Coastal Change and Archaeological Settings in Elis

John C. Kraft, George Robert Rapp, John A. Gifford, S. E. Aschenbrenner

Hesperia: The Journal of the American School of Classical Studies at Athens, Volume 74, Number 1, January-March 2005, pp. 1-39 (Article)

Published by American School of Classical Studies at Athens
DOI: https://doi.org/10.1353/hes.2005.0002

HESPERIA 74 (2005)
Pages 1–39

COASTAL CHANGE AND ARCHAEOLOGICAL SETTINGS IN ELIS

ABSTRACT

Since the mid-Holocene epoch, sediments from the Alpheios River in Elis, in the western Peloponnese, have been entrained in littoral currents and deposited to form barriers, coastal lagoons, and peripheral marshes. Three major surges of sediment formed a series of barrier-island chains. The sites of Kleidhi (ancient Arene), along a former strategic pass by the sea, and Epitalion (Homeric Thryon), built on a headland at the mouth of the Alpheios River, now lie 1 and 5 km inland, respectively, and other ancient sites have been similarly affected. Diversion of the Peneus River has led to cycles of delta progradation and retrogradation that have both buried and eroded archaeological sites. Coastal changes continue in Elis today, resulting in areas of both erosion and deposition.

INTRODUCTION

Three great sandy strandlines extend for more than 100 km along the coast of Elis in the western Peloponnese, Kiparissia to Katakolon, to Chlemoutsi, to Araxos (Fig. 1). Fed by sediments eroding from the uplands of Elis via the deltas of the Peneus, Alpheios, and Nedon rivers and numerous smaller streams, littoral processes have created a sequence of lagoons, marshes, barrier accretion plains, coastal dune fields, swamps, and deltas. This paper discusses the evolution of these coastal landforms over the past 7,000 years, since the peak Holocene (late Mesolithic/Neolithic) marine transgression.[1]

Because coastal Elis has been occupied since the Neolithic period, we have chosen to closely integrate archaeological sites and their settings into our discussion of the ever-changing coastal zones of Holocene Elis.[2] The dynamics of coastal landforms dictate variable site preservation, burial, and destruction in delta and coastal barrier settings, but, as Stanley and Warne posit for Holocene delta settings, "these resource-rich ecosystems [could have been] used by humans soon after their development. . . . [Such ecosystems were notable for their] accumulation of fertile soil, reliable water supply, perennial aquatic food sources, ease of travel and trade."[3] We

---

[1] In geological usage, Holocene is the time of the most recent glacial global warming and resultant sea-level rise, roughly the past 10,000 years.

[2] Hope-Simpson (1981, p. 153) noted that western Elis "has never been properly explored" for archaeological sites.

[3] Stanley and Warne 1997, p. 1.

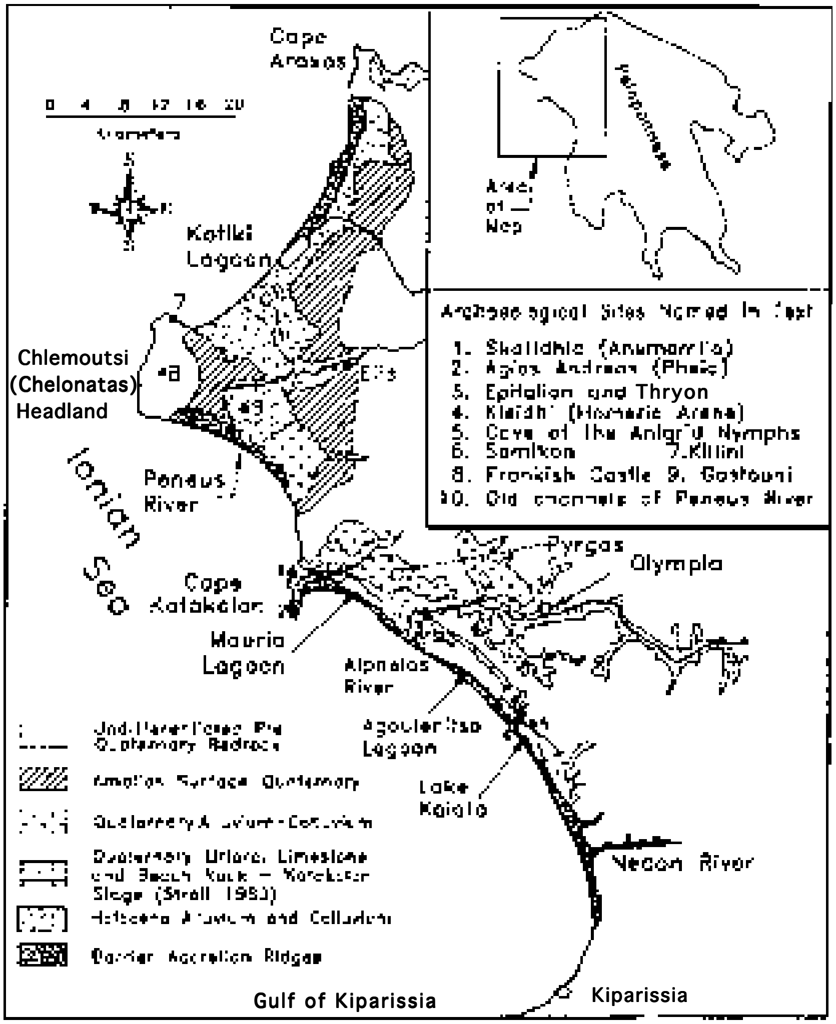

Figure 1. Coastal geologic elements of Elis, Holocene epoch, showing relationships between alluvial and coastal geomorphic environments and earlier Quaternary depositional units. J. C. Kraft, based on Loy 1967; Raphael 1973, 1978

thus hypothesize heavy occupancy of the western Elis coastal, delta, lagoon, and barrier regions since Neolithic times, and accordingly promote the search for archaeological sites.

To elucidate the possible relationships over the past 7,000 years between human occupancy of the coastal regions of Elis and the changing coastal landforms, we have mapped changes in coastal morphology in relation to all known archaeological sites. Using paleogeographic reconstructions, we present the raison d'être for many of these sites. To do this, we considered: (1) the effect of global sea-level rise and other forms of sea-level variance; (2) the sedimentologic evolution of coastal landforms, both erosional and depositional; (3) morphologies of archaeological sites at the time of occupancy; (4) reasons for anticipating new site discovery as well as the probable lack of sites of certain ages in some coastal landforms because of destruction or burial; and (5) the relationship of hinterland erosion processes that could have impacted the morphologic evolution of the coastal zone of Elis.

The geological research presented here is based on over fifteen drill cores taken in varied coastal settings. Sedimentary environments of deposition that we encountered allowed interpretation of past coastal morphologies and landscapes. We dated the geomorphologies shown herein using fundamental principles of sedimentology and stratigraphy, ^{14}C dates of peats and fossil shells, and archaeological dates of a few sherds recovered in our drill cores. All ^{14}C dates used are calibrated, and include the carbon reservoir correction for marine shell species. We also reviewed both modern and ancient literary sources that refer to the coastal region of Elis. Such syntheses should provide meaningful paleogeomorphologies for our archaeological colleagues to use in exploration and site interpretation, as well as challenges toward more definitive research on processes of geomorphic change in the inland drainage basins of the rivers adjacent to Elis. Although we present feasible correlations between the formation of coastal landforms and the degradation of adjacent hinterland soils from the Helladic to modern period, our chronological assessment of these variable events is at best circumstantially based, and final conclusions await precise dating of inland erosion events. We hope that this paper will lead to a fuller investigation of the interrelationships among relative sea-level changes, sedimentary processes, tectonics, and human effects on landscapes.

A basic premise of our research over the past three decades has been the synergism made possible by the merging of evidence from archaeology, history, the classics, and the broader body of ancient literature with geological methods of reconstructing ancient landscapes. Such interdisciplinary research is particularly useful in deltaic and sandy coastal zone regimes, where changes in landscapes at the coastlines have frequently exceeded tens of kilometers since the Neolithic and Helladic periods. The archaeological sites discussed below have been evaluated in their physiographic settings, while history, structure, and age determinations are taken from the literature. Although classical and other literature often contains descriptions of coastal and fluvial geomorphologies that are at variance with present morphologies, examination of geological processes of change in landscape morphology often demonstrates compatibility and direct correlation with ancient geographic descriptions. For a brief yet compelling example, we refer the reader to comments by Strabo and Homer that are compatible with paleogeographic reconstructions of the Troia embayment and lower Scamander River deltas of 2,000 to 5,000 years ago.[4]

GEOMORPHIC PROCESSES IN THE COASTAL ZONE

Our geologic approach to the investigation of Holocene coastal changes as they relate to archaeological site locations is to depict landscape evolution in terms of the morphology of sedimentary bodies, erosional features, and the vertical and lateral sequences of environments (sedimentary environmental lithosomes) that were created by coastal geologic processes.[5] These

---

[4] Kraft, Rapp, et al. 2003.

[5] Principles and concepts: Kraft 1971, 1972, 1977; Kraft, Aschenbrenner, and Kayan 1980, 1985; Kraft, Belknap, and Kayan 1983; Rapp and Gifford 1985. Troy: Kraft, Kayan, and Erol 1980, 1982; Kraft, Kayan, et al. 2003; Kayan et al. 2003; Kraft, Rapp, et al. 2003. Navarino-Pylos: Kraft, Rapp, and Aschenbrenner 1980. Messenia-Nichoria: Kraft, Rapp, and Aschenbrenner 1975; Rapp, Aschenbrenner, and Kraft 1978. Gulf of Malia-Thermopylae: Kraft et al. 1987. Ephesus: Kraft et al. 2000; Kraft, Kayan, and Brückner 2001. Acarnania-Acheloos River delta: Villas 1983. Thera (Santorini): Angelakos 1993. Epirus-Ambracian embayment: Jing and Rapp 2003. Epirus-Acheron River: Besonen, Rapp, and Jing 2003. Methoni: Kraft and Aschenbrenner 1977.

processes may include local and regional tectonism, relative sea-level and climatic changes, oceanic currents and wave regimes, types and quantities of sediments in transport, and the nature and intensity of human activity.[6] Such processes leave evidence of physiographic change in the sedimentary record; hence, our research methods relied heavily on geologic core drilling and intensive analysis of sedimentary sequences. In the analyses of low-lying coastal landforms, elevations in relation to sea level and precise definitions of the morphologies of depositional landforms are critical. We were fortunate to be able to utilize the many 1:50,000 scale geologic maps of the Institute of Geology and Mineral Exploration (Greece)[7] and the 1:5,000 scale topographic maps, based on precision aerial photography, of the Hellenic Geographic Service. In addition, major drainage engineering works of the 1960s allowed us precise elevation determinations as well as excellent accessibility to our vibrodrill core sites.

Coastal landform changes during the past 8,000 years in Elis have been dominated by the longshore redistribution of sediments from the deltas of the Alpheios and Peneus rivers. Prior to the 18th century A.D., the Peneus River flowed north of the Chlemoutsi headland and emptied into the Ionian Sea southwest of Kotiki Lagoon, but the river now flows southward into a deltaic swamp and dune region, burying a former lagoon-barrier coastal zone (Fig. 1).[8] The coastal plains of Elis are composed of the most extensive Holocene barrier accretion, lagoon, and deltaic deposits in the Peloponnese. Here, relatively rapid alteration of the coastal landscape occurs by both erosion and deposition. Normal coastal processes and landforms in Elis have often also been affected by tectonic instability.[9]

CAUSES AND CHRONOLOGY OF COASTAL LANDFORM CHANGES

Carpenter, in *Discontinuity in Greek Civilization,* proposed that a sequence of cyclic climatic events had had a dominating effect on the rise and fall of civilizations in the Mediterranean area.[10] Wright disagreed: “It may be a fair conclusion from pollen studies in Greece that no vegetational changes may be attributed with any certainty to climatic change.”[11] Davidson concluded that “major climate change [could not] account for patterns of vegetational change” and that “the inference is [clear] that individual drainage basins in Greece have varied markedly in their alluvial histories and thus the correlation of alluvial phases must be approached with great care.”[12]

Among others, Wagstaff demonstrated the problems of simplistic solutions to the dating of valley alluviation and the complexity and localization of actual depositional sequences.[13] Brückner espoused similar concepts regarding northeast Mediterranean alluviation events, further noting that relative sea-level changes and tectonic events may not be a primary cause.[14] Van Andel, Zangger, and Demitrack were more specific, noting that major soil erosion events and valley alluviation occurred at different times on the Greek peninsula: in Thessaly 4500–4000 B.C., in the Argolid

---

[6] Kraft 1972.

[7] Chamberis, Alexiades, and Philipe 1983; Perissoratis and Angelopoulos 1982; Streif 1980, 1982; Tsofilias 1977.

[8] Raphael 1973, 1978.

[9] Galanopoulos 1940; Galanopoulos and Delibasis, after Bornovas 1971; Kelletat 1974; Kelletat et al. 1976; Schröder and Kelletat 1976.

[10] Carpenter 1966.

[11] Wright 1968, p. 126.

[12] Davidson 1980, p. 156 and p. 149, respectively.

[13] Wagstaff 1981.

[14] Brückner 1986.

2500 B.C., in Messenia 2000 B.C. Their conclusions, that "most recorded Holocene soil erosion events are spatially and temporally related to human interference in the landscape" and that "a major phase of soil erosion appears to follow by 500–1000 years the introduction of farming to Greece," serve as a warning against sweeping claims about both climatic cycles and regional correlation of fluvial and coastal sedimentation events.[15]

In our previous studies, we noted that human activity such as deforestation of the hinterlands was the probable driving force for the surge of alluvial sedimentation into coastal zones during the mid- to late Holocene. We noted evidence of alluvial sedimentation into the head of the graben-like embayment of Navarino as early as 7000 B.C. at depths of over 10 m below present sea level,[16] although the greater surge of alluviation apparently did not occur until the Neolithic to Early Helladic periods. In one of the most thorough interdisciplinary scientific exercises in regional archaeology of the 1990s, the Pylos Regional Archaeological Project (PRAP), Zangger and colleagues state that "recent synoptic studies of the Holocene interrelations between people and landscape in Greece have argued that the first deforestation on hillslopes caused the most devastating soil erosion of the entire Holocene."[17] They also emphasize that the times and regions of the initiation of such events in ancient Greece are varied. The PRAP pollen analyses indicate that a major vegetation change from pine to deciduous forest began in the Neolithic period (5000 B.C.), but that the major denudation events in the Pylos region occurred in the Early Helladic (about 2000 B.C.) and Early Mycenaean periods (1600–1400 B.C.). Acceleration of major environmental change may have occurred in Classical to Hellenistic times when olive groves covered 25 percent of the Pylian landscape. In a careful analysis of erosion rates on the uplifted Pliocene marine marl surfaces, Zangger and colleagues further noted as much as 2 m of soil erosion since the Neolithic period, ca. 1 m attributable to the modern agricultural practice of deep plowing.

Questions remain about the drainage basin of the Alpheios River. Studies of soil denudation events in Elis cannot be dated as accurately as those in the Argolid and western Messenia. Certain events, however, are well known. Streif noted the involvement of comparative fluvial aggradation and shoreline progradation.[18] He posits three fluvial terraces in the Alpheios River valley: Ht_3, up to 6–7 m above the Kladeos and Alpheios rivers, which has covered the ruins at Olympia from the Roman period to today; Ht_2, the lower of the low terraces (at 0.8–1 m), which includes anthropogenic elements; and Ht_1, the upper of the low terraces (at 1.5–2 m), which is apparently sterile. Streif concludes that these three fluvial terraces correlate specifically with three coastal barrier accretion events adjacent to the Alpheios River delta. The landward, and thus earliest, "Mouria" accretion barrier (M.B.) correlates with Alpheios terrace Ht_1; the middle "Agoulenitsa" accretion barrier (A.B.) correlates with Alpheios terrace Ht_2; and his "actual (present) barrier system" (P.B.) correlates with terrace Ht_3 (Fig. 2).

Streif's correlations of fluvial terraces to coastal barriers form the basis for our detailed discussion of the evolution of the coastal landforms of Elis, with one major exception: the Neolithic coastal lagoons (Table 1).[19]

---

[15] Van Andel, Zangger, and Demitrack 1990, p. 379.

[16] Kraft, Rapp, and Aschenbrenner 1980.

[17] Zangger et al. 1997, p. 589.

[18] Streif 1964.

[19] Streif 1980, 1982.

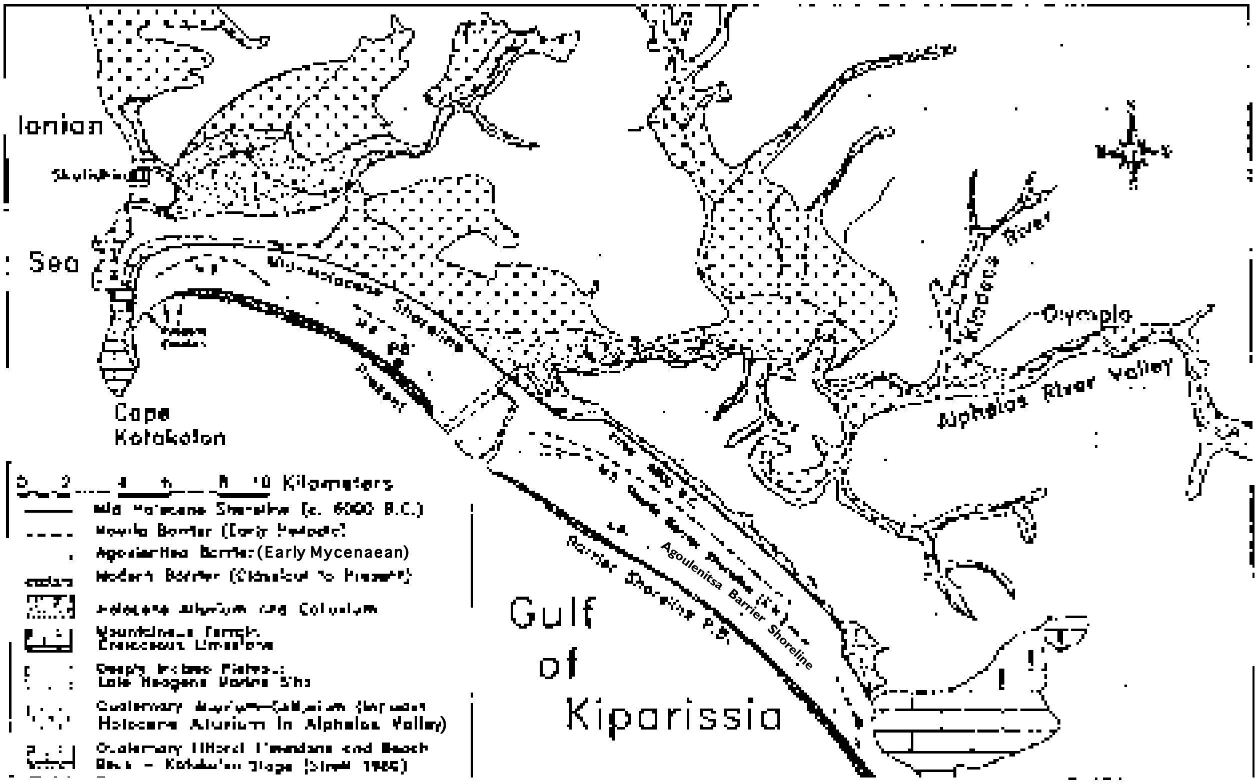

Figure 2. Schematic geologic map showing the peak mid-Holocene transgression cliff incision ca. 6000 B.C. Key: M.B. = Mouria Barrier (Early Helladic); A.B. = Agoulenitsa Barrier (Early Mycenaean); P.B. = present barrier (Classical to present time).

Our drill core evidence clearly demonstrates coastal saline/brackish water lagoonal sediments and their adjacent coastal marsh peats in the Lake Kasta area that date to the very end of the Mesolithic period (ca. 5500 B.C.). The lowermost occurrence of the pelecypod *Cerastoderma edule,* common in the lagoonal muds above the basal peat, dates to the Early Neolithic (4770 B.C.). A similar correlative shell bed in lagoonal muds occurs nearby at the same level in the subsurface of westernmost Lake Mouria, possibly the same coastal lagoon in the latest Mesolithic and Neolithic periods. Another basal peat (5256 B.C.) fringed and later underlay a coastal lagoon of the same time frame, now buried under the modern delta of the Peneus River south of Gastouni. Finally, a Neolithic marsh mud (3649 B.C.) underlies a lagoonal mud near the landward fringe of Agoulenitsa Lagoon. Thus, we show widespread coastal lagoons along the Elis strand in Neolithic and earlier times. We have not located the coastal barriers that restricted these Neolithic coastal lagoons, but the sedimentologic and fossil evidence and the ^{14}C data are clear. Streif's three sequences of coastal barriers demonstrably postdate the occurrence of Mesolithic–Neolithic lagoons. We therefore hypothesize that the barriers to the Neolithic coastal lagoons now lie buried seaward of the present coast or were destroyed in a shoreface erosion event.

In searching for human contributions to an alluvial surge into the coastal zone of Elis in Neolithic times, we find no definitive literary evidence. There is the common supposition that deforestation in the Mediterranean region started in the Neolithic period. Deltas in some areas, such as the Navarino region, show Neolithic progradation events.[20] Van Andel et al. note an alluviation event in the Argive Plain in the later Neolithic,[21]

---

[20] Kraft, Rapp, and Aschenbrenner 1980.

[21] Van Andel, Zangger, and Demitrack 1990.

TABLE 1. A QUADRIPARTITE EVOLUTION OF COASTAL LAGOONS IN ELIS

Barrier Sequence	*Accretion Barriers and Lagoons*	*Date*
4th	Present barrier and lagoons (P.B. 1, P.B. 2, P.B. 3)	Classical to modern times in at least three cycles. P.B. 1 = Classical
3rd	Agoulenitsa Barrier and lagoons (A.B.)	Early Mycenaean
2nd	Mouria Barrier and lagoons (M.B.)	Early Helladic
1st	Latest Mesolithic/Neolithic lagoons (from subsurface drillcore evidence: barrier locations unknown)	Late Mesolithic to Neolithic

while Zangger et al. show in their pollen records that extensive pine forests gave way to deciduous oaks,[22] but they do not attribute this event necessarily to human activity. A possible alternative scenario for the initiation of broad coastal lagoons in Elis is the relatively common agreement that the rate of world sea-level rise began to diminish sharply in the latest Mesolithic and early Neolithic times (ca. 5000 B.C.) and slowed further in the beginning of the Helladic (ca. 3000 B.C.). Assuming that the wave regime of the Ionian Sea was similar to that of the present, the impact of wave impingement on the deltas of the Alpheios and Peneus rivers during a period of a more slowly rising sea level could have initiated coastal barrier and lagoon development on the low-lying, shallow inner shelf of Elis. Accelerated input of sediment via the Alpheios River may have occurred with the initiation of Neolithic agriculture in the hinterlands. Thus, with the late Mesolithic Ionian Sea impinging at the foot of long arcuate sea cliffs (ca. 6000 B.C.; Fig. 2), followed by a dramatic slowdown in the rate of sea-level rise, we can postulate shoaling on the very inner shelf and the initiation of barrier-island accretion (Table 1: 1st barrier sequence). An alternative and possibly correlative hypothesis is that human activities increased the sediment supply, not yet proven for latest Mesolithic/Early Neolithic Elis.

Other scholars have dealt with alluviation events in the Alpheios and Peneus drainage basins. Büdel suggested major alluvial events at Olympia between the seventh and fourteenth centuries A.D.[23] Du Faure noted extensive alluvial events on the Alpheios River from the second to the sixth century A.D.[24] Vita-Finzi suggested that major alluviation on the Alpheios and Kladeos rivers began in Byzantine times.[25] While Judson suggested that a sedimentation event of the Kladeos River covered the ruins of Olympia,[26] Streif showed that the same sedimentary terrace that covers Olympia also occurs on the far side of the Alpheios River up to 4 km upstream,[27] and Raphael noted an acceleration of erosion and deposition in the Peneus delta in Classical, Hellenistic, and Roman times.[28] All of these may be correct, since the youngest beach accretion plain (Classical to present times) that is adjacent to the Alpheios delta is a composite that includes at least three cycles of barrier accretion. At present, however, we have no geological means of segregating and dating the obviously complex barrier ridges of our past two and a half millennia.

An intriguing aspect of the studies of coastal Elis is that the ancient literature is replete with references to flooding events of the Alpheios River caused by the catastrophic drainage of temporarily dammed lakes in the interior karst topography of western Arcadia. There, the Pheneos

---

[22] Zangger et al. 1997.
[23] Büdel 1965.
[24] Du Faure 1976.
[25] Vita-Finzi 1969.
[26] Judson 1985.
[27] Streif 1982.
[28] Raphael 1978.

sinkhole, with its subterranean connection to the Ladon Spring and the Ladon River tributary to the Alpheios, has a history of sudden drainage of lakes resulting from the removal of debris plugs. Higgins and Higgins conclude that the amount of sediment moved would be insignificant,[29] but we disagree: the terraces of the Alpheios River show many evidences of flood events.[30] To the observer in antiquity, such flash floods, possibly with no evidence of a correlatable visible meteorological event, may have indeed appeared catastrophic and would have carried significant sediment loads onto the Alpheios River floodplains and riverine settlements, including the city of Olympia. Schoo summarizes the pertinent statements of Strabo, Eratosthenes, and Pliny the Elder:

> Water disappearing from the plain of Pheneos [in Arcadia] comes to light again at the south side of the mountains. The river Ladon springs forth here at a distance of nearly 6 miles [9 km] from the plain at an 800 feet [260 m] lower level. The Ladon is the biggest tributary of the Alpheios which is the largest river at the west side of the Peloponnese. Strabo . . . reveals that the connection between the caves of Pheneos and the spring of the Ladon was well known in ancient times . . . (VII, 9): "Eratosthenes mentions that the river Aroanios (Olbios) forms marshes at Pheneos and thereafter dives in certain earthholes which locally are called 'zerethra' (same as 'katabothroi'). If these get plugged, then, sometimes, the water will flow over the land but, when they open again, the water rushes away from the plain and runs into the Ladon and Alpheios which, at one time, caused the temple area of Olympia to be inundated at the same time that the lake of Pheneos shrunk away." . . . According to Plinius such an event did not happen once but several times (Nat. Hist. XXXI, 5): "Earthquakes cause water to flow outward and they absorb them again as it has been established happened five times at Pheneos in Arcadia."[31]

Schoo also summarizes relevant observations of the English traveler William Leake from *Travels in the Morea:*

> When Leake visited the Valley of Pheneos in 1806, he found the plain dry and under cultivation. In 1821, the subterranean outlets got plugged and a lake came into existence that slowly increased in size until it had reached a length of five miles and a depth of around 125 feet. For a number of years the Ladon was deprived of water. In 1834, the water broke through and caused serious floods along the lower course of the Alpheios. The plain of Pheneos became dry and could be cultivated again.[32]

Human activities as well as natural events led to the flooding and aggradation of the Alpheios River floodplain terraces and delta. We can date the resultant lagoon-barrier coasts and their relative ages of formation based on limited radiocarbon age determinations in the paralic sedimentary sequences. We cannot, however, date the river terraces or major erosion events in the Alpheios and Peneus river basins. By extrapolating from the extant literature, recent work in the Argive Plain,[33] the results of the Pylos Regional Archaeological Project,[34] and our own ^{14}C dates, core

---

[29] Higgins and Higgins 1996.

[30] See Streif 1964, 1980, 1982; Judson 1985.

[31] Schoo 1969, p. 24.

[32] Schoo 1969, p. 24.

[33] Van Andel, Zangger, and Demitrack 1990.

[34] Zangger et al. 1997.

sediment, geomorphological observations, and archaeological data, we propose the following tentative time frame for the three post-Neolithic major sedimentation cycles in the barrier accretion plain sequences and the correlative denudation events: Early Helladic, ca. 2500 B.C. (Fig. 2, M.B.; Table 1: 2nd barrier sequence); Early Mycenaean, ca. 1600–1400 B.C. (Fig. 2, A.B.; Table 1: 3rd barrier sequence); and Classical to recent, ca. 500 B.C. to present times (Fig. 2, P.B.; Table 1: 4th barrier sequence). More precise timing of these recognizable sedimentologic events awaits future research and new dating evidence. Clearly the fourth barrier accretion sequence (Table 1) involves more than one major sedimentation event, possibly resolvable by discovery of datable artifacts, archaeological sites, or organics within or immediately adjacent to the many identifiable accretion ridges.

GEOLOGY AND GEOMORPHOLOGY

The arcuate strandlines on the northwest coast of the Peloponnese form the longest coastal sandy plains with barrier lagoons in Greece (Fig. 1). The southern arcuate lagoon-barrier system receives its sediments from the Alpheios River delta and a few smaller streams to the south. To the north, the sandy coastal zone from Cape Katakolon to the Gulf of Patras receives sediments mainly from the Peneus River, which at times during the geologic past flowed in a northerly direction into the arcuate embayment between the Chlemoutsi headland and the Gulf of Patras.

The Alpheios River delta is both prograding and aggrading with lateral overbank-floodplain components to the northwest and southeast (Fig. 2). During the last glaciation, the pre-Neolithic Alpheios River delta developed across the adjacent continental shelf to depths 100 to 130 m below present sea level. Strong and continuous coastal erosion and littoral transport occur in some locales to both the northwest and southeast.

The mid-Holocene geomorphology was quite different. In the Mesolithic–Neolithic periods, the shoreline of the Gulf of Kiparissia lay up to 5 km to the east. Incised, wave-cut cliffs formed an arcuate strand from Cape Katakolon in the north to the vicinity of Lake Kaiafa in the south, with a less definite incision farther to the south toward the city of Kiparissia (Fig. 1). We interpret these cliffs to have formed during the mid-Holocene high sea stand from six to seven thousand years ago, when nearshore marine waters were 2–3 m deep. These steep and high cliffs, incised into the Neogene marine sediments and adjacent Eocene limestones at Cape Katakolon and the Mesozoic limestones of the massif at Lake Kaiafa, must also be a product of multiple high sea stands throughout the Quaternary Period.

The arcuate coast from Cape Katakolon and northwest to the Chlemoutsi headland includes two important geomorphic elements, the wave-incised cliffs located from Cape Katakolon due north along a rocky headland coastline, and the modern sandy strand of the Peneus River delta located farther to the north and arcing westward to the Chlemoutsi outlier (Fig. 1). The Peneus delta includes a broad barrier system with extensive eolian dune fields that trap the waters of the meandering Peneus River, forming large coastal swamps. Evidence from maps and from literature indicates that the current Peneus River delta has been evolving since the 18th century A.D.[35] We can speculate that inhabitants of the 17th or 18th century A.D. may have diverted the Peneus River delta to the south from its former course to the northwest in order to create a less flood-prone plain for agriculture to the north and/or to create a new floodplain to the south.

The arcuate coastline from the Chlemoutsi headland and northeast to Cape Araxos at the Gulf of Patras received large amounts of sediment from the Peneus River delta throughout the late Holocene. Channels of the 18th and earlier centuries A.D. in the Peneus River delta and in a few smaller streams can still be seen in their courses to the northwest, now dry. The shoreline of this former Peneus River delta is one of marine transgression and coastal erosion, as is to be expected in a former delta now deprived of its sediment load. Sediment transport in this coastal segment is dominantly to the northeast where there occurs a series of ancient lagoons bounded by a broad barrier accretion plain with concomitant dunes along the crest of the ridges. Kotiki Lagoon is indicative of, and a remnant of, a long line of former lagoons behind the barrier accretion system. Here a mid-Holocene (Neolithic) wave-cut cliff extended NNE–SSW at the edge of the Quaternary Amalias terrace, which includes Pleistocene fluvial sediments overlying undifferentiated pre-Quaternary bedrock.

SEA-LEVEL CHANGES

Controversy continues over eustasy, i.e., world sea-level changes, during the mid- to late Holocene. The "Barbados dipstick" model, based on mid-oceanic island sea-level measurements, shows a rapid rise in sea level until about 7000 b.p., from a last glacial maximum (Würm) lowstand of 130 m, followed by a rapid deceleration until about 5000 b.p., and then a continually slower sea-level rise to present times.[36] Lambeck, correctly noting the limitations of a uniform global eustatic curve, has presented as an alternative the more complex concept of glacio-hydro-isostatic impact on sea levels in the Aegean region.[37] Lambeck's maps of predicted sea levels in the delta of the Alpheios River and Cape Katakolon, showing sea levels of −49 m 10,000 b.p., −4 m 6000 b.p., and −1.15 m ca. 2000 b.p., provided us with a valuable predictive tool in our examination of late Holocene sea-level fluctuations and their contribution to coastal erosional and depositional landscapes. We were dependent, as well, on evidence of local relative sea-level changes, since local tectonic events are a factor in both regional and eustatic sea-level curves. On the basis of geologic evidence along the western coast of Anatolia, for example, Kayan has clearly demonstrated a Neolithic (mid-Holocene) high sea stand (6000 b.p.) extending from Troy to Bodrum, and in the Argolid, offshore of the Franchthi Cave, van Andel has noted a Neolithic site (7610 ± 159 to 6220 ± 139 b.p.) at 11 m below sea level.[38] There is abundant evidence of such relative sea-level changes in strandlines worldwide, caused by a composite of both global and local/regional tectonic uplift and subsidence.[39]

[35] Raphael 1973.

[36] See, e.g., Fairbanks 1989.

[37] Lambeck 1996.

[38] Kayan 1988; van Andel 1987, 1989.

[39] Pirazzoli 1991; Scott, Pirazzoli, and Honig 1987; Flemming 1969.

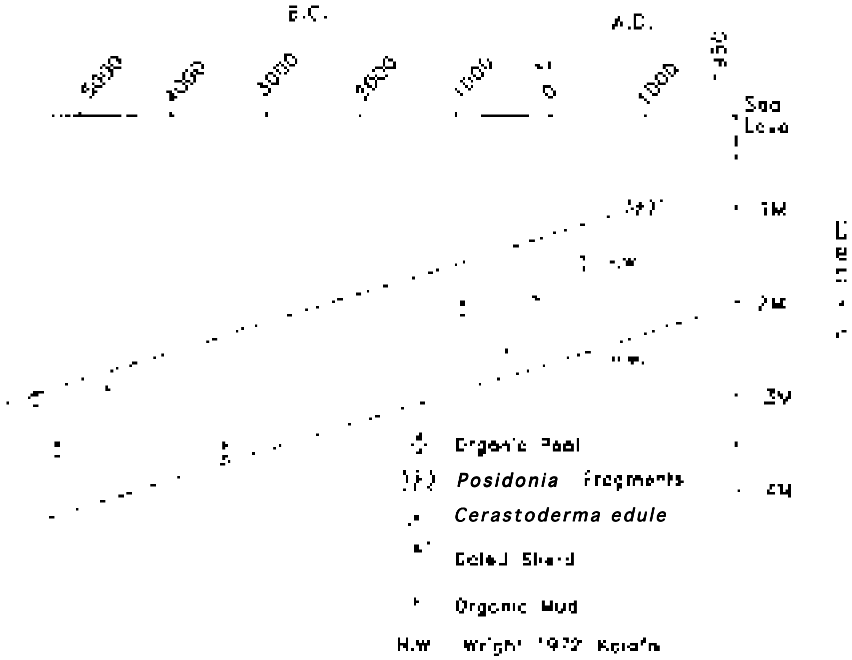

Figure 3. Schematic diagram showing local relative sea-level evidence, Lake Kaiafa region

Research on the evolution of coastal zone morphologies must acknowledge the limitations of local relative sea-level evidence, elevation measurement, and ^{14}C analysis. Because our ^{14}C dates of local relative sea levels (see Fig. 3 and Table 2) are based primarily on marsh and lagoonal organics and peats, which involve brackish water marsh-lagoon fringes and the very seaward edge of freshwater conditions, our data are on the "high side." Our geologic correlation and sedimentary environment profiles include evidence of the immediately adjacent lateral and vertical marine and brackish sedimentary facies. Relative sea-level positions that we propose here for the past seven millennia are within less than 1 m of the sea levels predicted by Lambeck for the Cape Katakolon region.[40]

ARCHAEOLOGICAL SETTINGS AND THEIR PALEOGEOMORPHOLOGIES

The sites discussed below are known archaeological and historical sites of coastal Elis, dated from the Early Helladic period (ca. 3000 B.C.) to the present. Archaeological evidence has provided little more than a sequence of a few successive phases, and our landscape reconstructions should help to associate these fragmentary sequences. Our research was mostly carried out in the area that extends, southeast to northwest, from the clifflike massif at Lake Kaiafa (Classical Samikon), to the Alpheios River delta (Classical, Hellenistic, and Roman Epitalion: Homeric Thryon), and to Cape Katakolon (ancient Pheia). A barrier accretion plain entrapped Lake Kaiafa, which, prior to the past several centuries, was an extension of Agoulenitsa Lagoon and not a separate lagoonal system (see Fig. 4); Agoulenitsa Lagoon to the southeast of the Alpheios River delta; and Lake Kasta and the shallow coastal Mouria Lagoon to the northwest of the Alpheios River delta.

---

[40] Lambeck 1996.

TABLE 2. RADIOCARBON DATES FROM ELIS

Lab. No.	*Core No.*	*Depth*	*Conventional Radiocarbon Age (b.p., ^{13}C Adjusted)*	*Location*	*Material*	*Dated Calibrated Age(s)*	*Calibrated Age Range (1σ)*	*Calibrated Age Range (2σ)*
UCR-1250	P2	−1 m	1055 ± 90	lagoonal mud under seaward barrier: Lake Agoulenitsa	organics *Posidonia* sp.	A.D. 1001	A.D. 892–1035	A.D. 784–1118
UCR-1251	P6	−3.5 m	4870 ± 100	base of layered marsh muds: Lake Agoulenitsa	marsh plant organics	3649 B.C.	3766–3535 B.C.	3935–3376 B.C.
UCR-1252	P7	−2.5 m	2400 ± 90	lagoonal mud: Lake Agoulenitsa	wood	408 B.C.	758–388 B.C.	793–207 B.C.
UCR-1255B	P9	−2.8 m	5870 ± 125	basal lagoon: Lake Agoulenitsa	*Cerastoderma edule*	4779 B.C.	4903–4573 B.C.	5052–4459 B.C.
UCR-1255A	P9	−2.9 m	6610 ± 135	basal peat: Lake Kasta	peat organics	5501 B.C.	5597–5388 B.C.	5705–5269 B.C.
UCR-1256	P9	−4 m	35,000	wood fragments in marine sediments: Lake Kasta	wood	—	—	—
UCR-1253	P11	−3.5 m	6300 ± 135	basal peat: Peneus River delta south of Gastouni	peat organics	5256 B.C.	5413–5070 B.C.	5447–4928 B.C.
UCR-1243	P15	−2.0 m	2835 ± 75	"pure" peat: southeast corner of Kotiki Lagoon	peat organics	991, 952, 948 B.C.	1112–901 B.C.	1253–819 B.C.

Core P9: *C. edule* date includes a 400-year reservoir correction.

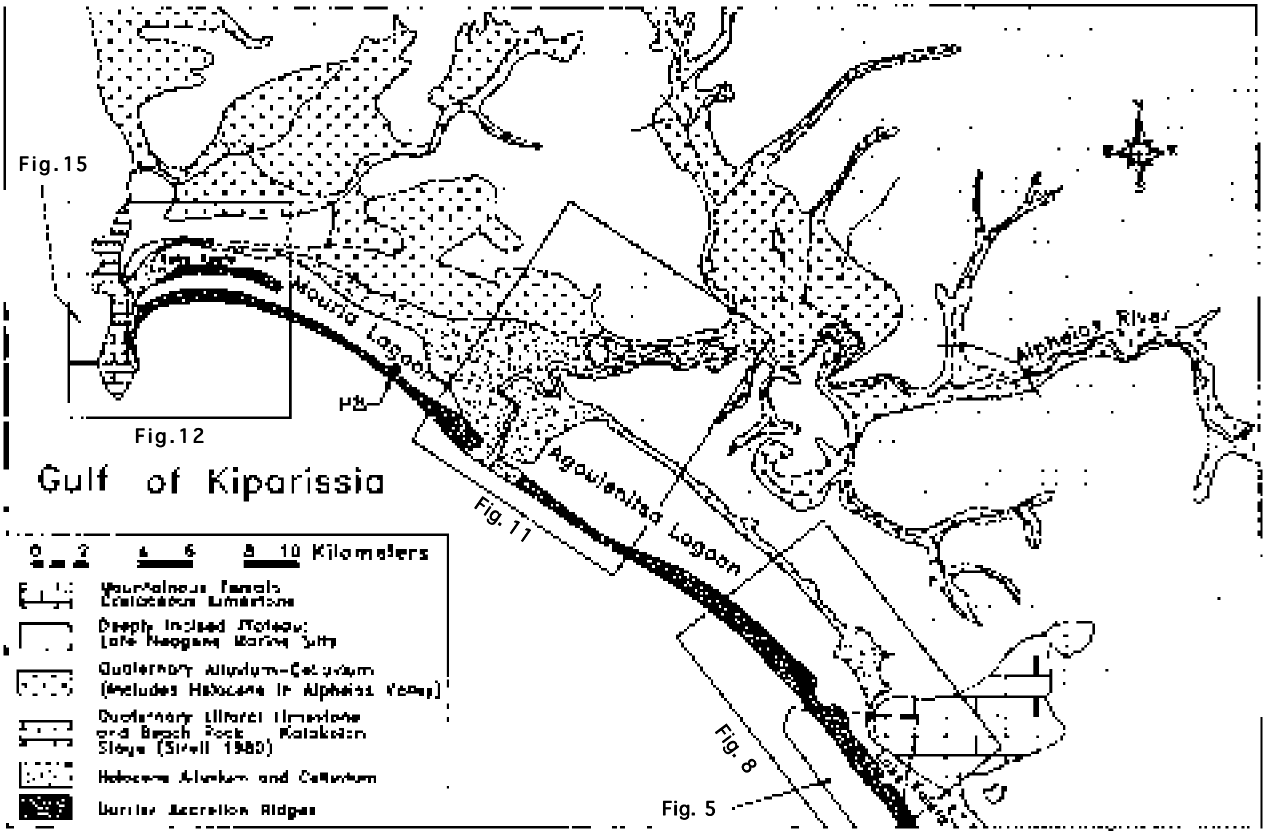

Figure 4. Index of areas studied, northwest portion of Gulf of Kiparissia

Cave of the Anigrid Nymphs: Lake Kaiafa

Lake Kaiafa is ca. 4 km in length and runs northwest–southeast, parallel to the coastline (Figs. 4, 5). A 400 m wide strip of sand dunes covered by a stand of Aleppo pines separates the sea from the brackish waters of the lake, which is connected to the sea only by a narrow channel. From the east, the small stream Mavropotami (ancient Anigros) drains into the lake. Submerged in the lake near a modern spa are long, linear foundations of large squared blocks that have been interpreted as a roadway or buildings.[41] The shapes of the blocks indicate a Classical or Hellenistic date, which is reinforced by the occurrence of some fragments of Classical roof tiles.

Historical sources indicate that Lake Kaiafa, originally a coastal lagoon, has probably changed considerably, and possibly has formed, since ancient times. Pausanias does not mention the lake, nor the larger Agoulenitsa Lagoon to its north, but, in remarks about the Anigros River, states that during storms, the sea moves sand to block its mouth (5.5.7) and that pilgrims, seeking a cure for diseases of the skin, swim the river to reach the Cave of the Anigrid Nymphs at the base of the cliff (5.5.11). This cave is today at the level of the lake.[42] During the 1980s, a larger boat mooring area and a narrow road to the adjacent springs were constructed, and more recently, a new causeway. Throughout antiquity and into modern times, however, the Cave of the Anigrid Nymphs had to be approached by boat or by swimming. Strabo, describing a spring near the cave that makes the area below swampy and marshy, states that "the greater part of the water

---

[41] Roadway: Sperling 1942, p. 81; McDonald and Hope-Simpson 1972, pp. 318–319. Buildings: Bisbee 1937, p. 525.

[42] Cave of the Anigrid Nymphs: McDonald and Hope-Simpson 1972, site no. 708; Sperling 1942, site no. 7.

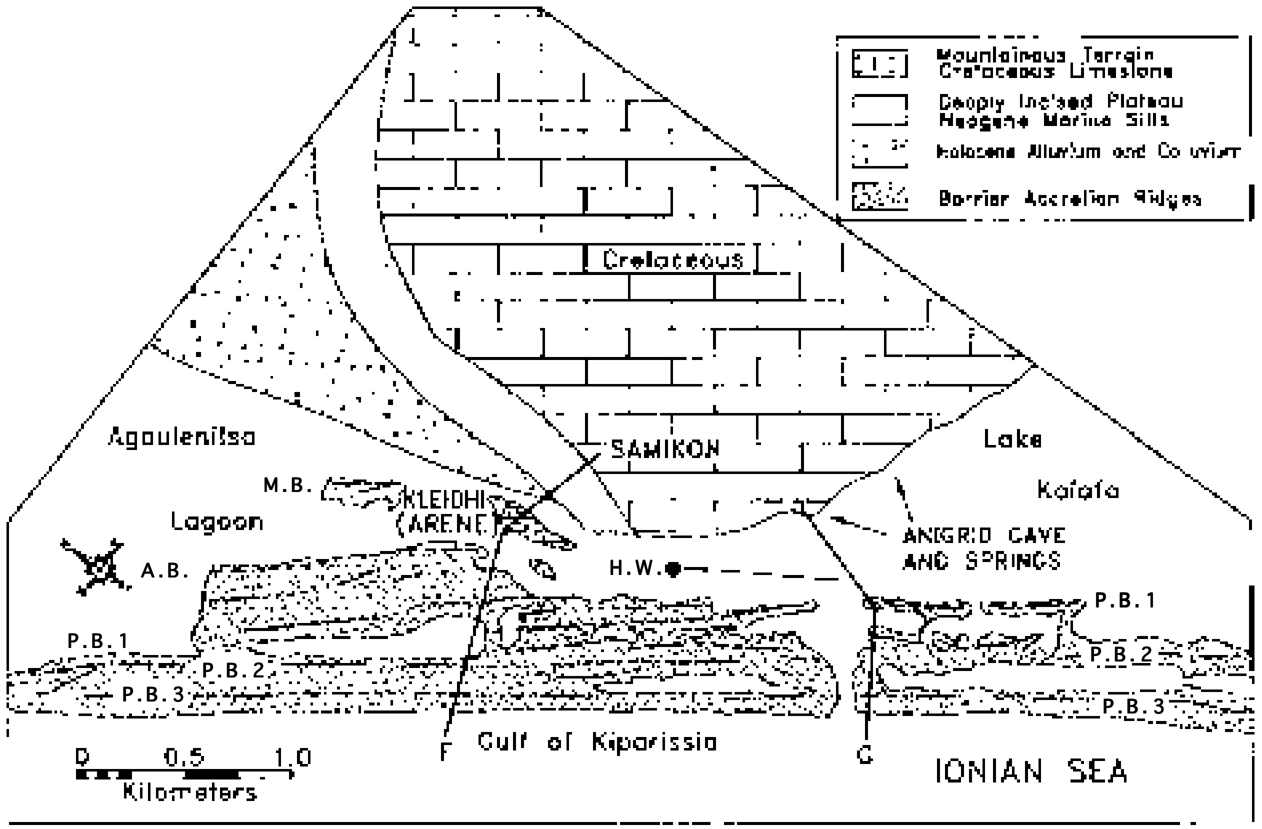

Figure 5. Coastal lagoon-barrier systems of Agoulenitsa Lagoon and Lake Kaiafa. Key: P.B. 1 = Classical barrier; P.B. 2 = undated middle barrier; P.B. 3 = latest barrier to present time; H.W. = drill core by H. E. Wright Jr.

[from the spring] is received by the Anigrus, a river so deep and so sluggish that it forms a marsh."[43]

Lake Kaiafa lies at the foot of a massive Cretaceous limestone outlier with steep wave-cut cliffs of 5,000 to 7,000 years ago dropping into the Ionian Sea (Fig. 5). Since then, the sands carried by littoral transport from the Alpheios River delta have formed barrier accretion ridges that have isolated a broad, shallow coastal lagoon. Core drilling shows that the lagoon was probably never as much as 5 m in depth (Fig. 6). We have not determined the date of the earliest coastal lagoon in the Kaiafa region, but the final Kaiafa lagoon was extant in Classical times. Our radiocarbon dates of marsh peats transgressed by the Ionian Sea or its coastal lagoons allowed us to construct a local relative sea-level curve for the mid- to late Holocene transgression (Fig. 3). Radiocarbon dates do not help to locate and date barrier accretion ridges; however, at Lake Kaiafa we identified three distinct barrier accretion ridge systems that correlate with the actual (present) barrier system (P.B.) of Streif in a seaward progradational sequence.[44] This barrier accretion system continues along the arcuate coastal system from Lake Kaifa to Cape Katakolon. The three barrier systems (P.B. 1, 2, and 3) are clearly shown on our maps (see Fig. 5), and the flooding waters of modern Lake Kaiafa and the swampy interbarrier areas indicate progradation since Classical and more recent times.

Wright's dates of A.D. 369 and 408 for marsh peats located under Lake Kaiafa, landward of the innermost beach accretion ridge, provide

[43] Strabo 8.3.19, trans. H. L. Jones, Cambridge, Mass., 1954.

[44] Streif 1982.

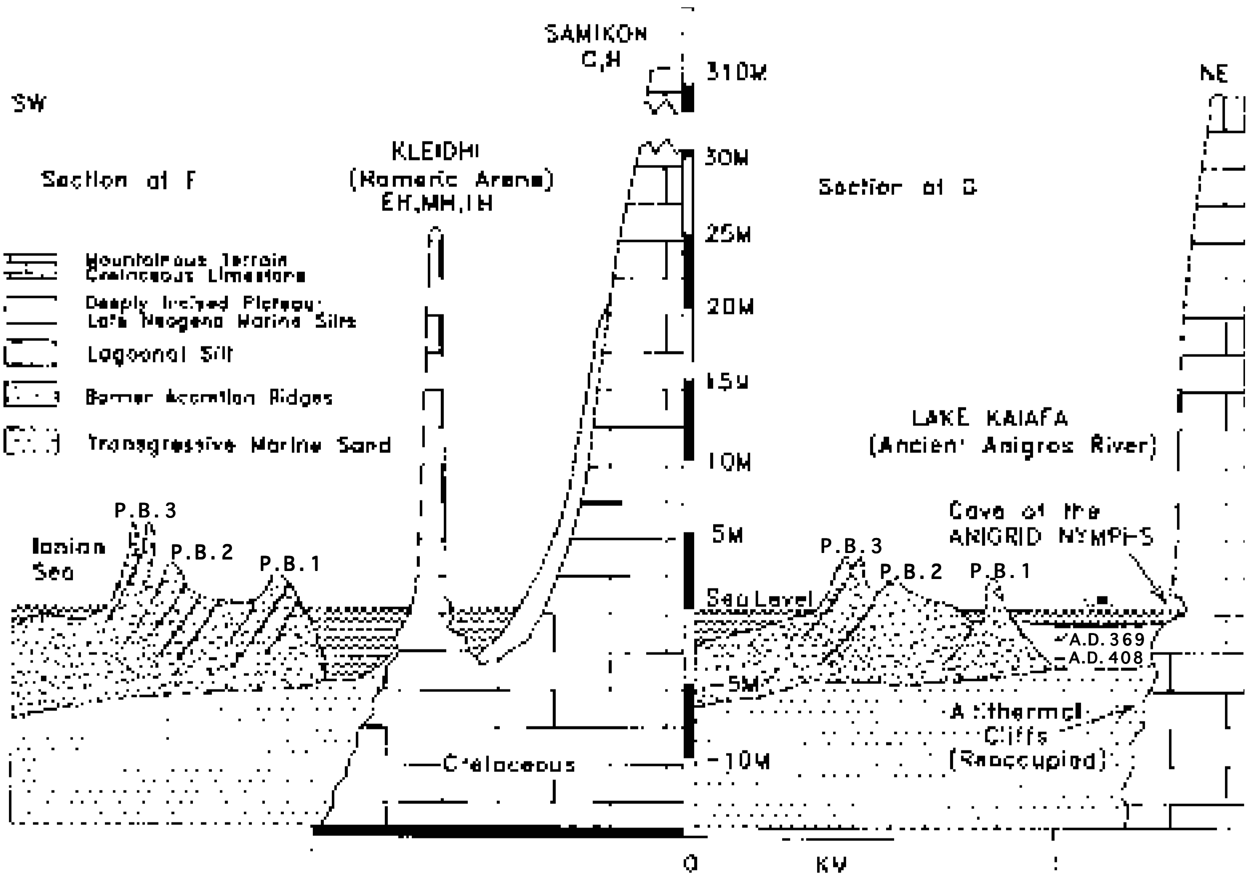

Figure 6. Geologic cross sections: F, through the barrier accretion plain at Kleidhi to Samikon; G, across the barrier accretion plain to Lake Kaiafa and the Cave of the Anigrid Nymphs. For locations, see Figure 5.

minimum dates for the formation of the lake (Fig. 6),[45] allowing the inference that the first barrier bypassed the Cave of the Anigrid Nymphs before A.D. 400. The date, however, is from lagoonal and peripheral marsh sediments and not from the barrier accretion sediments. The foundations of probably Classical or Hellenistic date that are submerged in Lake Kaiafa, as well as the comments of Pausanias and Strabo, indicate that the oldest of the three barrier ridge systems in Streif's present barrier system certainly predates Pausanias and Strabo.[46] A geologic profile shows that the crests of the coastal dunes become higher toward the sea (Fig. 6), suggesting a rapid increase in the amount of sand available to littoral transport and to eolian processes in the beach area. Such rising dune levels may be an indicator of a slowly rising sea level. Caution is required, however, since eolian processes can vary with short-term, high-wind events and do not necessarily closely reflect sea-level fluctuations.

In Strabo's reference to the Anigros River (8.3.19), he notes that the water is deep, and both he and Pausanias (5.5.8–10) comment also on the water's smell. What Strabo meant by "deep" is uncertain, though it does suggest a morphology different from that at present, and the mention of the water's smell suggests that sulfurous waters from the Cave of the Anigrid Nymphs may have fed the river. Of course, the Anigros River could have been a tidal/estuarine-type river, languid without strong currents and yet quite deep, particularly at the time when the barrier system was only beginning to form in this region and was broken by tidal inlets.

---

[45] Wright 1972.
[46] Streif 1982.

Figure 7. The former island at Kleidhi, now at the inner edge of the coastal plain *(at center)*. At left, the low rocky extension of the ridge to the southeast; at right, a sandy spit extension to the northwest.
Photo Hans-Jeorg Streif, ca. 1960–1963

KLEIDHI: THE SOUTHEAST END OF AGOULENITSA LAGOON

At the northern end of Lake Kaiafa lies the steep rocky point of Mt. Smerna, on top of which stands the Classical acropolis fortification of Samikon.[47] The point projects westward to narrow the coastal plain sharply to a natural pass, where a wooded sandbank separates Lake Kaiafa from the southern extremity of the larger Agoulenitsa Lagoon that extends northwest to the mouth of the Alpheios River. A low, isolated north–south ridge (25 m above the plain, 300 m long with a maximum width of 50 m) with three little hillocks rises above the surrounding salt marshes. This ridge site is fittingly called Kleidhi ("key"), as it commands the land route along the coast (Figs. 5, 6). Excavation and surface survey have established that the ridge carried EH, MH, LH I, and LH IIIB cemeteries and habitation sites, which included Cyclopean fortification walls.[48] Excavation of the northern hillocks by Yalouris showed that the cemetery consists of a rare MH–LH burial tumulus with 15 graves and a surrounding curb 7.5 m in exterior diameter.[49] The site is now identified as Homeric Arene. The ancient setting of the ridge could hardly have resembled the marshy strand of later times, which Leake describes as follows: "Between the extremities of the two lakes [Agoulenitsa and Kaiafa] there is a natural causeway, and a bridge in the middle of it over an occasional inundation that unites the two lakes."[50]

Strabo describes a temple of Poseidon located near the sea just below Samikon (8.3.13–17). In his commentary on Pausanias, Frazer notes that he saw an ashlar masonry wall some 20 m north of the hillocks, which he conjectured was part of the temple, but no recent observers have noted remains of it.[51]

Kleidhi is a small, rocky outlier of Cretaceous limestone with a small sandy spit extending to the northwest. This rocky hill and several smaller adjacent islets were clearly islands in the peak Holocene (late Mesolithic/

---

[47] Samikon: Bisbee 1937.

[48] Kleidhi: McDonald and Hope-Simpson 1961, p. 230; 1972, site no. 302 (old no. 19); Sperling 1942, site no. 1.

[49] Yalouris 1965.

[50] Leake 1830, vol. 1, p. 52.

[51] Frazer 1898, vol. 3, p. 480.

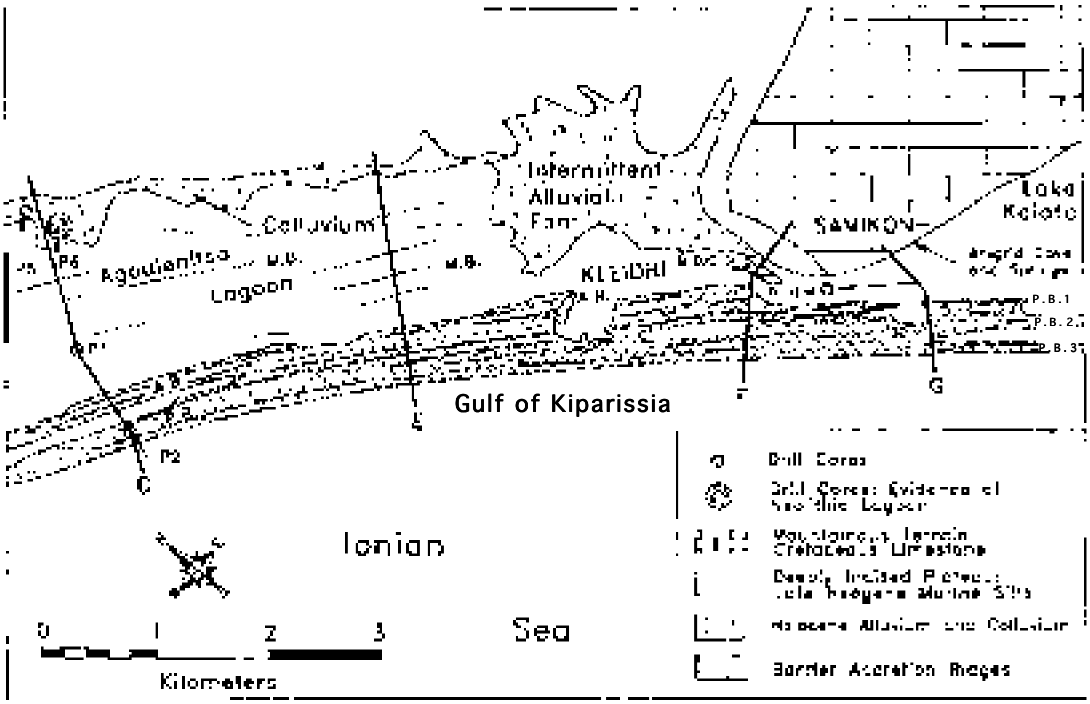

Figure 8. Southeast portion of Agoulenitsa Lagoon, Kleidhi, and the area of Lake Kaiafa. Sections F, G: see Figure 6; sections D, E: see Figure 10.

Neolithic), when the waters of the Ionian Sea reached their present interglacial high (Figs. 2, 4–8). The area is tectonically active,[52] and one might expect to see a series of wave-cut notches at the base of the immediately adjacent Mt. Smerna. However, the Pliocene (Neogene) marine silts are soft and the colluvial footslope is fairly steep; therefore, any notches incised into the Pliocene silts were probably not long-lasting and have been buried. We did not observe wave-cut notches higher than present sea stand in cliffs incised into Cretaceous limestones to the southeast of Samikon. The caves at Scouro, however, and the springs of the Anigrid Nymphs are most assuredly wave-cut erosional features of high sea stand times (probably during the last interglacial and Holocene times). Currently, the narrow coastal plain bounding the landward side of Lake Kaiafa is low-lying, with colluvial and perhaps small rivulet alluvial processes. Optimal locations for settlement sites from the Classical to Roman period would likely have been along these slopes and southeast of the Anigrid Cave. Occupancy of the adjacent coastal barrier was possible after Classical times, although freshwater resources may have been limited.

As noted above, Kleidhi was occupied throughout the Helladic period, but we cannot confirm whether or not it was attached to the mainland by a shallow swampy zone at the time (Figs. 5–8). We do have evidence for extreme flooding events at Agoulenitsa Lagoon in recent times (before the late-20th-century drainage project) that produced an island at Kleidhi: a farmer living on the northeast flank of Kleidhi spoke to us in 1989 about high flood levels on his farm in the 1960s. The northern end of the islet, a sand spit preserving remains of a tholos tomb, clearly was formed in the Early Bronze Age (Figs. 5–7). Our core data cannot establish whether this

---

[52] Kelletat et al. 1976.

Figure 9. Southeast portion of Agoulenitsa Lagoon and barrier accretion plain; dredged engineering channels at center right. View from the walls of Samikon.
Photo Hans-Jeorg Streif, ca. 1960–1963

spit extended into a lagoon surrounding the islet of Kleidhi or occupied an islet just off the coast in shallow waters of the Gulf of Kiparissia. Either would have been a strategic setting. No significant road has been discovered between Kleidhi and the mainland or along the base of the cliffs at the Anigrid Cave, but such features could be buried in colluvium or talus debris.

To the north of Kleidhi there are additional indicators of small barrier accretion ridges (Figs. 8–10). These barrier remnants are the earliest barrier accretion elements within Agoulenitsa Lagoon, and probably correlate with the landward Mouria Barrier to the northwest. Seaward is a complex of barrier accretion ridges that include at least four major progradational elements. The earliest of these ridges, an extension of the Agoulenitsa Barrier, was formed during the Bronze Age. The crests are low-lying relative to the crests of the modern barrier accretion ridges along the immediate shoreline of the gulf. Broad areas of marsh occur in and around the dune fields of the inner, older barrier accretion ridges. A number of radiocarbon dates of enclosed, interfingering marsh sediments would be required to definitively date the various beach accretion ridges in seaward sequence.

The southeast section of Agoulenitsa Lagoon has complex morphologic features (Figs. 8, 9). A number of palimpsest-like barrier accretion ridges that once extended across the area have now been submerged and partially buried within the ancestral Agoulenitsa Lagoon. A large alluvial fan, semi-arid and wet-dry, debouches into the lagoon at its southeast corner, northwest of the Samikon massif, and bows across the lagoon, covering or truncating earlier barrier accretion features and shorelines (Fig. 8). Some segments of the ancient barriers in this region are eroded, such as the barrier accretion field to the northwest of Kleidhi and a zone of "missing" barriers. While we cannot provide absolute dating, the relative sequence of these barriers is clear: Figure 10, section E, shows the modern prograding beach accretion ridges of this region, with elements of relict coastal barriers buried 1–2 km landward under the marshy islets of the southeast end of Agoulenitsa Lagoon.

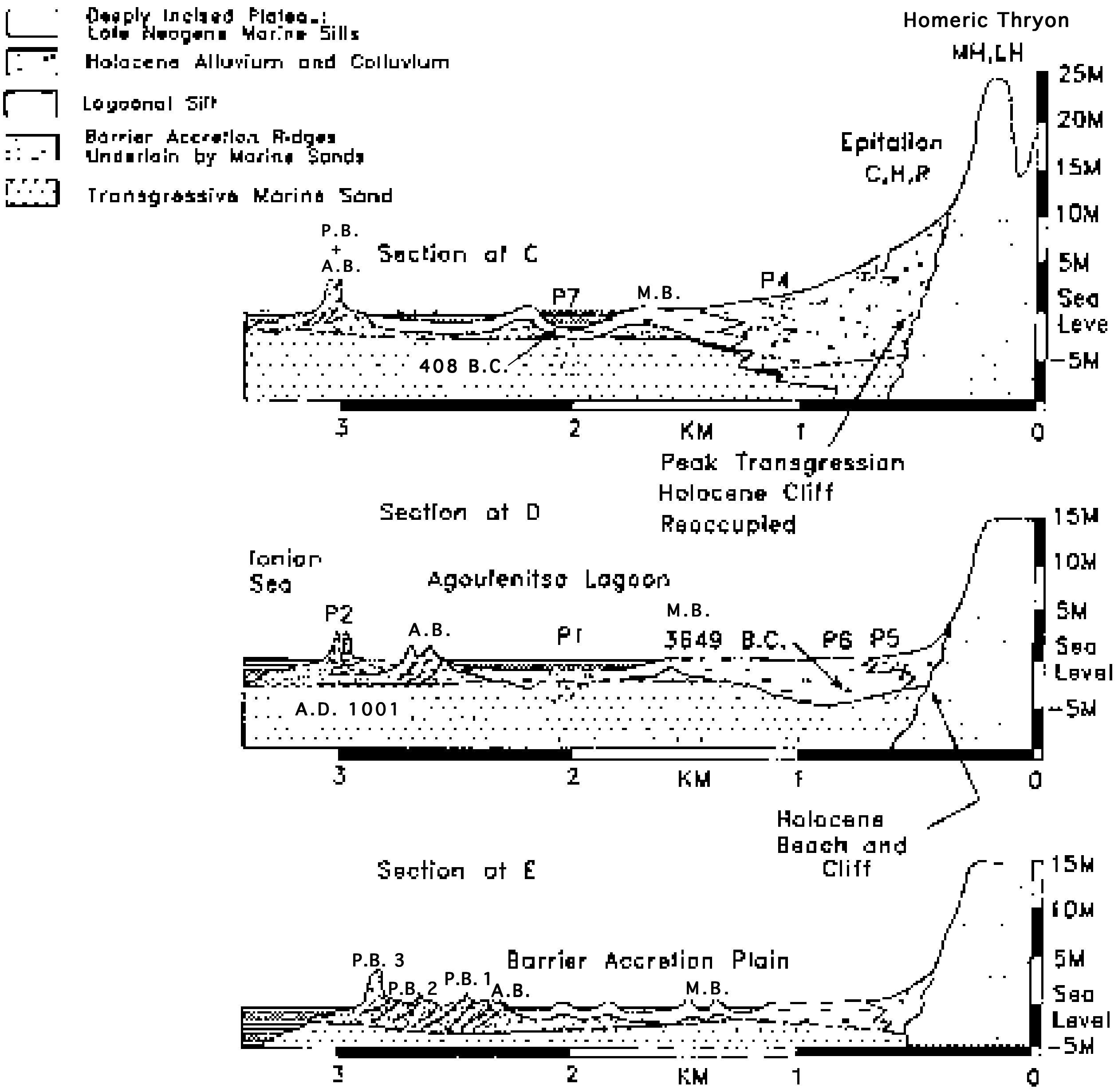

Figure 10. Geologic cross sections across colluvium *(top)*, Agoulenitsa Lagoon *(middle)*, and the coastal barrier accretion plain *(bottom)*. Sections C, D, E: for locations, see Figures 8, 11.

The seaward limits of the earliest dated lagoon(s) in the Agoulenitsa region are not known, but a lagoon existed here shortly after the peak marine transgression that created the wave-incised cliffs. Core P6 (Fig. 10, section D) clearly indicates the presence of a lagoon here in the Neolithic period, before the formation of the Mouria Barrier (see below, pp. 23–25), and Figure 8 shows an irregular sequence of beach accretion ridges that evolved throughout the mid- to late Holocene. Neolithic and Early Helladic inhabitants of the region could have lived around these small lagoons. They may well have utilized the abundant fish and shellfish, leading to increased occupation of the area. Occupancy of the barrier systems has never been proven, as the majority of the landward early barrier accretion ridges are now buried under marsh-lagoonal mud, and on the landward side, along the slope at the base of the ancient cliffs, colluvium could have buried small coastal lagoonal occupation sites. Figure 10 suggests the presence of submerged barrier accretion ridges, but does not prove them. Our cores and radiocarbon dates show a continuous local relative sea-level rise since the Early Helladic period (Fig. 3).

Figure 10, section D, shows a basal marsh peat of 3649 B.C. within 0.3 km of the mid-Holocene wave-incised cliffs. This date is indicative of the earliest lagoonal waters and peripheral swamps or marshes at this location. A coastal marsh peat date provides an approximate sea-level date; that is, the datum point is slightly above current local relative sea levels (Fig. 3, Table 2). The fauna of the lagoonal muds of Agoulenitsa Lagoon are mainly brackish, characterized by the edible pelecypod *Cerastoderma edule*. Figure 10, section D, also shows a marsh or swamp ecosystem at A.D. 1001, under the outer progradational barrier system at the edge of the Gulf of Kiparissia. This marsh feature under the barrier accretion ridges at core P2 indicates a transgressive event, possibly a storm wave overwash feature succeeded by continual progradation of the barrier accretion plain, or, perhaps less likely, evidence of an upward pulse in the late Holocene sea level.

Agoulenitsa Lagoon

Agoulenitsa Lagoon (ca. 13 km long and ca. 2 km wide) once extended along the coast from Lake Kaiafa to just south of the Alpheios River delta (Fig. 4). Today its fertile bottom is cropland, as a result of a lattice of drainage ditches connected to pumping stations. Leake, who passed along the coast in 1805, provides useful descriptions of the lagoon, which was at the time a fishery of considerable leased value in the Ottoman economy, extending from near Agoulenitsa village (ca. 1.5 km southeast of Epitalion) to near Lake Kaiafa. According to Leake, "a narrow sandy ridge covered with a wood of pines divides the lake from the sea; as we advance [southward] this ridge is wider and the woods thicken, occupying large islands in the middle of the lake, which becomes narrower, and more like a marsh."[53] At its south end, Agoulenitsa Lagoon is separated from the north end of Lake Kaiafa by the wooded sand bank at Kleidhi.

Research by Topping seems to indicate that this lagoon was smaller some centuries ago. He cites a Venetian document of 1701, which describes land areas and their use by the village of Agoulenitsa, as reporting the extent of the lagoon (or fishery) as 790 campi (i.e., 1,350,900 m^2) and the amount of arable land for the village as nearly seven times greater.[54] The ratio suggests that the lagoon was at the time notably smaller than it is today.

Figures 8, 10 (section D), and 11 show the central area of Agoulenitsa Lagoon, bounded at its northwest end by low, marshy shorelines. Prior to the engineered drainage of the 1960s, this broad, shallow lagoon was noted for abundant fish. Time-transgressive barrier elements suggest arcuate shorelines merging with coastal barriers of the Gulf of Kiparissia (Fig. 11). Even short-term (e.g., seasonal) fluctuations in water level would sharply vary the width of lagoons as shallow as Agoulenitsa.

[53] Leake 1830, vol. 1, p. 51.
[54] Topping 1972, p. 78.

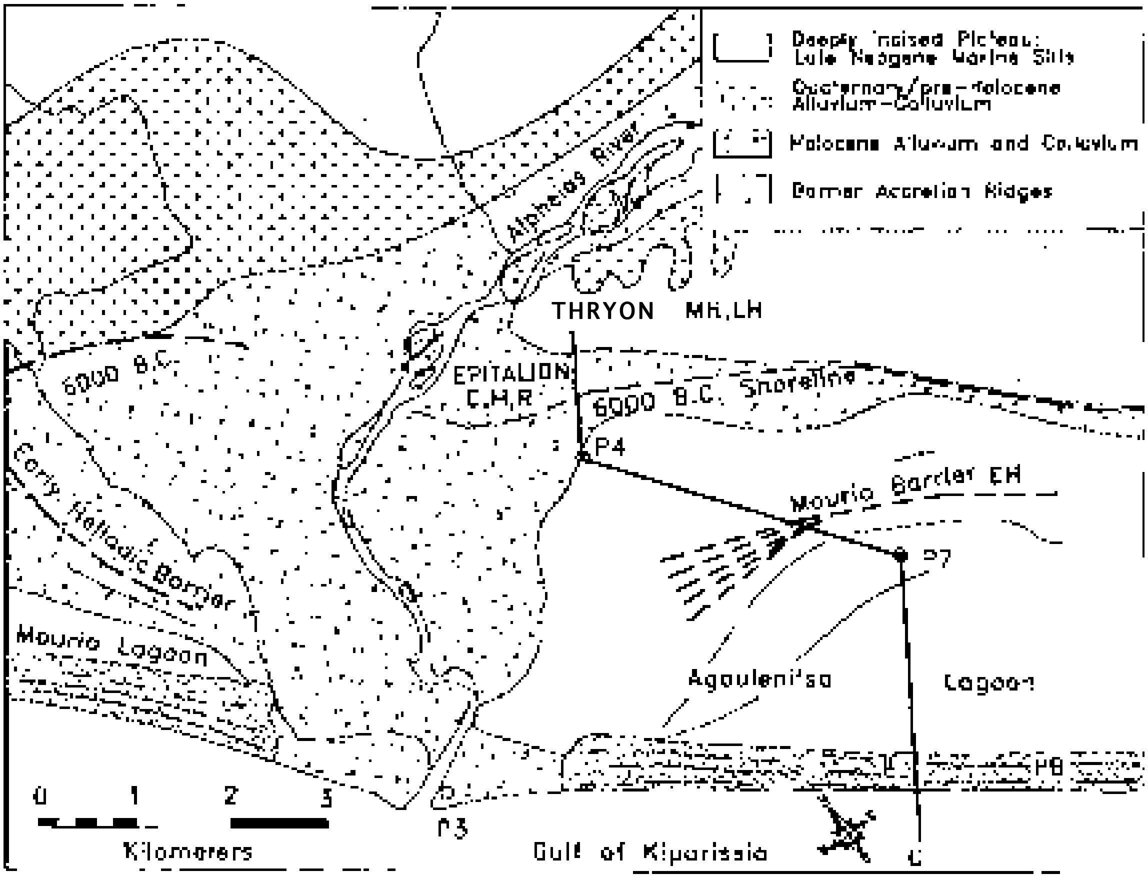

Figure 11. Morphology of the Mouria and Agoulenitsa lagoons, their barrier accretion plains, and the Alpheios River delta, Holocene epoch

Section C of drill core P7 (Figs. 10, 11) shows a date of 408 B.C. for organic sediments from the bottom of Agoulenitsa Lagoon, a position both then and now below present sea level. Clearly, the Agoulenitsa lagoons were in existence in the Classical, Hellenistic, and Roman periods, and were at those times potentially important fisheries resources.

The low barrier islets in the northwest end of Agoulenitsa Lagoon show an arcuate configuration of the Early Helladic Ionian Sea coast (Fig. 11). These sandy ridges were subsequently accentuated by, and conformed to, winds that blew across the broad waters of the lagoon.

The Delta of the Alpheios River

About 500 m south of the Alpheios Bridge, where the national highway is bordered on its east by a ridge of hills and on its west by an irrigation canal, the four hills of Ayios Yeoryios rise to a height of 60–70 masl.[55] Test excavations and surface surveys in this area have revealed LH habitations and possible LH cemeteries,[56] and the site is now considered to be the most likely candidate for Homeric Thryon (Fig. 11).

Initial digging for a modern canal on the plain just west of the highway (ca. 10 masl) exposed impressive ancient remains. Subsequent archaeological excavation of a 30 × 800 m area along the canal route revealed a bath, houses, workshops, and cemetery, all of the Roman period; a large

---

[55] Classical Epitalion (probably Homeric Thryon): McDonald and Hope-Simpson 1972, site no. 303 (old no. 12).

[56] Hope-Simpson 1981, p. 94; McDonald and Hope-Simpson 1961, pp. 227–228; 1969, p. 129; 1972, p. 302.

Hellenistic building and fortification wall; and other evidence of occupation from the Archaic through Late Roman periods. The settlement, now identified as ancient Epitalion, served as a base camp during invasions of Elis by King Agis of Sparta (402–401 B.C.) and Philip V of Macedonia (218 B.C.).[57] MH and LH sherds found at the sandy bottom of one trench were interpreted by the excavator as having washed down from the prehistoric settlement on the hills to the east,[58] a site which, overlooking the old Alpheios fort, offered obvious strategic advantages. As Themelis has noted, the site at the base of the hills was also of strategic importance, its coastal plain having formerly been much more narrow;[59] for this point, he cites Kaupert and Dörpfeld's placement of the ancient shore nearly 3 km inland, a mere 700 m west of the excavated ruins.[60]

Figure 11 indicates the broad triangular shape of the Holocene delta of the Alpheios River and, to the northwest, relicts of arcuate strandlines that show through the delta sediments. Some of these lineaments may be patterns incised by waves moving across the southeast end of Mouria Lagoon.

Section C (Figs. 10, 11) extends from Homeric Thryon, down steeply incised cliffs, and across the colluvium and alluvium on which Classical, Hellenistic, and Roman Epitalion was located. The Alpheios River presents no evidence of having made a major tributary debouchment into Agoulenitsa Lagoon in the past several hundred years, although the bulbous shoreline of the Alpheios River delta, as shown in Figure 11, does suggest a broad, swinging, fanlike pattern of migrating channels throughout the historical period.

Core P3, drilled at the present mouth of the Alpheios River, encountered only deltaic sediments, but core P4 on section C (Fig. 10) is critical for understanding the limits of land and shoreline and thus for determining the possible sites of Epitalion's ports. According to Leake, Epitalion had a fishing port on the shore of Agoulenitsa Lagoon, not on the Gulf of Kiparissia, and a commerce port on the Alpheios River.[61] The city was thus a major transshipping point, both for traffic to Olympia and into and out of the northwest Peloponnese. The raised Pliocene (Neogene) terrace-like surface upon which Homeric Thryon was located was clearly an important strategic location, near the Early Helladic shoreline of the Gulf of Kiparissia and the mouth of the Alpheios River. Along the foot of the cliffs below Thryon, at the landward side of the earliest Agoulenitsa Lagoon, colluvium and alluvium again overlie and obscure potential Bronze Age settlements.

Mouth of the Alpheios River

Leake reported that, in 1805, the Pyrgos district had two ports with customshouses and magazines, one at Katakolon and the other, where there was also a valuable salt pan or manufactory, at the mouth of the Alpheios River (then called the Rufia).[62] Based on Strabo's estimate of a distance of 80 stades from Olympia to the mouth of the Alpheios River (8.3.12), Yalouris, as well as Kaupert and Dörpfeld, located the ancient coast considerably inland from its present position, some 3 km according to Kaupert and Dörpfeld.[63]

[57] Themelis 1968a, p. 202.

[58] Themelis 1968b, pp. 165–170.

[59] Themelis 1968a, p. 204.

[60] Kaupert and Dörpfeld 1882, pp. 7, 9.

[61] Leake 1830, vol. 1, pp. 45, 47.

[62] Leake 1830, vol. 1, pp. 45, 47.

[63] Yalouris 1957, p. 32; Kaupert and Dörpfeld 1882, pp. 7, 9.

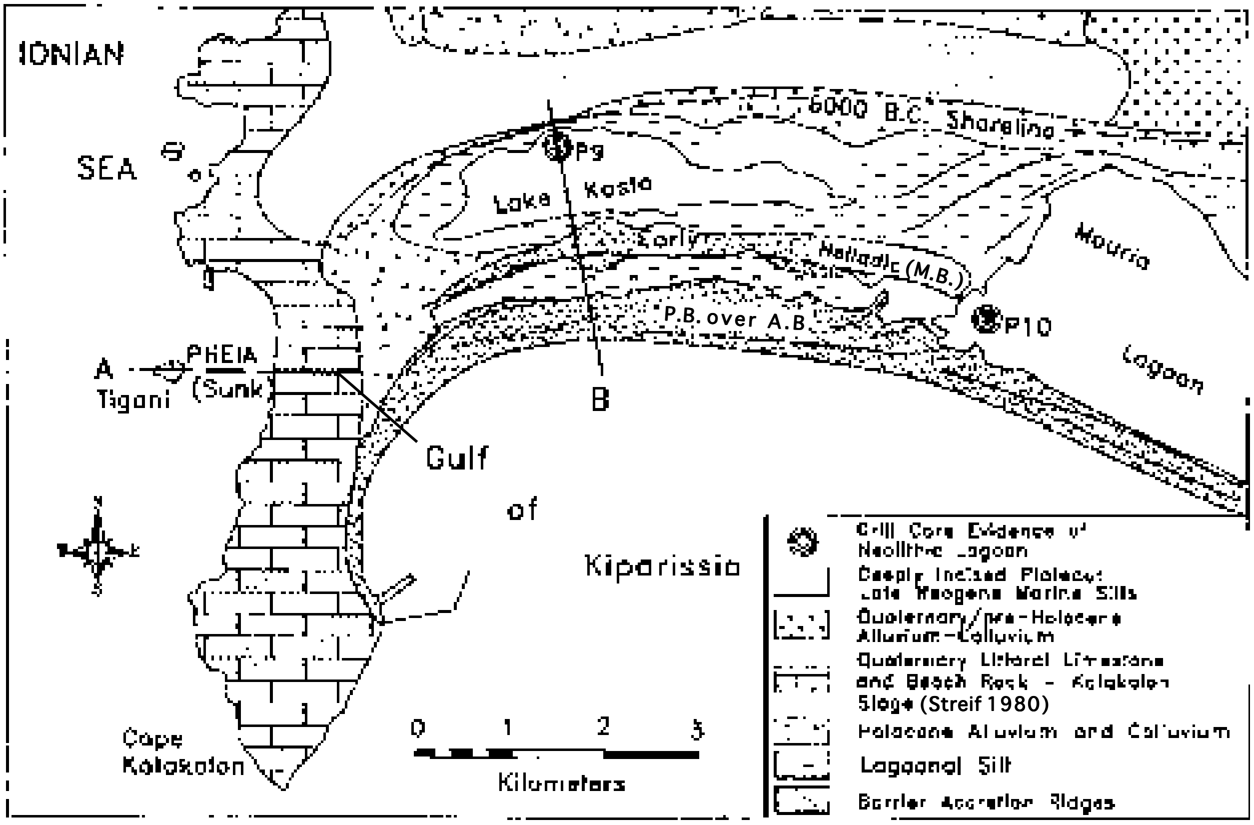

Figure 12. Geologic map of the arcuate strandline, Gulf of Kiparissia. Core P9: see Figure 13; section B: see Figure 14.

Lake Kasta and Mouria Lagoon

A third lagoon, the Mouria—like Agoulenitsa Lagoon, presently drained—lies along the coast of Elis, midway between the Alpheios River and Katakolon (Figs. 11, 12). It may be that Pausanias refers to it when he states that "about six stades distant from Letrini is a lake that never dries up, being just about three stades across."[64] Archaeologists have associated no remains with ancient Letrini, but most agree that it was in southern Elis, north of the Alpheios, and not far from the sea, perhaps between modern Pyrgos and Katakolon. If that is the case, it would seem that Pausanias's description is of the Mouria Lagoon, and that, on his evidence, it was in existence in the second century A.D.

The northwest corner of the arcuate strand lying between the delta of the Alpheios River and Cape Katakolon is composed of lagoon and barrier features (Fig. 12). Here, the coastal barriers present more elevated dune fields and occur in two distinct sequences: the inner EH Mouria Barrier and the outer composite barrier, which includes the EM Agoulenitsa Barrier overlain by the barrier of the Classical to present period.

Our subsurface studies show that in the latest Mesolithic and early Neolithic periods, one large lagoon encompassed the area now occupied by Lake Kasta and Mouria Lagoon. Following inundation by rising waters of the mid-Holocene epoch (ca. 6000 B.C.), a broad marine re-entrant of the Gulf of Kiparissia lay east–northeast of Cape Katakolon, well protected from the northerly and westerly wave patterns of the Ionian Sea.

---

[64] Paus. 6.22.11, trans. W. H. S. Jones, Cambridge, Mass., 1978.

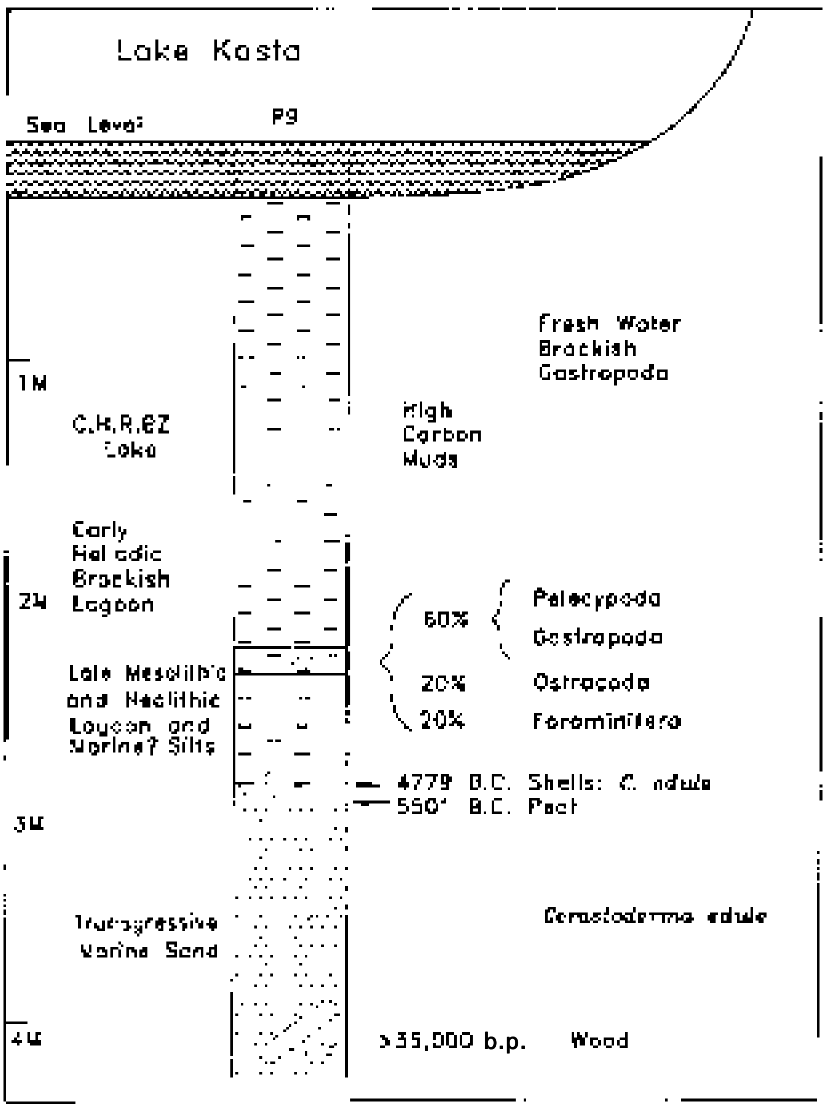

Figure 13. Schematic profile of core P9, Lake Kasta

According to our sedimentologic and radiocarbon dating evidence (Figs. 3, 13, and 14), however, the shoreline shifted seaward from the wave-cut cliff (6000 B.C.) to a coastal barrier, not located, of the latest Mesolithic to early Neolithic period (before 5500 B.C.). The fossil, sediment, and dating evidence in core P9 in the Lake Kasta region, supported by a similar sequence in core P10 in the western Mouria Lagoon (Fig. 12), as well as evidence of similarly dated marsh-lagoon features under the Peneus River delta south of Gastouni and in core P6 in Agoulenitsa Lagoon (Fig. 10, section D), all confirm the presence of widespread Neolithic lagoons with now missing or unlocated seaward coastal barriers.

Throughout the Holocene epoch, and from then until the present, the refraction of Ionian Sea waves around Cape Katakolon resulted in counterclockwise littoral transport of coarse sediment westward from the Alpheios River delta. We hypothesize that in this cycle, due to major human activity in the Alpheios River basin, a large surge of sediment became available and led to the development of the Mouria Barrier. This barrier

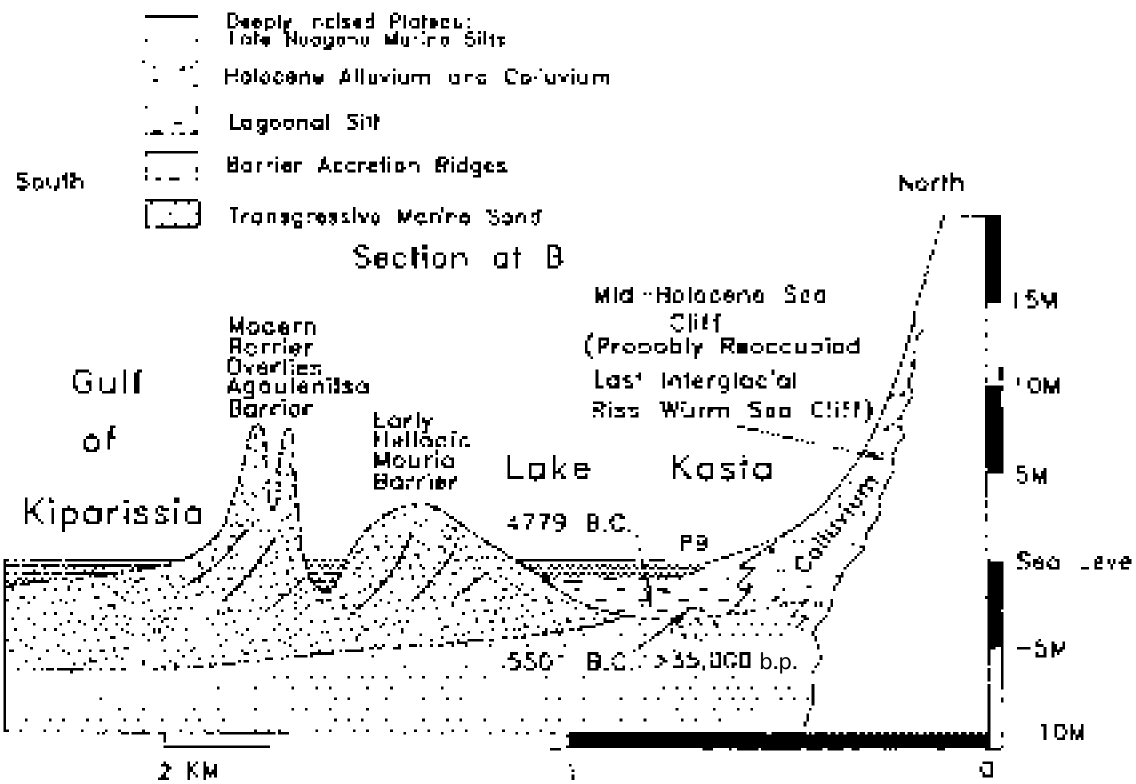

Figure 14. Geologic cross section B, Lake Kasta region, immediately east of Cape Katakolon; for location, see Figure 12.

isolated the early Kasta Lagoon (later Lake Kasta) and an early Mouria Lagoon much smaller than the later Mouria Lagoon that formed behind the Agoulenitsa Barrier. Core P8 contains elements of this later, possibly LM lagoon, now buried under the present barrier (Fig. 2).[65]

Our cross section across Lake Kasta to the shore of the Gulf of Kiparissia shows the vertical profile of the two large barrier features with high-crested dune fields that postdate the Neolithic lagoon (Figs. 13, 14). The northerly feature, dated to approximately the third millennium B.C. by inference from core P9, has a more muted surficial expression than the modern coastal dune field, probably as a result of slope erosion.

Above the Mesolithic marsh peat (5501 B.C.) of the transgressive lagoon and the Neolithic *C. edule* shells (4779 B.C.) of the saline lagoon, sediment and fossils in the drill cores indicate that the waters of Lake Kasta became brackish in the Early Helladic period, after their isolation by the Mouria Barrier system. From Classical to present times, Lake Kasta was essentially freshwater, but it may have received infrequent storm surges of brackish water from Lake Mouria, to its east. The narrow linear lagoon and mud flats between the present barrier and the older Mouria Barrier (Figs. 12, 14) probably remained brackish until modern times, influenced by more frequent overwash of storm waves and by flooding from Mouria Lagoon to the east. In core P9, at a depth of 4 m, we encountered wood fragments that date to earlier than 35,000 b.p., i.e., to perhaps the last interglacial high sea stand (Figs. 13, 14). Allowing that such wood debris could have been retransported, our sedimentologic data show 6000 B.C. as the earliest date for the maximum transgression of the mid-Holocene sea, provided the caveat of a small amount of tectonic uplift.

---

[65] For the later Mouria Lagoon, see Streif 1980, 1982.

In summary, the Helladic lagoon in the lee of Cape Katakolon varied in salinity from freshwater to brackish conditions, as evidenced by *Gastropoda* in the upper part of core P9. All of the muds in Lake Kasta/Mouria Lagoon were high in organic carbon. Classical, Hellenistic, Roman, and Byzantine Lake Kasta was freshwater with possible brackish water infusions from storms. This conclusion is based on the lack of marine or brackish fauna in the upper part of core P9 and on the relative isolation of Lake Kasta behind two large coastal dune fields and a low-lying coastal plain to the east.

Cape Katakolon and Ayios Andreas (Pheia)

Cape Katakolon, composed of uplifted early Quaternary coastal and shallow marine sandy limestones and beach rock, is a horst with a clifflike fault scarp on the east flank and, on the west, a lesser but sharp drop-off into the Ionian Sea and extending down to the site of ancient Pheia (Fig. 12).[66] An earthquake, probably in the sixth century A.D.,[67] has strongly modified the west coastline of the cape. Figures 15 and 16 show the relationship of Cape Katakolon to the Ionian Sea and to the northwest corner of the Gulf of Kiparissia. This high, rocky barrier has created a harborlike embayment to the east and north since the Mesolithic period, and today its southeast flank provides a harbor for the fishing fleet and a debarkation point for cruises visiting the nearby site of Olympia.

About 2 km north of the Katakolon port, on the west side of the north–south ridge that forms the Katakolon peninsula, a small bay creates a natural harbor, somewhat protected to the south and shielded by tiny Tigani Island and connecting shoals on the west (Fig. 15). Prior to the catastrophic earthquake of the sixth century A.D., the island and its southern shoals had protected the harbor of ancient Pheia. Evidence from investigations on land, and underwater in the shallow bay, indicate human occupation for most periods from Early Helladic through Roman, as well as Byzantine. Because coastal erosion is rapidly consuming what is left of the shoreline, especially at the south, and of the outer peninsula, now only a number of small islets, we relied largely on the descriptions of the area given by Yalouris.[68]

Yalouris found remains of many structures along the length of the shore, the ruins of some extending into the sea (Fig. 16). One building, which he observed under a modern tavern at the edge of the shore, has now disappeared. In the bay, buildings could be seen to a distance of 200 m from the shore, at a depth of up to 5 m, and Roman and Classical column drums and capitals were also visible. One wall of well-dressed blocks, measuring 80 m in length and 0.70 m in width, stood at the east side of the bay, parallel to the shore at a depth of 0.20 m below the surface of the water. Sherds dated from the Mycenaean to Roman period were recovered from the shallow sea near the coastline.

Three hundred meters south of Tigani Island lies a submerged ridge 150 m wide. This shoal occurs at a depth of 4 m, after which the depth increases sharply. The bottom here is full of broken natural rock with great

---

[66] Streif 1980. Classical Pheia (Byzantine Pontikokastro): McDonald and Hope-Simpson 1972, site no. 304 (old no. 1).

[67] For the ancient sources, see Yalouris 1957, p. 37; 1960.

[68] Yalouris 1957, 1960.

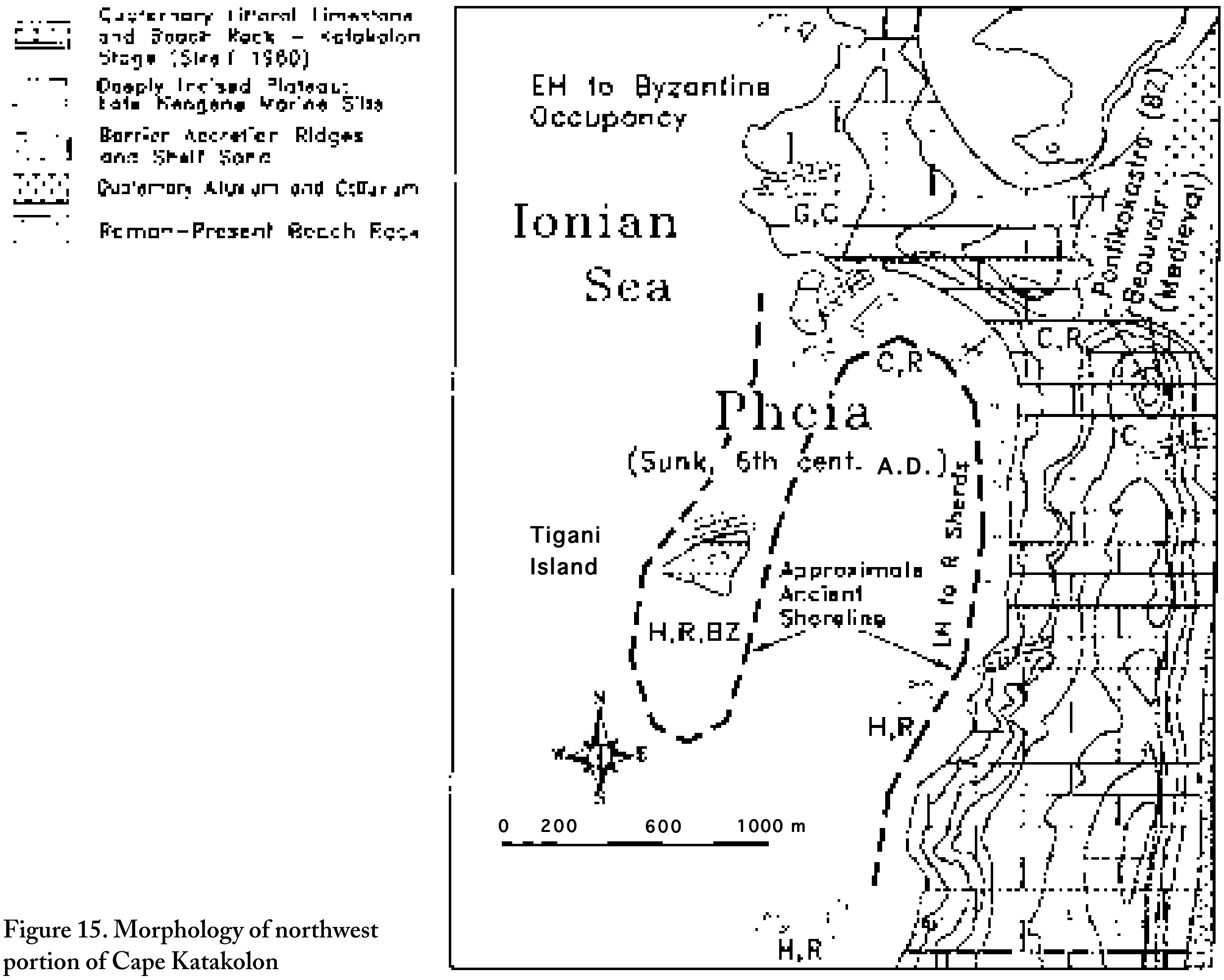

Figure 15. Morphology of northwest portion of Cape Katakolon

cracks and openings. Along the length of the south side of the bay, Yalouris found many large fragments of Hellenistic and Roman amphorae, and the area was strewn with Mycenaean and more recent sherds, many cemented into the beach rock.

Surface exploration shows a concentration of architecture and artifacts on the west side of the cape, but Hellenistic and Roman sherds were also found on Tigani Island, and the island preserves an extensive Roman cemetery at its east, south, and northwest. A Byzantine coin and post-Roman building foundations discovered on the island are probably to be associated with the Byzantine fortification at Pontikokastro, medieval Beauvoir, located on the cliffs east of the bay (Figs. 15, 16).

These remains, and others that Yalouris observed on land and in the sea to the north, establish the site of ancient Pheia and its harbor.[69] Yalouris concludes, on the basis of the evidence, that Pheia sank into the sea, probably in the strong earthquake of the sixth century A.D. that destroyed the city of Patras and completed the destruction of the Temple of Zeus at Olympia. This earthquake resulted in subsidence of the coastal portion of Pheia (Fig. 15) and in the uplift of the flanking hill of Katakolon (Fig. 16).

---

[69] Yalouris 1960, with the map facing p. 124, especially areas a, b.

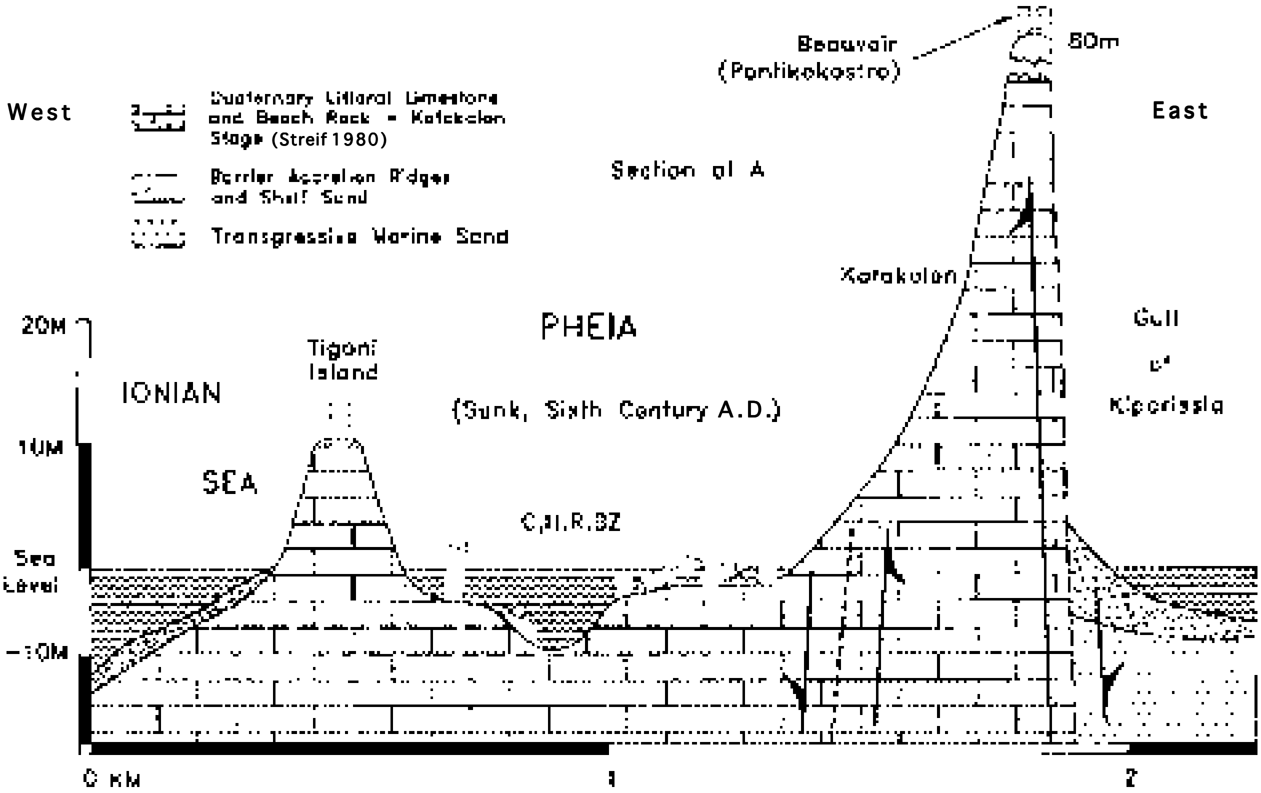

Figure 16. Geologic cross section A, ancient Pheia

Skafidhia (Anemomilo)

Skafidhia, situated on elevated Quaternary littoral limestones, extends from the present coastline to a position 150 m inland (Figs. 1, 2).[70] The ancient name of the site is unknown. Helladic, Hellenistic, and Roman remains are preserved on the promontory, and ruins of a Roman bath, explored by archaeologists, are fallen into the sea. On a hill southwest of the village and ca. 150 m from the shore, foundations, Bronze Age sherds, a Hellenistic statue, and Roman tombs have also been reported.[71] The location commands a wide view of the coastline to the north and also to the south, where the site of Ayios Andreas (Pheia) is situated some 3.7 km distant. Yalouris has aptly warned that "if preservation measures are not taken the fury of the sea will shortly destroy whatever time has saved up to now."[72]

The Peneus River Delta Coastal Plain

The Peneus River formerly flowed to the northeast of Chlemoutsi peninsula into the Ionian Sea (Fig. 17). A diversion in the 18th century A.D. or earlier—created, in our opinion, by local inhabitants, although we have no direct evidence—caused the river to flow, first, to the southwest, then south and southeast into the Ionian Sea.

Core P11, which we drilled in the lowermost swampy region of the Peneus River floodplain south of Gastouni, behind a broad coastal barrier

---

[70] Skafidhia (Anemomilo): McDonald and Hope-Simpson 1972, site no. 305 (old no. 2).

[71] McDonald and Hope-Simpson 1961, p. 225; 1972, p. 302.

[72] Yalouris 1970.

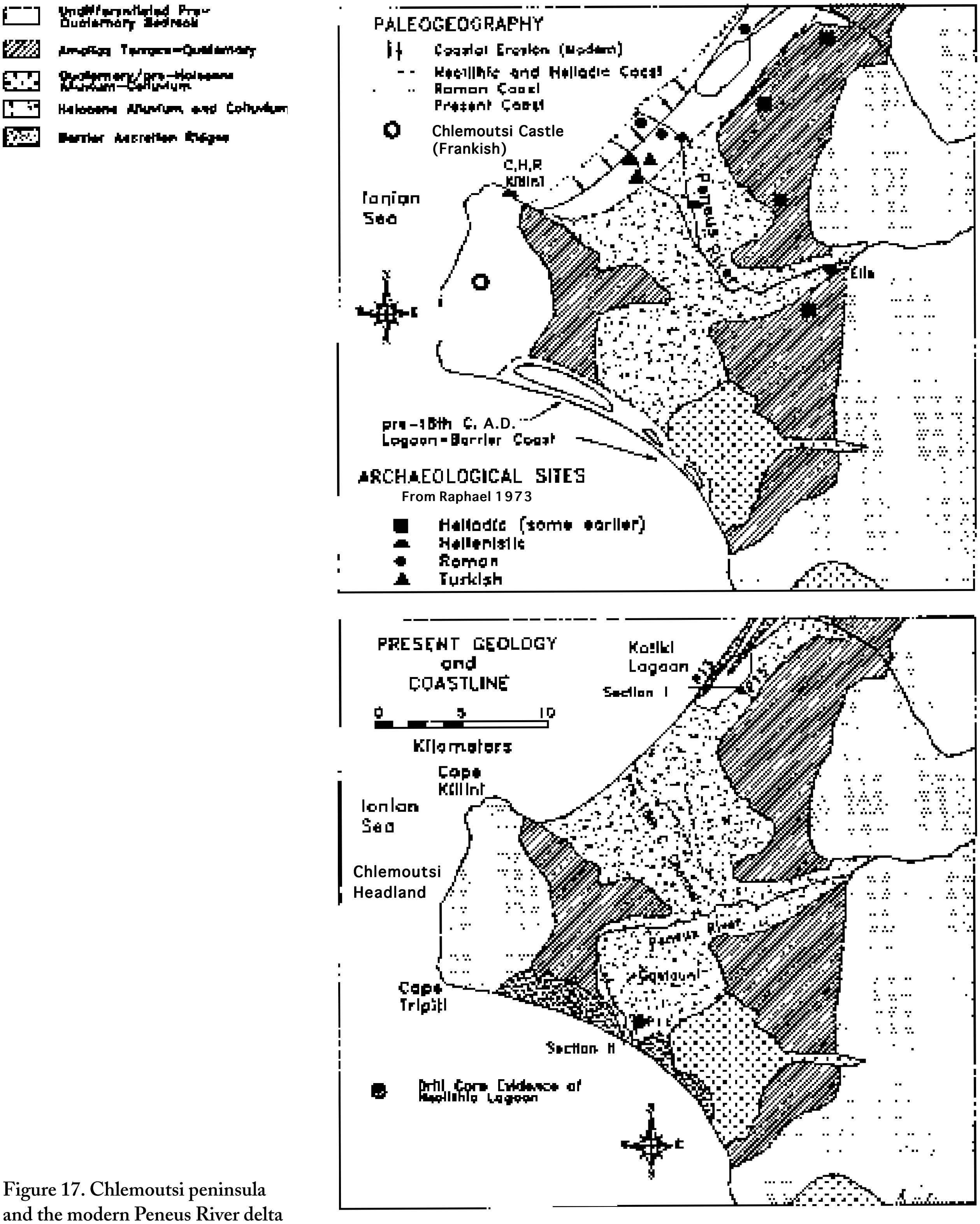

Figure 17. Chlemoutsi peninsula and the modern Peneus River delta floodplain: *(top)* paleogeography and *(bottom)* present geology and coastline.

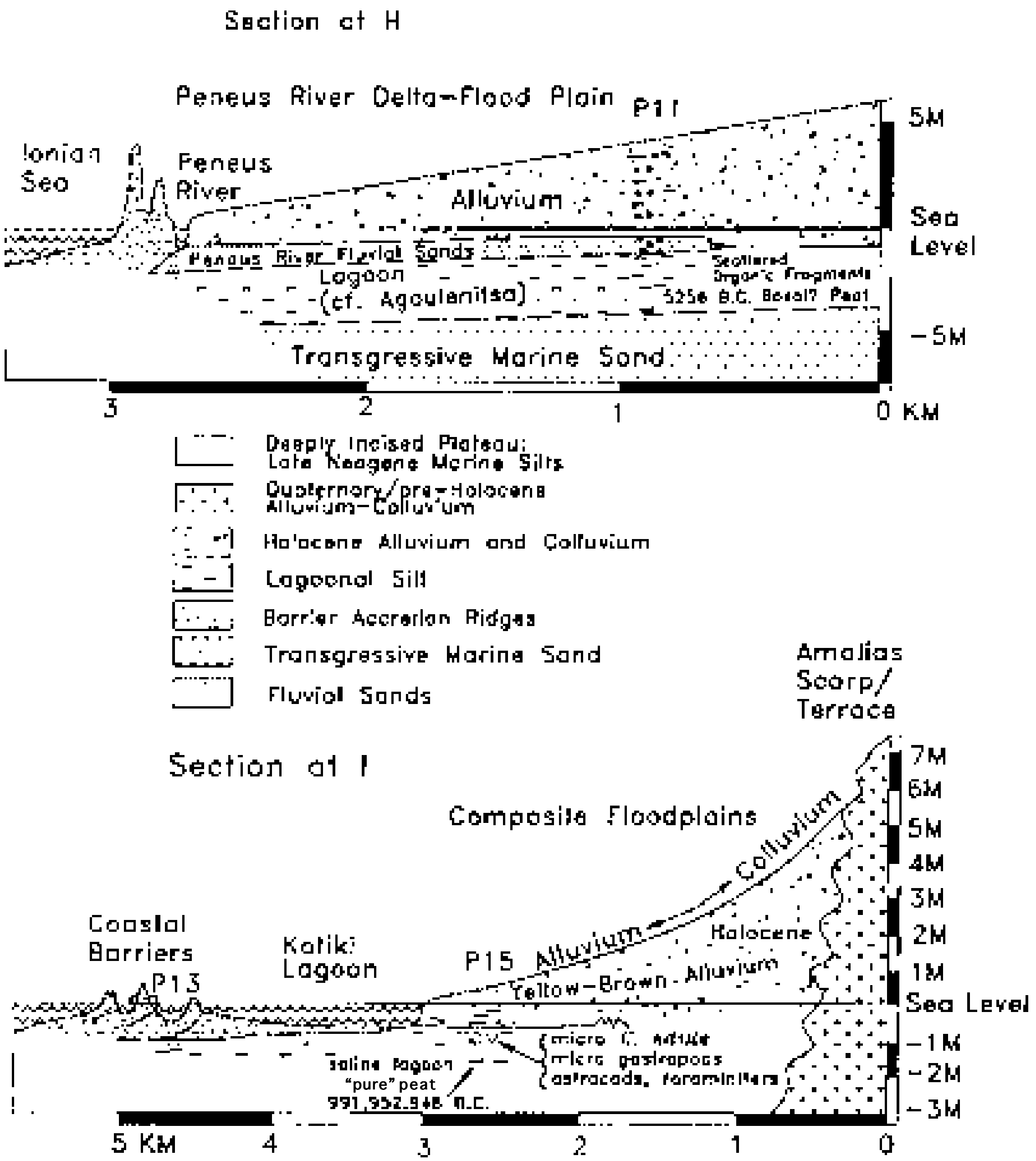

Figure 18. Geologic cross sections *(top)* across the modern Peneus River delta floodplain and adjacent coastal dunes and swamps and *(bottom)* in the vicinity of Kotiki Lagoon. Sections H, I: for locations, see Figure 17.

dune field, sheds considerable light on the pre-diversion morphology of the region. The upper 4.5 m of the core are floodplain silt deposits (Fig. 18, section H). These are underlain, within the first meter below present sea level, by a thin fluvial sand, presumably post-18th-century A.D. bed load of the Peneus River, mixed with paralic sands, which are underlain, in turn, by lagoonal muds, possibly extant since Neolithic times, and by a basal peat of 5256 B.C. Thus, the coastal region between Chlemoutsi and Cape Katakolon was a long-term Holocene lagoon-barrier coast dating from latest Mesolithic.

Currently, the Peneus River carries a large volume of sediment into the Ionian Sea. In the coastal zone, littoral transport redistributes the sand fraction of sediment along a long arcuate coastline. Prevailing southwesterly winds have blown sand inland into large coastal dune fields, which have created large back-barrier swamps. Modern drainage systems have allowed extensive development of agriculture in the lower delta area. The region is one of major coastal uplift,[73] and the Mesolithic basal peats located 3 m below sea level in an uplifted coastal zone are compatible with eustatic estimates for that time. Here again, as in the Mouria-Agoulenitsa area to the south, we were not able to identify a precise location for the requisite Mesolithic/Neolithic barrier, but we have documented its presence based on lagoonal muds and a ^{14}C date (see Table 1: 1st barrier sequence).

Coast of North Elis

Our studies of the strandline on the northwest coast of Elis were limited to the vicinity of the pre-18th-century shoreline of the Peneus River northeast of Chlemoutsi peninsula and the adjacent Kotiki Lagoon. These features are part of the broad barrier accretion plain that extends to the northernmost promontory of the Peloponnese, Cape Araxos (Fig. 1). The pre-18th-century Peneus River delta shoreline is now undergoing intensive erosion in response to the loss of its former annual sediment load. Raphael and Loy have each discussed the archaeological sites in the now-eroding area of the old Peneus River delta of the north.[74]

Among well-known sites of the region, the site of ancient Elis, from which the region takes its name, is located just south of the Peneus River, some 20 km inland from the Chlemoutsi headland (Figs. 1, 17). Here, there is evidence of occupation from the Early Helladic to Roman period.

To the west of Elis, on an isolated hill of Cape Chelonatas, lies the conspicuous Frankish castle Chlemoutsi, dating from A.D. 1220 (Figs. 1, 17). The castle was in use during the Turkish occupation, and there is evidence in the area for considerable Middle Helladic activity, as well as Mycenaean, Geometric, and Classical.

The third famous site of the region, Killini, just outside the modern harbor (Fig. 17), was the port of Elis in the Classical through Roman periods. Its location is suggested by the presence of Classical to Roman remains.[75] During Frankish times, when the site was named Clarence or Glarentza, it was not only the chief port but also the residence of the occupying princes, and remains of the walls are visible on the plain above the sea, although many large wall segments have tumbled over the edge due to erosion of the steep cliff. When the site was returned in A.D. 1428 to Constantine Paleologos, he destroyed the city.

In addition to Killini, nine other coastal sites of Elis are located north of Katakolon. These have been briefly described and summarized by Raphael.[76] We note summarily, below, various physical and archaeological details of the coastal setting, drawing largely on Raphael's work.

1. Dune ridges north of Kotiki. North of the lagoon is a group of well-developed beach ridges parallel to the current shoreline. These are undergoing erosion, and migrating sand dunes,

---

73. Kelletat et al. 1976.
74. Raphael 1973, 1978; Loy 1967.
75. Sperling 1942, p. 83.
76. Raphael 1973.

advancing 140 m, have buried some of the beach ridges. Pottery sherds, exposed in fine sediments at the base of the modern beach, date the beach ridges to the Roman period.

2. Kotiki barrier. The narrow barrier separating Kotiki Lagoon from the sea has migrated inland in recent years. A road that ran along the barrier in the 1830s A.D. has been breached and destroyed.
3. Offshore foundations. Local inhabitants report ancient foundations 100 m offshore at the south end of Kotiki Lagoon and Roman sherds washing ashore in the area.
4. Northern channel of the Peneus. Hellenistic sherds are found on the levees of this former channel of the Peneus River and on the most landward beach ridge, where this channel meets the modern shore. There is Roman pottery in the levee, 40 cm below the levee crest.
5. Southern channel of the Peneus. Stones forming the top of Turkish wells, in situ, and abundant sherds are found on the levee of this medieval channel, which is continually filling in.
6. Shoreline north of Korouta. The gravel plain that extends from the coast toward the northeast for a distance of several kilometers is overlain at the shoreline by parabolic dunes that were occupied in the Roman period. At several locations, Roman graves situated a few centimeters beneath the surface of the dunes indicate that the deposition of these dunes was completed by that period.

Data from our drill cores at Kotiki Lagoon defined the stratigraphic sequence of a lagoon-barrier shoreline much like that of the Agoulenitsa Lagoon to the southeast (Fig. 18, section I). The broad, shallow coastal lagoon and adjacent barriers consisted mainly of barrier sands and lagoonal silts. Core P15, which was drilled in a drag line pit along the southeast shore of Kotiki Lagoon, contained yellow oxidized clay and silt overlying a thin gray clay with marine micromollusks. These mollusks are indicative of an earlier, highly saline coastal lagoon and are underlain by a "pure" peat, which formed on the fringe of a lagoon. The peat dates to ^{14}C ages 991, 952, and 948 B.C. Here, the peat is indicative of a local relative sea-level rise of slightly less than 2 m in the past three millennia (Fig. 18, section I).[77] In northern portions of the pre-18th-century A.D. Peneus River delta, the composite floodplain slopes gently upward and southeast to the edge of the Amalias terrace, an elevated fluvial depositional surface of probable Pleistocene age (Figs. 17, 18).

The low-lying arcuate edge of the Amalias Quaternary fluvial terrace to the southeast of the present shoreline was also a wave-incised cliff in the mid-Holocene. Here again, it is probable that the sea cliffs are reoccupied cliffs of the last interglacial (Riss-Würm) high sea stand. Throughout the Holocene, the Peneus River channel may have shifted north and south of the Chlemoutsi headland, although, on the evidence of our drill cores, not between the Neolithic period and the 18th century A.D.

[77] Thus, sea level relative to land has risen 2 m, a composite of eustasy and/or tectonics (undifferentiated).

SUMMARY AND CONCLUSIONS

Geologic Processes, Geomorphic Response, and Archaeological Settings

We have shown that the geomorphic evolution of the arcuate strandline coastal systems of the northwest Peloponnese since the mid-Holocene (late Mesolithic, ca. 5500 B.C.) has had a dominant effect on the coastal morphologies available for human occupancy from the Neolithic period to the present. Large coastal lagoons have existed in the Alpheios coastal embayment and in the area of the modern Peneus River delta since the latest Mesolithic and early Neolithic period. The existence of coastal lagoons and barrier islands may imply a sediment surge related to Neolithic denudation of inland areas or a shoaling event concomitant with the mid-Holocene drop in the rate of eustatic sea-level rise.

In the Lake Kaiafa and Samikon region, wave-cut cliffs precluded settlement on barrier accretion plains, which did not exist until progradation of coastal sedimentary sequences started in the mid- to late Holocene (Helladic period). We have speculated on origins of the concept of the deep, odiferous Anigros River, which Pausanias and Strabo reported flowing in the vicinity of the Cave of the Anigrid Nymphs. A lagoon-barrier system existed in the Kaiafa region by the Classical/Hellenistic period. Our study supports Strabo's and Pausanias's remarks on the ancient geography in the vicinity of the Cave of the Anigrid Nymphs and the Anigros River.

We have placed Kleidhi (Homeric Arene) in the geomorphic context of Helladic times. This outlier of Cretaceous limestone was an emergent stack with a narrow wave-washed channel separating it from the mainland in the earliest Helladic period. Further, we have shown that variable water levels in the southern end of Agoulenitsa Lagoon, from the Bronze Age to the present, have sometimes isolated this little islet. A sandy spit on the northeast end of the islet either extended into the coastal Ionian Sea or into the southern edge of the earliest Agoulenitsa Lagoon during the Bronze Age. Clearly, the concept of Kleidhi, the key to passage between the northern and southern parts of the coastal zones of the Gulf of Kiparissia, is a well-deserved epithet applicable from the Helladic to Geometric period.

At the southernmost end of Agoulenitsa Lagoon, we have found evidence of many barrier features. An Early Helladic lagoonal system existed near the easternmost flanks of the present Agoulenitsa Lagoon. The area presented numerous individual barrier ridges or couplets of ridges with swales between. Human occupancy of the landward edge of Agoulenitsa Lagoon was possible throughout the Helladic period. However, alluvial and colluvial processes and possible later wave-erosion effects at the lagoonal margin have precluded the discovery of coastal archaeological sites now buried.

The city of Epitalion, occupied throughout the classical periods, was strategically located. Immediately adjacent to Agoulenitsa Lagoon, and its finfish and shellfish resources, and on or near the mouth of the Alpheios River, Epitalion was a port city on both the lagoon and the lower estuary of the river. Middle Helladic Thryon, on the narrow promontory above Epitalion, also occupied a strategic setting, controlling the Alpheios River traffic, the fertile deltaic agricultural zone, and the marine and lagoonal resources of early Agoulenitsa.

The vicinity of Lake Kasta and Cape Katakolon has provided a major shelter for shipping and fishing industries from the Neolithic period to the present. At the site of ancient Pheia was a small harbor of the Ionian Sea, enclosed on two sides by the hills of Cape Katakolon and on the third side by a rocky peninsula that extended south from the mainland and included the modern island of Tigani. Helladic to Byzantine occupation of Pheia was based on this optimal setting at a harbor with waters deep enough for all types of seagoing ships. Even during the French occupancy of Beauvoir, on top of the Katakolon ridge, in Crusader times, the Tigani peninsula was still extant, and a useful harbor may have existed then in the area of sunken Pheia.

During the last two centuries, the dominant geomorphic processes in the delta of the Peneus River have been progradation and aggradation. Large volumes of sediment entrained in littoral transport, and sand blown inland into large dune fields, have resulted in the formation of the coastal swamps of the lower Peneus River delta. It is possible that throughout most of antiquity, the Peneus River flowed to the northwest, its position prior to the 18th century A.D. We believe that most Helladic to early modern archaeological sites in the region of the present Peneus delta were situated in a setting of a coastal lagoon-barrier accretion plain, very similar to the present region of the Agoulenitsa and Mouria lagoons to the southeast and the Kotiki Lagoon and coastal plain to the north, and that the major sedimentologic events of the 19th and 20th centuries have compromised the search for those sites.

Evidence of occupation of the area northeast of the Chlemoutsi peninsula has been covered in part by sediments of the Peneus River delta that were deposited prior to the 18th century A.D. Coastal progradation isolated and buried a number of coastal lagoons, such as Kotiki, and supplied sediment to the broad beach accretion plains that extend northward to the promontory of Cape Araxos. Keraudren has discussed the distribution of late Quaternary archaeological sites in this region as well as the dating of the uplifted Tyrrhenian sedimentary deposits that commonly border the Holocene sediments, and Raphael has noted the probable burial by the Peneus River delta of many Helladic to Archaic sites over past millennia.[78] Following the diversion of the Peneus River in the 18th century A.D., a cycle of erosion is now occurring in the region east of Cape Killini, with resultant destruction of Hellenistic and Roman coastal sites. This coastline is now essentially starved of new sediment. Kotiki Lagoon, farther to the north, remains highly saline today, as evidenced by the micro- or reduced size of the marine fossil shells seen in core P15 (Fig. 18, section I). Recent erosion has exposed evidence of Roman to Turkish occupation of this coastline. There does not appear to be any evidence of town sites located along the strandline.

---

[78] Keraudren 1971; Raphael 1973, 1978.

RATIONALES FOR THE SEARCH FOR COASTAL ZONE ARCHAEOLOGICAL SITES

In our description of the ancient coastal geomorphologies of the rapidly evolving coastal zones of Elis, we have shown dramatically different landscapes of potential occupation from the Neolithic period to the present. Thus, the potential exists for future discovery of occupation sites of the past six millennia long buried or inundated under the present lagoons and their margins and along the transgressive shorelines of the Ionian Sea. Such depictions of long-gone or now much-altered landforms should prove useful to archaeologists in their search for undiscovered sites and artifacts. Ancient landscape reconstructions can reveal past potential resources such as freshwater springs, well sites, ponds, and lakes; formerly well-watered agricultural land; transportation routes; and finfish and shellfish resources. For instance, landward shorelines of the Neolithic and Early Helladic lagoons of the Gulf of Kiparissia are now buried under colluvium and alluvium and lagoonal muds. Ravines incised into the mid-Holocene sea cliffs may have had basal springs at the base of their slopes or may have provided optimal well sites. The varied shorelines of the lagoons, exposed by the extensive drainage projects in the 1960s, provide access for study of past landscapes in some cases not seen since Helladic times.

The large alluvial fan embouching into and covering the Bronze Age landscapes of the southeast corner of Agoulenitsa Lagoon and the talus and colluvial debris between Kleidhi and the Anigrid Cave may cover ancient sites, roadways, and the missing temple of Poseidon described by Strabo as lying just below Samikon. What of Pausanias's report of the city of Letrini about six stades from a lake that never dries up? Is this ancient Lake Kasta? Has anyone searched for the villages reported by Leake in the 19th century? Classical and Hellenistic Epitalion, located on the alluvial and colluvial slopes between Agoulenitsa Lagoon and the possibly navigable lower estuary of the Alpheios, may have had satellite villages or port sites on both bodies of water. In the modern Peneus River delta, sedimentation has been so rapid and pervasive as to cover any sites that may have been located along the now-buried Neolithic lagoon-barrier shorelines. In the delta, remote sensing will prove to be a necessary adjunct to coring and exploratory trenching in the search for archaeological sites. Geological concepts of rapid change in ancient coastal landscapes are of use in their own right to historians and archaeologists in their search for ancient sites. They may also lead to necessary correlative studies of Holocene denudation events and thus to more precise dating of fluvial terraces in the hinterlands of Elis. We have only begun to detail the nature of landscape changes in coastal Elis.

ACKNOWLEDGMENTS

The publication of this research was greatly facilitated by the efforts of two members of the Archaeometry Laboratory staff at the University of Minnesota, Duluth, Doris Stoessel, who prepared the text, and Russell Rothe, who prepared numerous illustrations. Hans-Jeorg Streif of the Niedersächisches Landesamt für Bodenforschung was extremely helpful in providing information he has gathered in the field. Christos Tziavos and Georgos Chronis of the National Centre for Marine Research, Athens, visited Elis with the authors and contributed their thoughts on local geomorphic changes. Both the National Science Foundation (Grant #EAR-8008210) and its Greek counterpart contributed to the field expenses for this project. The Hellenic Geographical Service kindly made available its 1:5,000 scale maps, which were essential for determining field elevations of our drill core sites in the now-drained areas of Lake Kasta and the Mouria and Agoulenitsa lagoons. These maps were critical in allowing us to determine the nuances of beach accretion ridge patterns and the multiple shorelines of the ancient lagoons as they existed over the past five millennia. Finally, we thank the anonymous referees of *Hesperia* for their helpful criticism, in particular their challenge to us to equate our evolutionary barrier accretion elements and delta progradation with hinterland human effects of denudation acceleration, a most rewarding exercise in which we have found relative dating obvious, yet precise timing, a future requisite and remaining challenge.

REFERENCES

Angelakos, M. 1993. "The Archaeogeometry of Coastlines on the Island of Thera, Aegean Sea, Greece: A Minoan Reconstruction" (M.S. thesis, Univ. of Delaware).

Besonen, M. R., G. Rapp, and Z. Jing. 2003. "The Lower Acheron River Valley: Ancient Accounts and the Changing Landscape," in *Landscape Archaeology in Southern Epirus, Greece* I (*Hesperia* Suppl. 32), ed. J. Wiseman and K. Zachos, Princeton, pp. 199–263.

Bisbee, H. L. 1937. "Samikon," *Hesperia* 6, pp. 525–538.

Brückner, H. 1986. "Man's Impact on the Evolution of the Physical Environment in the Mediterranean Region in Historical Times," *GeoJournal* 13, pp. 7–17.

Büdel, J. 1965. "Aufbau und Verschüttung Olympias: Mediterrane Flusztätigkeit seit der Frühantike," *Deutsche geographische Tagung. Tagungsberichte und wissenschäftliche Abhandlungen,* Heidelberg, pp. 179–183.

Carpenter, R. 1966. *Discontinuity in Greek Civilization,* Cambridge.

Chamberis, E., C. Alexiades, and G. Philipe. 1983. Geological Map of Greece 1:50,000. Amalias Sheet. Institute of Geological and Mining Research, Athens.

Davidson, D. A. 1980. "Erosion in Greece during the First and Second Millennia B.C." in *Timescales in Geomorphology,* ed. R. A. Cullingford, D. A. Davidson, and J. Lewin, New York, pp. 143–158.

Du Faure, J. J. 1976. "La terrasse holocene d'Olympie et ses equivalents méditerranéens," *Bulletin de l'Association géographique française* 433, pp. 85–94.

Fairbanks, R. G. 1989. "A 17,000-Year Glacio-Eustatic Sea Level Record: Influence of Glacial Melting Rates on the Younger Dryas Event and Deep-Ocean Circulation," *Nature* 342, pp. 637–642.

Flemming, N. C. 1969. *Archaeological Evidence for Eustatic Change of Sea-Level and Earth Movements in the Western Mediterranean during the Last 2,000 Years* (Geological Society of America Special Paper 109), Boulder.

Frazer, J. G. 1898. *Studies in Greek Scenery, Legend, and History, Selected from His Commentary on Pausanias' Description of Greece,* vol. 3, London.

Galanopoulos, A. 1940. "Du Seismizitat von Elis," *Garlands Beiträge Geophysik* 56, pp. 92–107.

Galanopoulos, A., and N. Delibasis, after J. Bornovas. 1971. Seismotectonic Map of Greece, Institute of Geology and Subsurface Research, Athens.

Higgins, M. D., and R. Higgins. 1996. *A Geological Companion to Greece and the Aegean,* Ithaca.

Hope-Simpson, R. 1981. *Mycenaean Greece,* Park Ridge, N.J.

Jing, Z., and G. Rapp. 2003. "The Coastal Evolution of the Ambracian Embayment and Its Relationship to Archaeological Settings," in *Landscape Archaeology in Southern Epirus, Greece* I (*Hesperia* Suppl. 32), ed. J. Wiseman and K. Zachos, Princeton, pp. 157–198.

Judson, S. 1985. "The Burial of the Site of Olympia, Western Peloponnese, Greece" (paper, Orlando 1985), abstract in *Geological Society of America Annual Meeting, Program with Abstracts,* p. 621.

Kaupert, J. A., and W. Dörpfeld. 1882. *Olympia und Umgegend: Zwei Karten und ein Situationsplan,* Berlin.

Kayan, İ. 1988. "Late Holocene Sea-Level Change on the Western Anatolian Coast," *Palaeogeography, Palaeoclimatology, and Palaeoecology* 68, pp. 205–218.

Kayan, İ., E. Öner, L. Uncu, B. Hocaoğlu, and S. Vardar. 2003. "Geoarchaeological Interpretations of the Troian Bay," in *Troia and the Troad: Scientific Approaches,* ed. G. A. Wagner, E. Pernicka, and H.-P. Uerpmann, Berlin, pp. 379–401.

Kelletat, D. 1974. *Beiträge zur regionalen Küstenmorphologie des Mittelmeerraumes: Gargano/Italien und Peloponnes/Griechenland* (*Zeitschrift für Geomorphologie* Suppl. 19), Berlin.

Kelletat, D., G. Kowalczyk, B. Schröder, and K. P. Winter. 1976. "A Synoptic View on the Neotectonic Development of the Peloponnesian Coastal Regions," *Zeitschrift der Deutschen Geologischen Gesellschaft* 27, pp. 447–465.

Keraudren, B. 1971. "Les formations quaternaires marines de la Grèce (deuxième partie)," *Bulletin du Musée d'Anthropologie préhistorique de Monaco* 17, pp. 87–169.

Kraft, J. C. 1971. "Sedimentary Facies Patterns and Geologic History of a Holocene Marine Transgression," *Geological Society of America Bulletin* 82, pp. 2131–2158.

———. 1972. *A Reconnaissance of the Geology of the Sandy Coastal Areas of Eastern Greece and the Peloponnese.* (University of Delaware, Technical Report No. 9), Newark.

———. 1977. "Late Quaternary Paleogeographic Change in the Coastal Environments of Delaware, Mid-Atlantic Bight, Related to Archaeological Settings," in *Amerinds and Their Paleoenvironments in Northeastern North America,* ed. W. S. Newman and B. Salwen, New York, pp. 35–69.

Kraft, J. C., and S. E. Aschenbrenner. 1977. "Paleogeographic Reconstructions in the Methoni Embayment in Greece," *JFA* 4, pp. 19–44.

Kraft, J. C., S. E. Aschenbrenner, and İ. Kayan. 1980. "Late Holocene Coastal Changes and Resultant Destruction or Burial of Archaeological Sites in Greece and Turkey," in *Proceedings of the Commission on the Coastal Environment Field Symposium, Coastal Archaeological Session, 24th International Geographical Congress, Shimoda, Japan,* ed. M. Schwartz, Bellingham, Wash., pp. 13–31.

Kraft, J. C., D. F. Belknap, and İ. Kayan. 1983. "Potentials of Discovery of Human Occupation Sites on the Continental Shelves and Nearshore Coastal Zone," in *Quaternary Coastlines and Marine Archaeology: Towards the Prehistory of Land Bridges and Continental Shelves,* ed. P. M. Masters and N. C. Flemming, London, pp. 87–120.

Kraft, J. C., İ. Kayan, and S. E. Aschenbrenner. 1985. "Geological Studies of Coastal Change Applied to Archaeological Settings," in Rapp and Gifford 1985, pp. 57–84.

Kraft, J. C., İ. Kayan, and H. Brückner. 2001. "The Geological and Paleogeographical Environs of the Artemision," in *Der Kosmos der Artemis von Ephesos* (Sonderschriften Österreichisches Archäologisches Institut 37), ed. U. Muss, Vienna, pp. 123–134.

Kraft, J. C., İ. Kayan, H. Brückner, and G. Rapp. 2000. "A Geological Analysis of Ancient Landscapes and the Harbors of Ancient Ephesus and the Artemision in Anatolia," *ÖJh* 69, pp. 175–233.

———. 2003. "Sedimentary Facies Patterns and the Interpretation of Paleogeographies of Ancient Troia," in *Troia and the Troad: Scientific Approaches,* ed. G. A. Wagner, E. Pernicka, and H.-P. Uerpmann, Berlin, pp. 361–377.

Kraft, J. C., İ. Kayan, and O. Erol. 1980. "Geomorphic Reconstructions in the Environs of Ancient Troy," *Science* 209 (4458), pp. 776–782.

———. 1982. "Geology and Paleogeographic Reconstructions in the Vicinity of Ancient Troy," in *Troy: The Archaeological Geology,* ed. G. R. Rapp Jr. and J. A. Gifford, Princeton, pp. 11–42.

Kraft, J. C., G. R. Rapp, and S. E. Aschenbrenner. 1975. "Late Holocene Paleogeography of the Coastal Plain of the Gulf of Messenia, Greece, and Its Relationship to Archaeological Settings and Coastal Change," *Geological Society of America Bulletin* 86, pp. 1191–1208.

———. 1980. "Late Holocene Paleogeographic Reconstructions in the Area of the Bay of Navarino: Sandy Pylos," *JAS* 7, pp. 187–210.

Kraft, J. C., G. R. Rapp, İ. Kayan, and J. V. Luce. 2003. "Harbor Areas at Ancient Troy: Sedimentology and Geomorphology Complement

Homer's *Iliad,*" *Geology* 31, pp. 163–166.

Kraft, J. C., G. R. Rapp, G. J. Szemler, C. Tziavos, and E. W. Kase. 1987. "The Pass at Thermopylae, Greece," *JFA* 14, pp. 181–198.

Lambeck, K. 1996. "Sea-Level Change and Shore-Line Evolution: A General Framework of Modelling and Its Application to Aegean Greece since Upper Paleolithic Time," *Antiquity* 70, pp. 588–611.

Leake, W. M. 1830. *Travels in the Morea,* 3 vols., London.

Loy, W. G. 1967. *The Land of Nestor: A Physical Geography of the Southwest Peloponnese* (Foreign Field Research Program, Division of Earth Sciences, Report 34), Washington, D.C.

McDonald, W. A., and R. Hope-Simpson. 1961. "Prehistoric Habitation in Southwestern Peloponnese," *AJA* 65, pp. 221–260.

———. 1969. "Further Explorations in Southwestern Peloponnese: 1964–1968," *AJA* 73, pp. 123–177.

———. 1972. "Archaeological Exploration," in McDonald and Rapp 1972, pp. 117–147, with Appendix, pp. 263–322.

McDonald, W. A., and G. R. Rapp Jr., eds. 1972. *The Minnesota Messenia Expedition: Reconstructing a Bronze Age Regional Environment,* Minneapolis.

Perissoratis, C., and J. Angelopoulos. 1982. Geological Map of Greece 1:50,000. Kiparissia Sheet. Institute of Geological and Mining Research, Athens.

Pirazzoli, P. A. 1991. *World Atlas of Holocene Sea-Level Changes* (Elsevier Oceanography Series 58), Amsterdam.

Raphael, C. N. 1973. "Late Quaternary Changes in Coastal Elis, Greece," *Geographical Review* 63, pp. 73–89.

———. 1978. "The Erosional History of the Plain of Elis in the Peloponnese," in *The Environmental History of the Near and Middle East since the Last Ice Age,* ed. W. C. Brice, New York, pp. 51–66.

Rapp, G. R., Jr., S. E. Aschenbrenner, and J. C. Kraft. 1978. "The Holocene Environmental History of the Nichoria Region," in *Nichoria* I: *Site, Environs, and Techniques,* ed. G. R. Rapp Jr. and S. E. Aschenbrenner, Minneapolis, pp. 13–25.

Rapp, G. R., and J. Gifford, eds. 1985. *Archaeological Geology,* New Haven.

Schoo, J. 1969. *Hercules' Labors: Fact or Fiction?,* Chicago.

Schröder, B., and D. Kelletat. 1976. "Geodynamical Conclusions from Vertical Displacement of Quaternary Shorelines, Peloponnesos (of) Greece," *Neues Jahrbuch für Geologie und Paläontologie* Monatsheft 3, pp. 174–186.

Scott, D. B., P. A. Pirazzoli, and C. A. Honig. 1987. *Late Quaternary Sea-Level Correlation and Applications* (NATO ASI Series C 256), Dordrecht.

Sperling, J. 1942. "Explorations in Elis, 1939," *AJA* 46, pp. 77–89.

Stanley, D. J., and A. G. Warne. 1997. "Holocene Sea-Level Change and Early Human Utilization of Deltas," *GSA Today* 7:12, pp. 1–7.

Streif, H.-J. 1964. "Beiträge zur Geologie der Bucht von Elis (Peloponnes/Griechenland)" (M.S. thesis, Univ. of Freiburg).

———. 1980. Geological Map of Greece 1:50,000. Pirgos Sheet. Institute of Geological and Mining Research, Athens.

———. 1982. Geological Map of Greece 1:50,000. Olympia Sheet. Institute of Geological and Mining Research, Athens.

Themelis, P. 1968a. "Thryon-Epitalion," *AAA* 1, pp. 201–204.

———. 1968b. "Ἠλεία: Ἐπιτάλιον," *ArchDelt* 23, B′1, p. 165–171.

Topping, P. 1972. "The Post-Classical Documents," in McDonald and Rapp 1972, pp. 64–80.

Tsofilias, P. 1977. Geological Map of Greece 1:50,000. Nea Manolas Sheet. Institute of Geological and Mining Research, Athens.

van Andel, T. H. 1987. "The Adjacent Sea," in *Landscapes and People of the Franchthi Region* (*Excavations at Franchthi Cave, Greece* 2), ed. T. H. van Andel and S. B. Sutton, Bloomington, pp. 3–64.

———. 1989. "Late Quaternary Sea-Level Changes and Archaeology," *Antiquity* 63, pp. 733–745.

van Andel, T. H., E. Zangger, and A. Demitrack. 1990. "Land Use and Soil Erosion in Prehistoric and Historical Greece," *JFA* 17, pp. 379–396.

Villas, C. A. 1983. "The Holocene Evolution of the Acheloos River Delta, Northwestern Greece: Associated Environments, Geomorphology, and Microfossils" (M.S. thesis, Univ. of Delaware).

Vita-Finzi, C. 1969. *The Mediterranean Valleys: Geological Changes in Historical Times,* London.

Wagstaff, J. M. 1981. "Buried Assumptions: Some Problems in the Interpretation of the 'Younger Fill' Raised by Recent Data from Greece," *JAS* 8, pp. 247–264.

Wright, H. E., Jr. 1968. "Climatic Change in Mycenean Greece," *Antiquity* 42, pp. 123–127.

———. 1972. "Vegetation History," in McDonald and Rapp 1972, pp. 179–188.

Yalouris, N. 1957. "Δοκιμαστικαὶ ἔρευναι εἰς τὸν κόλπον τῆς Φειᾶς Ἠλείας," *ArchEph,* pp. 31–43.

———. 1960. "Φειά," *ArchDelt* 16, Β′, p. 126.

———. 1965. "Μυκηναϊκὸς τύμβος Σαμικοῦ," *ArchDelt* 20, Α′, pp. 6–40.

———. 1970. "Σκαφιδιὰ-Μιραμάρε," *ArchDelt* 25, Β′1, p. 194.

Zangger, E., M. E. Timpson, S. B Yazvenko, F. Kuhnke, and J. Knauss. 1997. "The Pylos Regional Archaeological Project, Part II: Landscape Evolution and Site Preservation," *Hesperia* 66, pp. 549–641.

John C. Kraft

University of Delaware
DEPARTMENT OF GEOLOGY
P.O. BOX 250
SCHWENKSVILLE, PENNSYLVANIA 19473

George (Rip) Rapp

University of Minnesota, Duluth
ARCHAEOMETRY LABORATORY, DEPARTMENT OF GEOLOGICAL SCIENCES
10 UNIVERSITY DRIVE
DULUTH, MINNESOTA 55812-2496

grapp@d.umn.edu

John A. Gifford

University of Miami
ROSENTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE
CORAL GABLES, FLORIDA 33124

jgifford@rsmas.miami.edu

Stanley E. Aschenbrenner

University of Minnesota, Duluth
DEPARTMENT OF SOCIOLOGY AND ANTHROPOLOGY
1225 SW OAK TERRACE
LAKE OSWEGO, OREGON 97034

stana29@juno.com