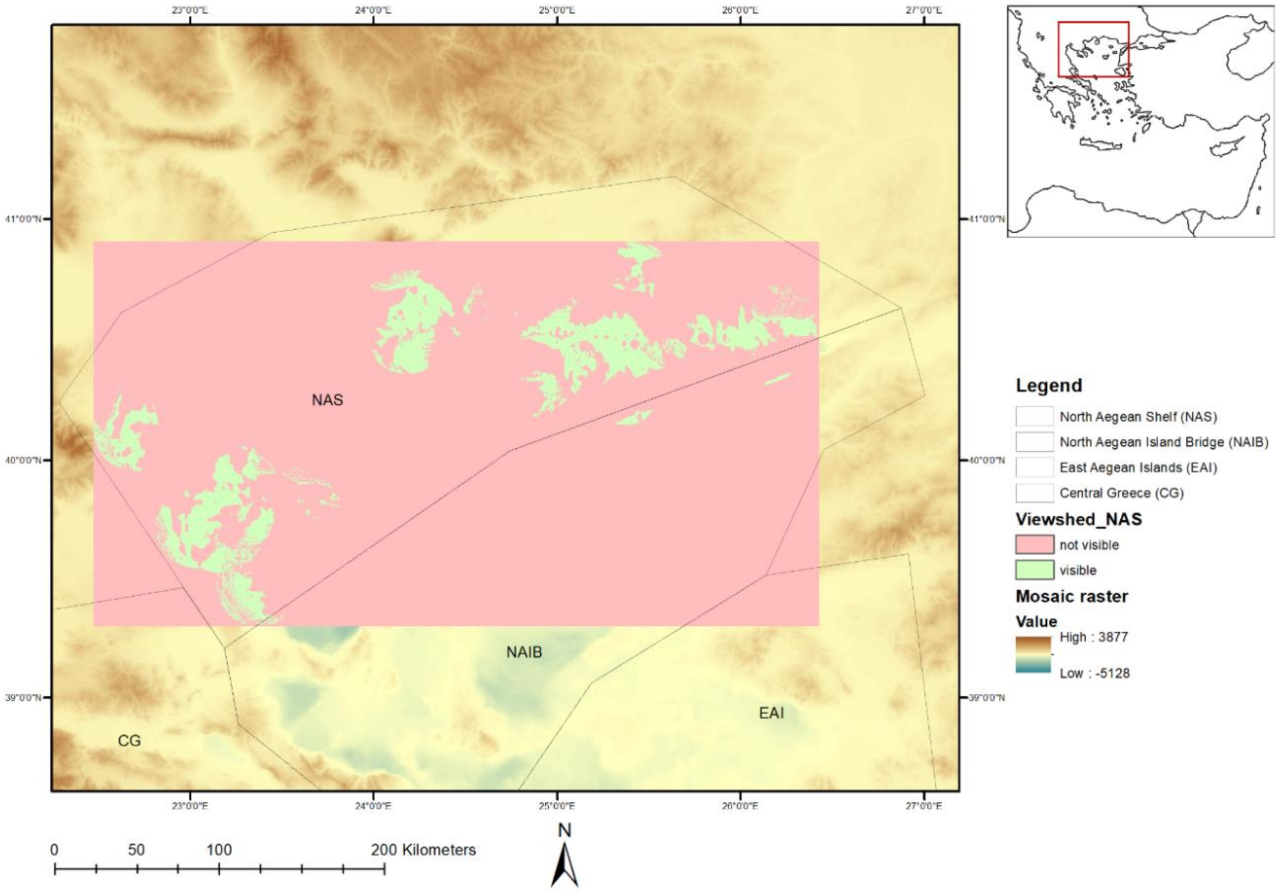


Figure 6.8. Multiple viewshed theme for the North Aegean Shelf (NAS) section. Green represents cells visible from any of the viewpoints within the NAS section (within a 25km radius) while pink represents areas that are not visible from any of the viewpoints. The division of the Aegean follows Sakellariou and Galanidou (2016). The base map corresponds to the mosaic raster (elevation and bathymetry). Geospatial data as in fig. 6.1

In order to combine the nine viewshed-themes and create one visibility surface, the cell statistics tool is used. The tool calculates a per-cell statistic from multiple rasters. In this case, the sum operation is selected in order to calculate the total of all values of the nine inputs. Because our viewshed rasters do not coincide in terms of extent (covering different areas), first a raster covering the entire visibility analysis extent needs to be created. Then it is reclassified to 0 value in order to be included in the cell statistics calculation (to indicate the full extent of the area that the tool needs to calculate the sum of values). Some environment parameters need to be set in advance: output coordinate system as in the zero value raster (full extent of visibility analysis); processing extent ”union of inputs”; set the 0 value raster as “my snap raster” in raster analysis settings, set the cell size and mask to the 0 value raster.

The resultant surface (cumulative viewshed – fig. 6.9) represents for each cell within the visibility observation area, the number of salient points with a direct line of site from that cell. The cumulative viewshed theme allows observations of patterns of visibility, within groups of salient viewpoints, enabling wider spatial comparisons – consistent with the large scale of the Aegean case study.

Some initial comments can be made, based on the visual inspection of the produced maps:

1. A larger number of salient viewpoints and a tighter distribution of salient features are observed over the northern part of the Aegean, specifically in the North Aegean Shelf (4589 viewpoints) and North Aegean Island Bridge (3908 viewpoints) geographic sections (fig. 6.6). The East Aegean Islands and Ionian Margin sections include a significant number of prominent features, located relatively close to each other (4624 and 2152 viewpoints respectively). In the Central Aegean Island Bridge, fewer landmarks (1646 viewpoints) and a more sparse distribution is observed. The Bosporus section has a similar number of viewpoints (1434) but in a more dense distribution. In Central Greece salient features are almost absent, with a few exceptions in the southern part of the section (119 viewpoints).
2. Salient features within the NAS, NAIB and, to a lesser extent, EAI sections are located along the margins of basinal structures of the northern and central Aegean, where the major water bodies from at least MIS 10-12 until at least MIS 8 would have been hosted, based on available palaeogeographical reconstructions (Lykousis 2009; Sakellariou and Galanidou 2016; 2017). The same pattern is observed along the margins of the Marmara Sea, where lacustrine phases have been documented during periods of low sea levels (Ch.4 – 4.5.3).
3. In the visibility analysis a significant overlapping in the long-visual ranges (RADIUS1) is observed within the NAS, NAIB, EAI and IM and BOSP (fig. 6.7). Such overlapping is also noticed between adjacent geographic sections: between NAS and NAIB, and between NAIB and EAI. In the CAIB, a similar pattern is not clearly demonstrated. Indeed, in the sum of the summary viewshed rasters (fig. 6.9), higher values occur in the NAS, NAIB, EAI, and interestingly enough in specific areas within the CAIB section – a pattern that was not obvious on the map with the overlapping visual ranges. Some average to high values are observed in the IM, ECS and BOSP. The higher the value, in the sum raster, the higher the number of times the landscape was visible from the viewpoints and vice versa (assuming reciprocal visibility). This is interpreted as an indication of a better order of the structural elements of the landscape and a better navigation potential across the high value parts of the terrain.

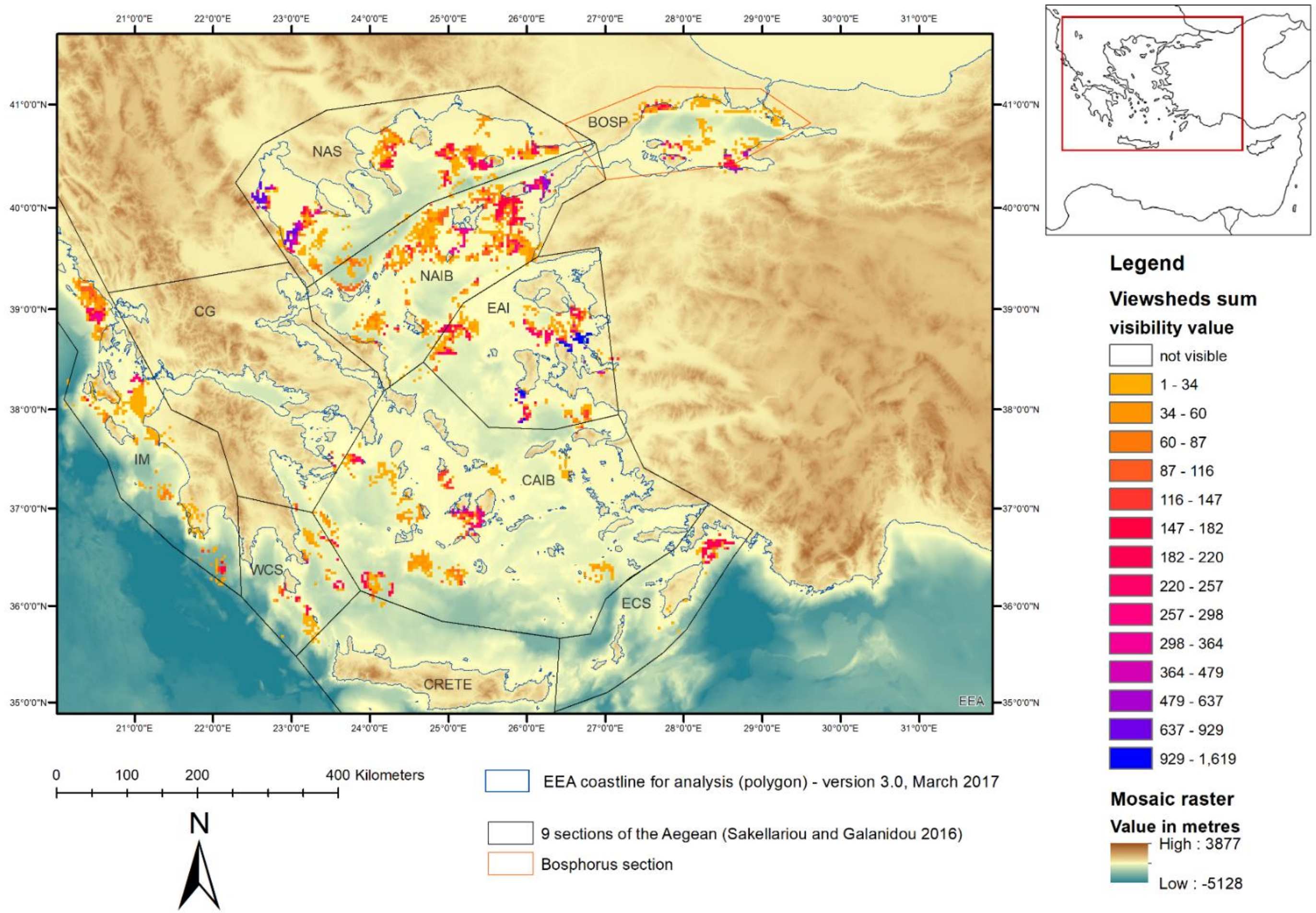
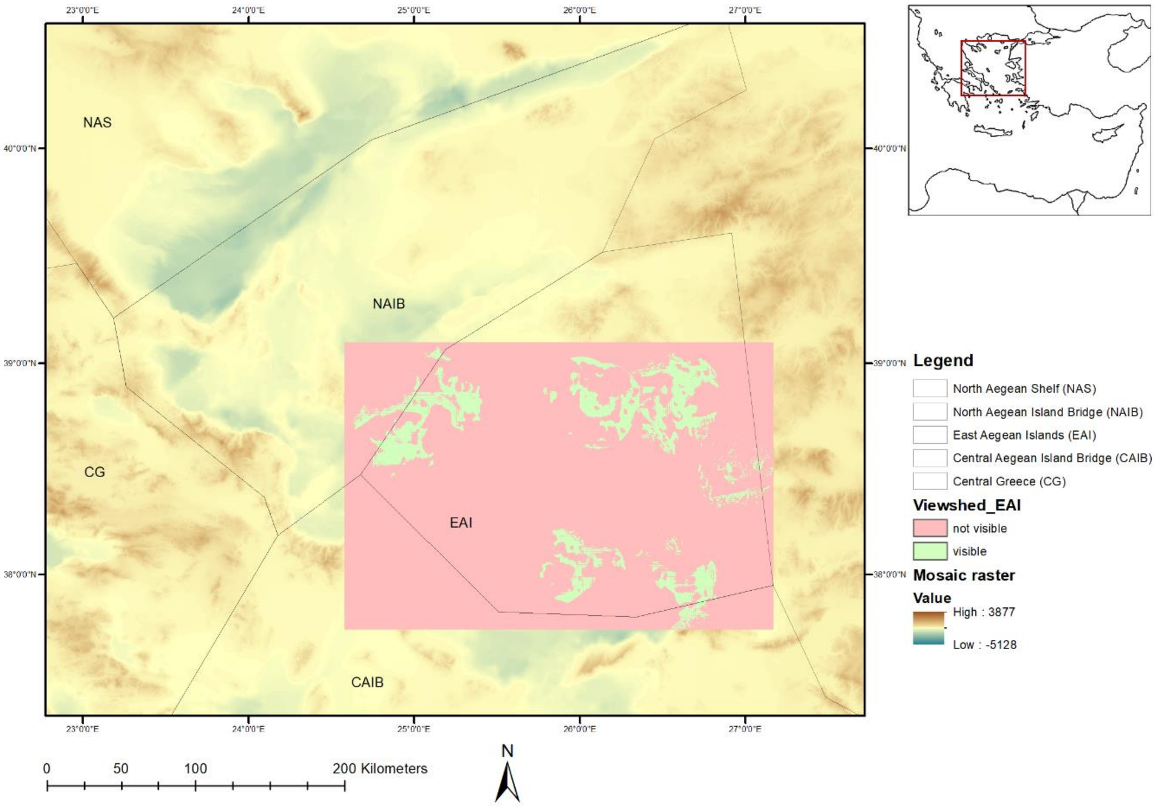


Figure 6.9. Sum of the viewshed themes from the Aegean region including the Bosporus section. The higher the values the higher the number of times the landscape was visible from the viewpoints and vice versa (assuming reciprocal visibility). The base map corresponds to the mosaic raster (elevation and bathymetry). Geospatial data as in fig. 6.1

6.5 Concluding remarks

The work presented in this chapter, adds one more strand in the exploration of the hominin factor over the Aegean dry land: landscape structure and its effects on hominin mobility. Complementing, in that sense, the suitability models (Ch.5) by placing hominins within their affording environment. Modern topography, as a proxy for the past configuration, allows only rough approximations. Still, some modest assumptions could be made to help research move forward. Firstly, the least-cost path models suggest that the northern and central parts of the Aegean could have been traversable, as a terrestrial landscape, at least based on modern elevation and bathymetry. Exact pathways followed by the Middle Pleistocene hominins cannot be defined and specific patterns of movement cannot be identified, at least not at this stage. Secondly, topographic prominence and visibility analyses provide some entirely new insights into the navigability potential of the Aegean exposed lands. Landmark identification and overlapping visual ranges of salient viewpoints indicate potential patterns of well-ordered sections particular over the northern exposed terrain (NAS), including the Bosporus, and other parts within Eastern Aegean Islands (EAI), Ionian Margins (IM) and the Cretan Straits (ECS, WCS), across which orientation and navigation would have been easier for the Middle Pleistocene navigators.

Opportunities for survival (suitability) and opportunities for dispersal (dispersibility) offered to the Middle Pleistocene hominins by the Aegean dry land environments (section 5.3.2.2-Ch.5 and sections 6.3-6.4 this chapter) can now be examined in parallel. High values of suitability and high values of dispersibility would indicate areas of optimum affordances, i.e. viable environments with preferable resources and terrains with good landmark coverage guiding smoothly hominin movement. This synthetic reading will promote specific areas as future targets for the LP research. Hopefully, filling some important gaps in the available records.



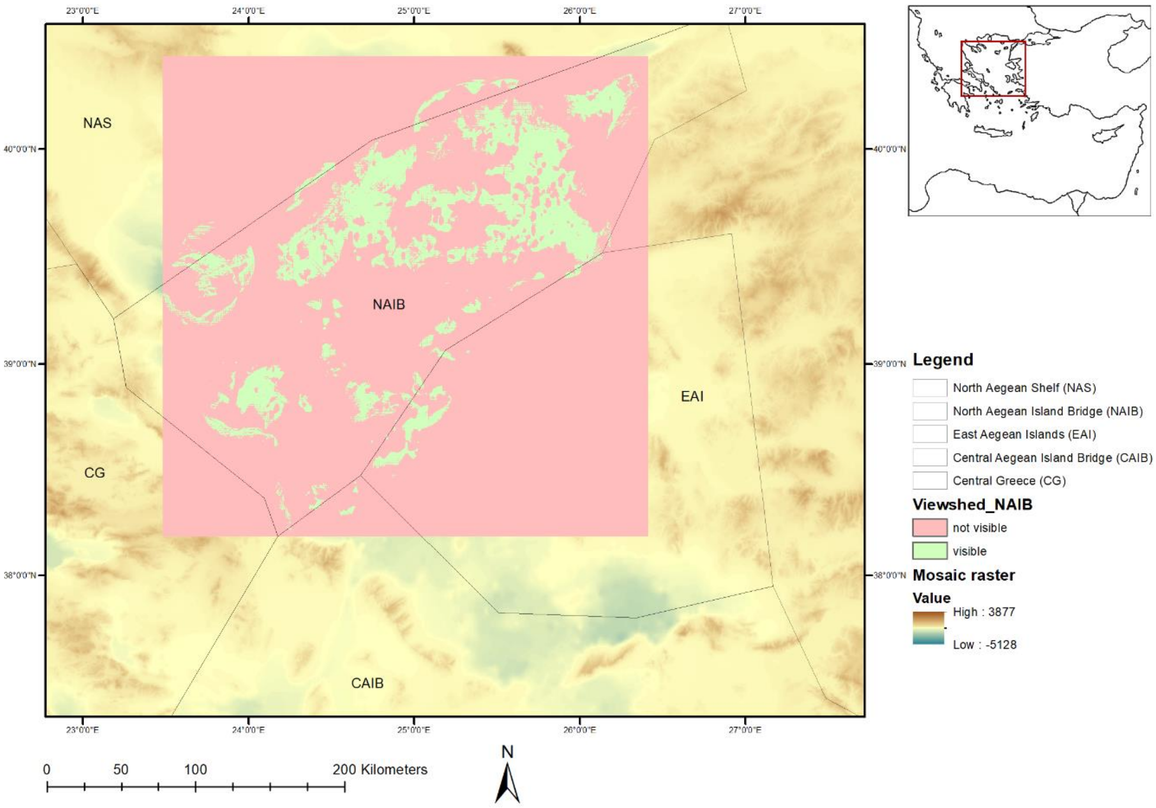


Figure 6.10. Multiple viewshed themes for the North Aegean Island Bridge (NAIB) (top) and East Aegean Islands (EAI) (bottom) sections. Geospatial data as in fig. 6.1.

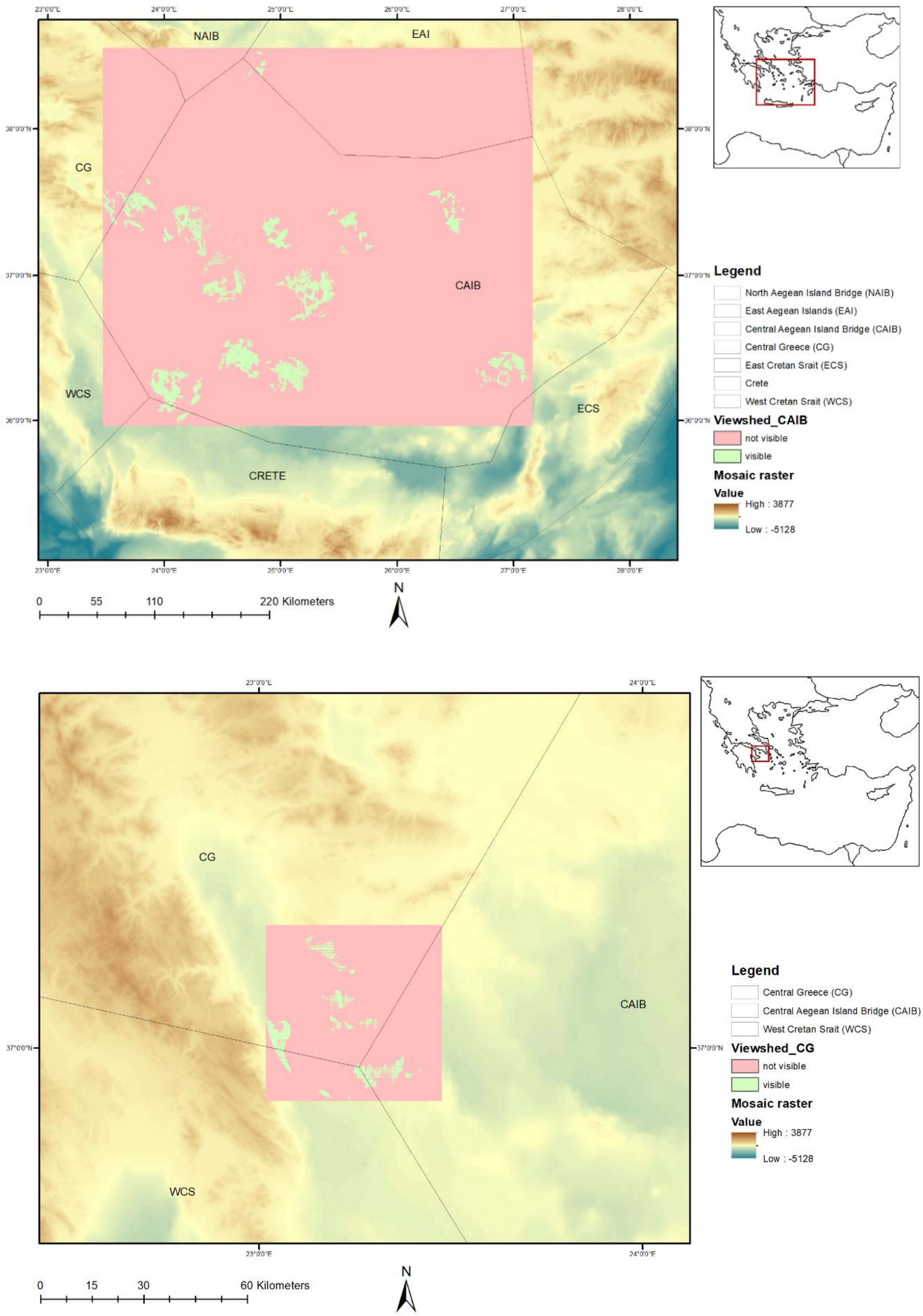
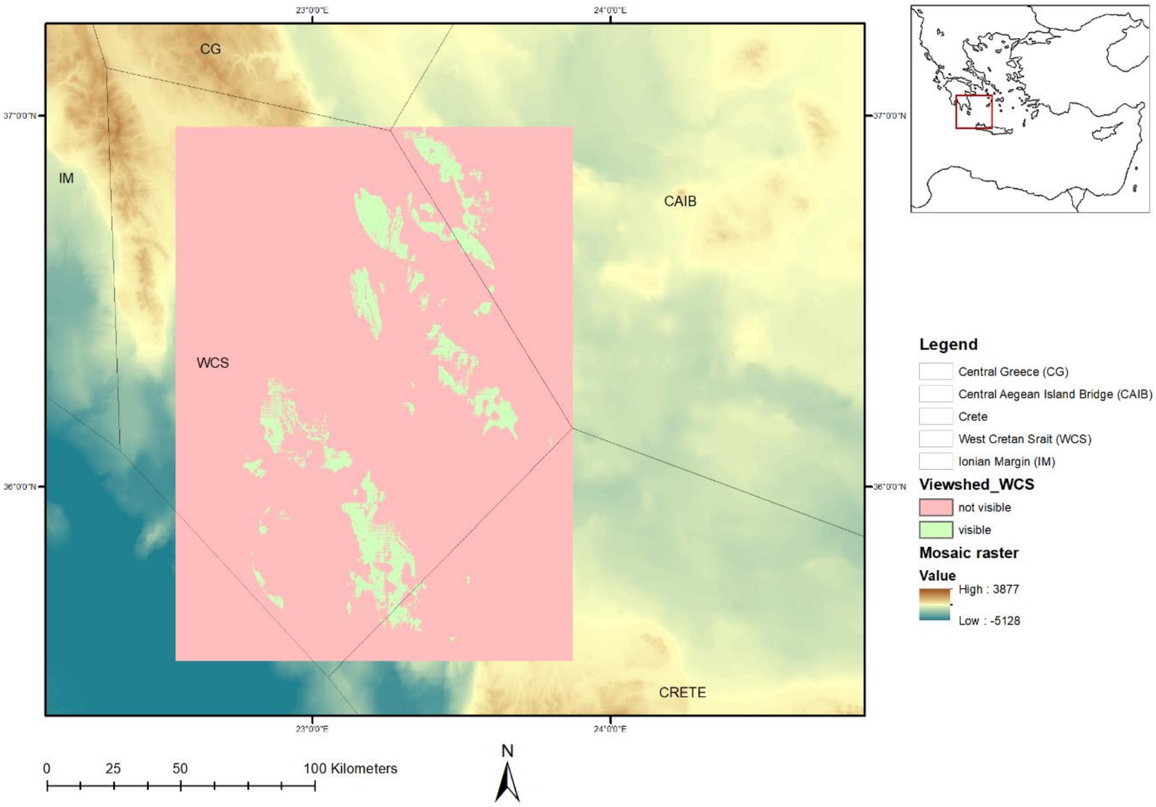


Figure 6.11. Multiple viewshed themes for the Central Aegean Island Bridge (CAIB) (top) and Central Greece (CG) (bottom) sections. Geospatial data as in fig. 6.1



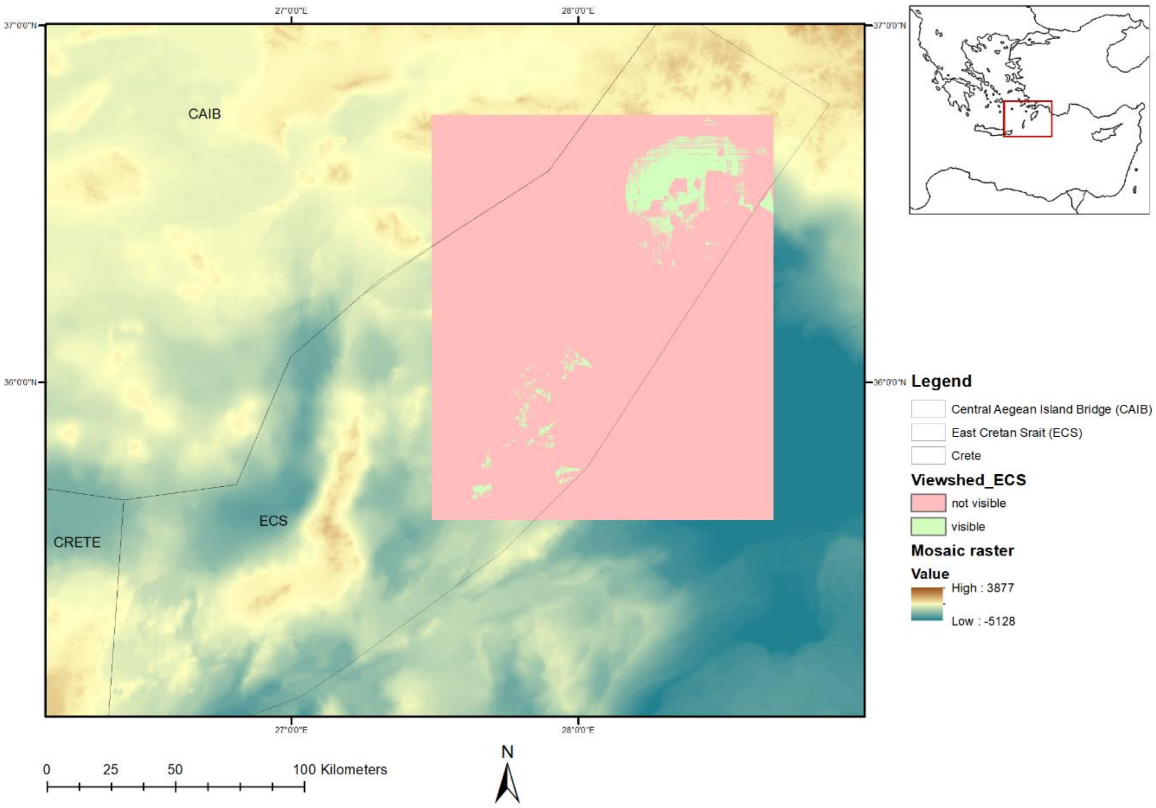
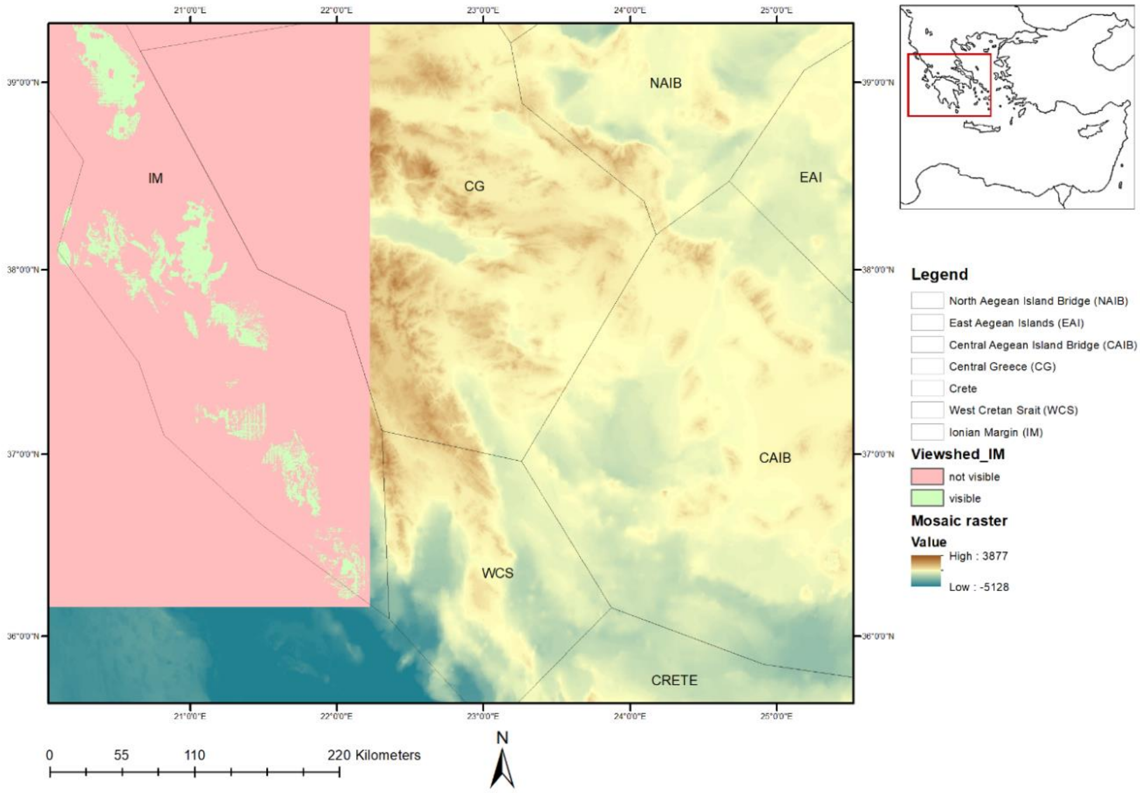


Figure 6.12. Multiple viewshed themes for the West Cretan Strait (WCS) (top) and the East Cretan Strait (ECS) (bottom) sections. Geospatial data as in fig. 6.1



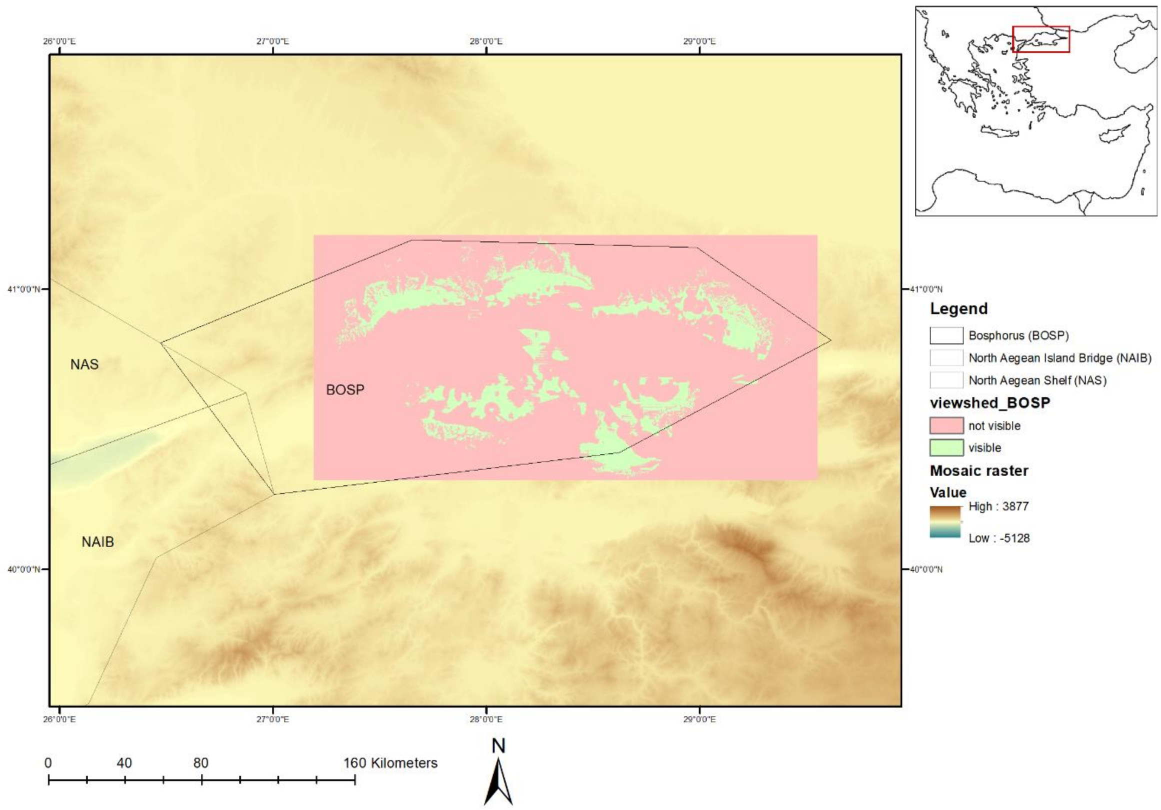


Figure 6.13. Multiple viewshed theme for the Ionian Margin (IM) and Bosporus (BOSP) sections. Geospatial data as in fig. 6.1

Chapter 7 Synthesis and Discussion

7.1 Introduction

The affordance based GIS framework built in this thesis in order to explore the suitability of the Aegean exposed landscape and the potential for dispersal for the Middle Pleistocene hominins, allows for new hypotheses on movement and occupation to emerge. This chapter will provide the interpretation of results (presented in Ch.5 and Ch.6), and a synthesis of evidence introducing a new concept: ***the affordance corridors of the Aegean***.

The following discussion will be twofold regarding archaeological and methodological advances. New ideas/hypotheses will be mapped onto the wider research background and the current research agenda investigating the big questions about the early hominin dispersals and the early settlements in the European continent. The contribution of the thesis towards this direction lies in three main points:

- Suggesting new areas with increased research potential for the lower Palaeolithic research in the Aegean region onshore and offshore;
- Triggering a revised discussion on the biogeographical role of the wider eastern – north-eastern Mediterranean during the Lower Palaeolithic;
- Reconsidering changes in paleogeography in eastern – north-eastern Mediterranean and their impact in the way we study, model and interpret the Lower Palaeolithic archaeological evidence.

The last point will open up the discussion on the methodological advances in the research of hominin movement and occupation over the Aegean landscapes that have since been submerged. The methodological scheme developed here offers a way to move forward, broaching the challenges commonly encountered in tectonically active areas, and adding to the limited existing literature.

Future work will be discussed towards the end of the chapter. The study of edaphics in the Aegean coupled with results from this work hold great research potential. Soil sampling and analysis from selected areas with high affordances, can highlight strategically prominent locations over the palaeolandscape, narrowing down the potential targets for investigating for LP evidence.

7.2 Interpretation of results and new hypotheses: the affordance corridors of the Aegean

The suitability model (Ch.5) and the assessment on the potential of the Aegean exposed lands for dispersal (Ch.6) permit the identification of specific territories in the study area with high affordance values. This means that in these particular parts, the interaction between the landscape and the hominin factor would have been positive indicating advanced survival and exploitation opportunities (as they have been explained and defined in Ch.5). Thus, helping to answer the research questions formulated in the first chapter:

1. Can we suggest possible zones of hominin activity that correspond to exploitation territories taking into account: (a) the topographic complexity of the landscape, (b) the suggested richness of natural resources during the Middle and potentially the Early Pleistocene and (c) the raw material availability (especially of volcanic origin) over the Aegean exposed landscapes?
2. Can we suggest possible corridors of opportunity for hominin dispersal traversing the Aegean exposed landscapes?

My work on suitability, least-cost paths and landscape legibility, covers the full extent of the study area, assuming a continuous, or relatively continuous, terrain between western Anatolia and mainland Greece. Based on available palaeogeographical reconstructions, the largest part of the northern and central Aegean was sub-aerially exposed for a substantial period of time (at least 300 Ka) in the Middle Pleistocene; with large parts being exposed during low sea-level phases from the first marine transgression during MIS 8 onwards (according to Lykousis 2009). However, as it has been stressed many times in this thesis, the Aegean is a tectonically active region, divided by numerous major and minor fault systems into subsiding and uplifted parts both onshore and offshore (see fig. 6 in Sakellariou and Galanidou 2016). This geotectonic mechanism creates constant landscape transformation and instability. In order to identify territories with high affordance values within this unstable context, and in a relatively reliable way, the identification needs to be restricted to areas where subsidence and deformation are limited. As such the discussion here will be focused on specific territories within the nine geographic sections of the Aegean – as divided by Sakellariou and Galanidou (2016; 2017) (fig. 7.1). This geographic division will provide the spatial and geotectonic frame of reference for articulating the discussion.

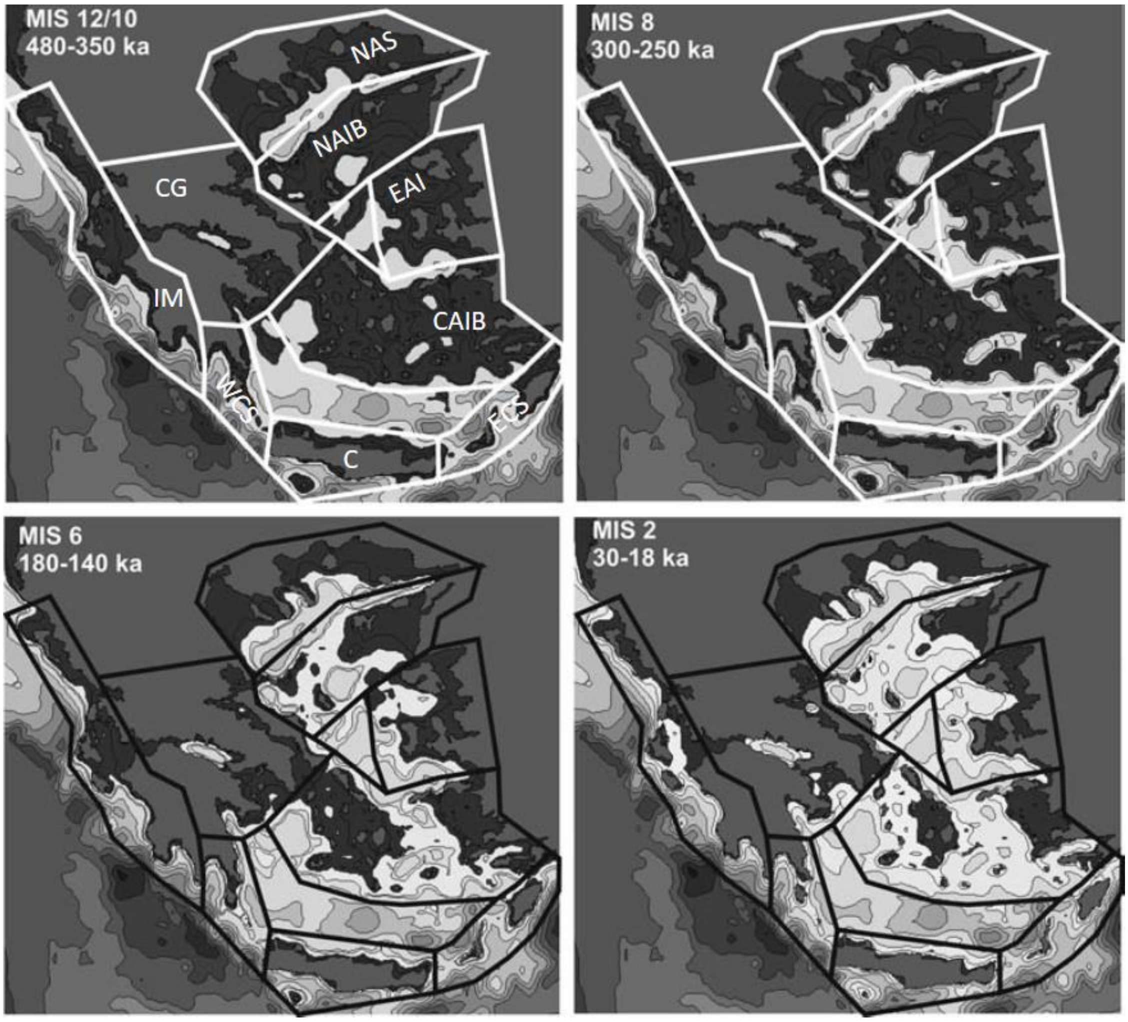


Figure 7.1. The palaeogeographical reconstruction for the Aegean and Ionian Seas for the past 400ka proposed by Lykousis (2009) and the outline of the Aegean morphostructural sections according to the division proposed by Sakellariou and Galanidou (2016; 2017) (modified fig 15.6 from Sakellariou et al., 2017). NAS: North Aegean Shelf, NAIB: North Aegean Island Bridge, EAI: East Aegean Islands, CAIB: Central Aegean Island Bridge, CG: Central Greece, WCS: West Cretan Strait, C: Crete, ECS: East Cretan Strait, IM: Ionian Margin

At least four such territories, combing high affordance values with a topographic context of relative stability and/or consistency though time, are discerned:

1. The northern Aegean continental shelf including the Chalkidiki Peninsula, the Thasos-Samothrace Plateau and the basinal system of the North Aegean Trough (North Aegean Shelf).
2. The southern part of the Cycladic Plateau along the Southern Aegean Volcanic Arc (Central Aegean Island Bridge) and its westward extension to the Greek mainland (W. Saronikos Gulf and the Gulf of Corinth) (Central Greece).
3. The Sperchios basin and the adjacent North Euboea Gulf (Central Greece).
4. The Greek islands along the Aegean coasts of Turkey, with special interest for the East Aegean Islands section.

All these areas appear to persistently retain some basic elements of their past landscape nature, including sub-aerially exposed parts during the Middle Pleistocene.

7.2.1 The Northern Aegean hotspot: the North affordance corridors

The northern part of the Aegean, including the North Aegean Shelf (NAS hereinafter) and the North Aegean Island Bridge (NAIB hereinafter) geographic sections, is highlighted for having high affordance values (section 5.3.2.2 – Ch.5). Highly suitable areas are suggested throughout the three time intervals of the suitability model while a good coverage of landmarks observed along the margins of the North Aegean Trough (NAT) basins in the visibility model indicates ease of navigation over this area.

Palaeogeographical reconstructions for the LGM, based on geological data, suggest rich water resources, permanent and ephemeral lakes, and extended landscape with riverine environments over the northern Aegean (fig. 4.8-Ch.4). The topographic character of the basins and the deep river channels, mapped on the submerged landscapes southern of the current coast, strongly suggest these would be persistent features despite the effects of subsidence, sedimentation and localised uplifting. During the earlier parts of the Pleistocene, these river systems must have supplied the North Aegean Trough (NAT) basins with fresh water. The basins, which are present in the topography throughout the Plio-Pleistocene and the Holocene, hosted major water bodies during MIS10-12 and before (≥480 Kya), until at least MIS 8 (300-250 Kya), as suggested by the absence of marine sediments and the prevalence of fresh and brackish water sediments over the northern part of the Aegean (Lykousis 2009).

The abundance of water resources made these lands, now lying underwater, attractive for hominins and other animals (fig 7.2). The catchment area in the Thermaikos deltaic platform during the LGM has been calculated to be 10% larger than today (Lykousis, Karageorgis and Chronis 2005). Similarly, attractive environments had prevailed along the extended terrain between the current coast of N. Greece and the NAT basins, expanding the spatial boundaries for foraging and exploitation (fig. 4.8-Ch.4) during the LGM, and most possibly before that, based on available palaeogeographical reconstructions. This is also supported (a) by the rich Plio-Pleistocene faunal evidence (2.6-0.4 Mya) with a pronounced concentration in Mygdonia basin (C. Macedonia) (fig 7.2), and (b) by archaeological evidence including the Petralona cave site (350-150 Kya) and several find-spots with stone tools attributed to the LP (e.g. Arethousa, Doumbia, Petrota). The high value of suitability for this area is clearly reflected in the model throughout the Early and Middle Pleistocene, and especially for the first and the last time intervals, ≥0.9 Mya and 0.4-0.2 Mya (fig. 5.12 and 5.14-Ch.5). This is in good agreement with the climatic/environmental model proposed by Leroy, Arpe and Mikolajewicz (2011) showing that the northern Aegean is one of the areas – part of a wider geographic corridor – with optimum climatic and vegetation conditions for the hominin dispersal during the Early Pleistocene. It is also consistent with current evidence suggesting that the earlier presence of hominins in Europe is dated at - or slightly prior to - 1 Mya (within the first time interval), while a more stable and continuous presence could be argued only from the Middle Pleistocene onwards (during the last time interval) (see section 3.4.2 – Ch3).

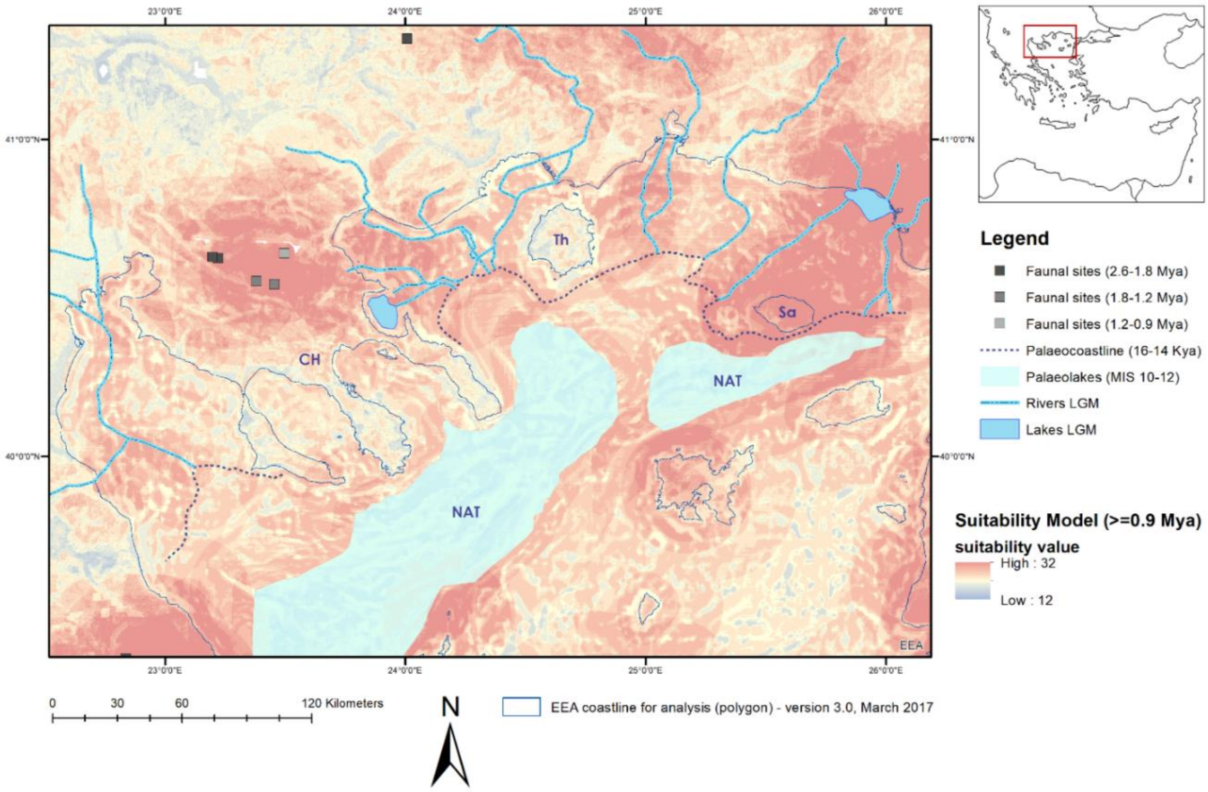


Figure 7.2. Suitability for the northern Aegean for the interval ≥0.9 Mya – with red indicating the higher values. LGM water resources are used as a proxy for the earlier parts of the Pleistocene. The water body hosted in the NAT basin from at least MIS 10-12 until MIS 8 was very likely connected to the river systems running across the northern Aegean continental shelf. Fluvial and lacustrine environments are indicated by geological evidence. Terrain data: ASTER Global Digital Elevation Map, version 2 (ASTERGDEM V2) (30m resolution), available at NASA Land Processes Distributed Active Archive Center (LP DAAC). Bathymetric data: Eastern Mediterranean Bathymetric Map (2016) (250m resolution) by courtesy of the Hellenic Centre for Marine Research. Coastline: European Environmental Agency (EEA), available in ArcGIS online. Coordinate system: WGS 1984 Web Mercator Auxiliary Sphere; Projection: Mercator Auxiliary Sphere; Datum: WGS 1984; Linear Units: meters. Map produced in ArcGIS 10.7. NAT: North Aegean Trough, CH: Chalkidiki Peninsula, Th: Thasos Island, Sa: Samothraki I.

The northern Aegean lies along the western part of the Bosporus passage, one of the proposed routes connecting W. Asia and Europe, and Africa and Eurasia (via W. Anatolia). Archaeological evidence including the excavated Yarimburgaz cave site and several find-spots in Bosporus, with a prevalence of Mode 1 stone tool tradition industries, offer further support to this suggestion. However, with the exception of Petralona and perhaps the findspots from central Macedonia (Axios and Lagadas basins), reliable LP evidence from northern Greece is missing. The only extensive, in spatial terms, survey was conducted at the end of the 1980's by Kourtesi-Philippakis (1996), focusing on eastern Macedonia (including parts of the Strymon and Nestos river basins and the Volakas sedimentary basin). The investigation offered useful insights into the distribution and the nature of available raw materials appropriate for tool knapping (quartz/quartzites, flints, and volcanic rocks), identified areas with good preservation potential, and produced some surface lithic finds that could potentially be attributed to the Palaeolithic, but with no solid dating evidence whatsoever. These results were very promising, setting the background to investigate further the northern part of Greece both in local and regional scales. As yet, this has not been fully implemented in the current LP research.

According to the least-cost path analysis for the MIS 8 period (300-250 Kya) (fig. 6.2-Ch.6), the most cost-effective way, based on modern slope, to move from the Yarimburgaz cave in Bosporus to Rodia FS-30 site in mainland Greece is by traversing the northern part of the Aegean that would have been exposed during the Middle Pleistocene. The route crosses the central part of the Marmara Sea (shallow parts that would have offered terrestrial passages during periods of low sea-level), and passes across the Samothraki Plateau, the Chalkidiki peninsula and the Thermaikos Gulf, until it reaches the Rodia site following the Pineios River, as an entry point to the mainland. As it has been already emphasised (Ch.6), the generated path should not be perceived as an actual dispersal route followed by hominins during the Middle Pleistocene, but only as an indication that this area provided traversable terrains and corridors of opportunity, with favourable conditions due to variable water resources. The path crosses low elevation areas, which are parts of the Pleistocene river plains along the northern margins of the major lakes formed within the basinal system of the northern Aegean (until at least the termination of MIS 8). The hinterland of the NAS, with the mountainous areas, away from the lakes and the palaeocoast, seems to be avoided by the model, representing perhaps a challenging zone to traverse not only in terms of elevation and energetic expenditure but also due to the heterogeneity of available resources. In this sense, it would be reasonable to expect more evidence of the hominin presence from areas along the northern Aegean continental shelf, now lying underwater. Still, onshore opportunities are not negligible. As suggested by Kourtesi-Philippakis (1996), Tourloukis (2010), and Litsios (2012), early evidence may have been preserved in certain areas along the modern coastal zone and the hinterland of northern Greece, especially in caves and rock-shelters (which are numerous), in river terraces, in tectonically controlled basins (such as Mygdonia) and in plateaus in higher altitude areas.

The visibility model for the Bosporus, North Aegean Shelf and North Aegean Island Bridge sections, indicates a well ordered landscape with frequent landmarks, and, in many cases, with overlapping visual ranges (fig. 6.13, 6.10, 6.9-Ch.6). The margins of Marmara, the Galibolu peninsula at the Dardanelles Strait, and the plateau around Limnos Island received high to very high values. This is perhaps the most reliable evidence on past landscape structure in the visibility model, considering that this part escapes subsidence and receives minimum sedimentation (Sakellariou and Galanidou 2016). Coupled with the continuous coverage of landmarks around the margins of the NAT basins, there seems to be an emerging pattern. If we hypothesise a movement from the Marmara area towards the west through the Bosporus, the visibility model suggests two ways to enter the Aegean (fig 7.3): (a) the northern route led by landmarks along the northern margins of the NAT basins, crossing the Thasos-Samothraki Plateau, the Chalkidiki peninsula and the southern part of the Thermaikos Gulf before reaching the mainland via the northern part of the Larissa basin – *identical to the least-cost pathway result*, and (b) the southern route led by prominent landmarks over the Galibolu peninsula, showing the way to the southern margins of the NAT basins and the Limnos Plateau. That second branch of the southern route following available landmarks leads to the northern margins of the N. Skyros basin, hosting a water body during the maximum land exposure, and through the Sporades archipelago to the Greek mainland via the Pagasitikos Gulf (fully terrestrial during the maximum exposure, and with lake environments during post MIS8 lowstands) and the southern part of Larisa basin or via the north-central Euboea.

Of course, this is an approximation for the navigability potential in the past, using topographic roughness as a proxy to make calculations of visibility. There are many factors that are expected to have affected the current configuration of the now submerged landscape. For example, the North Aegean Shelf has been receiving sediments from the active river systems of Northern Greece (see section 5.2.2 – Ch.5). Nevertheless, ease of navigation across these geographic sections would have been promoted also by the presence of major physiographic features such as the palaeorivers over the northern Aegean shelf and the palaeolakes in the NAT and the Skyros basins - corresponding to generalised spatial references stored in spatial memory and facilitating navigation especially when entering previously unknown landscapes. If we accept at this point, the presence of abundant salient landmarks as suggested by the visibility model, then movement could have been continuous/unobstructed along the proposed corridors with several spots of high suitability distributed along the way, representing perhaps niches appropriate for temporary or longer settling. The suggested entry points to the Greek mainland receive high values in the suitability model throughout the three time intervals (fig. 5.12-5.14-Ch.5). The same is happening for the Dardanelles straits, Samothrace and Limnos Islands and the northern and southern margins of the NAT.

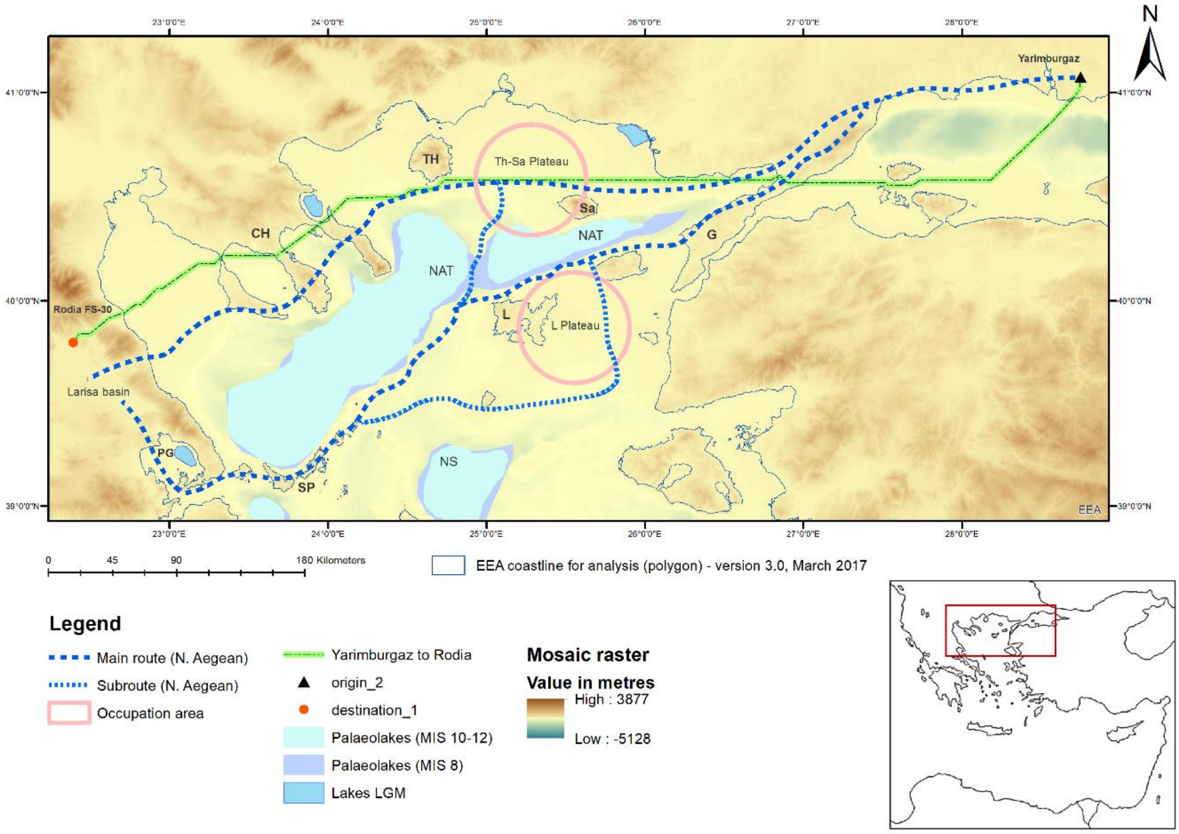


Figure 7.3. The blue dashed lines correspond to the proposed northern routes and subroutes over the NAS and NAIB sections. The pink circles indicate potential occupation areas. Within the NAS-NAIB sections, two such areas have been identified over the now submerged shelf: between the current islands of Thasos and Samothraki (Th-Sa Plateau/OA1) and between Limnos Island and the adjacent Turkish coast (Limnos Plateau/OA2). Geospatial data as in fig. 7.2. Th: Thasos Island, Sa: Samothrace I., L: Lemnos I., G: Galibolu Peninsula, CH: Chalkidiki P., NAT; North Aegean Trough, NS: North Skyros basin, SP: Sporades Islands

Hominins crossing the North Aegean Shelf – North Aegean Island Bridge zone would encounter an easy to navigate terrain with smooth topography and frequent natural landmarks to guide their movement, within an area of rich water resources and scattered volcanic rocks - especially over the NW part of the NAS, between Samothrace and Xanthi. Two main areas with high potential for occupation have been discerned: in NAS, between Thasos and Samothrace Islands (OA 1) and in NAIB, between Limnos Island and the Galibolou peninsula (OA 2). Both are located in plateaus with high affordance values (fig 7.3 and fig. 5.12-5.14-Ch.5).

These hypotheses could be further analysed by terrestrial and underwater research. Despite the fact that the northern Aegean continental shelf has been systematically investigated over the past decades resulting in a very good understanding of the LGM palaeogeography over the Thermaikos Gulf and the Ierissos-Aleandroupolis shelf, detailed evidence on earlier periods is missing and difficult to reconstruct. This is an important gap that needs to be filled. Two research targets are suggested within the NAS: (a) the shallow shelves along the three ‘legs’ of the southern Chalkidiki Peninsula that have never been investigated before, and (b) a renewed investigation over the

Thasos - Samothraki plateau offshore and onshore aiming to identify palaeogeographic features older than the LGM. It is worth mentioning that the islands of Thasos and Samothrace have never been systematically investigated for LP evidence. Two more targets are proposed within the NAIB, (c) the shallow shelves around Limnos, specifically the area between Limnos and the adjacent coasts of Turkey, the Gelibolu Peninsula and the Dardanelles, and (d) the Sporades archipelago. These targets hold increased research potential based on their morphotectonic characteristics - escaping the general trend of subsidence over the northern Aegean – (preservation of LP evidence) and the high affordance values (availability of the LP evidence).

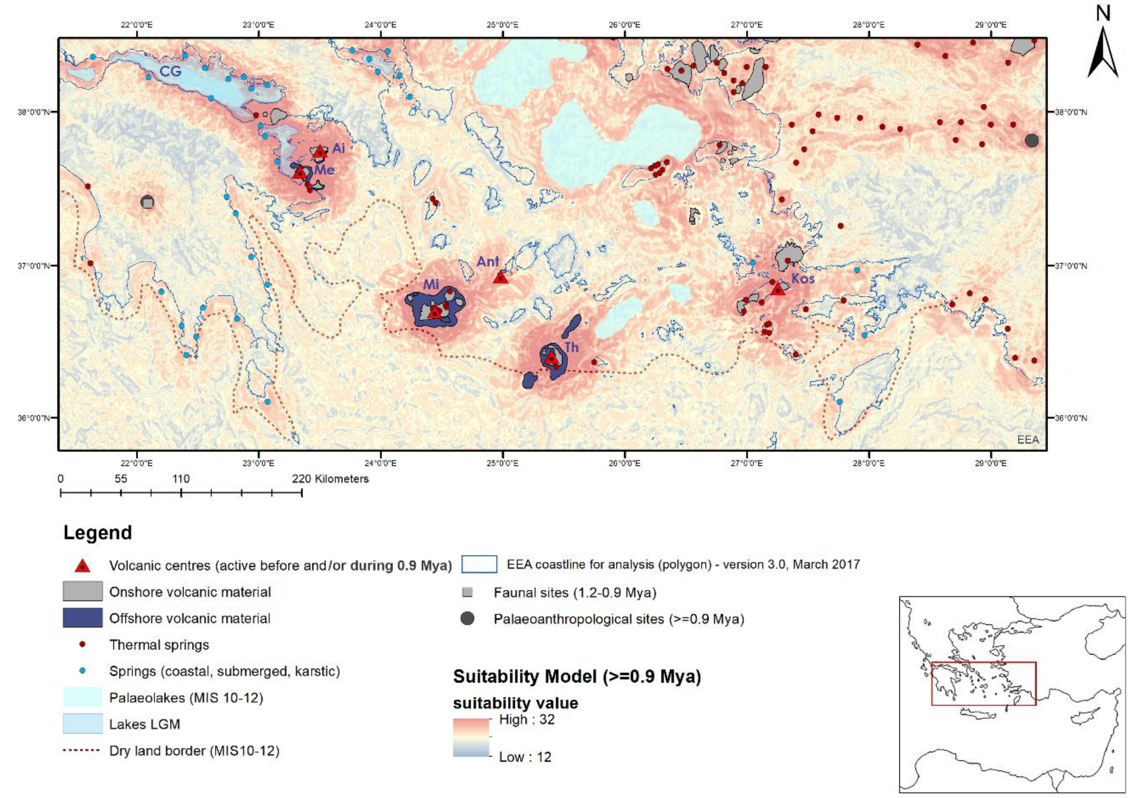
7.2.2 The Cycladic Plateau and the 'Volcanic Route' hypothesis: the South affordance corridors

Another geographic section highlighted by the suitability model for offering high exploitation and survival opportunities to hominins is the Central Aegean Island Bridge (fig 4.2-Ch4). The section is bounded by the inner and the outer volcanic arcs while the aseismic Cycladic Plateau lies in-between. It is worth emphasising, that although the volcanic arc itshelf represents a tectonically active zone during the Pleistocene and the Holocene (volcanism), the Cycladic Plateau represents a relatively stable area. The Plateau escapes the uplifting – consistent with the creation of the volcanic centres – and has been affected less by the overall subsidence trend in relation to the rest of the Aegean. In effect, the belt between the two volcanic arcs of the Aegean would have represented a broader corridor with a high elevation zone at its southernmost end, and smoother topography towards the northern more stable parts during the Middle Pleistocene.

During the maximum land exposure (≥ MIS 10-12), the outer volcanic arc marked the southernmost border of the dry land, migrating slightly northwards during MIS 8. Since MIS 6 that palaeocoastline ceased to exist and the marine connection between the central Aegean basin and the Sea of Crete was fully established through the narrow sea-strait separating the Cycladic Plateau (to the west) and the islands of Ikaria, Leros, Astypalaia and Kos (to the east). Despite Lykousis' (2009) claims that the strait was not open during the maximum land exposure, Sakellariou and Galanidou (2016: 165) are not convinced by available sedimentation evidence, leaving open the possibility that its southern part (between Mykonos and Ikaria, Amorgos and Leros, Astyplaea and Kos) could be an active marine channel, before MIS 6. Systematic underwater survey is required in this particular region, including coring/drilling, to help understand the sediment sequence (complementing/updating earlier work in eastern Cyclades by Lykousis et al., 1995).

Nevertheless, based on available evidence, during the maximum land exposure (≥MIS 10-12) and until MIS 8, one could assume a continuous southernmost dry land border. This corresponds to a corridor with great research potential due to: (a) the variability of resources, combining marine, coastal and continental resources - being an intermediate zone between the extended terrestrial landscape dotted with lake environments to the north and the open sea to the south, as well as (b) the availability of knappable volcanic rocks – products of the extensive volcanic activity along the outer arc throughout the Plio-Pleistocene. The current working hypothesis, developed in this thesis (section 5.2.4 – Ch5) is that the southern Aegean Volcanic Arc zone could provide a route, the ‘volcanic route’/ ‘corridor of fire’, as a possible passage, connecting SW Anatolia and mainland Greece during the Early and Middle Pleistocene (fig 7.4). The suitability model suggests that the route was viable in terms of favourable environments throughout the Plio-Pleistocene, despite the fact that the Nisyros and Yali centres became active by 0.2 Mya, i.e. by the time of the first marine transgression, according to Lykousis (2009) (fig 7.4).

The importance of the coastal zones for the dispersal and settlement of hominin populations has been highlighted in several recent works, in relation to two parameters. Firstly, the abundance and variability of nutritional resources found across these intermediate environments (between the land and the sea) enable movement across and temporary settling within viable niches (Bailey et al., 2015; Bailey et al., 2008; Westaway 2010). Although, this does not mean that the coastline was uniformly attractive but spatial and temporal variability should be expected (Bailey et al., 2015). Secondly, the exploitation of such environments, as a behaviour, appears to be much more archaic than has been suggested (Howitt-Marshall and Runnels 2016). There is growing evidence suggesting that species such as *H. heidelbergensis* and *H. neanderthalensis*, even *H. erectus*, were engaged in the exploitation of coastal and marine resources, and not exclusively anatomically modern humans (ibid 141-2, 143-5). Middle Pleistocene hominins had already cognitive (complex and abstract thought, some form of verbal communication, social structure) (Gamble 2013) and biological adaptations (genetically driven novelty-seeking traits, environmental wayfinding) (Bicho 2015; Leppard 2015) and technological capabilities (tool making, fire) (Morgan et al., 2015; Shea 2013:84-105; Gowlett and Wrangham 2013), necessary to adapt to and take advantage of coastal and marine environments. Such habitats would have been encountered along the southernmost part of the Aegean dry land i.e. along the proposed ‘volcanic route’, at the border between the exposed terrestrial landscape and the Sea of Crete. Moreover, the coastlines provide natural corridors in low elevation areas, structured by memorable landscape features/landmarks, which facilitate navigation for the dispersing population entering unknown territories (Guiducci and Burke 2016; Golledge 2003).



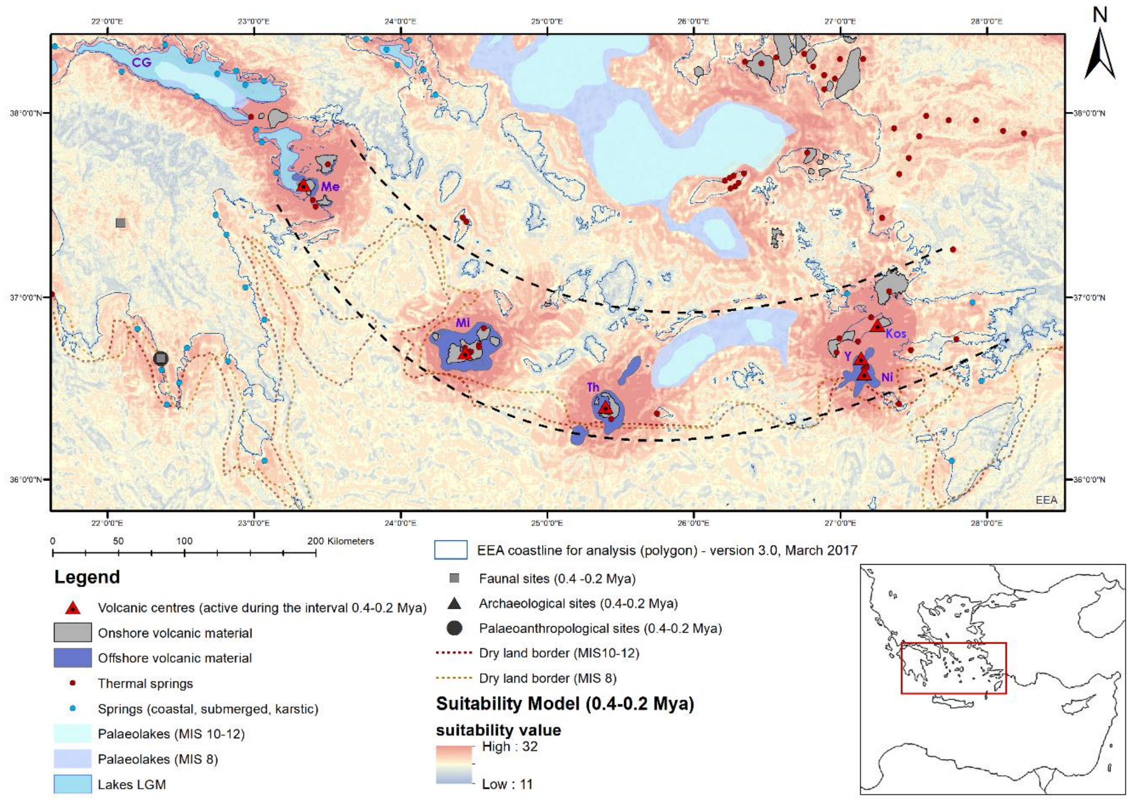


Figure 7.4. Suitability for the south-central Aegean for the ≥ 0.9 Mya interval (top) and for the 0.4-0.2 Mya interval (bottom). The 'volcanic route' is bordered by the black dashed lines (bottom). Geospatial data as in fig. 7.2. Ai: Aigina, Me: Methana, Mi: Milos, Ant: Antiparos, Th: Thera, Ni: Nisyros, Y: Yali. CG: Corinthian Gulf.

The visibility analysis shows that few areas along the margins of the suggested palaeocoastline would have been visible from salient landmarks and vice versa (assuming reciprocal visibility) (fig. 6.9-Ch.6). The landmark coverage is not as continuous as, for example, in the northern part of the Aegean. Does this mean that navigation would have been disrupted or blocked by the absence of landmark coherence over the southern part of CAIB? Not necessarily, because the palaeocostline itshelf, as a major physiographic feature, would have acted as a guide for movement. We could assume however, that this southernmost zone might have been challenging for hominins to traverse due to the steep topography along the volcanic centres. Still, moving across it, it would not have been impossible considering the variability of available resources along this intermediate/transitional zone, and the versatility of Early and Middle Pleistocene hominins.

Towards the north of this steep zone, the terrain becomes gradually smoother, entering the actual Cycladic Plateau area. It is worth noticing that the central part of the Plateau received some of the highest values in the visibility analysis, over the entire study area, which is suggestive of optimum navigation and dispersal potential. Specifically, the lowlands surrounded by the modern islands of Naxos, Koufonisia, Ios, Sikinos, Antiparos and Paros. One could presume that dispersal through the central part of the exposed Plateau might have been easier. Not solely because of the good landmark coverage facilitating navigation, but also due to the attractive environments for hominins and animal expected to be hosted in the lowland areas. Kapsimalis et al. (2009) suggested that the plain between Naxos and Mykonos, during the LGM land exposure must have been an attractive land for occupation. The same could be assumed for the earlier periods of the Pleistocene (OA 3) (fig 7.6). Favourable habitats during the Middle Pleistocene can be inferred by the presence of several water bodies (of various sizes) at the central Aegean within the CAIB, while the proximity of the sea (towards the south) would have had a positive influence on the climate resulting in milder conditions throughout the glacial-interglacial transitions over the Plateau. The primary target circle, defined before, could be further extended to the West and North of Naxos, to include a wider area with low elevation, bordered by the modern islands of Kimolos, Sifnos, Serifos, Kythnos, Kea, Syros, Tinos and Mykonos.

The Cycladic Plateau emerges as a primary target for future LP research due to the combined opportunities for occupation, in the attractive niches of the lowlands, and dispersal, following either the palaeocoastline or crossing the central part of the Plateau. In the suitability model, the area south of Naxos and Paros received average to high values of suitability. Thus, the suitability model alone would not be enough to identify the importance of this particular part of the palaeolandscape.

The westernmost end of the outer volcanic arc is also highlighted, including the Methana and Aegina centres and the Pausanias submarine volcano, with offshore volcanic material, as well as the Megara and Epidaurus basins, with their Plio-Quaternary sediments being covered by volcanic surfaces at certain submarine areas (fig. 4.5-Ch.4). During the maximum land exposure of MIS 10-12, Aegina, Salamina and Poros were part of the extended Greek mainland. The Methana-Aigina-Epidaurus complex lies at the entry point of the Corinthian Gulf, a feature that has been characterised as *"a miniature of the East African Rift System"* (Tourloukis and Karkanas 2012b: 12), subjected to extensive folding (high 'complex topography' index) and hosting environments with rich water resources. During the Middle and possibly during the Early Pleistocene, such mosaic-type environments in settings with topographic complexity would have been attractive to hominins, as suggested by evidence from Eastern Africa. Geological data indicate lacustrine conditions for the Gulf of Corinth for the period MIS10-12 and up to MIS 8 and during the glacial periods after MIS 8. Other fresh water supplies can be inferred by the presence of coastal and submarine springs along the coasts of the gulf (fig. 7.5). The favourable character of the area is also very clearly demonstrated in the suitability model throughout the three time intervals. These results, provide further support to Tourloukis and Karkanas (2012b: 12), who envisioned a possible route from Anatolia crossing the Aegean, passing through the Gulf of Corinth and leading to Europe via the extended continental shelf of western Greece, the Ionian Islands and the Dalmatian coasts, before reaching the Po Valley (a possible entry point to W. Europe).

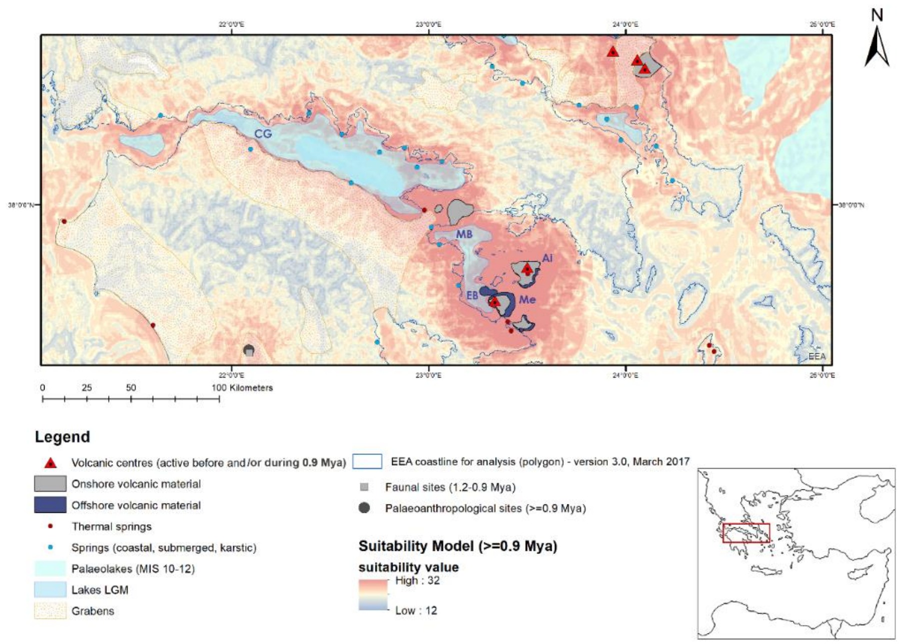


Figure 7.5. The Methana-Aigina-Epidaurus complex and the Gulf of Corinth. The Methana-Aigina-Epidaurus complex, laying at the westernmost end of the volcanic route and at the entry point to the Gulf of Corinth, could provide a further passage to the west, due to the combination of variable water resources and volcanic rocks. The area could also offer a preservation opportunity for the LP material (Epidaurus and Megara grabens). Geospatial data as in fig 7.2. Ai: Aigina, Me: Methana. CG: Corinthian Gulf, MB: Megara basin, EB: Epidaurus basin

In our hypothetical scenario with dispersal from an east to west direction, hominin groups from western Anatolia could follow the ‘volcanic route’, along the southern Aegean Volcanic Arc, all the way to the mainland following the palaeocoastline: from Kos or Nisyros to Astypalaia – Santorini – Milos – Kimolos – Sifnos – Serifos – Kithnos and Kea, or make a bypass via the central Cycladic Plateau before reaching the Saronikos Gulf. Extended terrestrial areas - up to at least MIS 10 – gradually diminishing, with isolated lakes - up to MIS 6 (Foutrakis and Anastasakis 2018a) over W. Saronikos constitute favourable environments that could support occupation (OA 4) (fig 7.6). From there, following the northern and /or southern margins of the Gulf of Corinth, traversing mosaic environments (variability of resources), along the shorelines of the palaeolake, they would reach the Ionian margin. The extended western coasts of the Greek mainland and the adjoining Ionian Islands would offer a passage to western Europe.

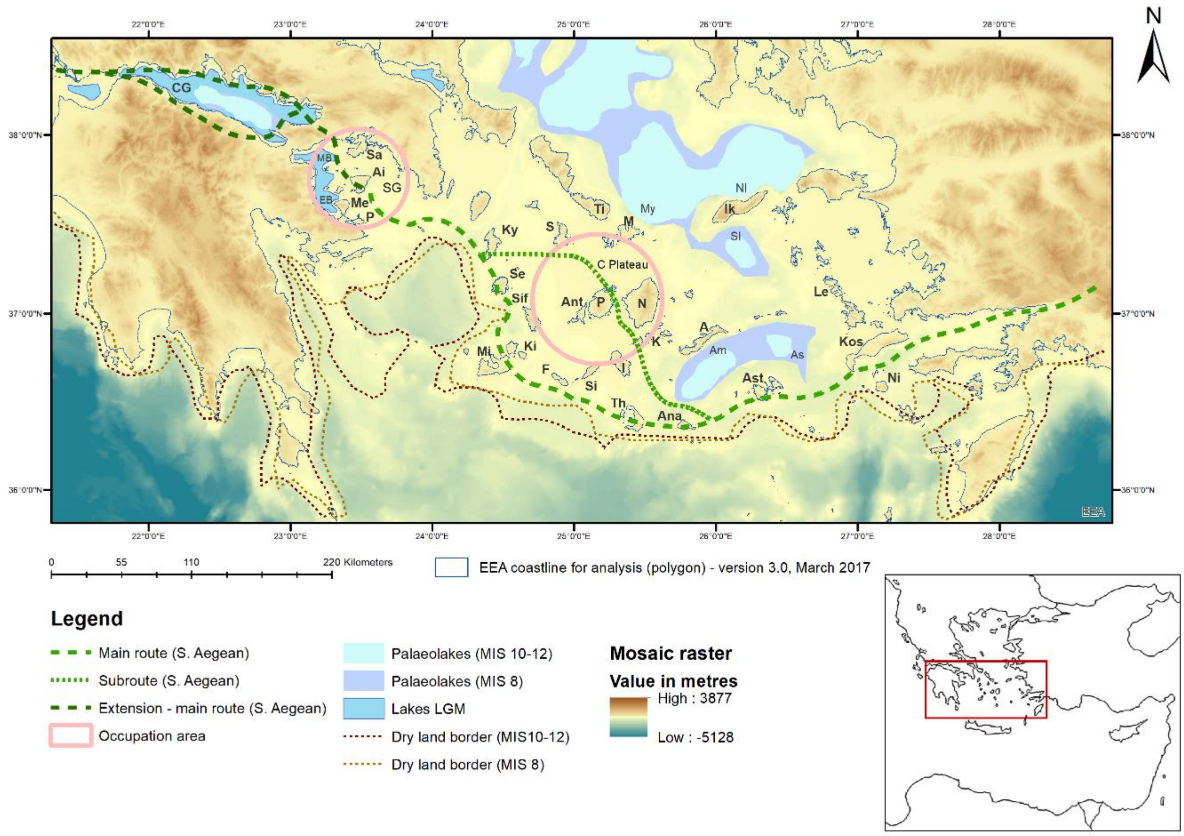


Figure 7.6. The green dashed lines correspond to the proposed route crossing the southern part of the Cycladic Plateau and the ‘bypass’ via the central Plateau, within the CAIB section. The route continues to the West via the Saronikos Gulf and the Gulf of Corinth to the Ionian Margin. The pink circles indicate potential occupation areas. Within the CAIB and CG sections, two such areas have been identified over the now submerged shelf: at the low elevation areas of the central Cycladic Plateau (OA3) and at the Saronikos Gulf (OA4). Geospatial data as in fig. 7.2. N: Naxos Island, K: Koufonisia I., I: Ios I., Si: Sikinos I., An: Antiparos I., P: Paros I. (circle A). F: Folegandros I., Ki: Kimolos I., Sif: Sifnos I., Se: Serifos I., Ky: Kythnos I., S; Syros I., Ti: Tinos I., M: Mykonos I. (circle B). Ik: Ikaria I., A: Amorgos I., Le: Leros I., Ni: Nisyros I., Ast: Astypalea I., Ana: Anafi I., Th: Thera (Santorini) I., Mi: Milos I., P: Poros I., Me: Methana peninsula, Ai: Aigina I., Sa: Salamina I. CG: Corinthian Gulf, My: Mykonos basin, NI: North Ikaria basin, SI: South Ikaria basin, Am: Amorgos basin, As: Astypalaia basin.

Indeed the visibility analysis indicates a well-structured terrain in terms of landmarks availability and visibility, at the entry-point to the Greek mainland and along the extended Ionian margin (fig. 6.9-Ch.6). This hypothesis needs further exploration but the available archaeological record is very promising, in this regard. Some of the key – find-spots attributed to the LP are located along the coasts of W. Greece (Preveza and Acheron valley locations), and on the Ionian islands (Corfu, Keffalonia, Lefkada). Recently, insular archaeological investigation coupled with seabed mapping in the Inner Ionian Sea archipelago produced exciting results (Galanidou 2018). The finds refer to the Middle Palaeolithic, but the whole expedition stresses how crucial the investigation of the sea and the offshore islands can be for enhancing our understanding of the Palaeolithic settlement, land use and pathways of dispersal – both terrestrial and marine.

My work on suitability and landscape structure, and the resulting hypotheses discussed above, suggest that this wider zone including the CAIB and its westward extension to Central Greece – the Aegina-Methana-Epidaurus complex and the Gulf of Corinth – could retain evidence of trans-Aegean crossings through terrestrial passages, which is in good agreement with recent results from Stelida on Naxos Island (Carter et al., 2019). However, with the exception of Stelida, which has been investigated systematically since 2012, and the surface finds from Milos island, this part of the Aegean remains largely unexplored regarding the LP.

Unstratified stone tools from Triadon Bay on Milos, made on volcanic rocks (rhyolites) have been attributed to the LP (or possibly the early Middle Palaeolithic) on a techno-morphological basis (Chelidonio 2001). As Sakellariou and Galanidou (2016: 166) have already noted, systematic work on Milos is required to understand the depositional context and make further assessments on the primary location of the Triadon Bay finds, and their potential age. Stelida, on Naxos Island, is one of the few sites in the Aegean (along with Petrota in Thrace and the Pindus localities in Epirus) offering evidence for on-site raw material exploitation and quarrying activities throughout the Palaeolithic and Mesolithic. Currently it bears the oldest evidence of such activities starting during the Middle Pleistocene, as recently established by absolute dates (Carter et al., 2019). The oldest stratified evidence from Stelida has been dated to ca. 200 Kya by luminescence dating (ibid), confirming the original suspicions for a Middle Pleistocene age – from observations of the surface finds. The lower find-bearing layer in the excavated sequence has been attributed to the Early-Middle Palaeolithic transition. The stone tool assemblage from this layer is relatively small (n=106), including many heavily weathered artefacts with only few diagnostic tools (a scraper and two denticulates). However, the LP component is clearly evident, in techno-typological terms, in the surface assemblage, including diagnostic tools such as, bifaces (cleavers, handaxes), unifaces, denticulates, notches and scrapers.

Skarpelis et al. (2017:821) observed some similarities between the Stelida LP component and stone tools found elsewhere in the Aegean (e.g. large cutting tools, unifaces and scrapers found in Rodafnidia, Lesbos Island and bifaces found in Plakias locations, Crete) and the Greek mainland (e.g. flake cores found in Rodia, Thessaly). Could these observed similarities signify trans-Aegean communications during the LP, thus connections via the exposed land? This could explain the suggested similarities between Stelida and Rodafnidia stone tools. Naxos and Lesbos until at least 250 Kya would have been connected by land, according to available reconstructions. And even after that, during MIS 6 (180-140 Kya) large parts of the Aegean remained exposed and connected to the mainland. This would explain the suggested similarities between Stelida and Rodia in central Greece. Naxos and Thessaly were part of the same extended Greek mainland until at least 140 Kya. The connection between Naxos and Crete, on the other hand, would always have required sea-crossings from the Cycladic Plateau to the Island of Crete.

When considering the palaeolandscape in the interpretation of available finds, new possibilities open up. The potential terrestrial connections during the Early and Middle Pleistocene, between LP locations, which are separated by the sea in the current geographical configuration, are interesting. But we are far from establishing such connections, let alone networks, in the Aegean region during the Lower Palaeolithic. This would require a larger body of archaeological and palaeoanthropological information that would allow wider comparisons. At the moment, the number of the known LP sites with reliable evidence in chronostratigraphic terms is small. However, the first indications are very positive and the research is ongoing; but before making any further assumptions, more detailed information is needed on the nature of the available lithic assemblages, their potential association(s) through comparative analyses, raw material sources and secure chronologies with absolute dates.

To the current research in the CAIB, which is in progress, a few more research targets should be added:

- Systematic fieldwork on the islands around the promising – now submerged – lowlands in the central part of the Cycladic Plateau, and offshore mapping of the seabed over the plains lying to the north and south of the Naxos Island. With dual aims (a) to spot potential LP archaeological finds on land and (b) to identify remnants of palaeolandscape features pre MIS 8 on land (e.g. marine terraces, palaeoriver sedimentary sequences) and underwater (e.g. palaeoriver channels and palaeolakes) and establish wherever possible on- and off-shore sedimentary associations. Contrary to the rich information from the northern part of the Aegean, for the central Aegean secure evidence about the prevailing conditions before MIS 8 and the timing of the transition from lacustrine to marine environments is missing. Underwater survey, including geological coring, would further inform available reconstructions.

- At the southernmost end of the Plateau, along the southern Aegean volcanic arc, the evolution of the palaeocoastline, from ≥MIS10-12 until MIS8, is of interest. This again would involve onshore investigation on the islands of the arc that have never been the subject of targeted LP research, and offshore investigation of their immediate surroundings. Here perhaps the volcanic sequences could be helpful to establish on- and off-shore associations.
- W. Saronikos and the Gulf of Corinth have been investigated extensively in terms of geotectonic and palaeogeographical evolution, offering now a solid base to plan systematic archaeological research in selected target areas: (a) Tourloukis has already stressed the high potential for availability and visibility of Early and Middle Pleistocene material at the southern part of the Gulf of Corinth, and for material ≥1 Mya to be preserved within the Megara basin (2010: 157-9), but these areas have never been surveyed. (b) The current islands of Saronikos (Aigina, Salamina, Poros), that used to be connected to the mainland for successive glacial lowstands until MIS2, representing the higher bits of the extended terrestrial landscape during the Early and Middle Pleistocene, may also hold valuable information. This aspect needs to be further explored with archaeological investigation.

7.2.3 Central Aegean and the Sperchios basin – Euboea complex

The Sperchios basin in mainland Greece and the semi-adjacent Euboea Island possibly represent another interesting area in terms of LP research potential, highlighted in the suitability model. The Sperchios River basin, is a dynamic area, controlled by tectonics (graben) and surrounded by Plio-Pleistocene volcanic centres in an arc alignment, from Volos-Atalanti in mainland Greece (to the NW), to Orio-Oxylithos in Euboea (to the SE) (fig.4.5 – Ch.4). Volcanic rocks (ages ranging from 1.7 Mya to 0.5 Mya) have been recorded in the Volos-Atalanti and Vromoneri areas (fig.4.5 – Ch.4) and in the vicinity of the Orio and Oxylithos volcanoes (associated with an earlier phase of the volcanic activity during the Middle Miocene ca. 13-14Mya). Tectonics and volcanism favoured the creation of multiple karstic and thermal springs (of moderate salinity) along the margins of the Sperchios graben and the North Euboean Gulf (fig. 7.7). Submarine and coastal springs have been recorded along the southern Euboea coasts and the neighbouring coasts of mainland Greece, implying abundance of water resources - fresh water sources included (fig. 7.7). During the Early and Middle Pleistocene until MIS 8, and during the glacial stages after MIS 8, the North and South Euboean Gulfs were occupied by lacustrine environments (Van Andel and Perissoratis, 2006;

Sakellariou et al., 2006; Perissoratis and Van Andel 1991). The accumulation of natural resources, including variable water supplies and volcanic material, in combination with the dynamic character of the area, may offer a promising combination, where favourable environments for hominins are found in topographic settings that favour preservation and discovery - following Tourloukis (2010; 2016) geoarchaeological scheme (fig. 7.7).

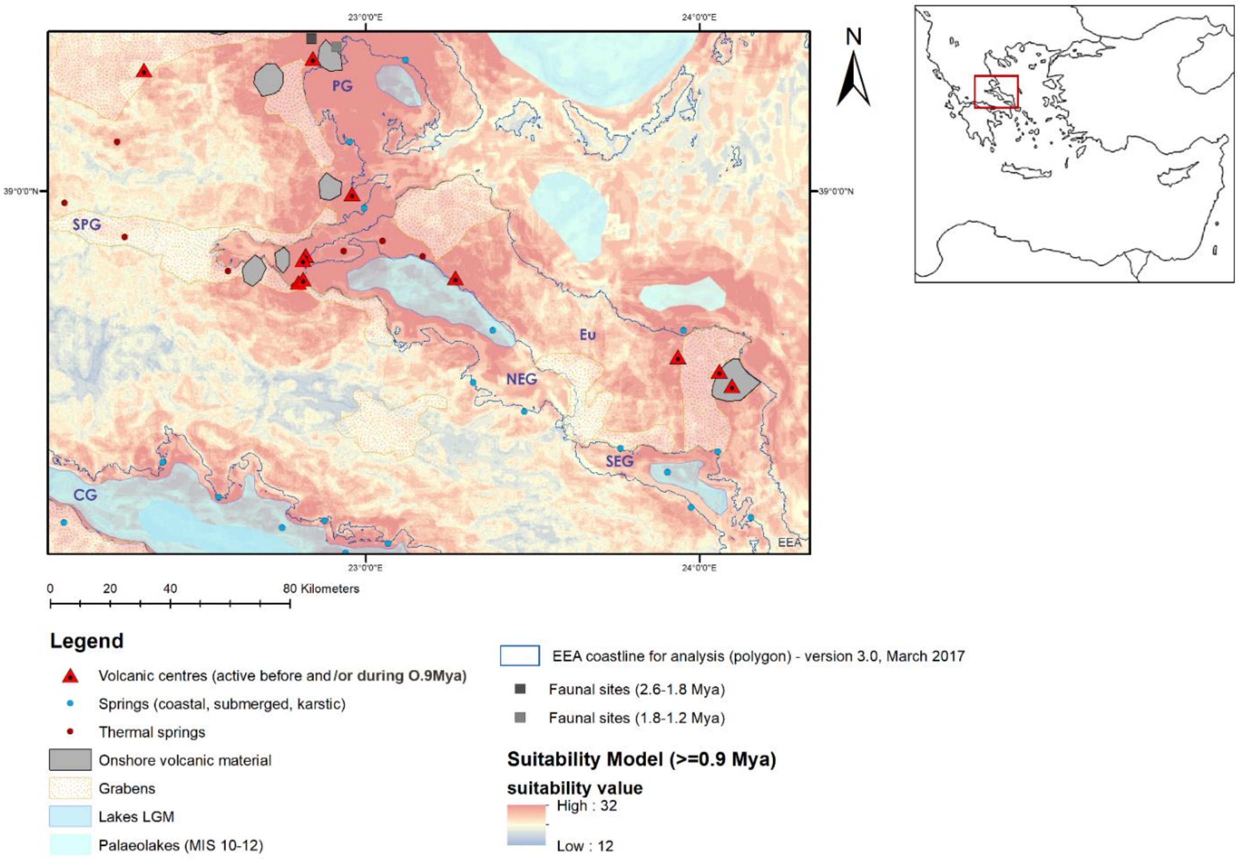


Figure 7.7. The Sperchios-Euboea complex may represent another 'target-area' for the LP research. The extensive volcanic activity during the Oligo-Miocene – with some later limited and localised expressions during the Pleistocene – associated with the mumerous thermal and karstic springs along the margins of the Sperchios graben and further south along the western coasts of Euboea. The graben environment may have favoured preservation of the LP material. Geospatial data as in fig. 7.2. PG: Pagasitikos Gulf, NEG: North Euboean Gulf, SEG: South Euboean Gulf, CG: Corinthian Gulf. SPG: Sperchios graben. Eu: Euboea

The Sperchios graben consist of sediments of great thickness (reaching under the delta 2 km), including, from past to present: Oligomiocene conglomerate, Pleistocene lacustrine deposits (conglomerates, sands and clays) under the alluvial deposits of the Sperchios River, and alluvial deposits of the Sperchios River (clays with intercalations of conglomerates and fanglomerates) (Apostolopoulos 2005). Radiocarbon dating and tectonic evidence show that the northern and southern parts of the Sperchios graben were uplifted during the Holocene (Pehlivanidou 2012: 41-42). The uplift at the northern part is visible over the Agia Paraskevi prehistoric settlement area, while at the southern part it is evidenced by the V type erosion (i.e. vertical erosion in the upper course of the river, generating steep-sided and narrow valleys) in one of the tributaries at the Oeti

Mountain. This situation perhaps signifies a preservation potential of material accumulated in the basin during the Early and Middle Pleistocene and exposed after the recent uplifting. It is also worth highlighting the presence of *terra rossa* deposits documented in the central part of the Sperchios basin (Pehlivanidou 2012: 36-37). *Terra rossa* environments frequently preserve early evidence as demonstrated in NW Greece, with Kokkinopilos being one of the most characteristic examples.

The least-cost routes produced for the two different time periods (≥ MIS 10-12, and MIS 8), both traverse the central Aegean, at the same point between the two major water bodies, on the east side of Euboea. The eastern part of Euboea coincides also with one of the potential entry points to the mainland at the termination of the southern branch of the southern route proposed in section 7.2.1. If we hypothesise the continuation of movement to the west, the extension of this branch would cross E-NE Euboea, traverse the N. Euboean Gulf - in fully terrestrial phases - or follow its margins - when lacustrine environments prevailed - before entering the Sperchios river basin. It would be fair to assume that the Sperchios basin would offer attractive habitats for occupation (OA 5) due to the richness of water resources, the scattered volcanic rocks and also due to the presence of geothermal springs (still active in Thermopyles, Kamena Vourla, Ypati and Aidipsos) (fig 7.9). The thermal springs and their potential role as microrefugia during the early prehistory remains understudied and needs to receive more attention in the future LP research. Warm and protected environments, especially during the cold phases, are expected to have been attractive for hominins and other animals.

From Sperchios basin, it would have been very difficult to overcome the major obstacle of the Pindus Mountain chain and disperse further to the west. Not impossible though, if one considers the evidence for the presence of Early Pleistocene hominins in the highlands of central Anatolia or the Middle Palaeolithic sites and find-spots recently recorded in the Samarina river beds on the actual Pindus Mountains in Grevena (Efstratiou et al., 2006). The latter associates with the abundance of local, good quality chert and the presence of fresh water (Samarina River). Early and Middle Pleistocene hominins had the biological and behavioural capacity to undertake the challenge of surviving in higher elevation areas and exploit available resources. From Sperchios basin, movement would have been easier towards the north following a narrow but highly suitable corridor leading to the Pagasitkos gulf (fully terrestrial during the maximum land exposure) and the Larisa basin with the Pineios drainage system being established at least since the Middle Pleistocene (fig. 7.9). Before that, during the Pliocene and the Early Pleistocene (until the end of the Villafranchian) lacustrine environments prevailed in eastern Thessaly (Tourloukis 2010: 80-9). Many of the trans-Aegean routes modelled here lead and/or terminate in the Larisa basin (fig. 7.10). Coupled with the attractive habitats, reflected in the Plio-Pleistocene faunal remains and the LP archaeological evidence from Rodia (with debatable age – see Tourloukis and Karkanas 2012b: 5-6) and the other findspots from the fluvial sequences, Larisa basin is highlighted as another potential occupation area (OA 6) (fig. 7.9).

An almost complete absence of salient landmarks from this geographic section is noticed in the visibility model, with the exception of a restricted area in eastern-central Euboea. Navigation would have been facilitated, however, by the pronounced natural features during the Early and Middle Pleistocene, such as the small water bodies hosted within the Skopelos basin and the North Euboea Gulf, the lacustrine (initially) and the riverine (subsequently) environments in the Sperchios and Larisa basins, and the thermal springs along the margins of the Sperchios basin and north Euboea. The latter would have potentially provided visible landmarks from a great distance across the palaeolandscape.

Still, the only available evidence from this specific geographic section comes from Nea Artaki in south-central Euboea, but its attribution to the LP is not secure in stratigraphic and chronological terms. However, the Sperchios-Euboea complex has never been subjected to systematic survey focusing on the LP. The high preservation potential coupled with the high affordance values, suggested by the model, indicate another possible target, with priority on the investigation of the Sperchios River beds, specifically the *terra rossa* deposits and the uplifted areas.

7.2.4 Western Anatolia and entry points to the Aegean dry land

The logical hypothesis that Anatolia was a landbridge towards the west, owing to its geographical location, has been recently challenged. Evidence suggests inhospitable conditions for hominins during the Plio-Pleistocene, due to climatic variability and topographic constraints. However, hominins were present in central Anatolia, in high elevation areas, at ca. 1 Mya or even before (Dursunlu and Kaletepe Deresi 3, Göllüdağ area). Their presence might be sporadic or even episodic before the arrival of the Acheulean culture (as suggested by Dinçer 2016). Nevertheless, early Pleistocene hominins apparently had the biological and technological adaptations to reach central Anatolia and possibly areas further in the west as indicated by the Gediz and Kocabaş finds in Asia Minor, with suggested absolute dates > 1 Mya (Maddy et al., 2015; Kappleman et al., 2008).

The suitability model suggests favourable conditions across western Anatolia throughout the Plio-Pleistocene due to the abundance of volcanic rocks, with extensive volcanic landscapes at the north-western part, and fresh water supplies, with multiple major river systems covering the whole extent from north to south (fig. 7.8). Fluvial conditions and valley formation processes prevailed in the tectonically controlled basins across the Aegean coasts of Turkey by the end of the Pliocene, around 2Mya (Erol 1981; Kayan 1999). Rivers have been attractive features for humans not solely for supplying fresh water – prerequisite for survival – but also because they acted as natural landmarks, facilitating orientation and navigation over the landscape, as suggested by ethnographic studies on modern hunter-gatherers (Kelly 2003).

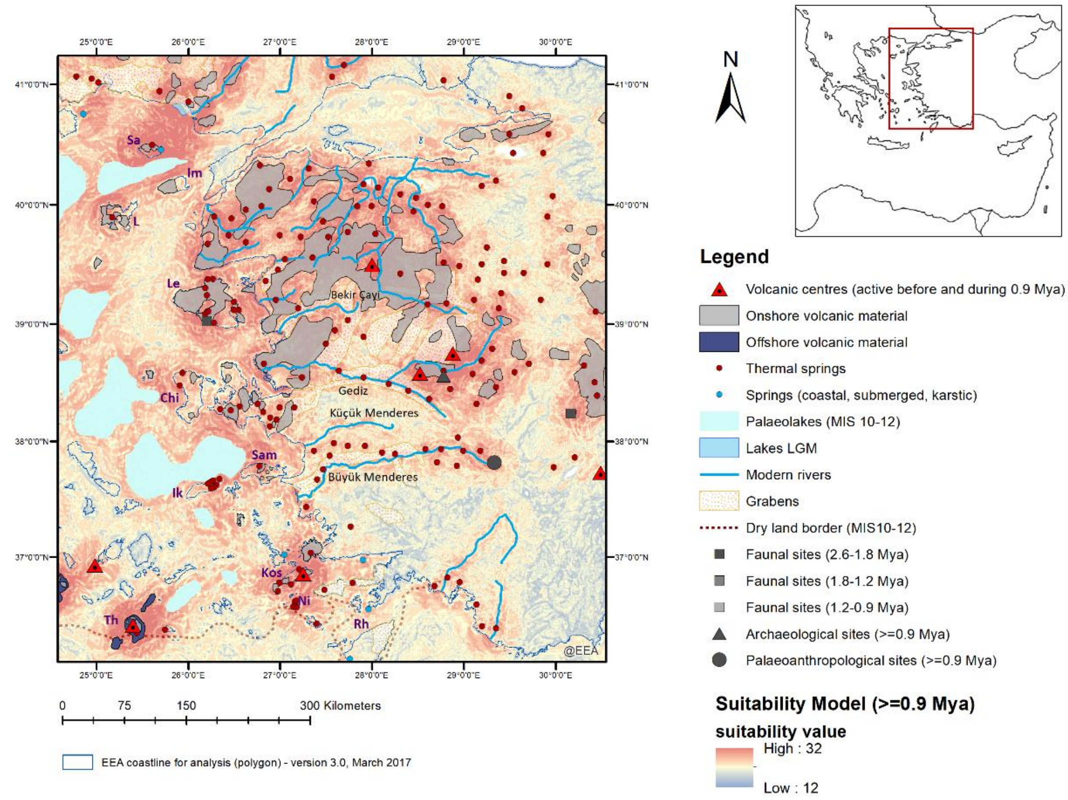


Figure 7.8. The model suggests high values of suitability over the Aegean coasts of W. Turkey throughout the three time intervals, due to the abundance of volcanic outcrops and fresh water supplies (the two affordance variables). The map corresponds to the fisrt time interval (≥ 0.9 Mya). Riverine environemnts, within graben formations, were established in the area by the late Pliocene (ca. 2Mya). During the Early and Middle Pleistocene, hominin populations from W. Anatolia could have reached the Aegean dry land following the natural pathways dictaded by the rivers. Geospatial data as in fig. 7.2. Sa: Samothraki I., Im: Imbros I., L: Limnos I., Le: Lesbos I., Ch: Chios I., Sam: Samos I., Kos: Kos I., Ni: Nisyros I., Rh: Rhodes I., Th: Thera I.

In the least-cost path analyses, the produced route from Karain (SW Anatolia) to Rodia (mainland Greece) follows the Gediz River before entering the Aegean region (fig. 7.9). This observation, combined with evidence from literature on wayfinding over natural landscapes, led to the current working hypothesis that during the Pleistocene, the ancient river systems of West Turkey (represented by the modern Bekir Çayi, Gediz, Kücük Menderes and Büyük Menderes rivers) could have provided natural routes leading to or across the Aegean dry land. Based on the geotectonic evolution of the area, it would be fair to assume that the palaeorivers during the Early and Middle Pleistocene would have been broadly analogous to their modern counterparts, at least in terms of location and direction.

In the visibility model, the area to the south – south-east of Lesbos Island, received very high values and some of the highest values in the whole study area (fig. 6.9-Ch.6). This indicates that navigation over this part would be facilitated by frequent landmarks with overlapping visual ranges, guiding the movement. During the maximum land exposure of the Middle Pleistocene and during the glacial lowstands from MIS 8 up to MIS 2 this part was exposed, connecting Lesbos, Chios and W. Anatolia. The terrain over the EAI section would be continuous from at least MIS10-12 until at least MIS 8, interrupted by three isolated lakes (MIS 10-12). Later on, during MIS8, the three lakes connected to form one major palaeolake separating the extended W. Anatolia mainland (to the east) from the extended Greek mainland (to the west) (fig. 7.9).

The Bekir Çayi and Gediz Rivers terminate exactly at the point with the high visibility values, where the rivers meet the Aegean Sea today. The logical assumption here would be that landscape structure, and thus the visibility results, have been affected to a certain extent by sedimentation and the consequent subsidence, since these systems have been discharging sediments throughout the Pleistocene and the Holocene into the Aegean (Aksu et al., 1987a,b). Bearing that in mind, we can still use the results consciously, as a rough approximation for the past landscape structure, focusing on the bits that still escape subsidence - the narrow zone of continental shelf between the current islands of Lesbos, Chios and the Turkish coast. Following the hypothesis that the major river systems of W. Anatolia could have provided natural corridors for dispersal, hominins following the Gediz palaeoriver would enter the Aegean dry land crossing a well-structured landscape between Lesbos and Chios Islands that could lead in three, at least, different directions (fig. 7.9):

(a) To the North, in Lesbos area via the southern part of the modern island where the gulfs of Gera and Kalloni probably hosted attractive lake environments during the Pleistocene lowstands, while the numerous thermal springs along the margins of these gulfs (Bencini et al., 2004) and the extended volcanic landscape covering the largest part of the island would have added more attractions in terms of available resources and protected environments for hominins and other animals. The Rodafnidia open-air site, with evidence for repeated hominin visits (Galanidou et al., 2016) during the Middle Pleistocene (possibly even earlier) and the Late Pleistocene, situated close to the Kalloni Gulf, could have been reached through one of these 'river routes'. The recurring presence of hominins (during the Pleistocene) and other animals (during the Plio-Pleistocene) within highly attractive habitats, signifies the potential of southern Lesbos to host occupation areas (OA 7) (fig. 7.9)

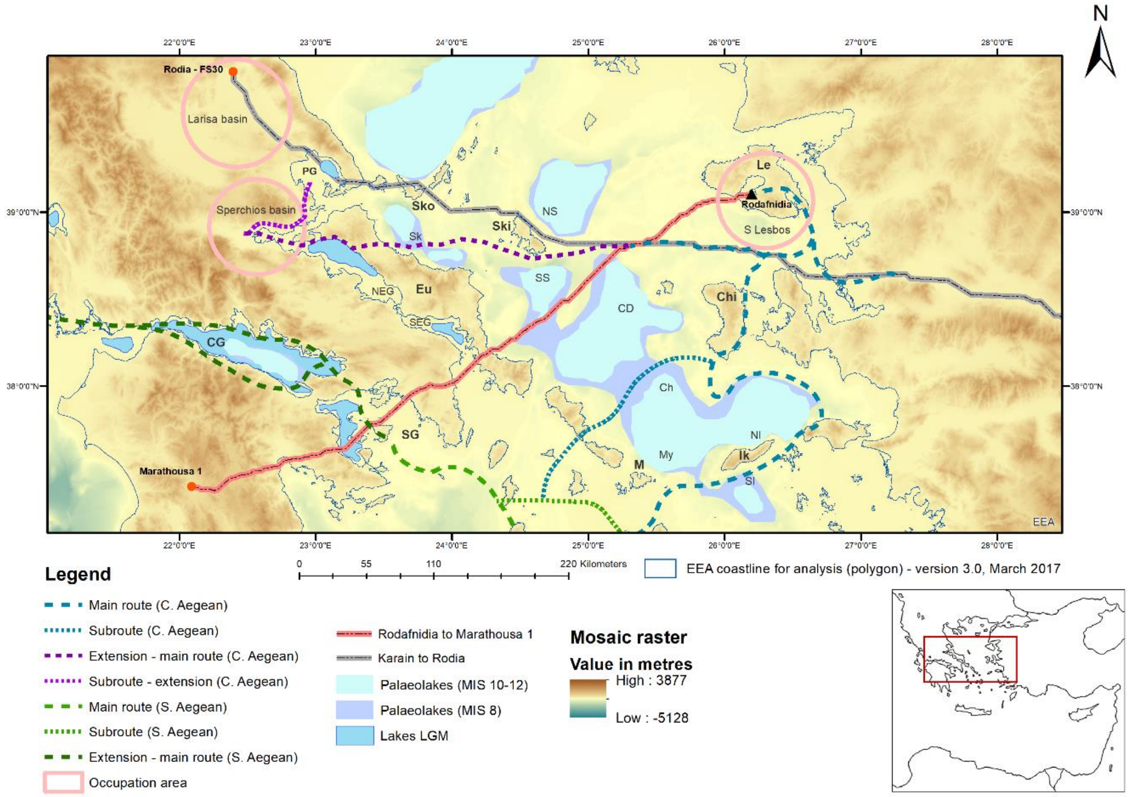


Figure 7.9. The purple dashed lines correspond to the proposed route leading to the Sperchios basin - as a westward extension of routes entering the Aegean via W. Anatolia. The route could continue to the North, entering the Larissa basin via a narrow but highly suitable passage. The dark-blue dashed lines correspond to the suggested routes and subroutes from the Gediz River entry point towards three directions: to the N, leading to southern Lesbos – a potential occupation area (OA 7); to the W, leading to central mainland; to the S, leading to the Cycladic Plateau and via the Saronikos Gulf either to central Peloponnese or to W. Europe following the Gulf of Corinth passage and the extended Ionian Margin. The pink circles indicate potential occupation areas. Within the CG section, another two such areas have been identified: the Sperchios basin (OA 5) and the Larisa basin (OA 6), where attractive habitats for hominins during the Early and Middle Pleistocene and preservation opportunities for the LP material are combined. The red line corresponds to the Rodafnidia – Marathousa 1 least-cost route, and the grey line to the Karain – Rodia least-cost route. Geospatial information as in fig 7.2. Sko: Skopelos I., Ski: Skyros I., Eu: Euboea. Le: Lesbos I., Ch: Chios I., Ik: Ikaria L., M: Mykonos I. CG: Corinthian Gulf, SG: Saronikos Gulf, NEG: N. Euboean Gulf, SEG: S. Euboean Gulf. Sk: Skopelos basin, NS: North Skyros basin, SS: South Skyros basin, CD: Cavo d'Oro basin, Ch: Chios basin, NI: North Ikaria basin, SI: South Ikaria basin. LB: Larisa basin, SPB: Sperchios basin, SL: Southern Lesbos

(b) To the south, in Chios area, and from there two new branches could begin following available landmarks, leading: (1) to the northern margins of the major water body hosted in N. Ikaria and Mykonos basins - at the south of Chios Island (fig. 7.9). During MIS10-12 a narrow terrestrial passage between that lake and the other major water body to the north (within the Cavo D'Oro basin) would permit further dispersal towards the west, to reach mainland Greece via the northern part of the Cycladic Plateau and the Saronikos Gulf. After MIS 8 that passage no longer existed. That first branch could extend to western Greece and the Ionian Margin following the Gulf of Corinth; (2) to the eastern and southern margins of the N. Ikaria-Mykonos basins – water body, and from there to the central part of the Cycladic Plateau – with the attractive lowlands (fig. 7.9).

(c) To the west, following the northern margins of the water body hosted in the Cavo D'Oro basin, crossing the narrow passage with available landmarks between the N and S Skyros basins - palaeolakes and reaching mainland Greece via east-central Euboea (fig. 7.9). This option is in agreement with the way suggested by the least-cost route from Karain to Rodia to cross the Aegean in order to reach the mainland. Alternatively, available landmarks between the S.Skyros basin and Cavo D' Oro basins could lead to the mainland via south Euboea, the Saronikos Gulf and from there either to the central Peloponnese, as suggested by the least-cost route from Rodafnidia to Marathousa, or further to the west via the Gulf of Corinth passage (fig. 7.6). The suitability model throughout the three time intervals attributes high values over Lesbos and Chios islands and the offshore area in between them and the adjacent coast of Turkey. Coinciding largely with the high visibility values. Lesbos was added in 2012 to the Eurasian LP map with the Acheulean assemblage from Rodafnidia (Galanidou et al., 2013; 2016). These recent finds provided solid evidence to reconsider the potential of an eastern gateway to Europe during the Early and Middle Pleistocene. The systematic archaeological investigation, which is ongoing, it is also combined with extensive geological research over the wider area, and underwater survey in the Kalloni Gulf, in order to clarify the depositional context of the finds and gain insight into the palaeolandscape and its affordances during the Middle Pleistocene (Galanidou pers. com. 2019). Chios Island and Psara, on the other hand, have never been researched for LP remains. Suitability highlights the northern, western and south-eastern parts of the current island of Chios and the surrounding shelf, while high visibility values are recorded at the south-west.

Similarities are observed between the EAI islands in terms of environments, including the presence of volcanic rocks and thermal springs. This is reasonable since the islands were part of the same continuous terrestrial landscape during the maximum land exposure of the Middle Pleistocene and during the glacial lowstands from MIS8 onwards. Miocene and Pliocene faunal remains from Lesbos, Chios and Psara provide clear evidence of that. The continental character of the represented species means that at least until the late Pliocene the islands were part of the extended W. Anatolia (De Vos et al., 2007: 320). The same applies for Samos, Karpathos and Rhodes. If hominins reached southern Lesbos during the Middle Pleistocene (if not earlier), they could have equally dispersed over similarly attractive environments across the extended W. Anatolia, from Imbros (in the north) to Rhodes (in the south). Thus targeting areas with preservation possibilities of the Early –Middle Pleistocene material on the Greek islands across the current Aegean coasts of Turkey should be a primary research aim. Rhodes may represent such an opportunity, with a well-established chronostratigraphy, through the extensive study (including sedimentology and palaeoecology) of the Late Pliocene to Middle Pleistocene coastal deposits on the northeastern part of the island (Cornée et al., 2006; Hanken, Bromley and Miller

1996). It is worth mentioning that in the visibility model the area between NE Rhodes and the current adjacent Turkish coast, part of which would have been exposed during the maximum land exposure, received average to high values, suggesting a well-structured landscape in terms of navigation potential – a potential entry point to the Aegean? (Fig. 6.9-Ch.6).

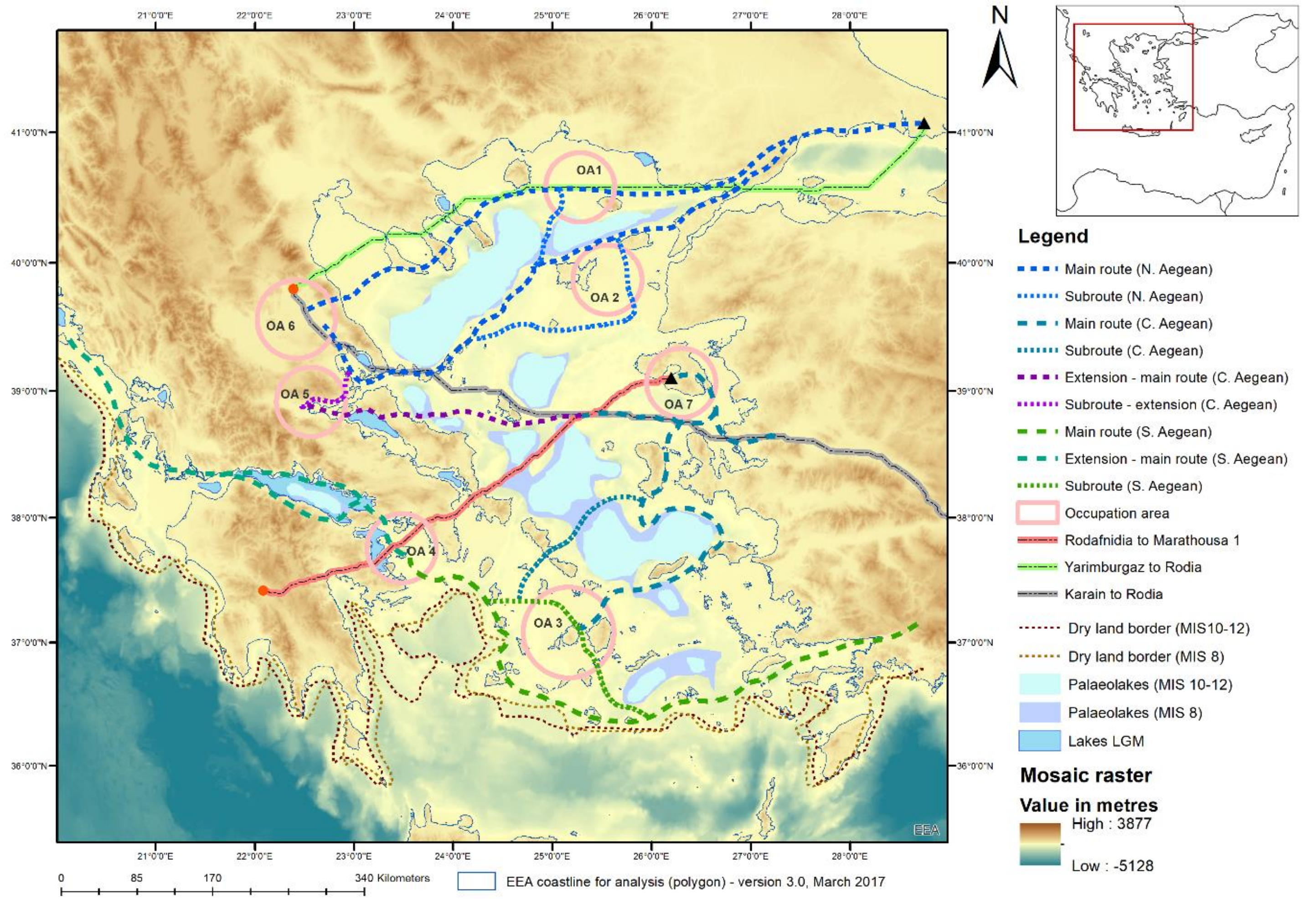


Figure 7.10. The suggested routes and occupation areas (OA) of the Aegean during the periods of the maximum land exposure of the Early and Middle Pleistocene. Geospatial data as in fig. 7.2

7.3 Reconsidering the prevailing Lower Palaeolithic narrative for Europe

The affordance corridors of the Aegean hypothesis reintroduces the Aegean region during the Early and Middle Pleistocene, as part of a single geographic terrestrial entity including south-eastern Europe and western Anatolia – demonstrating that the concept of the Aegean as a pathless water barrier is now outdated. The exposed lands constituted part of the southern Balkan *refugium*, a zone of extreme biogeographical importance for the survival and dispersal of hominin, and other faunal, populations during the Plio-Pleistocene (sections 3.3-Ch.3 and 2.3.5-Ch.2). The wider SE Europe and W. Anatolia (including the Aegean) area is highlighted in all existing dispersal scenarios for hosting niches with favourable conditions, even during glacials, and for offering multiple natural pathways for movement, open and available throughout the glacial-interglacial transitions of the Early and Middle Pleistocene (section 3.4-Ch.3). Here, the working hypothesis is that the Aegean palaeolandscape would not be any different. Following the 'source' and 'sink' population model proposed by Dennell, Martinon-Torres and Bermudez de Castro (2011), and further supported by Roksandic (2016) (section 3.3.-Ch.3), the Aegean palaeolandscape is envisioned, through the affordance corridors of the Aegean hypothesis, as part of the SE Europe-W. Anatolia core demographic area during the Middle Pleistocene. Source (local) populations could survive over the dry and hospitable lands, extending between western Anatolia and the Greek mainland during glacials, and perhaps during certain interglacials, (MIS 11, 9 and to a lesser extent 7), to repopulate deserted grounds and disperse to the north and the west, when the climatic conditions ameliorated. Ice-free, trans-Aegean corridors dictated by the natural structure of the dynamic landscape and the availability of sustainable natural resources, would offer undisrupted and continuous communication between southeast Europe and southwest Asia throughout the climatic cycles – suggesting that it was far from being an isolated peripheral area.

7.3.1 The Aegean ecological value

Available palaeogeographical reconstructions and reliable geological evidence (see references in Ch. 4) suggest abundant and variable water resources over the exposed Aegean landscape even during glacial stages, including extensive riverine environments (over the northern Aegean continental shelf), lacustrine environments (within the basins of the northern and central Aegean and the current gulfs of the mainland and the islands), and springs (karstic and thermal). However, one should not presume that all available water sources signify necessarily availability of fresh water, especially for the periods prior to MIS 8 - with largely unavailable evidence.

Sedimentological analyses from palaeolacustrine sequences (section 4.5-Ch.4) show moderate salinity and brackish environments prevailing during the transitions from marine to lacustrine phases, and vice versa, through glacial-interglacial oscillations from MIS8 onwards. Still, fresh water supplies across the palaeolandscape during the Early and Middle Pleistocene could be inferred, at least by the LGM remnants of the older palaeoriver systems recorded across the submerged landscapes of the northern Aegean shelf, and by the numerous coastal and submarine springs.

Nonetheless, the rich and densely distributed water resources over the exposed lands and the proximity to the Mediterranean Sea, lead us to assume increased moisture supporting a rich vegetation. Palynological and palaeoclimatic evidence for the Plio-Pleistocene reflect the gradual opening of the landscape initiated by the shift to colder and more arid conditions at 2.6 Mya. In SE Europe in particular, the dense forests are replaced initially by open grasslands and mosaic-like environments (2.6-1.8 Mya), followed by tree savannahs and mixed forest steppes (1.8-0.9 Mya; Ch.3). After the Middle Pleistocene Transition (ca. 800 Kya), the pronounced cold installed extensive steppe-tundra environments (450 Kya), covering a wide zone from C. Asia to Europe, but in eastern Mediterranean and the Transcaucasia, a variety of habitats persisted, ranging from closed forests to open meadow-steppes (see references in Ch.3). The deforestation had an east-to-west direction as demonstrated clearly in the palaeofaunal records. This means that open vegetation landscapes with mosaic-type habitats would have been available to hominins, for exploitation and dispersal, earlier in eastern/south-eastern Europe than in W. Europe. Perhaps, this could explain the delayed appearance of hominins in W. Europe at 1.4 Mya, some 400 Ka after reaching Dmanisi at 1.8 Mya, given early hominin's preference for such environments, as opposed to densely forested areas encountered at that time across central and western Europe (Sardella et al., 2018; Koufos and Kostopoulos, 2016: 276; Croitor 2018: 283; Leroy, Arpe and Mikolajevicz 2011). Following this line of evidence, an earlier presence of hominins in the Aegean region, before 1 Mya, could be reasonably anticipated.

7.3.2 The Aegean glacial *refugia*

Over the Aegean exposed lands – being part of the southern European *refugia* – one could envision clusters of vegetation even during glacials. Tree populations contracted during glacial periods within refugia, with the surviving taxa expanding again during the interglacials beyond these local optima (Tzedakis, Hooghiemstra, Pälike 2006). Such *refugia* should be expected to be hosted in suitable microhabitats in mid-altitude zones, and in low elevation and coastal areas, with locally continued availability of moisture throughout the climatic cycles, and increased levels of topographic variability (Tzedakis 2009). Variation in topography offers an important advantage to species that need to respond to climatic change: it widens the range of microclimates suitable for survival (ibid). These factors have been identified to determine the locations of *refugia* during the LGM across the Mediterranean (the Pyrenees, the southern flanks of the Maritime and Ligurian Alps, the western flanks of the Apennines, southern Apennines, the western part of the Dinarides and Hellenides, mount Olympus, the southern parts of the Taurides, the Ansariye and Lebanon mountains, the maritime Atlas of Algeria and the Atlases in Morocco), with the characteristic example of the Ioannina area *refugium* in NW Greece (ibid). Several locations over the exposed lands of the Aegean would match this description. The occupation areas suggested in the new scenarios, are located in low and mid- elevation areas, but with high topographic roughness, surrounded by higher altitudes, and in association with permanent or ephemeral water bodies and/or other water resources – confirmed or inferred. The points of temporary or longer settling in southern Lesbos, western Saronikos, the Samothrace Plateau, the Cycladic Plateau, the Limnos Plateau, the Sperchios and Larisa basins, could also be envisioned as possible *refugium* areas, where local flora and fauna populations would be sustained/survive during extreme environmental phases to provide the source populations for spreading outside the refugia with the outset of the interglacial conditions. It is worth emphasising that thermal springs within these settings (Lesbos, Sperchios and W. Saronikos) offering warm and protected micro-habitats, easily detected across the palaeolandscape, would further attract early navigators and settlers. In Lesbos in particular, the thermal springs are directly associated with evidence for repeated presence of different hominin groups during the Middle and the Late Pleistocene, with Acheulean and Mousterian tools made on hydrothermal chert, locally available in abundance (Galanidou et al., 2013; 2016).

Based on estimations, made by Dennell, Martinon-Torres and Bermudez de Castro (2011:1518) during the glacial maxima of the Middle Pleistocene, 60-100 hominin groups of 25 hominins (1500-2500 hominins) would constitute the whole European population. Thus, the 7 potential glacial *refugia* of the Aegean would sustain a population of 175 hominins – if all available and used at the same time. In other words, 1/8th or the 1/14th of the whole hominin population of Europe during a glacial phase. These numbers would double during interglacial phases. Most importantly, according to the 'source' and 'sink' population model, these pulsating 'source' populations, even in low densities and growth rates, would be able to survive locally throughout most, if not all, the glacial phases of the Early and Middle Pleistocene (ibid 1521), suggesting a permanent and continuous hominin presence across the southern European glacial *refugia* – contra to the discontinuous and intermittent nature of the LP record for the central and northern Europe.

7.3.3 Rereading the current archaeological evidence from the Aegean

Available and proxy data for the palaeoenvironment and the palaeoclimate attribute a high ecological value to the exposed lands of the Aegean during the Early and Middle Pleistocene. The undisputed, in biogeographical terms, vital role of this part of Eurasia comes in total contradiction with its peripheral character in the prevailing Lower Palaeolithic narrative.

The current account for the early colonisation of Europe, favours the western part of the continent, due to the rich evidence for the presence of hominins in the Iberian and Italian Peninsulas and in France before 1 Mya, with suggested ages reaching 1.4 Mya (Baranco León) or even 1.6 Mya (Pirro Nord) (Torro-Moyano 2013; Arzarello, Peretto and Monchel 2015). Similar evidence from eastern Europe, excluding Dmanisi at 1.8 Mya, is much more fragmented and rare. However, recent archaeological and palaeoanthropological finds from E. Europe and W. Anatolia reflect variability and diversity, which is not consistent with the placement of this part of Eurasia at the margins of the Lower Palaeolithic world. The earliest hominin presence in the wider Aegean region is now being pushed back to the Early Pleistocene, based on recent archaeological and palaeoanthropological finds from the Aegean coasts of Turkey older than 1 Mya (section 2.2.1.2-Ch.2) with reliable dates documenting the presence of hominin groups in NE Aegean and the Greek mainland at 400-500 Kya (sections 2.3.2 and 2.3.4-Ch.2). Moreover, recent studies on palaeoanthropological remains, reveal the potential presence of different hominin species during the Middle Pleistocene in the Aegean region (*H. erectus, H. heidelbergensis, early H. sapiens, H. neanderthalensis*), of multiple origins with both African and Asian affinities being identified in the represented species (section 2.3.5-Ch.2).

7.3.4 Refining the narrative

The growing body of evidence suggesting a rather central position for the wider Aegean during the Lower Palaeolithic can no longer be ignored. The current discourse needs to be refined including an updated perception of the Aegean palaeolandscape. The exposed lands of the Aegean could offer an eastern gateway to Europe during the Early and Middle Pleistocene either as a westward extension of the Levantine and Asia Minor route – followed by African populations during the Early and Middle Pleistocene (direct Out of Africa dispersal scenario and diverging populations scenario) (Arribas and Palmqvist 1999; Martínez-Navarro 2010; Palombo 2010; Rolland 2013) or as the western branch of the corridors followed by 'core' populations established in W. Asia (Trans-Caucasus—Asia Minor and the wider Aegean region) and further expanded to the west –with the first such expansion recorded around 1.2-1.3 Mya (out of Asia dispersal scenario) (Spassov 2016; Koufos and Kostopoulos 2016). In this respect, the affordance corridors of the Aegean hypothesis is complementing the existing scenarios, by broadening, in spatial terms, the spectrum of survival, exploitation and mobility possibilities for hominins over the eastern and north-eastern Mediterranean; and in that sense, widening the geographical range for the LP investigation.

7.4 Remarks on methodology and future steps

Over the last thirty years the intensified investigation of submerged prehistoric landscapes worldwide, led to the recent establishment of a discrete discipline, the *Continental Shelf Prehistoric Research* (Flemming et al., 2014). This is rather the result of crossing "*unfamiliar disciplinary boundaries*", as eloquently put by Bailey (2014:291), between archaeology and other scientific fields, in particular geosciences and environmental sciences. It was the progressive (and still not fully established) acknowledgement by archaeologists that in order to understand key aspects of prehistory, such as the early hominin dispersal events and the out of Africa settlements, one needs to think beyond the current geographical/natural configuration. The present-day land surface and the submerged areas of the continental shelf constituted a seamless whole during certain phases of prehistory. Thus, for a valid reading of the archaeological record, multiple evidence from above and below the sea-levels needs to be integrated, to form a complete – as possible – body of information. This notion, as a theoretical concept and as a practice, seems to be now gaining a momentum that needs to be further developed (Evans, Flemming and Flatman 2014; Flemming et al., 2014). Significant avenues for investigation are opening up, with new ideas, beyond prevailing narratives, being explored (see e.g. the DISPERSE, SPLASHCOS and ACROSS projects) and with cutting-edge technologies, beyond archaeology, being employed for archaeological purposes (e.g. acoustic sub-seafloor mapping and 3D imagery for recording underwater elements). The COST (European Cooperation in Science and Technology) Action SPLASHCOS (Submerged Prehistoric Archaeology and Landscapes of the Continental Shelf), in particular, is a milestone in this progression setting the foundations to further the investigation of the early prehistory in submerged contexts, by establishing a large-scale pan-European network of collaboration. The products of this action were recently published in four key-collective volumes: *Under the Sea: Archaeology and Palaeolandscapes of the Continental Shelf* (Bailey, Harf and Sakellariou 2017)-providing an overview of the four-year multi-disciplinary and multi-national research program, the *Submerged Landscapes of the European Continental Shelf: Quaternary Palaeoenvironments* (Flemming et al., 2017)-dealing with the geology of the submerged shelves across Europe, and the *Oceans of Archaeology* (Fischer and Pederson 2018) and *The Archaeology of Europe's Drowned Landscapes* (Bailey et al., 2020)-focusing on the prehistoric archaeology preserved on the European seabed.

7.4.1 The Continental Shelf Prehistoric Research in the Aegean: current state of art

In this context, the interest for the Aegean prehistoric submerged landscapes is advancing. The palaeogeographical reconstructions by Lykousis (2009) and Sakellariou and Galanidou (2016; 2017) represent key-studies, through which the Aegean region was introduced to the international continental shelf prehistoric research community as a promising new target, contributing greatly to the establishment of the new discipline itshelf. Sakellariou and Galanidou, in particular, developed innovative ideas and research directions that have been the starting point and inspiration for this thesis. More importantly they demonstrated, with their active and ongoing collaboration between geologists and archaeologists that continental shelf prehistoric research can only be practised successfully within an inter-and cross-disciplinary matrix. This is a new endeavour for Greek archaeology, with many prehistorians still being suspicious about the Aegean dry land hypothesis and its archaeological implications (Darlas pers. com. 2019).

Though bounded by several methodological and interpretation challenges (Ch.5), the investigation of the Aegean submerged landscapes is expected to fill some important gaps in the existing Greek Lower Palaeolithic record, affecting the wider understanding of hominin movement and occupation patterns during the LP. It also represents a window of opportunity for testing new methodologies. Despite the observed progress in the continental shelf prehistoric research, there is no fixed methodology, except for some standard practices/techniques. Given the variability in (a) local conditions (formation processes, erosion, palaeoecological conditions etc.), (b) scale of research (local, regional) and (c) the wide range of the investigated subjects, it is highly doubtful that one single approach would ever achieve the purposes of the continental shelf prehistoric research. One of the current objectives is to actually refine available tools and develop new approaches that would fit better the research needs (Flatman and Evans 2014:3; Flemming et al., 2014).

Considering that full marine surveys, which are necessary to understand in detail the submerged landscapes, are rare (due to practical difficulties and funding requirements), the chance of finding actual archaeological remains is poor. In practical terms, this means that the submerged prehistoric landscape archaeology has been limited to mapping and general discourse, which is by no means negligible. On the contrary, it has been stressed that before searching for actual underwater archaeology - which may or may not be preserved, or the level of preservation may vary – the first step is to achieve a finer reconstruction of the physical features and the environmental characteristics of the submerged landscapes (Bailey 2014; Bailey et al., 2015). This in return may provide a background for making useful associations with the terrestrial evidence, syncing information from the land surface and the seabed into a unified record for the palaeolandscape.

Recently, Sakellariou et al. (2017) made a preliminary identification of areas on the seabed of the Aegean, where the potential of preservation for the Prehistoric material (≤ LGM) should be expected to be high. Their identification of possible targets for underwater archaeological research is structured upon the available palaeogeographical reconstructions combined with estimations on the effect of erosion. Climatic, environmental and geological parameters associated with erosional processes (e.g. sedimentation, active tectonics, precipitation, speed of winds and waves), affecting the coastal areas and the shallow shelves, have been considered using LGM and post-LGM data and present-day proxies. It is worth noticing that many of the targets for future LP research that have been highlighted in this PhD thesis (section 7.2 and fig. 7.10 – this chapter) include areas with high preservation potential as identified by Sakellariou et al. (2017) (fig. 7.11).

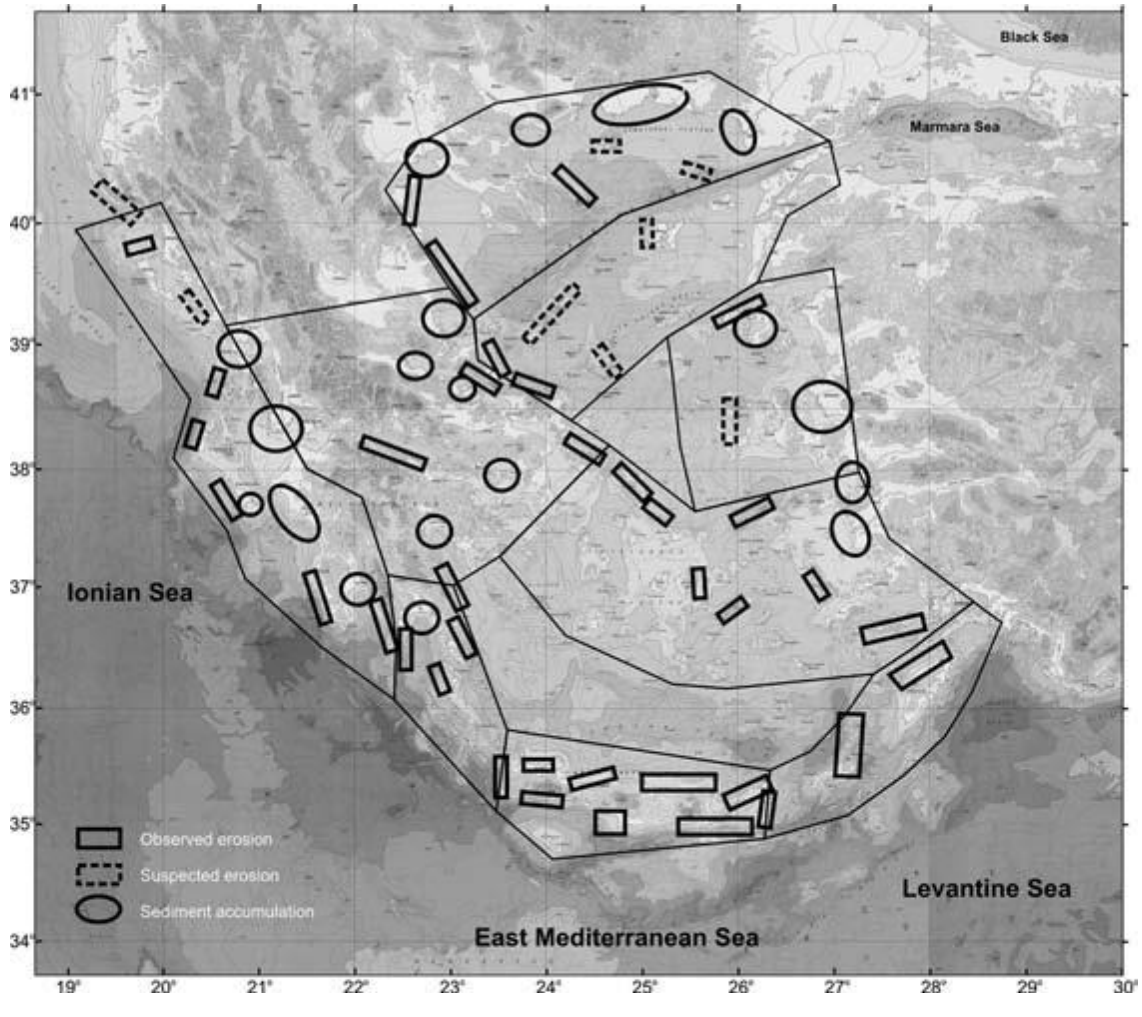


Figure 7.11. Areas with observed erosion (rectangular), suspected erosion (dashed rectangular) and sediment accumulation (circle) over the Aegean, as identified by Sakellariou et al. (2017). Notice that several of the occupation areas (e.g. OA 1, OA 2 or OA 3) and parts of the corridors of opportunity for dispersal suggested by this PhD study (see fig. 7.10) are located in areas where the erosional effect is suggested to be minimal (from Sakellariou et al., 2017: fig. 15.8)

7.4.2 The new methodological scheme: contribution

The methodological scheme developed in this thesis for the study of the Aegean submerged landscapes (Ch.5), moves one-step forward. It is using available evidence on palaeogeography and palaeoenvironments to establish a better understanding of the connection(s) between the hominins and their environments. The positive impact of this relationship (suitability and navigability) is spatially recorded, offering predictions for areas potentially preserving archaeological and/or paleoanthropological evidence/remains, above and below the current sea-level. The scheme, though developed for the specific region, could be applied/tested in similar contexts in the wider eastern Mediterranean and beyond, tackling some of the issues frequently encountered in the LP research, and especially in tectonically active environments: the regional scale of analysis – resolution issues; temporal limitations – availability of data for the Early and Middle Pleistocene; preservation of the LP material; extensive spatiotemporal discontinuities.

This thesis, which is only a first step towards this newly established research direction, generated a series of new hypotheses about hominin movement and occupation during the Early and Middle Pleistocene over the Aegean, adding a new strand in the current discussion about the early out of Africa dispersal events and settlements. The logical next step would be to evaluate the new methodological scheme by checking the areas highlighted in the predictive model with archaeological investigation on- and off-shore. However, the retrieval of archaeological remains should not be an end in itshelf, at least not at this point. Before moving on with the actual archaeology – many steps ahead from the current status – other pressing issues require our attention. In the interpretation of results (section 7.2), it is clearly demonstrated that more detailed information about the palaeolandscape is necessary, more specifically about: the pre-LGM natural structure and physiographic elements, the nature of available water resources during the Early and Middle Pleistocene, the timing of the establishment of marine conditions in the central Aegean, and the paleogeographical evolution of the southernmost dry land border/palaeocoastline. First order palaeogeography is required in order to establish a solid chronostratigraphic framework, both in local and regional scales, and an integrated understanding for the palaeolandscape as a whole. To this end, drilling, refinement of available rates of sedimentation, subsidence, uplifting etc., and mapping of palaeochannels are essential. Otherwise, our future assessments on hominin behavioural patterns would not improve in terms of accuracy and resolution.

7.4.3 Future steps

Towards this goal, the study of edaphics (5.2.2-Ch.5) could provide a very useful tool for exploring further the nature of the lost (now submerged) environments within a more holistic consideration of the Aegean past landscape and its affordances. By investigating the availability and distribution of specific soil nutrients onshore and offshore, direct connections could be made between the current terrain and the now submerged parts – that used to be exposed in the past, in terms of soil composition and ecological value. This approach has never been tested, so far, in submerged landscapes nor in mixed environments such as the Aegean - including terrestrial and submerged areas. It would require, of course, soil samples not only from the land surface but also from the seabed.

Underwater soil sampling for edaphics is a new and as yet untried addition to the methodology. Analysis of the nutrient potential of submerged soils is, theoretically, perfectly feasible (Kübler pers. com. 2019), but has never been tested before in archaeological studies. A reasonable assumption here is that even if some chemical properties change through submergence and the transition from an oxidizing to a reducing regime, underwater soils will maintain some of the chemical properties they had prior to submergence that are important for an edaphic assessment, such as concentrations of carbonates and trace elements. Still, another important factor that needs to be considered is the preservation potential of soil horizons in the offshore sedimentological records. Such horizons would be found only in certain contexts - i.e. rapid flow event and immediate burial with no erosion episode happening in between - which are rare. Perhaps, transitional environments, such as the shores of a palaeolake, would hold advanced chances of preservation and retrieval of soils from previously exposed land surfaces.

Examples from terrestrial contexts in Israel and E. Africa (Kübler et al., 2015; 2016; 2019; Devès et al., 2014; 2015), suggest that chemical analyses of current soils, in tectonically active environments, can reveal fascinating aspects of hominins' behaviour regarding exploitation and mobility, which could not be inferred by the available archaeological evidence alone. For the Aegean a first promising pilot-study, would examine southern Lesbos focusing on Rodafnidia LP location and its immediate surrounding area, including the submerged landscape in the current Kalloni Gulf, to the NW. In a way, this would represent a laboratory (a) for testing the new approach in a local scale before attempting wider spatial associations, and also (b) for evaluating the effectiveness of the method in establishing reliable links between present day soils and past conditions (through chemical compositions) in transitional environments and between currently on-and off-shore areas. The application of edaphics in a pilot-study of this nature would only be the starting point to develop a methodology with a wider reach, beyond the Aegean Palaeolithic, suitable to investigate other eastern Mediterranean hot spots during early prehistory, such as the Cypriot-Levantine passages, or even similar contexts outside the eastern Mediterranean such as the Red Sea.

7.5 Final remarks

The methodological scheme developed in this thesis, should be viewed as a work in progress within a fast-accelerating new discipline. In that sense, the proposed models are far from being complete or perfect in their detail. They could, and certainly should, be enhanced with the addition of new variables (e.g. paleoclimate, soil quality) and refined information on palaeogeography and palaeoenvironments. Nevertheless, this initial step allowed for the first time a synthetic reading of the available evidence from the Aegean region, over time and space. Despite methodological challenges and practical limitations, the results from this work are considered solid enough to contribute a twofold contribution in the current discourse: (a) new scenarios regarding hominin dispersal routes and settlement areas in north-eastern Mediterranean during the Early and Middle Pleistocene and (b) new ways to model and conceptualise hominin activity and mobility. Both are left to future LP research to be confirmed or rejected.

Chapter 8 Concluding remarks

This thesis centres around two main research questions (hereinafter RQ):

1. Can we suggest possible zones of hominin activity that correspond to exploitation territories taking into account: (a) the topographic complexity of the landscape, (b) the suggested richness of natural resources during the Middle and potentially the Early Pleistocene and (c) the raw material availability (especially of volcanic origin) over the Aegean exposed landscapes?
2. Can we suggest possible corridors of opportunity for hominin dispersal traversing the Aegean exposed landscapes?

Followed by three sub-questions:

I. Is it possible to identify areas with high potential for the Lower Palaeolithic research over the Aegean?
II. Consequently, can we target specific areas to investigate for the Lower Palaeolithic evidence?
III. To what extent is it possible to observe and conceptualise hominin movement and occupation patterns over the Aegean regional scale?

The investigation of behavioural patterns, such as hominin movement and occupation, in the Aegean region during the Lower Palaeolithic is complex and controversial, conditioned by two interrelated factors: massive changes in the landscape due to active tectonics, and poor availability and fragmented preservation of the archaeological and paleoanthropological material. In practical terms, this means that the current geographical configuration is only partially representing the past landscape, with significant parts over which hominins settled and navigated during the Early and Middle Pleistocene, now laying beneath the sea; and that the chance of recovering archaeological and palaeoanthropological remains from this area is small and restricted to specific spatiotemporal windows of opportunity. Although this seems like a daunting situation, the results from this thesis demonstrate that aspects of hominin movement and occupation can still be explored through the development of new hypotheses.

The methodological challenges emerging from the Aegean context, however, could not be addressed successfully by archaeological methodologies alone. In order to answer the research questions, an interdisciplinary approach is required. In the affordance-based GIS framework built here, various lines of evidence, and proxy data, from archaeology, palaeoanthropology, palaeogeography and palaeoenvironments are integrated within a GIS environment, leading to a better understanding of the nature of the past landscapes and the place of hominins within their natural world. The points of interaction between the hominin factor and the palaeolandscape is key to identify areas with high research potential over the modern landscape.

The affordance corridors of the Aegean hypothesis, generated within this framework, highlights certain areas over the submerged landscapes of the northern and central Aegean that correspond to potential zones of hominin activity (exploitation and settlement) (RQ 1) and corridors of opportunity for movement/dispersal (RQ 2) during the Early and Middle Pleistocene (from at least MIS 10-12 until at least MIS 8), when these parts would have been exposed. The suggested areas on the modern landscape (on-and off-shore) coincide with certain parts of the palaeolandscape where opportunities for hominins regarding survival, exploitation and dispersal would have been high based on suitability. Suitability is built upon the concept of affordances, and associates with the occurrence and distribution of certain landscape features/natural resources (water supplies, knappable volcanic rocks, and topographic prominence) – parameters set in RQ 1 – that would improve the chances of survival, exploitation and dispersal for hominins being able to take advantage of those resources. The new methodological scheme can be further expanded with the addition of new affordance variables that would affect suitability. Climatic evidence and soil quality (edaphics) could offer new insights regarding landscape use and exploitation strategies, contributing significantly towards this direction in the future research.

The complex topography concept is a structural element, in this approach. The study of the modern dynamic landscape in the Aegean, on-and off-shore (by recording surface roughness), reveals useful information about the topographic complexity of the past, especially in stable areas and/or where the main palaeolandscape features remain unchanged in the current configuration. This offers only an approximation for the nature of the past environments and their affordances, but it permits the treatment of the palaeolandscape-including the modern-day land surface and the submerged parts of the continental shelf-as a whole, with a preliminary identification of areas with research potential above and below the current sea-level (RQ I).

In this thesis, drawing inspiration from the phenomenolological approach, the Early and Middle Pleistocene landscape is perceived as a lived space, where early settlers and navigators left their marks. This does not mean however, that the method developed here aims to produce an accurate representation of the deep past. It would be naive given the limitations, which are inherent in the LP Aegean context, and improbable in practical terms. The method is rather providing a framing heuristic to test new ideas on hominin movement and occupation over changing, dynamic landscapes (RQ III). In that sense, the results should not be interpreted as suggestive of specific occupation areas and corridors for dispersal *per se* across the Aegean during the Early and Middle Pleistocene, but only as indicative of areas with conditions that would favour survival (RQ1) and facilitate dispersal (RQ2), based on the specific variables examined. As such, these areas signify targets for the future research holding increased potential for retrieving evidence of the hominin activity during the LP (RQ II).

The interpretations provided here, rely to a great extent, on proxy data and GIS modelling. This is not negligible nor necessarily problematic, but it can only be meaningful if these results are continuously updated and refined through testing against new field data.

This study is laying the foundations for a more holistic consideration of the Aegean region during the Early and Middle Pleistocene, (a) contributing to the methodological discourse within the new but fast-advancing discipline of the continental shelf prehistoric research, and (b) enhancing the arguments for the re-positioning of the north-eastern Mediterranean towards the centre in the discussion about the early out of Africa dispersals and settlements. An alternative reading of the available LP evidence from this part of Eurasia is proposed; one that would require seeing beyond the current viewing angle:

A. Our perception of the palaeogeography of eastern and north-eastern Mediterranean and specifically of the Aegean region needs to be re-adjusted. The existence of extended exposed lands during the Middle, and possibly during the Early, Pleistocene over the area now covered by the northern and central Aegean Sea, needs to be embedded in the archaeological thought and practise.
B. Instead of adopting the prevailing 'terrestrial Eurocentric' point of view in the discussion for the initial peopling of Europe and the dispersal routes followed by early hominins, the Balkans and western Anatolia, including the exposed lands of the Aegean, are viewed as a core area for the survival and circulation of populations during the Early and Middle Pleistocene. Offering an alternative or perhaps a complementary scenario to the existing ones, involving also the eastern gateways to Europe.

Appendix A Faunal species - names

Source: BioLib (https://www.biolib.cz/en/main/) [accessed 07-09-2018]

Scientific name	**Family**	**Common name**
Equus apolloniensis	*Equidae*	Horse
Pontoceros ambiguous mediterraneus	*Bovidae*	African Antelope
Soergelia brigittae	*Bovidae*	Ox
Hemitragus orientalis	*Bovidae*	Tahr-Wild Goat
Praeovibos mediterraneus	*Bovidae*	Giant Maskox
Ovis sp.	*Bovidae*	Sheep
Bison sp.	*Bovidae*	Bison
Praemegaceros pliotarandoides	*Cervidae*	Deer and Moose
Arvernoceros sp.	*Cervidae*	Deer and Moose
Canis	*Canidae*	Wolf, Coyote, Jackal, Dingoes and Dog
Pachycrocuta brevirostris	*Hyenidae*	Spotted Hyena
Megantereon cultridens	*Felidae*	Saber-toothed Cat
Lynx issiodorensis	*Felidae*	Bobcats
Megatherion whitei	*Felidae*	Saber-toothed Cat
Praemegaceros sp.	*Cervidae*	Deer and Moose
Hippopotamus antiquus	*Hippopotamidae*	European Hippopatamus
Stephanorhinus sp./Rhinorerotidae - rhinoceroses	*Rhinocerotidae*	Rhinoceroses
Equus cf. aluticus	*Equidae*	Horse
Bison priscus	*Bovidae*	Steppe Bison
Bos primigenius	*Bovidae*	Bos

Appendix A

Scientific name	**Family**	**Common name**
Capreolus sp.	*Cervidae*	Deer and Moose
Dama sp.	*Cervidae*	Deer and Moose
Cervus elaphus	*Cervidae*	Deer and Moose
Hippopotamus	*Hippopotamidae*	Hippopotamuses
Sus scrofa	*Suidae*	Wild Boar
Stephanorhinus kirchbergensis	*Rhinocerotidae*	Rhinoceroses
Stephanorhinus hemitoechus	*Rhinocerotidae*	Rhinoceroses
Palaeoloxodon antiquus	*Elephantidae*	Straight-tusked Elephant
Crocuta/ hyenidae - hyena	*Hyenidae*	Hyena

Appendix B One-sample Kolmogorov-Smirnov test

I. Examining the distribution of the LP sites with respect to surface roughness

To analyse statistically the distribution of the Aegean LP sites with respect to surface roughness, a one-sample Kolmogorov – Smirnov test is calculated.

One-sample significance tests, such as this one, allows us to test an archaeological sample (in this case the locations of the LP sites) against a spatial variable, a background environment – which consists of the population (in this case surface roughness), to ascertain whether characteristics from the sample are unusual or depart significantly from what is the norm in the population (Kvamme 1990). GIS applications make the generation of the values required for this kind of analysis very easy. The grid cells of the surface roughness raster are treated here as the population, and the cells corresponding to the location of the LP sites as the sample. In this way, the characteristics of the sample can be directly compared with the characteristics of the population. The test will ultimately help us to understand if the LP sites are preferentially distributed on particular values of surface roughness, by testing two opposing hypotheses.

The null hypothesis (H_0) supports that the distribution of the sample values is random in regards to the distribution of the population values, while the alternative hypothesis (H_1) supports a non-random pattern.

The null hypothesis set here is that:

H_0 = the locations of the LP sites over the Aegean region are randomly distributed with respect to surface roughness

In order to run the test, the following information is required:

1. The overall distribution of surface roughness values in the TPI grid – the ‘population’ values.

The grid corresponds to the Topographic Position Index (TPI) (3km radius) raster – which has been selected as the best metric for recording topographic roughness in the Aegean region, for the purposes of this study (see section 5.2.3.3 in chapter 5).

2. The number of LP sites in each surface roughness class – the ‘sample’ values.

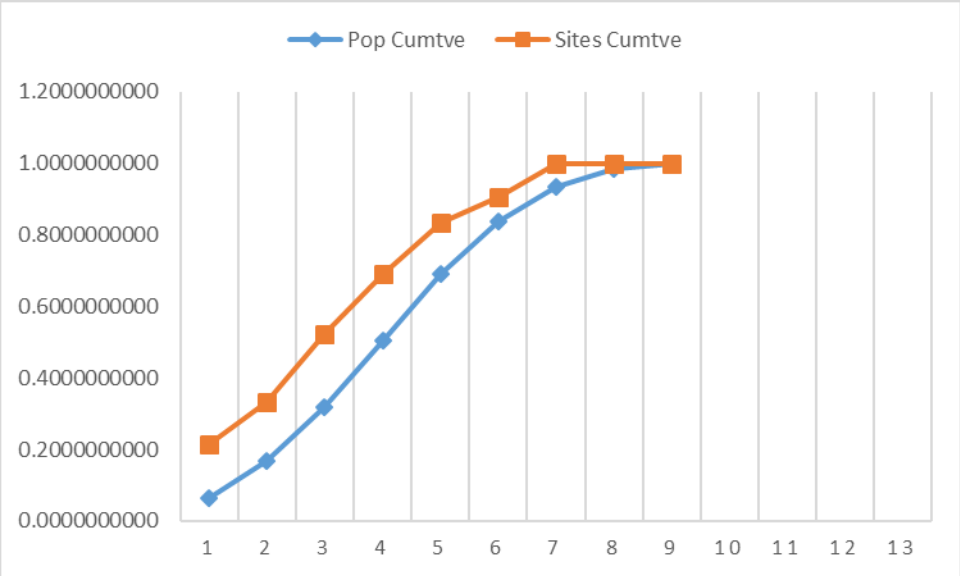
The Kolmogorov-Smirnov test, provides a probability of the observed pattern to be a product of chance (random or non-random distribution), by comparing the cumulative distributions of the sample and the population values. In other words, whether or not the sample deviates significantly from the population (Wheatley and Gillings 2002: 140). If the maximum difference between the cumulative distributions (D_{max}) is greater than a calculated (theoretical) value (d) (derived from probability theory), then it can be argued that the sample is not randomly drawn from the population values, rejecting the null hypothesis. The threshold value corresponds to an expected value based on the number of the sample (n) and the level of significance (α).

Population values are extracted from the TPI (3km radius) raster. What we need to know is how many grid cells are contained in each of the surface roughness values. To make things easier, the raster is reclassified into 10 classes (Spatial Analyst Tools> Reclass> Reclassify> Quantile method). In the reclassified raster, in the attribute table, under the Count column we have now the required information, the count of the grid cells - i.e. the distribution of population values, in each of the 10 classes. The table is exported (Export> from the table menu, in dbf format), and then opened in an excel worksheet.

To generate the sample values, we need to know how many LP sites occur in each of the topographic roughness classes, used above. This is done in two steps. First, the surface roughness class values are added to the LP locations point file as a new column (Spatial Analyst tools> Extraction> Extract values to points; input raster: reclassified (10 classes) surface roughness; input shapefile: point file with the locations of the LP sites). Then the new column (RASTERVALU) in the point file attribute table is summarised to count the LP sites in each surface roughness class (right click on the RASTERVALUE column> select 'Summarize' from the menu> leave the summary statistics un-checked> and specify an output table (dbf format). This table is opened in Excel as before, and it shows how many LP sites occur in each of the frequency bands. This is the sample data that will be compared with the population data – acquired in the previous step.

All information is gathered in one excel sheet in order to run calculations – see Table below. The VALUE column corresponds to the topographic roughness classes, the COUNT to the number of cells included in each class (population values) and the LP_LOC to the number of LP sites found in each class (sample values). Each value needs to be expressed as a proportion of its total, so that they can be compared. This is done by dividing each value from the COUNT and the LP_LOC by its total. Results can be seen in the PopProp and LocProp columns. These proportions need to be converted now into cumulative proportions for the Kolmogorov-Smirnov test. These can be found in the PopCumutv and LocCumutv columns, where each value has occurred by adding the values from the cell above it, plus the one to the left of it. Lastly, the maximum difference between the two cumulative distributions is calculated. In this specific example, the maximum difference occurs in value 3 of the suitability classes, where the difference is 0.2050505722.

VALUE	COUNT	Pop prop	Pop Cumtve	SITES	Sites prop	Sites Cumtve	Diff
1	113677323	0.0649271498	0.0649271498	9	0.2142857143	0.2142857143	0.1493585645
2	181258982	0.1035266206	0.1684537704	5	0.1190476190	0.3333333333	0.1648795629
3	263160953	0.1503051812	0.3187589516	8	0.1904761905	0.5238095238	0.2050505722
4	324729028	0.1854699750	0.5042289266	7	0.1666666667	0.6904761905	0.1862472639
5	325984456	0.1861870166	0.6904159432	6	0.1428571429	0.8333333334	0.1429173902
6	254902269	0.1455882086	0.8360041518	3	0.0714285714	0.9047619048	0.0687577530
7	170526377	0.0973966605	0.9334008123	4	0.0952380952	1.0000000000	0.0665991877
8	88979095	0.0508206816	0.9842214939	0	0.0000000000	1.0000000000	0.0157785061
9	27625706	0.0157785063	1.0000000002	0	0.0000000000	1.0000000000	0.0157785061
TOTAL	1750844189	1.0000000002		42	1.0000000000		



Appendix B - Graph 1. Graph from excel data depicting the two cumulative frequencies. The maximum difference between the population (Pop Cumtv) and the sample (Sites Cumutv) cumulative distributions is observed in value 3 of the surface roughness values. Population=topographic roughness and Sample=LP sites

In this example, the maximum difference between the cumulative frequencies is 0.205050 and occurs in value 3 of the surface roughness values.

For our sample size (n=42), with a level of significance α=0.05, the theoretical (critical) value from Table 1, below, is:

$$\frac{1.36}{\sqrt{n}}$$

Which equals 0.209852. The observed value (0.205050) is less than the critical value, thus according to the test, the null hypothesis that the locations of the LP sites over the Aegean region are randomly distributed with respect to surface roughness, can be confirmed.

n	$\alpha = .20$	$\alpha = .10$	$\alpha = .05$	$\alpha = .02$	$\alpha = .01$
1	.900	.950	.975	.990	.995
2	.684	.776	.842	.900	.929
3	.565	.636	.708	.785	.829
4	.493	.565	.624	.689	.734
5	.447	.509	.563	.627	.669
6	.410	.468	.519	.577	.617
7	.381	.436	.483	.538	.576
8	.358	.410	.454	.507	.542
9	.339	.387	.430	.480	.513
10	.323	.369	.409	.457	.489
11	.308	.352	.391	.437	.468
12	.296	.338	.375	.419	.449
13	.285	.325	.361	.404	.432
14	.275	.314	.349	.390	.418
15	.266	.304	.338	.377	.404
16	.258	.295	.327	.366	.392
17	.250	.286	.318	.355	.381
18	.244	.279	.309	.346	.371
19	.237	.271	.301	.337	.361
20	.232	.265	.294	.329	.352
21	.226	.259	.287	.321	.344
22	.221	.253	.281	.314	.337
23	.216	.247	.275	.307	.330
24	.212	.242	.269	.301	.323
25	.208	.238	.264	.295	.317
26	.204	.233	.259	.290	.311
27	.200	.229	.254	.284	.305
28	.197	.225	.250	.279	.300
29	.193	.221	.246	.275	.295
30	.190	.218	.242	.270	.290
31	.187	.214	.238	.266	.285
32	.184	.211	.234	.262	.281
33	.182	.208	.231	.258	.277
34	.179	.205	.227	.254	.273
35	.177	.202	.224	.251	.269
36	.174	.199	.221	.247	.265
37	.172	.196	.218	.244	.262
38	.170	.194	.215	.241	.258
39	.168	.191	.213	.238	.255
40	.165	.189	.210	.235	.252
Over 40	$\frac{1.07}{\sqrt{n}}$	$\frac{1.22}{\sqrt{n}}$	$\frac{1.36}{\sqrt{n}}$	$\frac{1.52}{\sqrt{n}}$	$\frac{1.63}{\sqrt{n}}$

Appendix B - Table 1. Critical values for the Kolmogorov-Smirnov one-sample statistical test

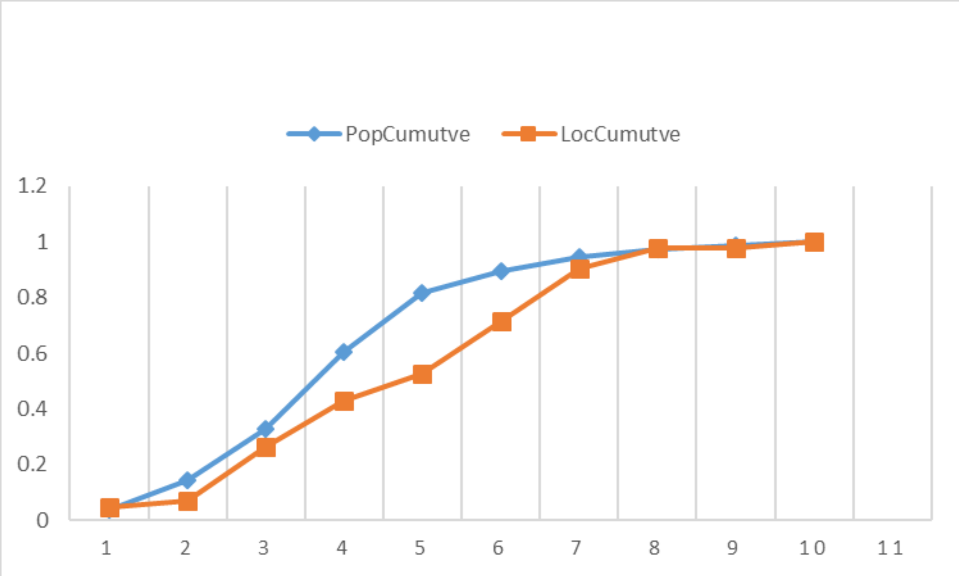
II. Examining the distribution of the LP sites with respect to suitability

The same process, as described before, is followed in order to analyse statistically the distribution of the Aegean LP sites with respect to suitability (see section 5.3.2 – Ch.5).

In this example, the population values are extracted from the grid that corresponds to the Suitability Model for the 0.4-0.2 Mya interval, since most of the known LP sites from the Aegean (with available dates either absolute or relative) are dated between 400Kya and 200 Kya, with the exception of Marathousa 1 and Rodafnidia, which are older than 400 Kya.

The calculations on the population (suitability values) and the sample values (LP locations) for the Kolmogorov-Smirnov test can be found in the table below:

VALUE	COUNT	PopProp	PopCumutv	LP_LOC	LocProp	LocCumut	Diff
1	63791871	0.03667788	0.03667788	2	0.047619	0.047619	0.010941
2	186323894	0.10712908	0.14380696	1	0.02381	0.071429	0.072378
3	322548038	0.18545274	0.3292597	8	0.190476	0.261905	0.067355
4	475786434	0.27355893	0.60281863	7	0.166667	0.428571	0.174247
5	369521740	0.21246081	0.81527944	4	0.095238	0.52381	0.29147
6	140098441	0.08055122	0.89583066	8	0.190476	0.714286	0.181545
7	85164780	0.04896648	0.94479714	8	0.190476	0.904762	0.040035
8	47930640	0.02755828	0.97235542	3	0.071429	0.97619	0.003835
9	26086942	0.01499899	0.98735441	0	0	0.97619	0.011164
10	21993800	0.01264559	1	1	0.02381	1	0
Total	1739246580	1		42	1		



Appendix B - Graph 2. Graph from excel data depicting the two cumulative frequencies. The maximum difference between the sample (LocCumutve) and the population (PopCumutv) cumulative distributions is observed in value 5 of the suitability values. Population=suitability index and Sample=LP sites

The maximum difference between the cumulative frequencies is 0.29147 and occurs in value 5 of the suitability values.

For our sample size (n=42), with a level of significance α=0.05, the theoretical (critical) value from Table 1, below, is:

$$\frac{1.36}{\sqrt{n}}$$

Which equals 0.209852. The observed value (0.29147) is greater than the critical value, thus according to the test, the null hypothesis that the locations of the LP sites over the Aegean region are randomly distributed with respect to suitability, can be rejected.

Appendix C Metadata

Software	Description	Source
ArcMap (versions 10.4 - 10.7)	ArcMap is a facet of the ArcGIS desktop suite. It has been used for geoprocessing and editing of data and for conducting spatial analyses and creating maps	Software and licence for use provided by the University of Southampton
Metadata	**Description**	**Source**
Digital Elevation Model	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 2 (GDEM V2) (30m resolution), released Oct 2011	NASA Land Processes Distributed Active Archive Center (LP DAAC) – open access
Bathymetry	Eastern Mediterranean Bathymetric Map (250m resolution) – released Apr 2016	Provided by courtesy of the Hellenic Centre for Marine Research – now available through the EMODnet Bathymetry Portal

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