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The Geoarcheology of Greece: Shaping Landscapes Versus Crises and Resilience of the Past

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Abstract

Greece is recognized worldwide for its archeological remains. These bear witness of a long human history, from the early stages of the Neolithization of Europe, ca. 8500 years ago, to the apogee of city-states in ancient Greece. This early occupation by populations of farmers and stock breeders had a long-term impact on the environment. Deforestation and soil erosion associated with prescribed fire and the development of agricultural practices have significantly contributed to shaping the geography of the country, from the Balkan Mountains to the Aegean coast. The anthropogenic imprint on the environment has not been without consequences, and past societies had to adapt to environmental crises, such as climate fluctuations, sometimes caused or reinforced by anthropogenic factors. Greece is also a place where Western science emerged and where scholars could discuss at a very early stage the role of these practices in the transformation of the environment. A synthesis of the intensive research conducted in the area of geoarcheology, paleoenvironment, and geohistory on the dynamics of coastal and continental areas evidences the magnitude of changes observed over the last ten millennia. It also reveals a huge and lasting geographical legacy and illustrates the way societies brought, were subjected, or adapted to change. We will discuss here issues relating to geographical and climate determinism, socio-environmental crises, and the ability of societies to adapt to environmental change.

Keywords (separated
by “ - ”)

Geoarcheology - Environmental crises - Coastal dynamics - Geohistory -
Human footprint

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2

4 Laurent Lespez and Matthieu Ghilardi

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Keywords

Geoarcheology · Environmental crises · Coastal dynamics · 34
Geohistory · Human footprint 36

Introduction

37
38 In the Critias, Plato compares Attica with the “bones of a
39 wasted body... a mere remnant of what it once was.” This
40 has been interpreted by many scholars as a testimony of the
41 effect of an extensive erosion already observed in ancient
42 times. Greek landscapes are often viewed as degraded
43 because of the cumulative actions of agro-pastoral and urban
44 societies since the Neolithic period. For some the process
45 leads to the *Ruined Landscape* concept and to the mourning
46 of a *Lost Eden*, arguing that human action resulted in a
47 cumulative degradation and desertification of Mediterranean
48 landscapes (Grove & Rackham, 2003). Therefore, the
49 responsibility of past human societies in the transformation
50 of Aegean environments, which causes land alteration, is a
51 key area of focus for researchers interested in the study of
52 long-term landscape and environmental changes.

53 The issue has led to the multiplication of works in a range
54 of disciplines (physical geography, geomorphology, micro-
55 morphology, palynology, carpology, anthracology, etc.)
56 based on the study of archeological sites or their immediate
57 surroundings with the purpose to define paleoenvironmental
58 dynamics (Fig. 2.1). These interdisciplinary initiatives define
59 what constitutes the *geoarcheological approach*. Some con-
60 sider that agro-pastoral systems develop through a co-
61 production mechanism associating society and its
62 surrounding environment. Sedimentary archives on- and off-
63 site are the main source of information for the agro-pastoral
64 activities of past societies and more generally for the man-
65 agement of natural resources. This research is based on the
66 analysis of sediments accumulated over the last millennia
67 and is only supplemented by written sources from the Late

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Fig. 2.1 The Minoan palatial city of Phaistos and the Messara Plain (Crete). (Source: M. Ghilardi 2012/12/20)

68 Bronze Age onwards. The layers of sediments deposited by
 69 river runoff on the base of slopes (colluvium) and in valley
 70 bottoms, coastal plains (alluvium) or lakes (lake deposits)
 71 then constitute the chronicles of a history to be decrypted.
 72 This investigative work operates using two spatial scales:
 73 first, the place of record, the evolution of which can be
 74 traced; and the watershed level (or beyond), because sedi-
 75 ments brought by rivers or winds, like pollen, also integrate
 76 what happens on a larger scale. Exploiting the data collected
 77 from natural archives means establishing an accurate chro-
 78 nology based on the use of archeological evidence or
 79 methods deriving from absolute radiocarbon¹ or Optical
 80 Stimulated Luminescence (OSL)² methods (Table 2.1).

¹In its lifetime, the carbon of living organisms remains in balance with its environment (atmosphere and hydrosphere). When death occurs, ¹⁴C decays at a known rate in relation to ¹²C and this process allows for sample dating.

²OSL method use quartz and feldspar grains. During the grain deposit period within a sediment, the electrons are trapped in a crystalline structure. Under light stimulation, they may be released from the trap and emit a photon. By measuring the emitted luminescence, we can quantify the amount of ambient radiation stored in the crystal. Dating is done through a comparison between the radiation emitted by the studied grain and the average radiation received by the sediment per year.

The Emergence of Cultural Landscapes in Greece

81 During the last glacial period (Pleistocene), Greece was
 82 mainly characterized by both an open steppe composed of
 83 Artemisia and shrubs, with a poor diversity of species, except
 84 in places of refuge where tree vegetation had retreated. At
 85 the beginning of the Holocene (9700 BCE),³ global warming
 86 led to the development of a forest cover consisting mainly of
 87 deciduous oaks accompanied by elms, lime trees, and hazel
 88 trees, whereas pines and firs took on a more important place
 89 with an increase in altitude (Masi et al., 2018). In drier areas
 90 such as Crete (Fig. 2.2), the maximum extent of forest covers
 91 seems to be reached only later (Bottema & Sarpaki, 2003).
 92 From 8500 BCE to the Late Neolithic period (4000 BCE),
 93 forest covers become more diverse due to a reclamation pro-
 94 cess resulting from a more humid and warmer climate (the
 95 Holocene climate optimum), which leads to a greater and
 96 more gradual contribution of organic matter to soil formation
 97 and development. This in turn favors the growth of vegeta-
 98 tion and generates an increased diversity observed in succes-
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 100

³Before the Common Era, year notations for the Gregorian calendar.

Table 2.1 Reference chronology used for Greece with the corresponding cultural and historical phases

Time: Before the Common Era (BCE)/ Common Era (CE)	Cultural and historical period
1460–1832	Ottoman
641–1460	Byzantine
324–641 CE	Late Roman/early byzantine
31 BCE–324 CE	Roman
323–31 BCE	Hellenistic
480–323 BCE	Classical
700–480 BCE	Archaic
1050–700 BCE	Early iron age
1650–1050 BCE	Late bronze age
2000–1650 BCE	Middle bronze age
3200–2000 BCE	Early bronze age
4000–3200 BCE	Final Neolithic
5500–4000 BCE	Late Neolithic
6000–5500 BCE	Middle Neolithic
6800/6500–6000 BCE	Early Neolithic

Source: From Weiberg et al. (2019)

sions that obey the ecological laws specific to each plant species (cycles of installation and development, aptitudes for interspecific competition, etc.). The beginning of the period is marked by the development of pistachio trees in the warmer areas and then by hazelnut, lime, elm, ash, and fir, and finally by the expansion of oriental hornbeam, hop hornbeam in deciduous oak forests, and beech and fir at the montane level (Willis, 1994; Kotthoff et al., 2008; Masi et al., 2018). In the early Neolithic period, local communities could thus benefit from a forest environment supplying multiple resources.

Whether landscapes were shaped by Neolithic farmers and to which extent is an issue precisely addressed in several regions of Greece. The first Neolithic societies developed in the Aegean world between 6800 and 6200 BCE (Perlès, 2001; Lespez et al., 2013). To the south, cutting down oaks, grazing herds, burning scrubland, and planting olive trees are among the human activities recorded in the pollen diagram of Lake Kourmas in Crete at the end of the Early Neolithic (Bottema & Sarpaki, 2003) and during the Late Neolithic in the Peloponnese (Weiberg et al., 2016). We exemplified the renewal of knowledge about environmental change caused by human action in Greece through research carried out in Eastern Macedonia over the last years. These investigations reveal that the local environment was considerably more open during the Early Holocene than it was supposed to be (Kotthoff et al., 2008). More specifically, the edge of a large wetland typical of intramountainous basins was covered by fallow lands and meadows (Glais et al., 2016a), whereas deciduous oak was characteristic of southern Greek landscapes (Weiberg et al., 2019). Further, agricultural practices were detected near some Early Neolithic sites, such as Dikili Tash (circa 6500–5700 cal BCE; Glais et al., 2016a).

The Late Neolithic (5500–3900 BCE) was marked by an increase in the number of regional settlements—a phenomenon observed throughout Greece (Weiberg et al., 2019). The geographical permanence of habitat over 1500 years, with 25 villages known in the Philippi-Drama Plain, questions the impact of Neolithic societies on their environment. The occurrence of coprophilous Non-Pollen Palynomorphs confirms the development of pastoralism while zooarcheological research validates the existence of livestock management at some sites such as Dikili Tash. The discovery of cereals at a distance of 2 km away from the archeological site of Dikili Tash is related with the identification of stored cultivated crops of the Neolithic package on sites (einkorn, naked barley, lentil, bitter vetch, grass pea, and flax) (Glais et al., 2017). This indicates a large expansion of cultivated fields around the Late Neolithic village (Marinova & Ntinou, 2018) even though hunting and gathering persisted (Valamoti, 2015).

The data obtained from Dikili Tash confirm that farmers adopted subsistence practices that had gradually altered the landscapes within a radius of at least 2 km around the settlement during the second phase of the Late Neolithic (4500–3900 cal BCE). Growing practices, the beginning of anthropogenic fires, and the development of secondary anthropogenic indicators (anthropic-nitrophilous and anthropozoogenous taxa) indicate that agriculture created a mosaic of landscape units combining open areas with grazing and farming activities, fallow lands, and secondary forest patches or relicts of the original forest (Glais et al., 2017; Weiberg et al., 2019). Everywhere, the abundance and careful management of natural resources seem to explain the longevity of settlement patterns. In Eastern Macedonia, this results in a regional scale change confirmed by pollen data collected in the Lower Strymon Valley about 50 km further west (Lespez et al., 2016).

The Bronze Age (ca. 3200–1050 cal BCE) reveals a significantly more complex social structure (Bennet, 2013) and shows a continuous decrease of forest covers confirming large-scale land clearing by agricultural practices in Greece. The decline of mixed deciduous oak woodlands and the expansion of evergreen Mediterranean vegetation is observed in many Greek areas (Weiberg et al., 2016). Regardless of human activities, the process is the consequence of a climate Mediterraneanization in the Aegean area after 2500 cal BCE, which resulted in increased winter-season precipitation and intense summer aridity (Kuhnt et al., 2008). Moreover, agrosystems became increasingly complex as indicated by a greater diversity of cultivated plants (Weiberg et al., 2016). For example, palynological data suggest that olives may have been exploited since the Late Neolithic in southern Greece and Crete. They would have played a significant local role during the Bronze Age (Bottema & Sarpaki, 2003; Kouli, 2012; Kyrikou et al., 2020).



Fig. 2.2 Hydro-topographic map of Greece and location of the sites mentioned in the text. (Source: L. Lespez, M. Ghilardi)

187 Despite similarities in the observed general trends, it is
 188 clear that we do not deal with a uniform crop pattern through-
 189 out Greece. The development of regionally diversified land
 190 management systems takes place within a rural world that
 191 uses all the available space through a variety of activities.
 192 During the Late Bronze Age in Crete and southern Greece,
 193 the density of archeological sites—palaces, “large resi-
 194 dences,” rural settlements, and isolated farms—suggests an
 195 exploitation of almost all arable land. Land appropriation in
 196 lower areas is complete and there is considerable growth in
 197 sheep breeding (Poursat et al., 2008). During the Mycenaean

period, the palaces managed tens of thousands of sheep
 divided into flocks of several hundred heads, mainly for wool
 production (Rougemont, 2014). Alongside agricultural
 intensification due to improved techniques, the construction
 of terraces is also testified (Betancourt & McCoy, 2012) and
 extensive breeding develops, using much of the available
 land, particularly in mountain areas. In many regions of
 Northern Greece and specifically in Eastern Macedonia,
 extensive agricultural and herding strategies appear to be a
 complement to small-scale, mixed, and more intense farming
 practices (Glais et al., 2017).

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209 To sum up, in the history of Greek landscapes the Bronze
 210 Age is a key period characterized by the creation of a
 211 Mediterranean countryside made of woodlands and cultivated
 212 areas quite similar in proportion to contemporary landscapes.
 213 Moreover, the making of rural landscapes in diverse cultural
 214 and political contexts testifies to the birth of a truly varied
 215 regional geography. Thus, the emergence of Greek antiquity
 216 took place in a world already largely and sustainably
 217 anthropized during a long Paleo-Anthropocene era (Foley
 218 et al., 2013). This is the context surrounding the testimony of
 219 Theophrastus in Eastern Macedonia: “at Philippi there was
 220 formerly more freezing of trees; but at present now that the
 221 water has for the most part disappeared underground and
 222 been dried out, and the whole country has come under cultiva-
 223 tion, there is much less”.⁴ This account is very stimulating
 224 because it is one of the first testimonies relating a change in
 225 land use with climate change. Theophrastus, a skillful natural-
 226 ist, gives credence to this description even though the informa-
 227 tion provided could not be testified until the completion of
 228 recent inquiries (Lespez, 2008, 2016). The scenario grants a
 229 large place to the action of Greek people in the agricultural
 230 transformation of lower areas after the Macedonian conquest,
 231 which led to the foundation of the city of Philippi in
 232 357 BCE. However, the extensive research undertaken failed
 233 so far to demonstrate the draining of marshlands bordering the
 234 city in the Macedonian era. Recent paleoenvironmental
 235 research shows that this area was a wetland site until the
 236 1930s, even though there are indications of land use intensifi-
 237 cation on the edge of the marsh, associated with herding prac-
 238 tices (Glais et al., 2017). We hypothesize that the center of this
 239 flat plain, north of the main marshy areas, well served by the
 240 royal road, was the object of agricultural development during
 241 Macedonian times (Lespez & Tirologos, 2004). The
 242 Theophrastus testimony is probably not devoid of prejudice
 243 against the Thracian populations that occupied the region
 244 before the conquest and, therefore, of political intention.
 245 Rather than a founding event, this is most certainly the last
 246 development stage of agriculture in the Philippi Plain. The
 247 landscape is already largely anthropized, heralding the final
 248 construction phase of the farming world in northern Greece.

249 Mind the Gap: A Complex Relationship 250 Between Upstream Erosion and Downstream 251 Delta Creation

252 One of the direct consequences of land use development for
 253 agricultural practices and anthropogenic fire activity is soil
 254 erosion. Under Mediterranean climate, with high-intensity
 255 precipitation events and steep slopes, soil exposure through

cultivation or overgrazing can be particularly problematic. 256
 Based on the testimony of Plato and many observations 257
 made of current situations, a significant body of geomorpho- 258
 logical research has been conducted to assess and discuss the 259
 origin of soil erosion in Greece, from the upper slopes of 260
 catchment areas to the downstream sectors made of alluvial 261
 terraces leading to fluvio-deltaic river mouths (Walsh et al., 262
 2019). The Holocene alluvial history of rivers in Greece is 263
 partly documented and focuses mainly on the reconstruction 264
 of deltaic environments while the relationships between 265
 upstream erosion and sediment accumulation mid- and 266
 downstream remain under-explored. Reconstructing the his- 267
 tory of alluvial deposits of Greek mainland rivers is done 268
 through geomorphological and geoarcheological studies 269
 mainly conducted in the Peloponnese, Macedonia, and 270
 Crete (e.g. Dufaure, 1976; Wagstaff, 1981; van Andel et al., 271
 1990; Zangger, 1994; Fouache, 1999; Krahtopoulou, 2000; 272
 Lespez, 2003; Pope et al., 2003; Macklin et al., 2010; Glais 273
 et al., 2016b). These works evidenced major phases of allu- 274
 viation, mainly from the Late Neolithic era. The origin of 275
 alluvial crises has long been discussed. Some mention a mix- 276
 ture, more than a real combination, of natural and anthropo- 277
 genic factors (Bintliff, 2002), others propose an 278
 anthropo-climate model (Lespez, 2003). 279

The research conducted in Eastern Macedonia, from the 280
 Island of Thasos to the Strymon Valley, over the last 20 years 281
 brings opportunity to study the process of sedimentary cas- 282
 cade during the Holocene and the role played by human 283
 activities deployed in watersheds. These investigations are 284
 based on a multiscale approach and combine similarity anal- 285
 yses comparing the alluviation rate for 15 small river basins 286
 mainly controlled by local anthropogenic or climatic events, 287
 with connectivity analyses allowing for a better understand- 288
 ing of the sedimentary cascade between headwaters and 289
 regional floodplains (Lespez, 2007; Fig. 2.3). This provides 290
 an opportunity to discuss the role of climate (events or oscil- 291
 lations) and land use changes resulting from the history of 292
 habitat and the evolution of land use practices. 293

At the local scale, the chronology of alluvial-fill sequences 294
 varies between each individual river basin (0.2–45 sq. km). 295
 Soil erosion and the subsequent alluvial aggradation along 296
 river valleys, on alluvial fans or in coastal plains, are rarely 297
 recorded from the Early Holocene to the Bronze Age. 298
 Nevertheless, anthropogenic soil erosion started locally in the 299
 early Neolithic period (c. 6000 BCE) at the bottom of the 300
 Dikili Tash site. The acceleration of soil erosion comes later, 301
 running from the Thracian period (Iron Age to Classical Greek 302
 period in southern Hellenic areas) to the Roman era. The role 303
 of Thracian settlements has often been underestimated in the 304
 shaping of landscapes in Northern Greece although it played a 305
 major role and initiated a period of widespread farming and 306
 grazing development stepping up over the Hellenistic period, 307
 the Greek conquest, and the Roman Empire. 308

⁴Theophrast - De causis Plantarum, books V-VI. Trad. B. Einarson and G. Link (Editors). 1990. Harvard University Press.

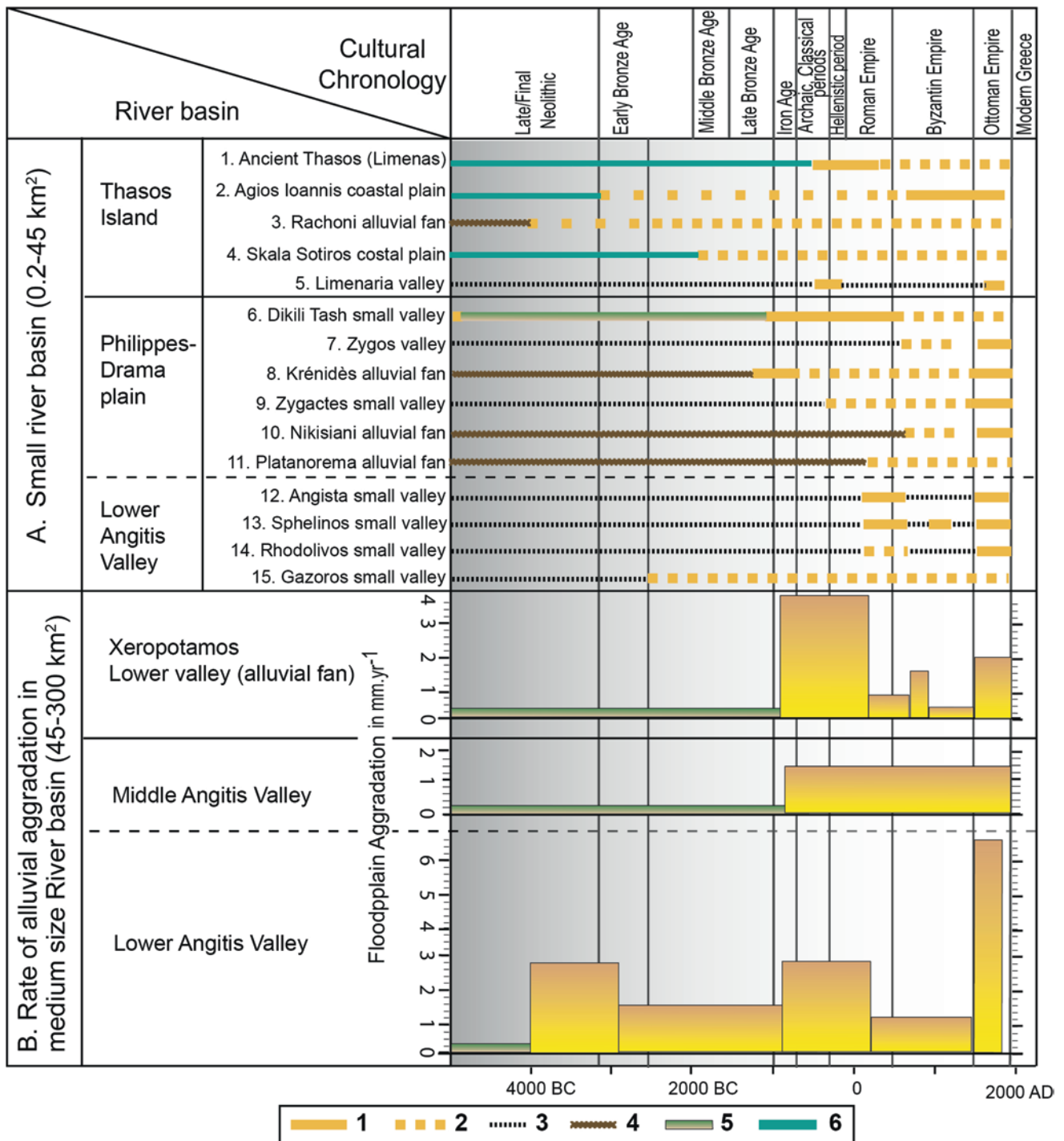


Fig. 2.3 Rate of alluvial aggradation in Eastern Macedonia during the Middle and Late Holocene between small river basins and main rivers. (Source: L. Lespez modified from Lespez, 2007; data from Lespez, 2003, 2007; Lespez et al., 2016, 2017; Glais et al., 2016a, b, 2017) (a) The nature and rate of the alluvial aggradation for small river basins: (1). Continuous detritic sedimentation (overbank deposits);

(2). Discontinuous detritic sedimentation; (3). Erosion-Incision; (4). Soil formation; (5). Thin organic and detritic sedimentation; (6). Marine deposits. (b) Evolution of the rate of alluvial aggradation for different time intervals for medium-sized catchments: the height of the bars is proportional to the sediment accumulation of the alluvial plains expressed in mm/year

309 A second period of soil erosion and alluvial aggradation
310 is recorded during the Ottoman era. It corresponds to more
311 frequent floods that might be explained by the Little Ice Age,
312 but this climatic period is complex in Greece with differenti-
313 ated effects observed on the west coast of the Balkan penin-
314 sula and in the Aegean world (Koutsodendris et al., 2017;
315 Styllas et al., 2018). In fact, this time mainly corresponds to
316 an increased agricultural pressure on foothills and in river
317 valleys, but it also demonstrates the growing incidence of
318 intensive farming and grazing in mountain areas (Lespez,
319 2008) as elsewhere in the Mediterranean world (McNeil,
320 2003; Grove & Rackham, 2003). Thus, soil erosion and allu-
321 vial aggradation along small river basins in Northern Greece
322 are clearly triggered by local human activities, sometimes in
323 connection with the local impact of meteorological events,
324 such as storms and their associated flash floods.

325 This chronology of arrived sediment does not allow
326 assessing the rate of alluvial aggradation along the flood-
327 plain of the main river valleys in the region. In fact, along the
328 Angitis River, which drains the Philippi-Drama plain, the
329 pace of alluvial aggradation begins to speed up sooner. A
330 centennial alluvial event has been recorded in the Lower
331 Valley after 4000 BCE and it is clearly linked with the 4500–
332 3000 BC period of Rapid Climatic Change (RCC) observed
333 at the global scale (Mayewski et al., 2004). Some other short
334 phases of alluvial aggradation can be explained by peak
335 flood flows corresponding to wetter periods recorded at the
336 global scale as it happened during the early Byzantine era
337 along the Xeropotamos (sixth to ninth century CE).

338 Nevertheless, studies of the main river valleys and flood-
339 plains show two historical phases of alluvial aggradation and
340 soil erosion from the Thracian period to the Roman times
341 (eighth century BC–third century CE) and more significantly
342 during the Ottoman period (beginning of the fifteenth to the
343 twentieth century CE). They confirm the role of long-term
344 cultural and land use expansion cycles in the rate of flood-
345 plain aggradation during the Holocene. These periods partly
346 correspond to well-identified climate changes like the wetter
347 periods of the middle of the first millennium BC and proba-
348 bly of the Little Ice Age. For the main rivers, the centennial
349 hydroclimatic oscillations establish the chronology of flood
350 events and control the process of sediment transfers. They
351 stand out as the main control factor explaining the timeline
352 of alluvial aggradation even though the rate of sedimentation
353 is controlled by sediment delivery mainly explained by the
354 history of human activity and particularly farming and graz-
355 ing until the twentieth century. Thus, the research conducted
356 in Northern Greece emphasizes the need for a multiscale
357 approach when attempting to understand the human impact
358 in relation with other changes in medium-sized river basins.

359 Unfortunately, few comparable studies are available about
360 mainland rivers. These have so far been little studied for
361 reconstructing the Holocene alluvial environments based on

robust chronological methods. As demonstrated by the
Eastern Macedonia example, the central course of rivers
could be of great interest to reconstruct the sequence of allu-
vial pulses although the main sedimentary archives inform-
ing us about the Holocene depositional history are to be
found in Greece within deltaic environments (Fig. 2.4).
Deltas are sedimentary features where alluvial material is
deposited within shallow marine environments, and their
growth is both dependent on the bulk and intensity of sedi-
ments that accumulate in a short period of time.

Over the last 50 years and starting with the pioneering
works carried out by Kraft along the Aegean coast (Kraft
et al., 1977), an impressive number of case studies focusing
on the paleogeographic reconstruction of Greek mainland
deltas has been completed. Among these, we can cite the
robust works conducted by Zangger in South Argolida
(Zangger, 1994) and Boeotia (Zangger, 1991). Analysis of
results evidenced an early development of deltas from the
Late Neolithic to the Early Helladic era, a timeline similar to
the one obtained by Kraft et al. (1977) for the Sperchios delta
(West-Central Aegean area). A similar dating of the initial
phase of the Holocene delta progradation has been observed
elsewhere in Greece, in Euboea at Eretria and Amarynthos
(Ghilardi et al., 2018a, b), in Attica (Goiran et al., 2011), or
in the Aliakmon-Axios-Loudis-Gallikos deltaic plain
(Ghilardi et al., 2008a, b).

The rise in sea level and its following stabilization around
2000 BCE play a crucial role in the development of deltas in
Mediterranean areas. Indeed, the melting of ice sheets first
led to a rapid rise (about 12 mm/year) before a slower trans-
gression (0.7 to 1 mm/year) began in the Late Neolithic
(Lambeck, 1995). Within the active and fragmented tectonic
framework of Greece, the restitution of sea-level dynamics is
a complicated exercise, which triggered many research (e.g.
Vött, 2007; Pavlopoulos et al., 2006; Desruelles et al., 2009;
Kolaiti & Mourtzas, 2016; Karkani et al., 2019). A large part
of the coastal plains that existed during the Mesolithic and
Neolithic periods is submerged today and thus out of reach
for terrestrial archeological prospecting. This explains, per-
haps, the scarcity of discoveries for these periods. But with
the stabilization in sea level, delta progradation suggests an
increase in sediment delivery towards the sea by the fluvial
system.

Generally, chronostratigraphic sequences derived from
the radiocarbon dating of the transition from marine to
lagoon/brackish environments assists in indirect identifica-
tion of the first signs of detrital input. In most studies, it is
noteworthy and quite uncommon to identify and date the
detrital input itself. Along both the Aegean and Ionian coasts,
paleoenvironmental studies derived from borehole analyses
(Vött, 2007) have shed light on a general progradation mech-
anism starting with the Late to Final Neolithic, while evi-
dence of environmental disturbance by human practices is

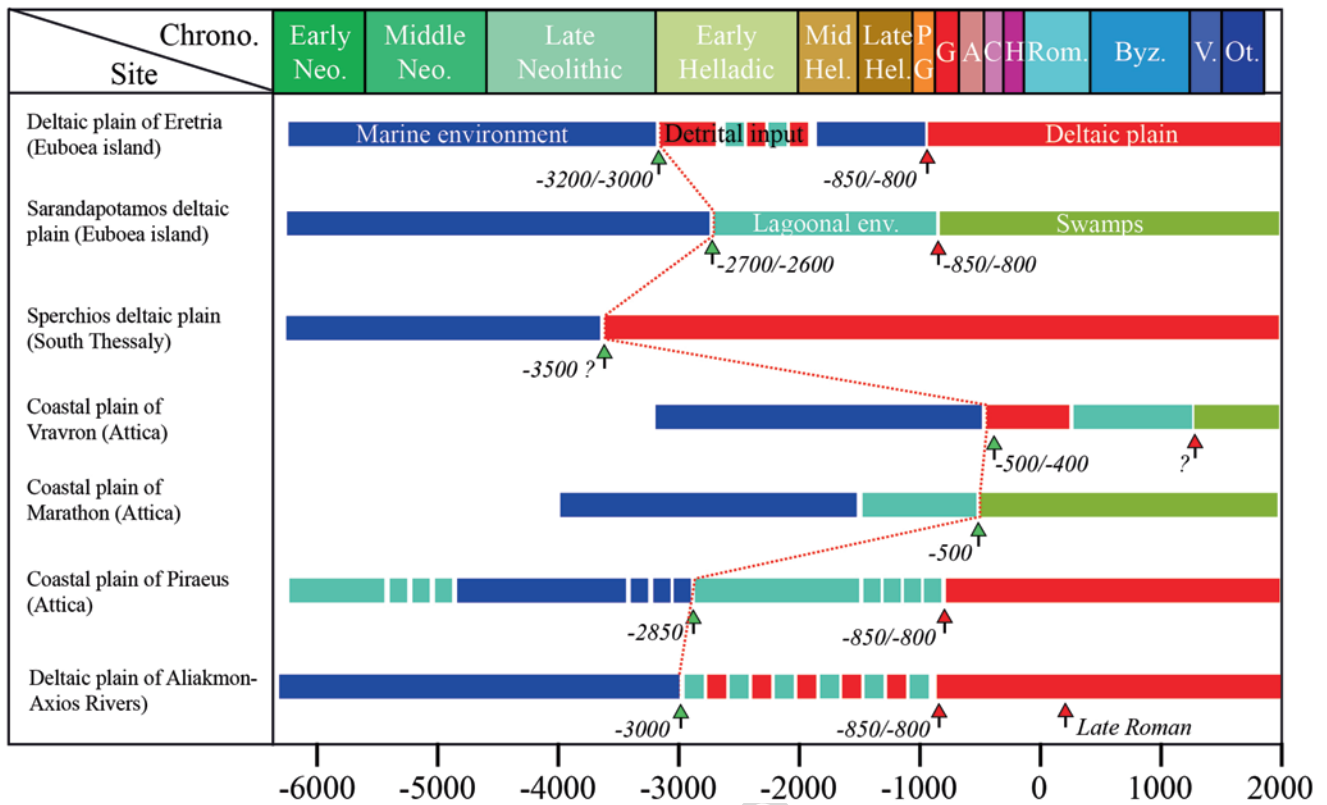


Fig. 2.4 Chronology of delta progradation in the Aegean Sea. (Source: M. Ghilardi)

415 documented from the Early Neolithic age with a greater spa- 441
 416 tial imprint at the beginning of the Bronze Age because 442
 417 demography substantially increased the need for arable land. 443

418 Following the initial deltaic progradation mechanism 444
 419 observed along many large rivers between the Late Neolithic 445
 420 and the Early Bronze Age, several sequences of delta 446
 421 advances are recorded. Among them, we note an intense 447
 422 phase at the beginning of the Geometric period (ninth cen- 448
 423 tury BCE) in Euboea (Central West Aegean Sea) at Ancient 449
 424 Eretria and Amarynthos (Ghilardi et al., 2014 and 2018). The 450
 425 same happens in Attica at Piraeus (Goiran et al., 2011) and in 451
 426 the Central Macedonian Plain (Ghilardi et al., 2008a, b). 452
 427 Later, another important phase of alluvial deposit is recorded 453
 428 during the Classical period (fifth century BCE). Several 454
 429 authors (Bintliff, 2000) inform us about the important soil 455
 430 erosion and sediment transfer observed throughout Greece at 456
 431 that time, although no clear relationship is established with 457
 432 the deltaic progradation of rivers. Quite recently, through the 458
 433 study of sedimentary archives collected in the Aliakmon- 459
 434 Axios deltaic complex it appeared that ancient Pella—the 460
 435 former capital of the Macedonian Kingdom, originally 461
 436 located on the shore of a lagoon—received a huge amount of 462
 437 water and sediments from a river called in ancient times 463
 438 “Borboros” separating the main city from the fortress. The 464
 439 results of the sedimentological analysis carried out by 465
 440 Ghilardi et al. (2008a, b) indicate that a new river input

441 occurred around the fifth century BCE, before Pella emerged 442
 443 as the new capital of the Kingdom. 444

445 In Attica, the Vravron swamps were flooded and received 446
 447 a massive alluvial input that generated a small delta at the 448
 449 beginning of Classical times (Triantaphyllou et al., 2010). 450
 451 Nearby, the Marathon Plain was created during the same 452
 453 period, thanks to a massive detrital input into a shallow 454
 455 marine bay (Pavlopoulos et al., 2006). It is also noteworthy 456
 457 that the Roman colonization of Greece did not deeply affect 458
 459 the morphological evolution of Greek deltas. A last phase of 459
 460 deltaic progradation is observed during the Ottoman period, 461
 462 coinciding with the Little Ice Age climate episode and an 462
 463 increase of land use in mountain areas. This achieves the pro- 463
 464 cess of deltaic plain formation that provided its contempo- 464
 465 rary face to coastal Greece. We must emphasize the decisive 465
 466 long-term human impact on the formation of Greek coastal 466
 467 plains. 467

458 Can the Collapse of Past Civilizations 459 460 Be Explained by Climate Change? 461

462 Paleoenvironmental research in the Mediterranean provides 463
 464 evidence for a significant climate instability with notable 464
 465 periods of Rapid Climatic Change (RCC) observed on the 465
 466 global scale during the Holocene (Mayewski et al., 2004, 466
 467 467

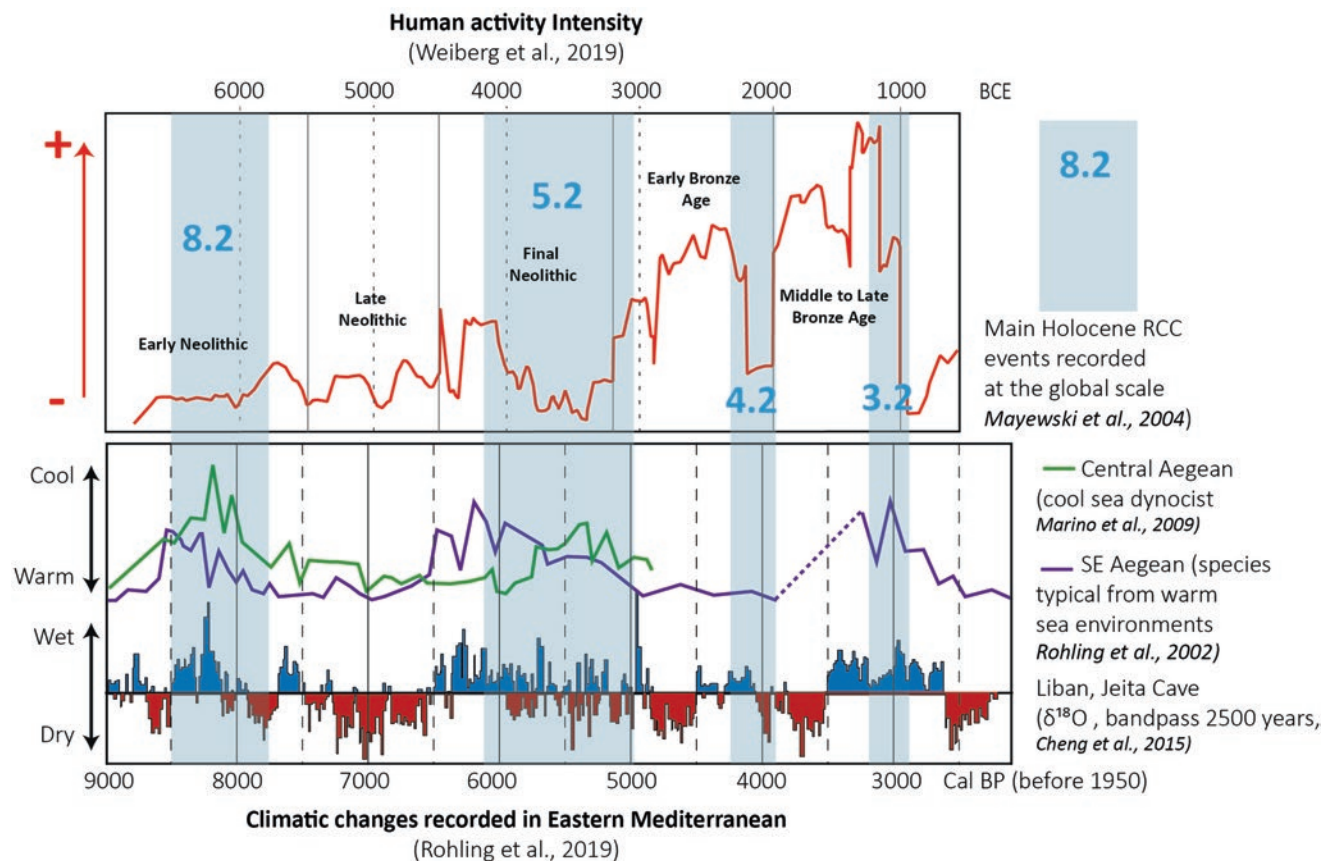


Fig. 2.5 Coincidence or causality? Rapid climatic change and demographic changes in Greece. (Source: L. Lespez after Weiberg et al., 2019 and Rohling et al., 2019)

The red line indicates the intensity of human activity. It is derived from a consensus model combining evidence from surveyed sites and radiocarbon dating based on data from prehistoric Peloponnese (Weiberg et al., 2019). The climate curves are discussed in Rohling (2019). The green curve records the content of dinoflagellate cysts characteristic of

cold waters. The purple curve shows the percentage of species characteristic of warm water in the South East Aegean. The last curve shows the positive and negative anomalies in the isotopic record ($\delta^{18}\text{O}$) of a speleothem from Jeita Cave, Lebanon. The red areas indicate dry anomalies, the blue areas wet anomalies. Regarding the 5.2 event, it should be noted that it has a very large temporal extension. This is largely due to the varying definition of its duration and timing in different studies. For a discussion of this in Greece, see Lespez et al., 2016

464 Fig. 2.5). Climate modeling was carried out in the Eastern
465 Mediterranean using geochemical and paleobiological proxies
466 derived from speleothem studies, marine and lake core
467 analyses (Bar-Matthews et al., 2003). RCC periods are well
468 identified in the Aegean world (Rohling et al., 2002; Gogou
469 et al., 2007; Marino et al., 2009; Triantaphyllou et al., 2009;
470 Geraga et al., 2010; Finné et al., 2011; 2014, 2019; Seguin
471 et al., 2020). These events are oscillations occurring over
472 150–500 years and leading to the driest/coldest recordings in
473 comparison with the preceding and subsequent periods of
474 relatively stable climate.

475 Paleoclimate studies are a growing field of research in
476 environmental sciences. They try to establish a connection
477 between climate changes, mainly aridification in Eastern
478 Mediterranean areas, and civilization collapses (Drake,
479 2012; Weninger et al., 2014). According to this determinis-
480 tic theory, human societies would face so many difficulties
481 during RCCs that they would fail to adapt, which would

lead to radical societal changes (e.g. Drake, 2012; Weninger
et al. 2006, 2009, 2014; Weiss 2017; Finné et al., 2017).
“Decline in precipitation and its cascading effects through
the economy” (Drake, 2012) generate crop failure, famine,
invasions, and conflicts leading to collapse (Kaniewski
et al., 2015). These hypotheses are advanced for all periods
where a decline in the recording of archeological sites coin-
cides with an RCC: Neolithic expansion (6200 BCE, i.e.
8.2 ka BP event), Neolithic/Bronze Age transition (4000–
3000 BCE, i.e. 5.2 ka BP event), Middle Bronze Age
(2200 BCE, i.e., 4.2 ka BP event), and Late Bronze Age
(1200 BCE, i.e. 3.2 ka BP event). However, most works
investigate places far away from any site of human occupa-
tion, which does not really allow us to analyze the capacity
of past human societies to resist multi-decadal or centennial
climate alteration (Butzer et al., 2012; Flohr et al., 2016).
Therefore, geoarcheological research has been developed in
excavated archeological sites with the idea of testing the

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hypothesis (Lespez et al., 2016) and clarifying the “Coincidence-Causality” dilemma (Coombes & Barber, 2005).

One key unaddressed problem is the 6200 BC event (8.2 ka BP) and its perceived impact on Early Neolithic societies (Wenninger et al., 2014) that had moved from western Turkey to northern Greece at that time (Lespez et al., 2013). Rivers and wetland systems in Northern Greece present continental archives where this climate event and its local impact were recorded. Research conducted in the surroundings of known archeological sites demonstrates the reality of hydrogeomorphological responses to the early Holocene RCCs in valleys, alluvial fans, and lake-marsh systems (Berger et al., 2016). These works highlight the importance of Holocene sedimentation and post-depositional disruptions during the Mesolithic-Early Neolithic transition (Ghilardi et al., 2008a, b).

Terrestrial records still reflect the heterogeneity of paleoclimate restitution. They suggest a probable tripartite timing for the 8.2 ka BP event, thus illustrating the complex relationship between climate change and Neolithic development (Berger et al., 2016). The early Neolithic colonization of the northern Aegean (c. 6400 BCE), prior to the second peak phase of this RCC event, shows that the Neolithization process promoted by certain researchers is more complicated than it would appear (e.g. Wenninger et al., 2014). The climate event indicates overall drier conditions (Peyron et al., 2011) but in a cooler climate. This drier, short-lived event could thus paradoxically be concomitant with a local rise in the water table, and flood risks could have involved finding higher settlement areas on alluvial fans, as observed at Dikili Tash for Early Neolithic populations (Lespez et al., 2017). Only new research closely connected with multidisciplinary analyses of archeological sites could optimize our understanding of the local impact of climate change and forms of socioenvironmental resilience.

The second case study discusses the nature-society interaction in the Middle Holocene. At the end of the Late Neolithic, the period between 4200 and 3000 BCE is one of the least studied as regards RCC episodes and their societal impact. But this age is characterized by a dramatic decline in the number of settlements and reveals a cultural disruption lasting over five centuries in the South Balkans—the “Lost millennium” (Tsirtsoni, 2016). This breakdown stimulated reflection on the role of climate change on settlement patterns at a regional scale (Wenninger et al., 2009). High-resolution paleoenvironmental proxy data obtained in northern Greece enables us to examine the societal response to an abrupt climate change (Fig. 2.5, Lespez et al., 2016). The development of a lasting fluvio-lacustrine environment followed by enhanced fluvial activity is evident from c. 4000 BCE in the Lower Angitis and Strymon Valleys.

Paleoecological data show a succession of three dry events at 3800–3700, 3450, and 3000–2900 BCE. Compared with the available regional data, it appears that these events correspond to the incursion of cold air masses into the eastern Mediterranean, confirming the instability of Middle Holocene climate transition.

Two periods when farming and pastoral activities are observed in the Late to Final Neolithic (4300–3600 BCE) and the Early Bronze Age (3100–2700 BCE) correspond to an obvious increase in the number of settlements on a regional scale. The intervening period is marked by environmental changes, but the continuous occurrence of anthropogenic taxa and fire signatures suggests the persistence of human activities and, in particular, pastoralism despite the absence of archeological sites dating from that period and the weakness of archeological evidence of continuity, which in turn raises the question of changes affecting settlement patterns. Local populations moved to cope with environmental change and the unexpected, but they also left the areas most affected by rising water table to resettle on foothills. The permanence, even slightly diminished, of anthropogenic indicators confirms the continuity of settlements in the Lower Angitis and Strymon Valleys. As in other Eastern Mediterranean areas, the abrupt succession of wet and dry periods could have affected the population of Northern Greece, but the drier and cooler conditions of short-time climate events were probably insufficient to trigger alone the observed societal changes.

The last climate event corresponds to a dry moment recorded around 1200 BCE—also known as the 3.2 ka BP event. The episode is of special interest to explain the end of Bronze Age civilizations. Several works concluded that East Mediterranean civilizations (Kaniewski et al., 2013, 2019; Drake, 2012; Finné et al., 2017), and Greece in particular, collapsed due to a dry period that lasted for approximately 300 years (Kaniewski et al., 2019). Although nobody disputes the aridification process observed at the end of the Bronze Age, it seems that evaluating its paleoenvironmental and societal implications is a more complicated task. For example, during this period, lacustrine areas remain away from the palatial center of Phaistos in Crete (Ghilardi et al., 2018a, b), whereas in Northern Greece, climate did not impact the agropastoral activities revealed by pollen records (Lespez et al., 2016), which questions the role of aridification for Late Bronze Age populations in Greece.

These examples underline the uncertainties pertaining to RRC and their consequences at the local/regional scale. In most cases, timing does not provide enough indication to be sure that climate events precede social phenomena. The causal relationship remains confuse. Indeed, uncertainty about radiocarbon dating is around 100–200 years and modeling constraints are in the region of 50 years at best, which

604 does not allow for precise comparison between archeological
605 and paleoenvironmental data. Thus, the timeline of climate
606 events is blurred. Transforming coincidence into causality is
607 a daunting process, particularly for periods when the radio-
608 carbon calibration curve reaches a plateau that prevents
609 accurate ages from being obtained from any type of dated
610 samples.

611 Even more important, we need to increase the number of
612 case studies on a local and regional scale if we are to reason-
613 ably discuss the effect of climate change on cultural transfor-
614 mation. The impact of human activities on ancient
615 Mediterranean ecosystems through cultivation, herding, and
616 fire (Connor et al., 2019) makes it difficult to identify the
617 outcomes of climate events on continental anthropized envi-
618 ronments. Furthermore, the spatial heterogeneity of Greek
619 landscapes is often underestimated. The Aegean geography
620 is made of extremely varied environments that would need to
621 be better understood, including continental or coastal wet-
622 lands and mountain peaks above 2000 meters. As Rohling
623 et al. (2019) say about the Eastern Mediterranean: “*our*
624 *results illustrate that apparent covariations between warm/*
625 *cold and arid/wet conditions for any given climate event*
626 *should not be expected to apply over a wide region, but*
627 *instead are likely to differ spatially, and possibly also with*
628 *altitude.”* Environmental conditions often vary over very
629 short distances.

630 Natural Hazards and Ancient Societies

631 In addition to such long-term co-adaptation mechanisms,
632 other phenomena pertaining to the nature–society relation-
633 ship need careful consideration. These relate to natural haz-
634 ards and the associated catastrophic events, the outcomes of
635 which are able to deeply alter balances almost instantane-
636 ously. In Greece, as in the Mediterranean world in general,
637 the diversity and instability of environmental conditions are
638 the rule. Plate tectonics is responsible for recurrent episodes
639 of telluric violence while climate environment explains the
640 frequency of brutal hydrological events. Earthquakes and
641 floods are frequent phenomena.

642 Regularly, short events of high-intensity rainfall (200–
643 400 mm within 48 h), which represents between one-third
644 and one-half of annual precipitation, result in soil erosion,
645 slope gulying, destruction of agricultural terraces, river
646 bank erosion and massive alluviation in downstream flood-
647 plains. From the Late Bronze Age, socioeconomic evolution
648 and technical progress motivated the development of infra-
649 structure facilities able to mitigate certain environmental
650 risks, such as agricultural terraces. Hydraulic control devel-
651 ops during the Mycenaean period. The Minyans, in Central
652 Greece, reclaim land around wet depressions and develop

hydro-agricultural systems: they build levees, canals, and a
653 tunnel to partly drain Lake Copais. But the Mycenians also
654 used their hydraulic knowledge to control the effects of tor-
655 rental floods, as in Tiryns (Zangger, 1994). After a cata-
656 strophic flood that destroyed part of the lower city during the
657 Late Helladic III B-C, the inhabitants undertook the con-
658 struction of a 10 m high dam and a 1.5 km long torrent diver-
659 sion canal to protect the palace and houses from flooding.
660 These examples testify to the adaptation and planning capac-
661 ities of Late Bronze Age societies facing natural hazards in
662 the southern part of the Aegean world. 663

664 The subduction of the African plate under the Eurasian
665 plate south of Crete and the development of the North
666 Anatolian Fault in the northeastern Aegean Sea constitutes a
667 strike-slip system between the Eurasian and Anatolian plates,
668 which continues to grow at a high rate of 2–4 cm per year
669 and generates chronic tectonic instability (Fig. 2.6). Large
670 earthquakes have occurred regularly in the Aegean world and
671 they have often been evoked to explain local or regional
672 destructions. The knowledge accumulated in recent years
673 shows that the identification of earthquake destruction from
674 archeological excavations remains a difficult exercise
675 (Jusseret & Sintubin, 2017). Nevertheless, a number of
676 exceptional events were precisely described. The 8.5 magni-
677 tude earthquake dated 365 CE associated with a reverse fault
678 off southwestern Crete caused a 9-meter uplift in western
679 Crete (Stiros, 2010). Thus, the Phalasarna harbor, at the
680 extreme west of Crete, gained 6.6 m in height and perma-
681 nently escaped marine influence (Pirazzoli et al., 1992). For
682 some, this event is correlated with a series of other major
683 destructive earthquakes and defines a two-century period of
684 tectonic paroxysm: The ‘Early Byzantine Tectonic Paroxysm’
685 (Pirazzoli et al., 1996). Nevertheless, in spite of its magni-
686 tude, the scale of destruction does not make it a catastrophic
687 event leading to a global collapse of regional settlement. For
688 example, Gortyn (near Phaistos, Fig. 2.3), the most impor-
689 tant Cretan town in the Roman Era, was destroyed by the
690 365 CE event and other smaller, subsequent earthquakes, but
691 it recovered quickly because political decision supported a
692 plan for rebuilding the city (Stiros, 2001).

693 A further consequence related with the regional tectonic
694 setting of Greece is the development of a volcanic back-arc
695 behind the subduction zone. This arc extends across the
696 Aegean from east to west and the Santorini Volcano is to be
697 found in its center. The Late Bronze Age eruption was one
698 of the most powerful events ever recorded on earth during
699 the last 10,000 years, with an estimated volcanic explosiv-
700 ity index reaching 7 (Druitt et al., 2019). It took place at a
701 time between 1620 and 1525 BCE, but defining the exact
702 date was a difficult task, partly because of the shape of the
703 radiocarbon calibration curve during the eruption period
704 (Pearson et al., 2018). There has also been a long running

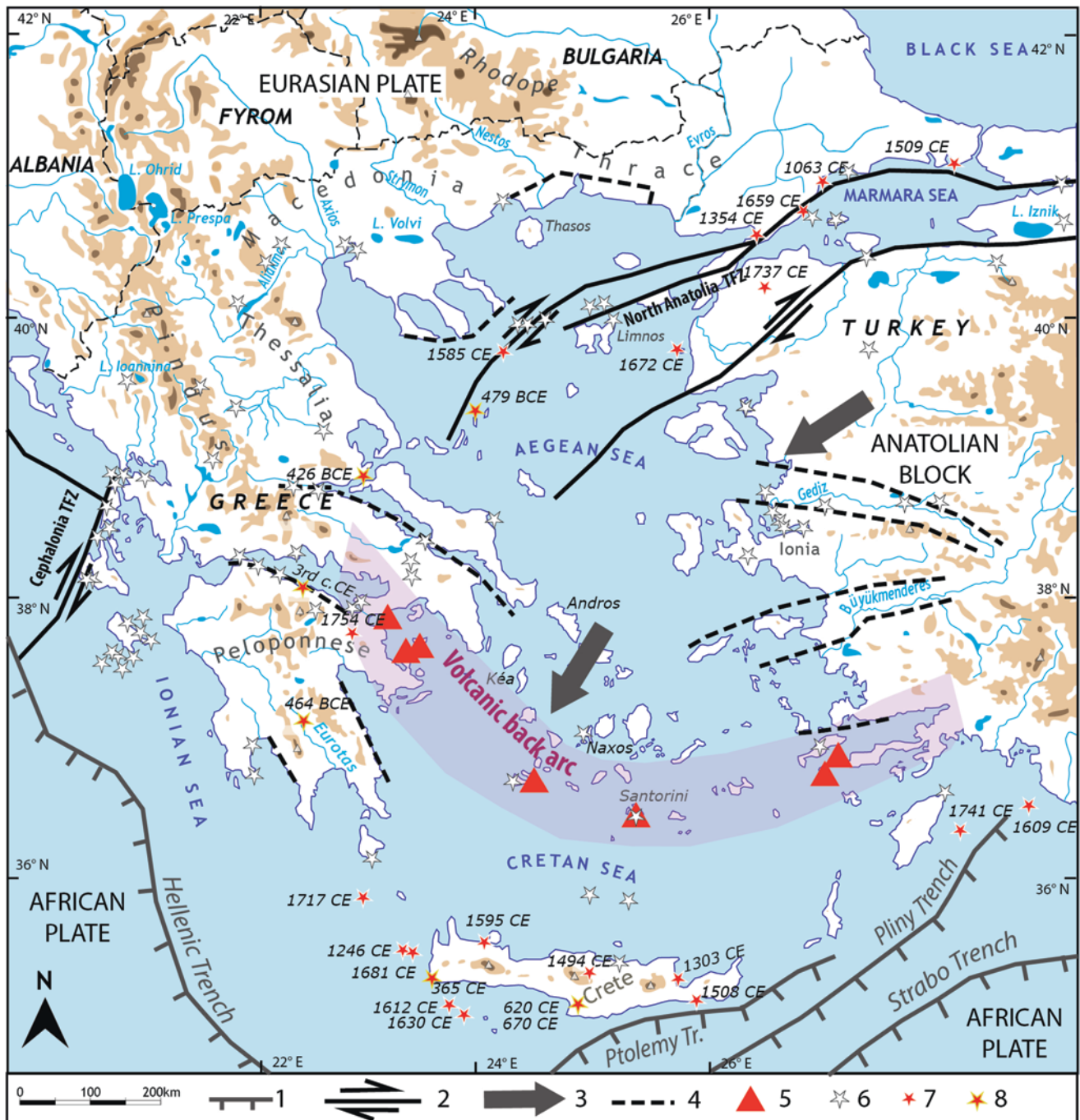


Fig. 2.6 Schematic map of the main tectonic structures and the main historical earthquakes (before 1750) of Greece and its surroundings. (Source: L. Lespez after European Archive of Historical Earthquake Data and Kassaras et al., 2020)

The relationship between the distribution of known ancient earthquakes and active plate tectonic boundaries or active faults or fault zones should be noted. 1. Trenches: depressions on the seafloor that form at the boundary of tectonic plates; 2. Main Transformation Fault Zone when two tectonic plates move past one another (the direction of movement is indicated by the half arrows); 3. The arrows indicate the main

Plate movement; 4. Major active faults or fault zones; 5. Active volcano; 6. Large earthquakes (epicentral area) known between 1000 and 1750 AD; 7. Extra-large earthquakes (epicentral area) known between 1000 and 1750 AD with their dates (Items 6 and 7 from the European Archive of Historical Earthquake Data (Extra-large and Large earthquakes defined in the catalog, https://www.emidius.eu/AHEAD/query_event/, website accessed on May 18th 2023); 8. Some major earthquakes discussed by the ancient sources and the paleoseismology and archaeoseismology after Freitag and Reicherter, 2019; Papazachos and Papazchou, 2003; Stiros, 2001, 2010, 2016; Papadopoulos, 2017

705 discrepancy between archeological dating based on syn-
 706 chronisms with ancient Egypt (Wiener & Wharburton,
 707 2009) and certain argued radiocarbon dating ranges
 708 (Friedrich et al., 2006; Manning et al., 2006). The eruption
 709 led to the destruction of the town of Akrotiri on Santorini
 710 Island (Doumas et al., 2015) while tephra fallout has been
 711 reported all over the eastern Mediterranean (Johnston et al.,
 712 2012; Athanasas et al., 2018). Recent research suggests that
 713 large waves were generated by the eruption (Nomikou
 714 et al., 2016). Modelling established that waves several
 715 meters high (up to 20 m) propagated up the north coast of
 716 Crete (Minoura et al., 2000; Novikova et al., 2011; Bruins
 717 et al., 2008). However, although many observations testify
 718 for ash deposits all across the Eastern Aegean Sea, from
 719 Crete to Southwest Turkey, and in spite of much research,
 720 evidence of tsunamis remains scarce (Dominey-Howes,
 721 2004). The most convincing observations were recently
 722 obtained in eastern Turkey (Minoura et al., 2000; Şahoğlu
 723 et al., 2022), at Malia, in northern Crete (Lespez et al.,
 724 2021) and the eastern tip of Crete at Palaikastro (Fig. 2.7)
 725 although some of these deposits still raise many questions
 726 (Driessen, 2019). Thus, the magnitude and kinematics of
 727 the tsunami and its paleogeographic outcomes are largely
 728 unknown. The debate about its impact remains open
 729 (Driessen & McDonald, 1997; Friedrich, 2013; Driessen,
 730 2019). This underlines the need for an enhanced under-
 731 standing of natural phenomena and their impact on Aegean
 732 societies through the development of new paleoenviron-
 733 mental and geoarcheological research.

Conclusion

734
 735 Considering the exceptional accumulation of cultural heri-
 736 tage and the impressive list of archeological discoveries
 737 achieved in the country, from the Neolithic Era to modern
 738 times, Greece remains a privileged place for geoarcheological
 739 research. A large number of research works shows the early
 740 impact of farming societies on the environment. For about
 741 8500 years, long before the Anthropocene Era, Greek envi-
 742 ronments and landscapes have been shaped by human societ-
 743 ies. We continue to reap the benefits of these co-constructed
 744 environments and ecosystems that would deserve a better
 745 protection in the face of the sixth extinction of biodiversity
 746 and the global change. Research in Greece allows us to put
 747 into perspective the sometimes very deterministic approaches
 748 conducted in the Levant and the Near East about natural
 749 dynamics and societies. Geoarcheological investigations con-
 750 firm that the geographic determinism related to settlement
 751 patterns at the local and regional scale must be examined
 752 carefully (Lespez et al., 2014). They also show that human
 753 adaptation to external environmental forcing, such as climate
 754 oscillations or telluric and hydrologic events, has to be exam-
 755 ined precisely through the development of a cross-disciplin-
 756 ary research combining archeological and paleoecological
 757 works in the immediate surroundings of archeological sites.

758 We thus have to get away from the paradigm of a climate-
 759 induced collapse. The idea may have pedagogical virtues in
 760 the short term, but above all it runs the risk of oversimplify-
 761 ing reality and downplaying the complexity of socio-



Fig. 2.7 The deposit (between white lines) attributed by Bruins et al. (2008) to the Late Bronze Age tsunami resulting from the eruption of the Santorini volcano, just below the Palaikastro Minoan site (Eastern Crete). (Source: L. Lespez 2020/09/19)

762 environmental processes. For this reason, following Müller
763 & Kirleis (2019), we promote the notion of *socio-*
764 *environmental transformation*, which implies to precisely
765 describe the relationships between societies and their envi-
766 ronment (including climate) at the local and regional levels.
767 This method allows for accurately addressing the resilience
768 of socio-technical systems, or not, and the ability of societies
769 to reform themselves, or not, through the detection of thresh-
770 olds in the society-environment trajectory (Berger et al.,
771 2019). Understanding climate risk also supposes to deal with
772 social vulnerability, and the complexity of its socio-political
773 dimension, today as in the past.

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