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Paleogeographic Reconstructions of Coastal Aegean Archaeological Sites

Geological analyses yield information on coastal paleogeographic settings of archaeological sites.

John C. Kraft, Stanley E. Aschenbrenner, George Rapp, Jr.

Early archaeological studies emphasized analysis of archaeological sites in interpreting the civilizations they represent. Over the past decade, archaeologists have begun to pay more particular attention to the immediate geomorphic setting, the regional geomorphology of the area, climatic change, geology, and so forth in an attempt to determine the reason for the establishment of various towns and cities at particular locations and for shifts of centers of civilization. In so doing, they have asked scientists from many disciplines to apply their efforts to the problem. In a number of expeditions an interdisciplinary approach has been used to study archaeological sites. Some of these efforts have succeeded spectacularly; others have failed to achieve their expectations. One important reason for the lack of success of a number of expeditions has been failure to investigate the subsurface sedimentary stratigraphy of the environs of the archaeological sites to achieve a local and regional perspective.

Geological Processes

In the subsurface lies the record of sedimentation throughout the Holocene Epoch (the past 10,000 years). These sediments contain many clues to the nature of the landscape at various times during the Holocene. It is important to correlate these clues with the times of occupancy of archaeological sites. Figure 1 is a map of the Aegean Sea and the surrounding landmass, showing basins of sedimentary deposition in the Holocene Epoch and portions of such basins from the earlier Quaternary Period. Archaeological sites associated with these areas of deposition might best be evaluated, in terms of paleogeomorphology, by analysis of the subsurface stratigraphic record. Much of the area covered in Fig. 1 includes a surface veneer of sediments from the Holocene overlying sediments of earlier ages of the Quaternary (approximately the past 1½ million years). Many of these areas are tectonically controlled grabens (downfaulted basins) and are flanked by horsts (upthrown blocks of older rock). All of them include the major drainage systems of the past 10,000 years. Thus, they tend to be extremely important in terms of interpretation of archaeological settings and civilization as it has evolved from the Neolithic to the present time.

Much of the present topography of Europe was shaped by the last glaciation and has since been modified by four interrelated natural processes. (i) Climatic change has altered hydrologic and vegetation regimes affecting erosion and deposition in coastal regions. (ii) Sediment infilling has enlarged deltaic and other coastal land areas in many regions. (iii) Eustatic sea-level rise since the late Pleistocene deglaciation has had dramatic effects on many coastal areas. (iv) Regional or local vertical tectonic movements have shifted landmasses in active areas sufficiently to prevent detailed application of worldwide sea-level fluctuation curves to the solution of local paleogeomorphic problems. Starkel (*1*), Carpenter (*2*), Loy (*3*), Vita-Finzi (*4*), and others have commented in detail on these subjects. As Loy (*3*) observed, "the possibilities of geomorphic explanation offered by general theories of denudation rates, sea level variations, and epeirogenetic crustal changes seem endless. There have been too many variations in rates of denudation, alluviation, and crustal movement in both time and place to allow the strict application of alleged world-wide sea-level fluctuations to any place in Greece. Each problem [of geomorphology] must be solved, if it is to be solved, locally with local evidence."

Our effort has been concentrated on securing sufficient evidence in archaeologically important areas to reconstruct the paleogeographic changes during the last 10,000 years. The geological framework and methodology have been described (*5*). In this article we summarize the results of our work related to archaeological sites in the Aegean.

Geographic Change in Historical Times

The historical record contains numerous statements regarding geographic change in Classical-Hellenistic-Roman and later times. Pausanias, Herodotus, and Aristotle frequently commented on geographic change. Vita-Finzi (*4*) states "the principle was familiar to Pausanias [who said]: that the Echinadian Islands have not yet been joined to the mainland by the Achelous is due to the Aetolians; for they have been driven out, and the whole country has been turned into a wilderness. Hence, Aetolia remaining untilled, the Achelous does not wash down so much mud on the Echinadian Islands as it would otherwise do. In proof of this,

John Kraft is chairperson and professor of geology and marine geology at the University of Delaware, Newark 19711. Stanley Aschenbrenner is assistant professor of anthropology and archaeology and George Rapp is professor of geology and archaeology and dean of the College of Letters and Science at the University of Minnesota, Duluth 55812. Dr. Aschenbrenner and Dr. Rapp are associated with the Archaeometry Laboratory of the University of Minnesota, Duluth.

I can point to the Meander: flowing through the lands of Phrygia and Caria, which are plowed every year. It has in a short time turned the sea between Priene and Miletus into dry land" (Fig. 2).

Russell (*6*) noted that alluviation of river valleys concomitant with sea-level rise has led to numerous floodplains enclosed within deep valleys in some of the most densely occupied historic and prehistoric areas surrounding the Aegean Sea. Figure 3 shows an example of this effect. The valley of the Büyük (Big) Menderes River shows a particularly large amount of alluviation or valley infill since Classical times. Important cities such as Miletus, Heracleia, and Priene lie along the edge of the former Gulf of Miletus, into which flowed the sediment-laden Büyük Menderes River.

After Classical to Late Roman times, all three of these port cities were isolated inland as the alluviation of the river valley continued building the delta seaward to its present position. The city of Heracleia (Fig. 3) now lies along the edge, partially under water, of Bafa Gölü, an inland freshwater lake which was previously an arm of the sea. The site of ancient Miletus is now connected to Lada, an island in Classical times. A famous naval battle was fought between Miletus and the island of Lada in Classical times, indicating deep water. The cliff city of Priene, which was once an important port overlooking a broad marine embayment, is now abandoned inland (Fig. 2).

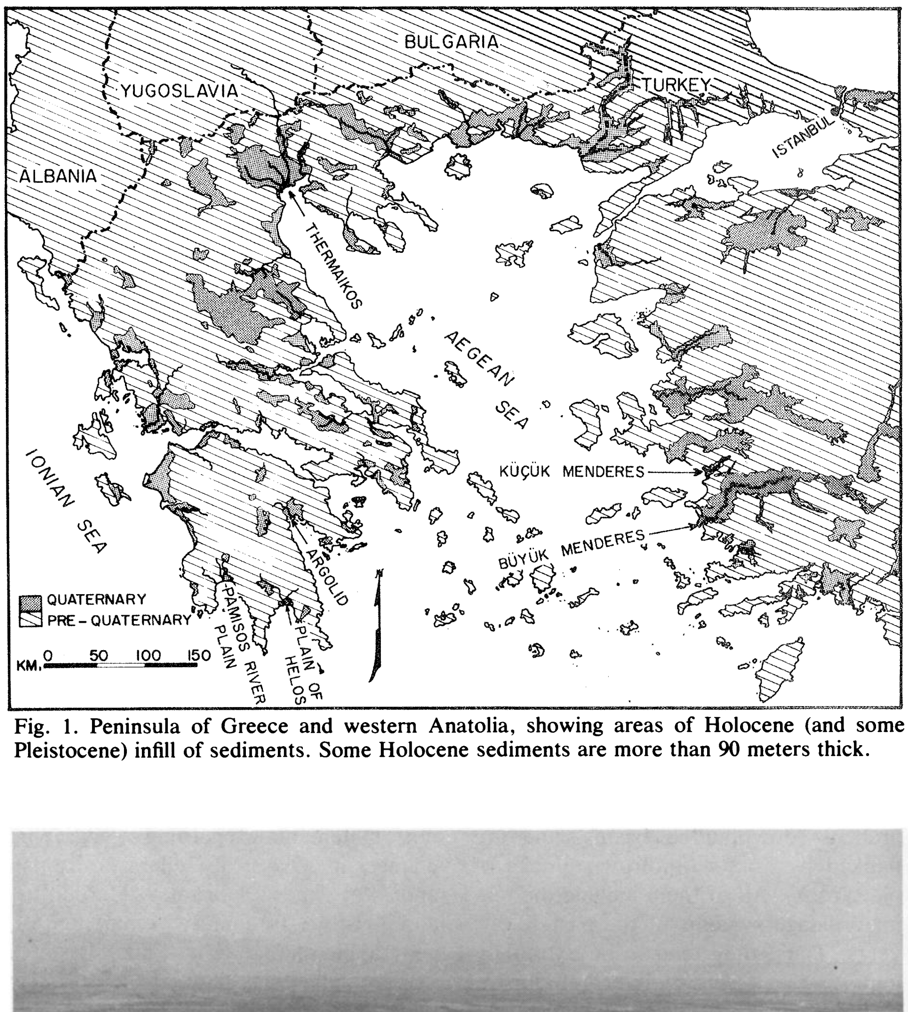


Fig. 1. Peninsula of Greece and western Anatolia, showing areas of Holocene (and some Pleistocene) infill of sediments. Some Holocene sediments are more than 90 meters thick.

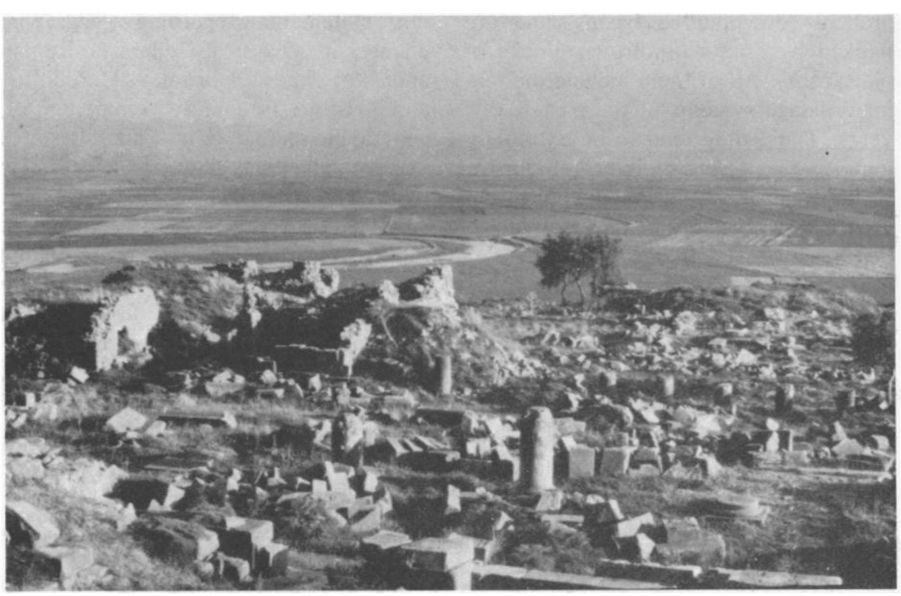


Fig. 2. Upper portion of the port city of Priene overlooking the infilled embayment of Miletus. On the other side of this formerly large and deep embayment of the Aegean Sea lie the ruins of the ports of Heracleia and the megalopolis of Miletus.

Similarly, Fig. 4 shows the alluviation of the Küçük Menderes River in the Gulf of Ephesus, just to the north (*7*). The shoreline has been traced from Ionian through Hellenistic time, through Roman time, and through "late ancient time" as alluviation proceeded to the present shoreline position. The short dashed lines in Fig. 4 show the efforts of the Ephesians to keep their harbor and port open by dredging until it was finally swamped by the sediment of the Küçük Menderes River.

A similar effect was mapped by Eumorphopoulos (*8*) in the area of the Thermaikos, formerly a deep marine embayment that lay to the west of Saloniki in the northwestern corner of the Aegean Sea (Fig. 5). Here the historical records are good. For instance, we know that Pella, which lay on the northwestern corner of the Thermaikos when it was the capital of Philip of Macedon, was a seaport. Other small port cities surrounded the Thermaikos. At present, Saloniki lies near the site of ancient Therma, in the very eastern part of the Thermaikos Gulf. Four rivers have poured sediment into the Thermaikos basin, infilling much of it since 500 B.C. The Axiós River, flowing southward out of Bulgaria, now carries the major sediment load into the gulf. Using the past as a key to the present and predictor of the future, one can see clearly the threat to Saloniki, Greece's second largest city and seaport. Should present and past depositional processes continue, it is inevitable that Saloniki will be cut off from the Aegean Sea and be usable as a port only if extreme measures are taken by geologists and engineers, such as those used in late ancient times by the Ephesians in keeping open the port of Ephesus in Ionia.

There is much disagreement about the basic causes of these well-known changes in paleogeomorphology. For instance, relative sea-level change must be considered. Flemming (*9*) believes that absolute sea level has not changed over the past few thousand years, but rather that local tectonics has warped the Peloponnese. On the other hand, Hafemann (*10*) states that sea level has risen in the eastern Mediterranean area at a rate of 2.5 to 2.8 meters per year over the past 2500 years. During the early Holocene Epoch, sea level did rise rapidly; approximately 6000 to 7000 years ago the rate of rise began to slow down drastically, and at present sea level is probably slowly rising. Further, Wendel (*11*) noted that minor tectonic changes may have disrupted the flow of waters to the sea and increased the rates of alluviation compared to normal rates of river plain deposition near Ephesus. Wang (*12*) observed that catastrophic change could be caused by tsunamis, such as one probably generated by the volcanic explosion at Thera.

Wright (*13*) states that there is no indication of climatic change in the region over the past 4000 years, based on palynological evidence from the southwestern Peloponnese. It is well known that there was a climatic optimum in mid-Holocene time. However, as pointed out by Wright (*14*), it cannot be clearly stated that this Holocene climatic effect would cause worldwide geomorphic change. Thus, the combined efforts of scientists from various disciplines are needed to determine the causes of major geomorphic changes that took place during historic and, in particular, prehistoric times.

Subsurface Stratigraphy

Over the past 6 years we have been studying the subsurface geology of the major embayments in the Peloponnese and part of the northern mainland of Greece. Kraft (*15*) pointed out the likelihood that during the Early through Middle Helladic (Bronze) periods the major archaeologic site of Tiryns was a port, and the plain of Helos in Laconia, in the southeastern Peloponnese, was much reduced in size, overlooking a much larger gulf. In addition, a major marine transgression had occurred into the plain of the Pamisos River Valley in Messenia in the southwestern Peloponnese (*16, 17*), where more than 85 meters of sedimentary infill were deposited during the Holocene Epoch (*5*). This transgression occurred between 3710 and 3360 B.C. This was followed by a regression to approximately the present coastal position at the head of the Gulf of Messenia. Figure 6 shows a geologic cross section of the Holocene sediments, our evidence for transgression and regression in the area in Late Neolithic time. Figure 7 shows the present geomorphology of the Pamisos River floodplain and its present shoreline. In addition, it shows the shoreline of approximately 3500 B.C., along which important Early Helladic sites such as Akovitika and Bouxas were located. These Early Helladic sites, which are now inland, lay near the shoreline of their time. Accord-

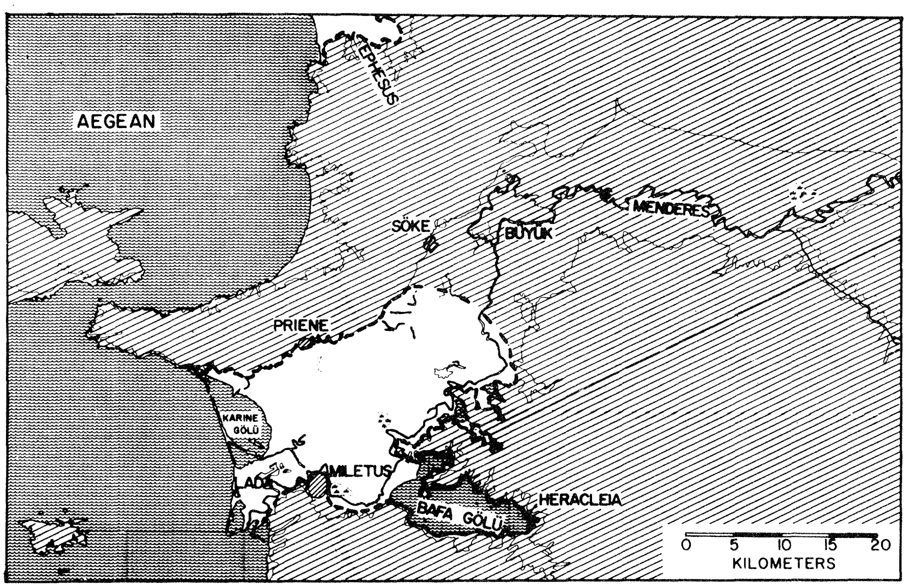
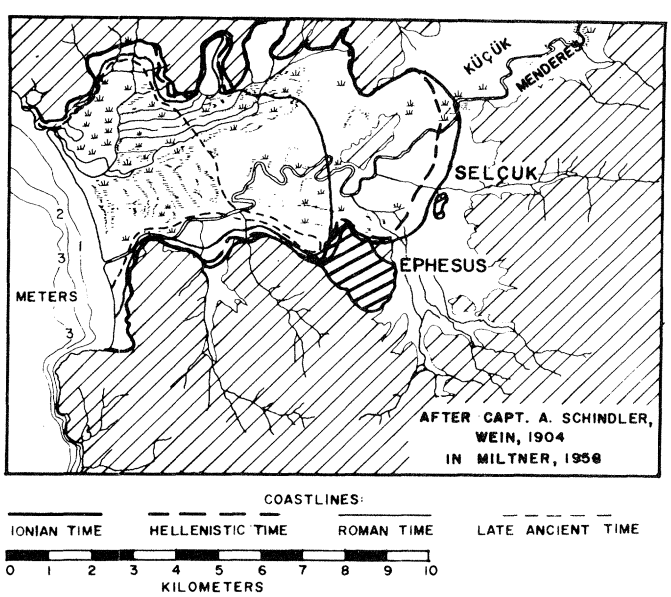


Fig. 3. Büyük Menderes River alluvial plain with a reconstruction of the Gulf of Miletus in Classical times. Hachured areas are upland pre-Quaternary hills, which are mainly limestone. The clear area surrounded by the dashed line indicates the extent of the marine embayment in Classical times. The wavy pattern indicates present areas of water.



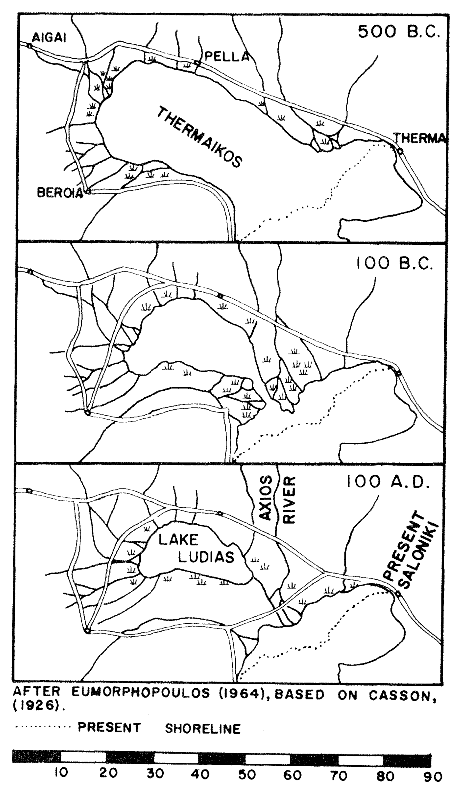
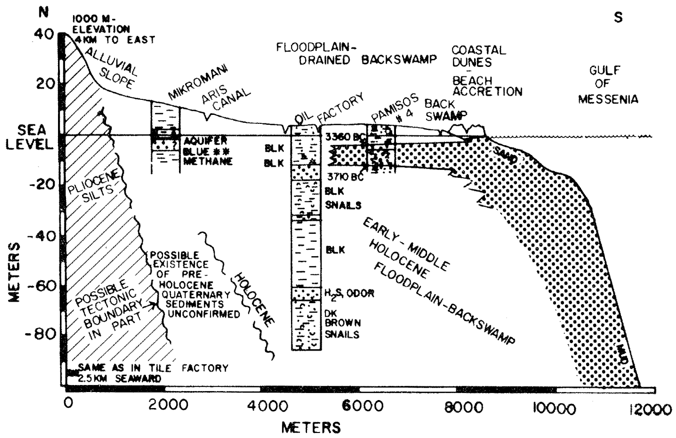


Fig. 4 (left). Küçük Menderes alluvial plain and its relation to the city of Ephesus and the gradual alluviation of the Gulf of Ephesus. Various ancient shorelines (dashed and solid lines) show infill of the Gulf of Ephesus into late ancient times, when the harbor became extinct. The rows of lineaments or beach ridges parallel to the present shoreline indicate more recent shoreline positions. [After Schindler (*7*)] Fig. 5 (right). Map sequence showing the paleogeography of alluviation or sedimentary infill of the Thermaikos from the Macedonian capital Pella in the northwest to the present-day city of Saloniki.



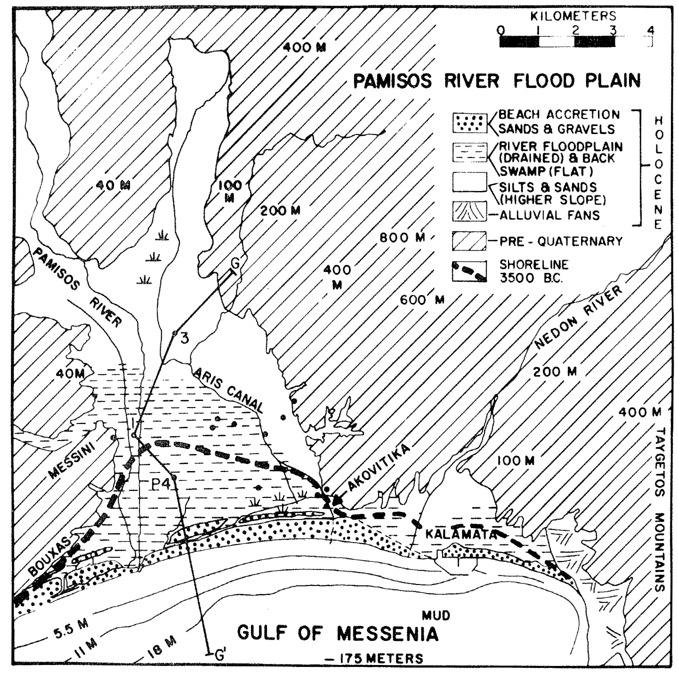
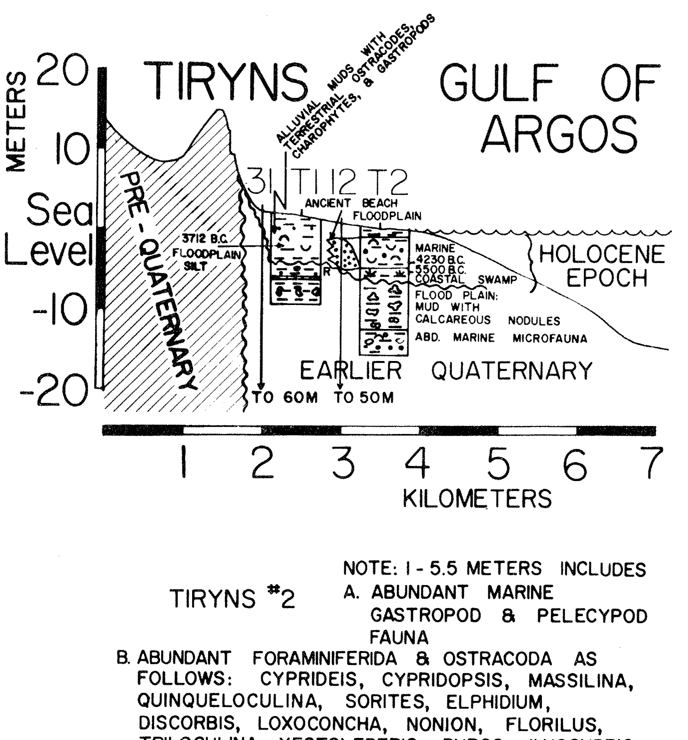


Fig. 6 (left). Geologic cross section of the Pamisos River system in Messenia Province, showing the relationship of the Neolithic-Helladic coastal, marine, and floodplain environments to present-day surficial environments [from Kraft *et al.* (*5*)]. See Fig. 7 for the line of cross section. Fig. 7 (right). Geomorphic map of the Pamisos River plain of Messenia and its coastal zone, showing prehistoric Early Helladic sites and the position of the shoreline at the end of Neolithic–Early Helladic time.



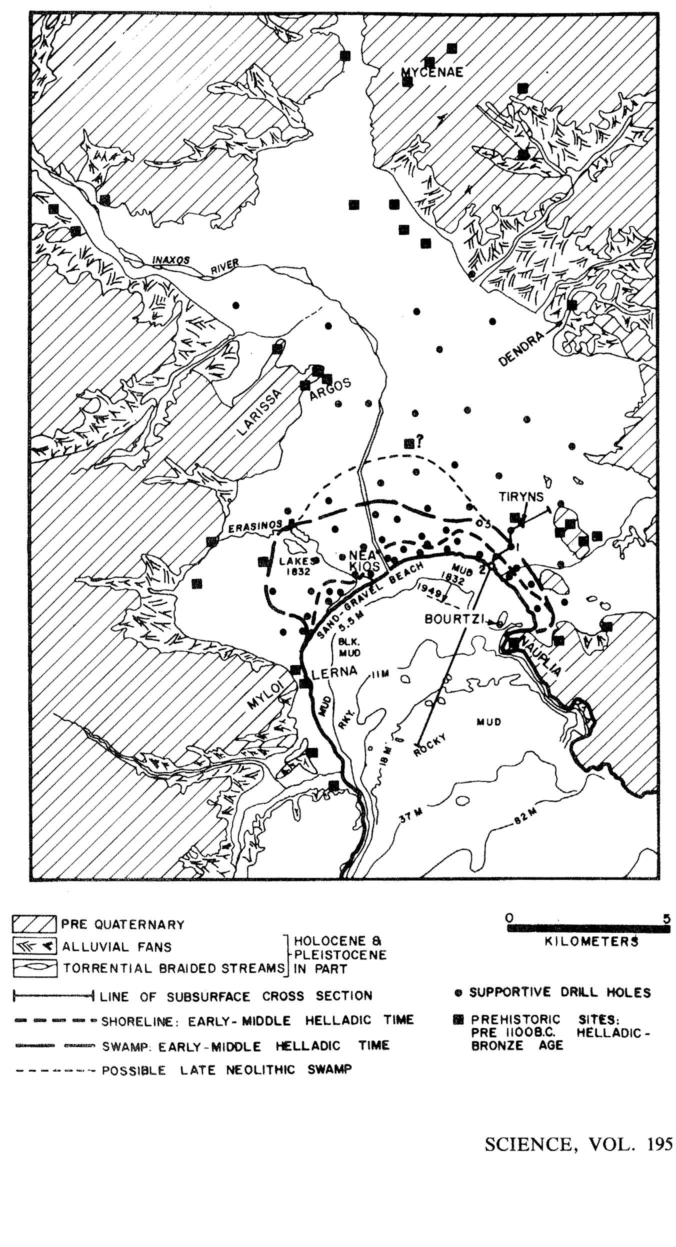


Fig. 8 (left). Geologic cross section showing the subsurface interpretation of the floodplain, shoreline, and coastal-shallow marine environments from Neolithic time to the present in the vicinity of Tiryns in the Argolid. See Fig. 9 for the line of cross section. Fig. 9 (right). Map of the present geomorphic environments of the plain of the Argolid and its surroundings, showing the area of prehistoric occupancy and a shoreline-marsh interpretation from Neolithic to Helladic time.

ingly, the meaning of their occupation and construction must be reconsidered.

With respect to the plain of the Argolid, Fig. 8 presents a geologic cross section from the site of Tiryns seaward into the Gulf of Argos. Various German expeditions have discovered a lower town along the foot of the clifflike fortification of Tiryns; the fortress lies to the northwest. The subsurface data prove that Tiryns was much closer to the shoreline of the Gulf of Argos in Late Neolithic and Early and Middle Helladic times. In Fig. 8, the floodplain, beach, marine, and coastal swamp sediments are easily identified in the subsurface. The plain of the Argolid is underlain by much thicker sequences of sediments of earlier Quaternary ages, which have not been studied in detail. Our drill core data were used to construct Fig. 8 and applied to a map of the plain of the Argolid and its surrounding mountainous area in Fig. 9. These data, plus data supplied to us by the Greek Service of Land Improvement [Yperesia Eggeion Beltioseon (YEB)], have enabled us to draw paleogeographic maps for Neolithic to Helladic times, showing the former landscapes of the plains of the Argolid and Helos.

Use of detailed subsurface stratigraphy allows the archaeologist to better understand the paleogeomorphology of prehistoric sites. Some prehistoric sites might be covered by later sedimentation across the floodplains, although such sites tend to occur in logical paleocoastal environments (Fig. 9). Bintliff (*18*) began geomorphologic studies in 1973 with goals similar to ours, using both surficial geomorphic and archaeological techniques. One of his publications and his unpublished data (*18*) indicate similar preliminary results to ours (Figs. 9 and 12).

Prehistoric Paleogeographic Change

The shoreline of Early to Middle Helladic time (Fig. 9) was much closer to the lower town of Tiryns and its fortification. Our drill core data show that a broad swampy area extended around the shoreline of the lower plain of the Argolid. It is possible that this swampy plain extended still farther northward in the plain of the Argolid in Late Neolithic time and possibly to the extreme northern limits in earlier Neolithic times. This paleogeographic interpretation confirms Schliemann's quotation from Aristotle (*19*, p. 8): "At the time of the Trojan War, the land of Argos being swampy, it could only feed a scanty population, whilst the land of Mycenae was good and therefore highly prized. But now the contrary is the case, for the latter has become too dry and lies untilled, whilst the land of Argos, which was a morass and

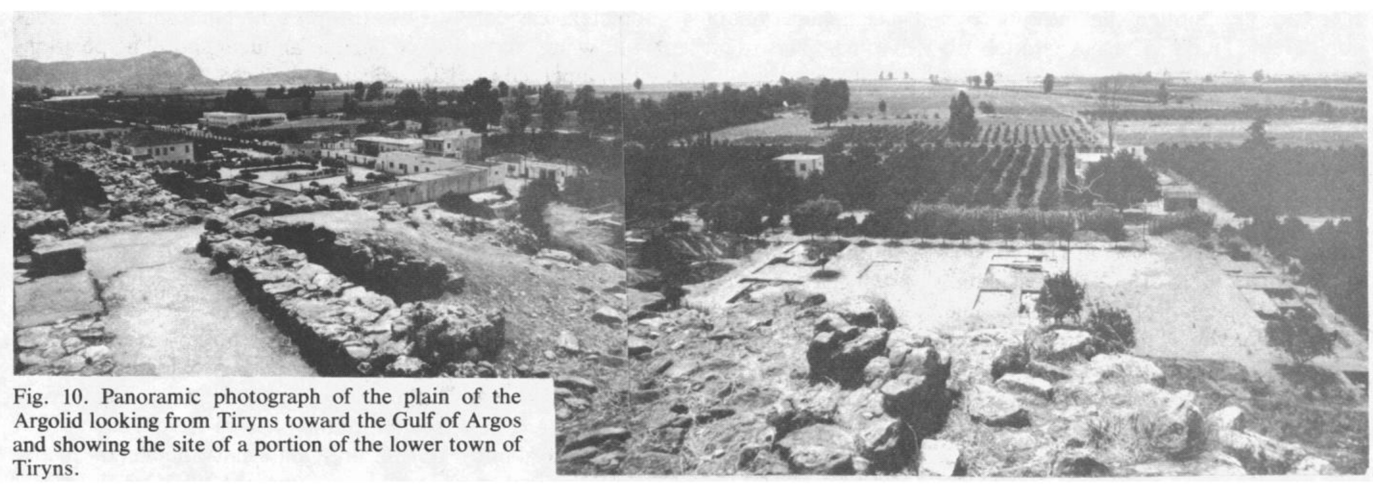
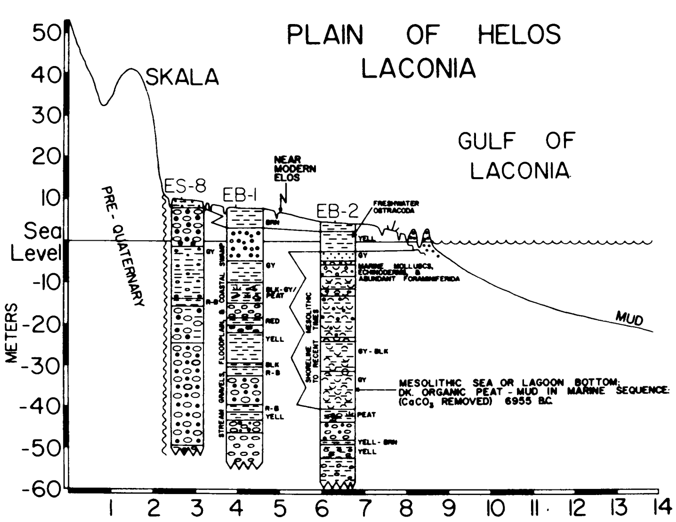


Fig. 10. Panoramic photograph of the plain of the Argolid looking from Tiryns toward the Gulf of Argos and showing the site of a portion of the lower town of Tiryns.



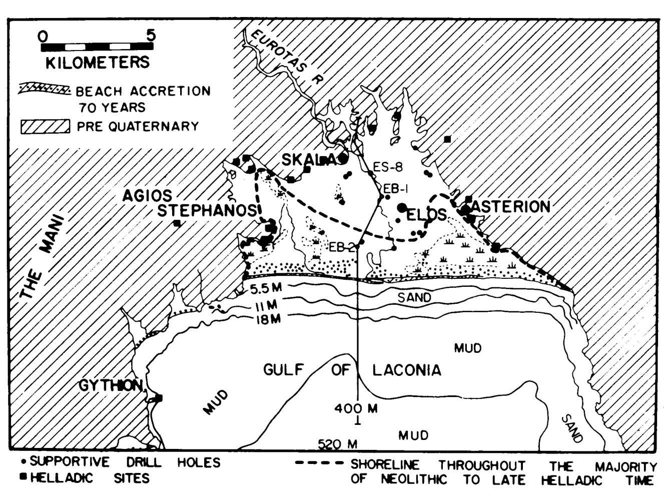


Fig. 11 (left). Geologic cross section across the plain of Helos, showing the subsurface interpretation of floodplain and coastal-shallow marine environments and the position of the shoreline throughout the Holocene Epoch. See Fig. 12 for the line of cross section. Fig. 12 (right). Geomorphic map of the plain of Helos, showing present-day environments, prehistoric sites, and the approximate position of the shoreline in Neolithic to Helladic time.

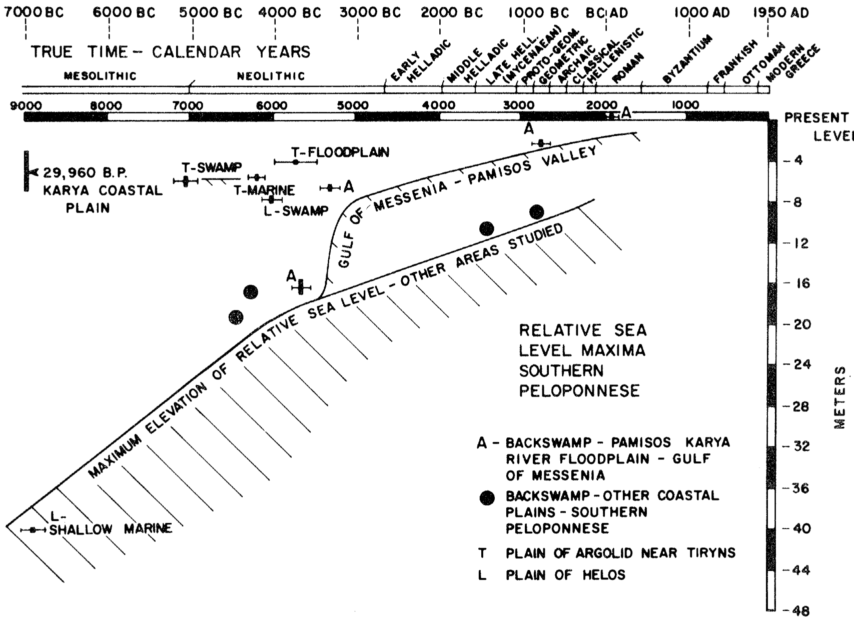


Fig. 13. Relative sea level and other environmental positions relative to the sea and time for the plains of the Argolid, Helos, and Pamisos in Peloponnese.

therefore lay untilled, has now become good arable land." Thus, Aristotle's observations about events of a time 1000 years before his own life are apparently correct. It further confirms Schliemann's own observation on a note of Eustathius, that "the first name of Tiryns was Haliis or Haleis, fishermen having been the first settlers on the rock" (*19*, p. 2), a sensible statement in view of our reconstruction of the paleogeomorphology of the time. (This is not the Haleis currently being excavated near Porto Kheli.) The Helladic peoples, in particular the Mycenaeans, may have had some effect in altering the nature of the lower plain of the Argolid. For instance, Balcer (*20*) noted that a dam had been built in Mycenaean times about 4 kilometers east of Tiryns. This dam cut off water flow through a shallow valley that emerged to the north of the fortress of Tiryns and into the lower town. The water was shunted partially to dug channels flowing elsewhere and to a deeper valley to the east, which flowed into the Gulf of Argos south of Tiryns. Thus, the delta of this river may have contributed significantly to infilling the harbor area in front of Tiryns and making it less viable as a port, while at the same time ensuring that floods did not continue to damage the lower town of Tiryns.

Scholars have long speculated about the reasons for two large fortifications, the one at Tiryns and another at Mycenae approximately 4 kilometers due north, existing at the same time. Possibly there was a close interrelationship between the two fortifications and their rulers. Mycenae may have been the key to the main pass overland to the Gulf of Corinth, while the role of Tiryns was to protect the harbor area and commerce and the flanking upland agriculture between Tiryns and Mycenae. The plain of the Argolid continues to rise by alluviation while sediment fills in the edge of the Gulf of Argos, and relative sea level, which is actually slowly rising, appears to slowly regress. This is due partly to a drainage program and partly to the sediments flowing down the Inaxos and its tributary rivers. Later historical sites have tended to be covered by this continuing infill of the plain of the Argolid. Figure 10 shows a photographic panorama of the plain in front of Tiryns looking toward the Gulf of Argos. As may be seen in Fig. 10, the lower town, located approximately 2.5 to 3 meters below the present land surface, would have been in an ideal shoreline position, as indicated in Fig. 8.

Farther south, in the southeastern corner of the Peloponnese, lies the plain of Helos. At the time of the Trojan War it was considered that "Elos, the Castle by the Sea" (*21*), being tributary to Sparta and Mycenae, contributed a number of ships to the war. To date, scholars argue about the location of prehistoric Elos. Our studies have not provided an answer, but they have provided some limitations. Figure 11 is a geologic cross section of the plain of Helos, from Skala on the pre-Quaternary highlands to the north across to the Gulf of Laconia. Here again, using our own drilling data

Table 1. Radiocarbon data from the sediments underlying the coastal plains of the Argolid, Helos, and the Pamisos River in Peloponnese, Greece. The $\delta^{14}C$ values are per mil enrichments in carbon-14. Radiocarbon ages in column 3 incorporate a tree-ring correction factor (*22*). Sample numbers beginning with I- are those used by Isotopes, Inc.; those in parentheses are field sample numbers.

$-\delta^{14}C$	Radiocarbon age (years): Based on ^{14}C half-life of 5568 years	Radiocarbon age (years): With MASCA correction	Date (B.C.)	Elevation from mean sea level (m)	Sedimentary environment	Material	Sample numbers
432 ± 7	4545 ± 95	5310	3360	−6.5 to −7.0	Backswamp	Plant debris in greenish-black mud and sand	I-7228 (Pamisos No. 4, #13)
457 ± 7	4905 ± 95	5660	3710	−15.5 to −17.3	Backswamp	Plant debris and dark gray, very fine sand	I-7226 (Pamisos No. 4, #37–41)
457 ± 18	4905 ± 270	5662	3712	−2	Alluvial floodplain	Total organic carbon and mud, with $CaCO_3$ removed	I-8432 (T1-Tiryns)
485 ± 7	5330 ± 110	6180	4230	−5 to −5.5	Shallow marine	Shallow marine shells (mollusks)	I-8420 (T2-Tiryns)
535 ± 9	6150 ± 155	7450	5500	−5.5 to −6.5	Swamp	Organic fragments plus total organics ($CaCO_3$ removed)	I-8423 (T2-Tiryns)
670 ± 6	8905 ± 150		6955?	−40	Shallow marine	Total organic carbon from lagoonal and marine mud and peat ($CaCO_3$ removed)	I-7230 (YEB2-HELOS)
481 ± 7	5270 ± 100			−6 to −14	Backswamp	Clay and peat	I-7803 (YEB3-HELOS)

plus data from supportive well drilling furnished by the YEB, we have been able to determine the paleogeography of the area in prehistoric times. The cross section in Fig. 11 is particularly relevant in that it indicates that the shoreline position was relatively stable on the central portion of the plain of Helos for a very long period, possibly back to Mesolithic time. Clearly the southern part of the plain is underlain by a thick sequence of shallow marine to deeper marine fossiliferous sediments, whereas the middle and northern parts are underlain by coastal swamps, floodplain deposits, and stream sands and gravels. Thus, during the major portion of the Holocene Epoch, the Gulf of Laconia extended farther north. Then, toward the present, the regression of the marine environment occurred and a floodplain developed to the present shoreline position. Figure 12 is a geomorphic map of the plain of Helos and the surrounding pre-Quaternary highland region. Modern excavations may identify the fortification-settlement at Agios Stephanos as the ancient Elos. However, many other sites appear to be eligible (*18*). The small village of Elos that is now in the middle of the plain of Helos could be at the site of the ancient city. Subsurface data show marine conditions to the south of modern Elos and floodplain-alluvial conditions to the north. It is possible that ancient Elos may lie deeply buried beneath the sediments of the past several thousand years, under or near the present settlement. An early 18th-century map shows a coastal lagoon with Elos located exactly where it is at present, at the head of a lagoon.

One of the greatest problems in dealing with the subsurface geologic record in a tectonically active area is that other factors such as the effects of humans, changes in climate, and the imprint of pre-Holocene geologic events come into play and must be considered. On the other hand, changes in the level of the sea relative to land must have had an overwhelming effect, equal to that of the sedimentary infill of the embayments. Figure 13 is a relative sea-level curve based on our current data for various embayments in the Peloponnese. There is considerable variation among the embayments. Some of our data, which are not yet fully analyzed, are shown as black dots in Fig. 13. Table 1 presents the radiocarbon data in support of Fig. 13 and the geological subsurface cross sections used in making the paleogeomorphic analyses presented here.

Summary

Many studies have been made of ancient Greek topography, some of the more recent ones based on modern techniques. However, most still ignore the subsurface dimension of coastal and other environments and hence fail to fully explain coastal and alluvial-colluvial processes, rates of change of geomorphology, and the effects of coastal change on humans. In this article subsurface geological analyses have been used to elucidate paleogeographic coastal settings of major archaeological sites around the Aegean Sea. Similar approaches could be applied in the Middle and Far East and elsewhere in the Mediterranean.

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