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## ABSTRACT

There are three structurally low indentations along the inner edge of a long narrow ridge which separates the Karamenderes flood plain from the Aegean Sea. These are named here Yeniköy, Kesik and Kumtepe from South to North. Suggestions appear in the literature that in the Bronze Age these indentations were possibly used as convenient harbour-sites, and even that Yeniköy and Kesik "harbours" were connected to the Aegean Sea to the West by man-made canals. Our borehole-studies on the floors of the indentations have shown that these lowlands were really small coastal embayments or bays opening onto the "Troia Bay" which was situated in the present position of the Karamenderes flood plain 10,000-6,000 years ago. But the thresholds between the sea and the Yeniköy and Kesik plains are at a level higher than has ever been reached by the sea, and there has never been any connection by water across these thresholds, whether naturally or artificially.

Although there is today a small ditch through the threshold to the West of the Yeniköy plain, it has been dug to supply fresh water from the Pınarbaşı springs to the Beşik coastal plain. There is also a small gate to the West of the Kesik plain, but there is no evidence showing that this ditch was used for any other purpose than passage on foot.

$^{14}C$ dates of shells taken from the transition-level between the marine- and overlying flood-sediments in the Yeniköy, Kesik and Kumtepe plains indicate that the Yeniköy plain silted up and was transformed into an alluvial plain about 5000 years ago, and likewise the Kesik plain 4000 years ago. This means that these small indentations of the Karamenderes plain were indeed small bays in earlier times, and it is possible that they were used as natural harbours during the Early Bronze Age. But no specific evidence has been found to indicate that these embayments were ever used as harbours.



## ZUSAMMENFASSUNG

Entlang der Innenkante des langen schmalen Landrückens, der das Karamenderes-Schwemmland von der Ägäis trennt, gibt es drei tektonisch flache Einbuchtungen. Diese werden hier von Süd nach Nord Yeniköy-, Kesik- und Kumtepe-Bucht genannt. In der Literatur wurden Vermutungen geäußert, daß diese Einbuchtungen in der Bronzezeit möglicherweise als günstige Hafenplätze dienten und der Yeniköy- und Kesik-"Hafen" sogar mit der Ägäis im Westen durch künstliche Kanäle verbunden waren. Unsere Bohruntersuchungen im Boden der Einbuchtungen zeigten, daß diese Niederungen in der Tat kleine Küsteneinbuchtungen waren, die sich zur "Troischen Bucht" hin öffneten, welche sich vor 10 000–6000 Jahren an der Stelle des heutigen Karamenderes-Schwemmlandes erstreckte. Die Erhebung zwischen der See und der Yeniköy- sowie Kesik-Ebene liegt jedoch auf höherem Niveau als jemals der Meeresspiegel, und es gab dort nie eine Wasserverbindung über diese Erhebung hinweg, weder eine natürliche noch eine künstliche.

Auch wenn heute ein schmaler Durchstich durch die Erhebung in die Yeniköy-Ebene existiert, so wurde dieser angelegt, um Frischwasser von den Pınarbaşı-Quellen zur Beşik-

Ebene an der Küste zu leiten. Ferner gibt es dort auch einen schmalen Durchlaß zur Kesik-Ebene, und nichts weist darauf hin, daß dieser Durchlaß jemals für einen anderen Zweck als den eines Fußweges bestimmt war.
$^{14}C$ Daten von Muscheln, die dem Übergangsniveau zwischen Meer- und darüberliegenden Überflutungsablagerungen in den Yeniköy-, Kesik- und Kumtepe-Ebenen entnommen wurden, zeigen, daß die Yeniköy-Ebene verschlammt ist und vor etwa 5000 Jahren in eine alluviale Ebene verwandelt wurde, die Kesik-Ebene ebenso vor 4000 Jahren. Das bedeutet, daß die schmalen Einbuchtungen der Karamenderes-Ebene in früherer Zeit in der Tat schmale Buchten waren, und es ist möglich, daß sie in der Frühbronzezeit als natürliche Häfen genutzt wurden. Es wurde jedoch kein spezifischer Hinweis gefunden, daß diese Einbuchtungen jemals als Häfen genutzt wurden.

## Introduction

Our research into the changing natural environment of the Troia area has been carried out as a part of the archaeological research, excavation and restoration project led by Prof. Dr. Manfred Korfmann.[1] Archaeological evidence obtained from the Troia area and its locality shows that the history of settlement and related land-use goes back to 6800 B.P. in this region.[2]
It is generally believed that the people lived in a rather different natural environment in those times, and that important changes have since occurred to the landscape. For instance, there is much discussion as to whether the area of the present alluvial plain surrounding Troia was an estuarine bay, and whether Troia was first established as a coastal settlement. Our aim is to reconstruct the natural environment of the earliest periods of Troia and other archaeological sites in the surrounding area, and to delineate changes in the environmental characteristics over the course of time.
For this purpose, a large number of boreholes has been made over the Karamenderes (Scamander) and Dümrek (Simois) alluvial plains surrounding Troia.[3] In this way, different subsurface sedimentary units have been distinguished, and their environmental characteristics and changes have been defined on the base of their sedimentary characteristics. For example, a marine mud unit below the surface indicates that there was a shallow bay in the area of the present Karamenderes flood plain. Overlying sandy sediments represent environmental change from marine to delta flood-plain. Coarse sandy coastal sediments at the bottom of the marine mud unit, and deltaic-coastal sediments between the marine and fluvial units indicate transgressive and regressive sequences of the marine period. Organic material, especially marine shells, have been used for $^{14}C$ dating, and based on these data it has been possible to make stratigraphical correlations and to delineate environmental changes on the paleogeographical maps. Various analyses, including the determination and interpretation of the macro- and micro-fauna represented in the borehole samples, have been carried out by Dr. John C. Kraft and Dr. George R. Rapp since 1990. Their results will be published in a more complete and detailed paper when they are ready, probably in one of the next volumes of *Studia Troica*.
During the course of our research into the changing environment of Troia, some individual topics or problems have appeared important, and have required special attention. One of them forms the topic of this paper: the question whether in antiquity there were harbours and canals to the West of the Karamenderes plain. There is a low narrow ridge running in a North-South direction separating the plain from the Aegean Sea (Fig. 1).[4] The ridge is only a few hundred meters wide in some parts. Although the highest spots lie at about 70 m, the ridge has lower parts between them. Towards these lower parts the Karamenderes plain makes three extensions. These are, from South to North, the small plains of Yeniköy, Kesik and Kumtepe.[5] These low, alluvial extensions of the main Karamenderes flood-plain were covered by water

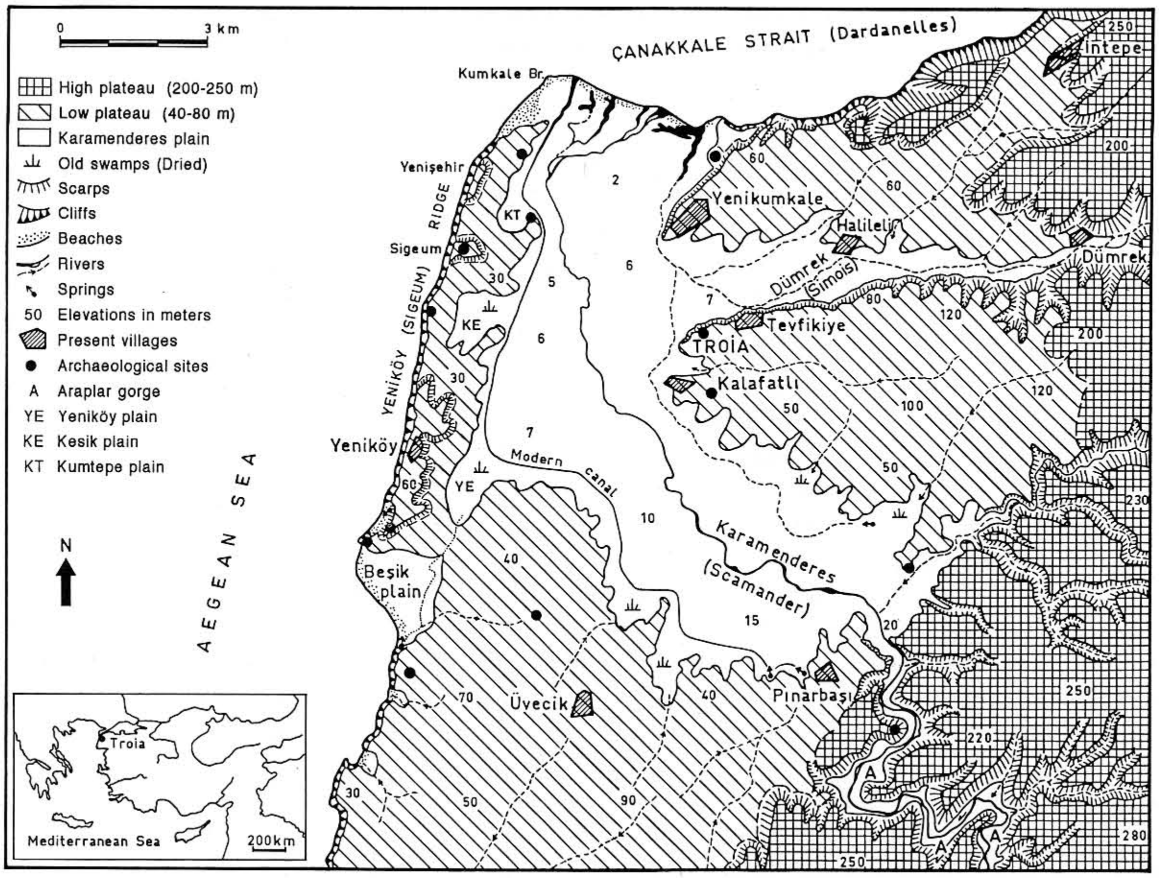


Fig. 1 Geomorphological outlines of the Troia area and the Karamenderes plain.

from the Pınarbaşı karstic springs and were fresh-water swamps until the 1960s.

This conformation has given rise to the hypothesis on the part of some investigators that the Yeniköy and Kesik plains in particular may have been used as harbours when the Karamenderes plain was an estuarine bay. It has been emphasized that such an interpretation also entails the assumption that canals connected the Yeniköy and Kesik embayments to the Aegean Sea. It is supposed that from the Aegean Sea ships could have made a short cut to the harbours through the canals much more safely than by entering them via the mouth of the Çanakkale Strait (Dardanelles). These canals have been examined and discussed frequently. Most of the main arguments on this subject are summarized in Cook's book on the Troad.[6] Indeed, there are canal-like ditches running between the sea and the Yeniköy and Kesik plains. A detailed survey, with a great number of bore-hole-studies, was made in 1991 and 1992 in order to test the canal hypothesis. Some samples of organic material, especially marine shells, were taken for dating from relevant levels and were dated by Dr. Bernd Kromer at the Institut für Umweltphysik der Universität Heidelberg. The expectation was that interpretation of all the evidence might resolve these old arguments relating to possible harbours and canals to the West of the Karamenderes plain. This paper presents the results. In the following sections, the geological and geomorphological characteristics of the Karamenderes plain and Yeniköy ridge will be first described, then the Yeniköy, Kesik and Kumtepe plains will be examined separately, and finally all of the evidence will be discussed and conclusions will be drawn.

## The Karamenderes (Scamander) Plain and the Yeniköy (Sigeum) Ridge

The Karamenderes (ancient Scamander) is the biggest river of the region. It drains a wide area and its upper tributaries collect water from the Kaz (Ida) Mountain in the South. It takes much fine-grained alluvium from the Neogene sediments of the Bayramiç-Ezine basin. The Araplar gorge connects this basin to the lower plain; this was formed by the incision of the Karamenderes river into a 200–250 m erosional plateau-surface extending over the old geological formations of the region (crystalline limestones and serpentine formations of Palaeozoic and Mesozoic geological times, and volcanic rocks of the Tertiary).[7] There is a narrow alluvial floor between the steep sides of the gorge, which opens on to the Karamenderes delta flood-plain (Fig. 1). This plain is about 15 km long and on average 3 km wide. The trend of the plain is Southeast-Northwest between Pınarbaşı and Kalafatlı villages, then it draws a wide curve and tends toward the North, reaching the sea at the southern mouth of the Çanakkale Strait (Dardanelles). The plain becomes wider where it is joined by the valley floor of the Dümrek (Simois) river to the North of Troia.

The flood-plain of the Karamenderes river lies between low plateau ridges to the North of Pınarbaşı. These are parts of a low undulating erosional surface, and are about 40–80 m high. The ridges run in a West-East direction in the East, and in a North-South direction in the West. They were formed on limy-clayey-sandy stratified sediments which were deposited in a wide, shallow gulf extending toward this region from the Black Sea during the end of the Miocene.[8] They were uplifted by tectonic movements and broken up into large blocks. Some of them rose as a whole without any distortion of the strata, but some of them tilted. For example, the eastern ridges rose by tilting toward the South; as a result the northern slopes of the Yenikumkale and Troia ridges are steep, while the southern slopes are gentle; the Dümrek valley lies between them. On the other hand, the Yeniköy (Sigeum) ridge in the West, between the Karamenderes plain and Aegean Sea, is slightly tilted toward the East. As a result a steep cliff-line has formed along the seaward side of this ridge (Fig. 1). Although the coastline formed along a young fault-line, interior structural lineations of the ridge reflect the effects of previous tectonic movements in a Northeast-Southwest direction. This means that at first the Yeniköy ridge tilted slightly to the Southeast. Then, during a younger period of tectonic movements, it was cut by faults in a North-South direction, and its steep western slope was worked by waves into a line of cliffs. Consequently the western slope of the Yeniköy ridge is steep and straight, while the eastern slope near the Karamenderes plain is indented and slightly inclined. The great indentations along the edges of the Karamenderes plain are therefore related to the shapes of the uplifted blocks of the Neogene strata. Rivers settled in the long depressions between the uplifted blocks and formed the present valleys. In other words, the Karamenderes and Dümrek rivers have not formed their present valleys themselves, but have found tectonic depressions in which to settle between the uplifted and tilted fault-blocks. Equally the lower parts of the present Karamenderes and Dümrek valleys have not been formed by river erosion but by alluvial deposition. This deposition has been controlled by the changing sea-level.

In the Neogene bedrock structure of the Yeniköy ridge it is possible to distinguish three litho-stratigraphical units. At the bottom, there is a light coloured (white, beige and yellowish) marly-limy sandstone with hard limestone layers in some levels. The stratified structure of this unit can be seen along the steep, cliffy coastline in the West. The strata generally dip slightly toward the East and Southeast, and are gently bent and faulted. It is overlain by a reddish, light-brown mudstone unit with many large, well-rounded pebbles in some parts. Although the bedding structure is not clear, it overlies the lower strata concordantly with their slight inclination to the East or Southeast. The unresistant lithology of this unit has an effect on the morphology of the gently-inclined eastern

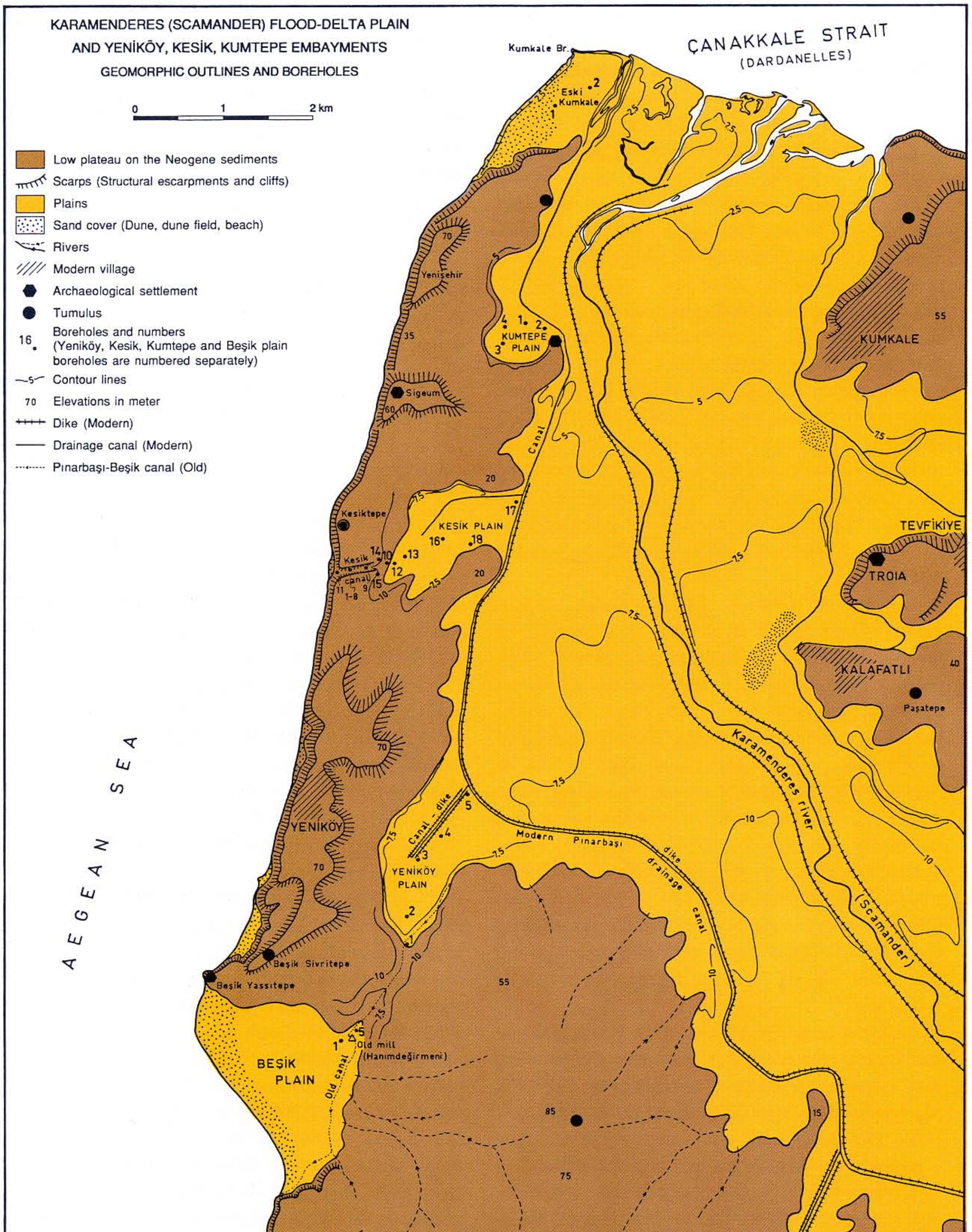


Fig. 2 The Karamenderes (Scamander) delta flood-plain and Yeniköy, Kesik, and Kumtepe indentations. Geomorphic outlines and boreholes.

slope of the Yeniköy ridge. At the top of the Yeniköy ridge there is a hard, rigid limestone unit. The strata are almost horizontal. As a result this unit forms platforms (mesas) which are visible at three main points along the top of the ridge (Fig. 2). They are encircled by rocky scarps. The southernmost platform is the widest, and is the site of the present-day village of Yeniköy. A little further North is Subaşı Hill, site of the ancient city of Sigeum. Furthest North is a small platform which is also site of the old settlement of Yenişehir. All three platforms form the highest parts of the ridge at about 70m. They are remnants of an earlier continuous platform completely covering the top of the ridge, and have been separated by erosion. Between the remaining parts of the platform there are low gates. Elevations are only about 20–30 m on these gates, and they therefore form thresholds between the Karamenderes plain and the sea. The Yeniköy, Kesik and Kumtepe plains are extensions of the Karamenderes plain toward these gates (or thresholds).

A fall of about 100m in sea-level during the last glacial period caused river-incision, especially on the coastal plains. However, sea-level rose again rapidly after the glacial period as the ice-sheets covering high latitudes melted. Thus, the sea intruded into the mouths of the rivers and formed long indentations or bays (ria or estuary). These changes affected the more recent formation of the delta flood-plains of the Karamenderes river and of its lowest tributary, the Dümrek (Simois) river. During our earlier research in this area, sedimentological evidence and $^{14}C$ datings obtained from borehole-samples showed that the sea intruded up to the North of Pınarbaşı about 7000 years ago and that Troia, during its first stages, was a coastal settlement.[9]

Subsequent borehole-studies in the Beşik plain on the Aegean coast made it possible to understand the final sequence of sea-level changes (Fig. 3).[10] The sea rose to its present level about 6000 years ago. Since this postglacial rise was a rapid one, the coastline was able to intrude into the mouths of rivers in spite of a great deal of alluvial deposition, and estuarine bays formed in such places. However, subsequent sea-level changes were much smaller in scale. There is enough evidence to indicate a fall in sea-level starting about 5000 years ago and ending in the period between 4000–3000 B. P. when sea-level was about 2 m below the present. This fall can be named the "Bronze Age Regression". Subsequently, the gradually-rising sea reached almost its present level around the time of Christ. In a place filled by a great deal of alluvium, as the mouth of the Karamenderes is, it is difficult to determine the effect on the coastline of sea-level changes of only about 2 m over several thousand years. In the period 3000–2000 B. P., for example, the coastline of the Karamenderes Plain moved towards the sea despite a rise in sea-level because alluvial progradation of the delta was more effective than the slow rise in sea-level.

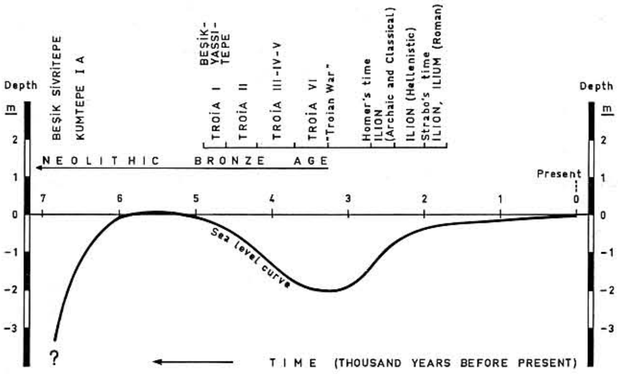


Fig 3 Relative changes in sea-level on the Beşik coast during the last 6000 years (after Kayan 1991).

In our borehole-studies in 1977, coarse sandy, coastal sediments were found in the Karamenderes Plain at different depths (about 30–40 m deep in the middle part). These sediments were deposited in the valley along the coastline of the advancing sea during the Holocene transgression. $^{14}C$ datings showed that these environmental changes occurred about 9000–8000 years ago.[11] The coarse sediments were overlain by finer sediments of a wider marine environment (estuary). Later still, the Karamenderes river filled the bay with alluvium, and fine marine sediments were covered by coarse sandy deltaic-coastal sediments during the late Holocene. This layer represents a regressive sequence in the sedimentation. Finally, fine sandy-silty flood-plain sediments were deposited over the top and formed the present plain.

During our more recent research in 1988–1993,

similar results relating to geomorphological change in the environment of the Karamenderes plain were obtained from a great number of borehole-studies. However, with more precise measurements this time, no marine sediment was found higher than the present sea-level. We can therefore see that the sea-level did not rise higher than its present level during the Holocene. When the boreholes descend below the present sea-level, sediments all over the plain always have a marine nature or some characteristics related to the marine environment. This means that the Karamenderes river incised its course as a consequence of the fall in sea-level during the last glacial period; but, starting about 15,000 years ago (Holocene transgression), the rapidly-rising sea reached and intruded into the lower valley of the Karamenderes river, and about 9000–8000 years ago formed an estuarine bay (Troia bay) here. At that period the level of the floor in the middle of the valley was at least 20–30 m below the present surface of the plain.
On the other hand, the borehole-evidence shows that during the Early Bronze Age the depth of the sea was about 2–4 m in the middle of the plain. Among the severe dynamic effects and the alluvial sedimentation of the Karamenderes delta flood-plain, it is difficult to distinguish the Bronze Age fall in sea-level. However it can be posited that the Bronze Age regression accelerated the deltaic progradation and that most of the plain changed into land during this period. This new plain-surface has been covered by coarse sandy sediments in the parts closer to the river-course, and by finer sandy-silty flood-sediments (back-swamp in some places) on both sides of the plain.

## Yeniköy Plain and Beşik Canal

The outlines of the land-forms of the Karamenderes flood-plain and of the surrounding area were first shaped by tectonic movements in the manner described above. Lineations of the landforms are various. For instance, in the East of the plain they run in an East-West direction, but in the West they run South-North. Moreover, there are other important lineations running in Southeast-Northwest and Northeast-Southwest directions. For example the southern part of the Karamenderes plain lies in a Southeast-Northwest direction. In the middle part it bends toward the North on a Southwest-Northeast structural line (or a low belt). This line is seen in the morphology as a low junction between the Yeniköy and Üvecik ridges (Fig. 2). Beşik bay and plain are formed on the Southwest coastal end of the same line. Towards the interior the Karamenderes plain makes an indentation again on the same line. This low area is where the Yeniköy plain has formed. The small alluvial plains of Beşik and Yeniköy are separated by a low flat threshold only about 10 m high (Figs. 4–5). Bedrock is visible on the surface here.
The bedrock of the threshold between the Beşik and Yeniköy plains consists of weak Late Miocene sandstone. The slopes toward Yeniköy in the Northwest and Üvecik in the Southeast rise with different lithological layers of the same formation (generally sandy marl and limestone). They were deposited in a shallow marine environment during the Late Miocene (much earlier than the Holocene marine transgression), and contain marine shells. Superficial appraisal could suggest that the loose surface-cover of the threshold, in fact formed by disaggregation of the bedrock, was sediment deposited during a Holocene marine transgression, and that during this transgression the Beşik and Troia bays were connected by a natural channel. However, investigations on the threshold and borehole-examinations on either side, in the Beşik and Yeniköy plains, have shown that the sea never rose up to this threshold during the Holocene, or even during the entire Quaternary, and that no marine connection through the threshold ever occurred. As a matter of fact, the marine sandstone of the threshold belongs to much earlier geological periods (Late Miocene); and all plateau-like ridges in the area, including Yeniköy and Troia ridges, were formed on this formation by many different tectonic and erosional processes over a long span of geological time (about 5–6 million years).
There is a small ditch, looking like a natural creek, between the Beşik and Yeniköy plains. Although it is not known when this was first dug, it is clear that the purpose of this canal was to bring fresh water to the Beşik plain from the Pınarbaşı springs in the South of the Karamenderes plain. This canal is shown on old descriptive maps as in good shape.[12] This means that the canal was important

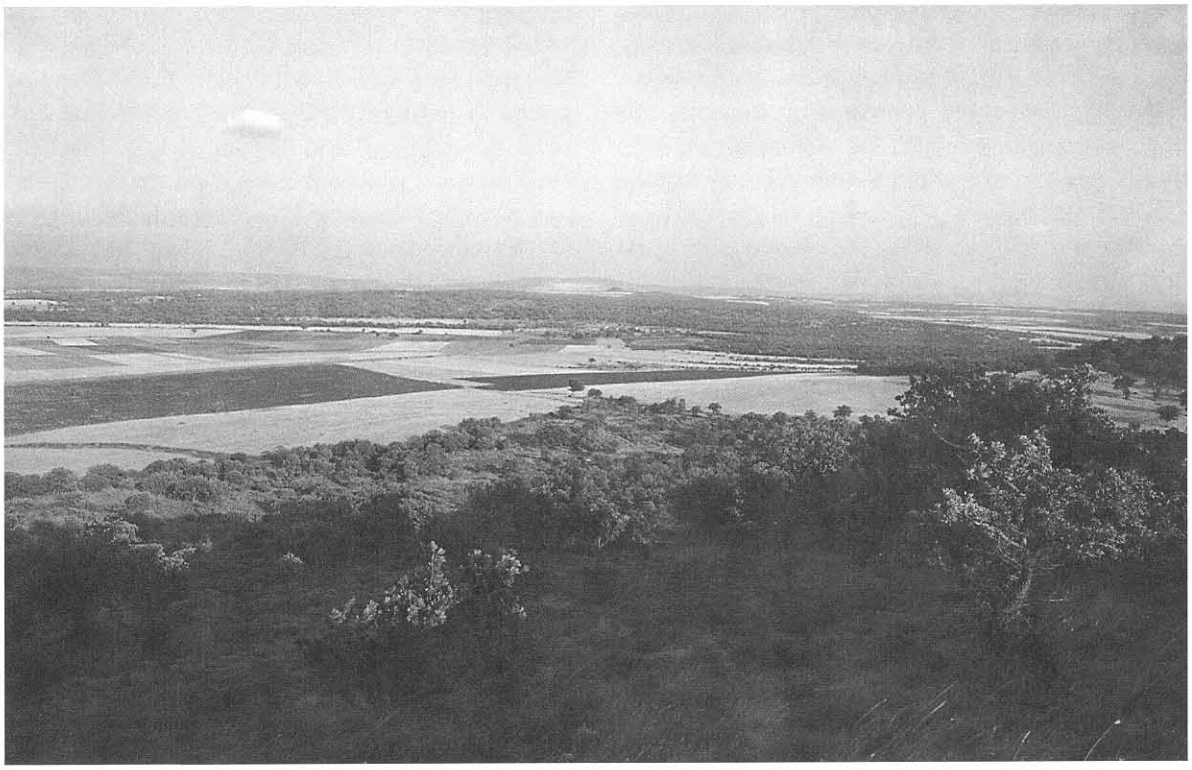

Fig. 4 Threshold between the Yeniköy plain (left) and the Beşik plain (to the right), seen from the Yeniköy ridge. Üvecik mound can be seen on the Üvecik ridge in the background.

Fig. 5 Low profile of the threshold between the Yeniköy plain (front), and the Beşik plain (back), seen from the East. To the right is the Yeniköy ridge, to the left is Üvecik. The lowest part of the threshold lies at about 10 m above sea-level. The cement factory on the horizon is situated on the south coast of the Beşik bay.

in ancient times. After passing the threshold, the canal runs along the eastern edge of the Beşik plain and reaches the sea in the South (Fig. 2). There are some Roman and Byzantine ruins in the South of the Beşik plain. It may be supposed that the canal derives from the same period and was dug to bring water to these buildings. It is known that the canal has been dredged and cleaned up, most recently in the 1950s when Balkan immigrants settled here. Some large blocks of sandstone layers from this excavation can be seen on the surface, half-buried in the loose sand covering the surface. It is understood that the last use of the canal was limited to working a water-mill at the point where the ditch opens onto the Beşik plain. The mill is known as "Hanımdeğirmeni" or "Hamamdeğirmeni", and its main building and aqueduct are still standing. However, it has not been used for a long time.

The Yeniköy plain was at one time covered by a swamp which was formed by the spreading of the water of the Pınarbaşı karstic springs from the South. The swamp was dried out in the 1960s by drainage canals, and the plain became an arable area. Its elevation is a little over 5 m at the lowest part of the plain, and reaches 8m at the beginning of the threshold. The old ditch coming from the Pınarbaşı springs enters the threshold at that level, because it follows the foot of the slopes along the edge of the plain. Although we did not make any special topographical measurement here, the 1/5000 cadastral map shows the 10 m contour-line passing through the ditch (or canal) on the threshold. Accordingly, the canal would have to have been dug about 2–3 m deep to keep the water flowing. This depth can be seen today in the ditch only in some parts because mostly it became filled with earth and bushes after it was abandoned. The surface-elevation is about 2–3 m near Hanımdeğirmeni (the water-mill at the beginning of the Beşik plain). These surface features indicate that the ditch could not have been used as a canal for ships to pass back and forth between the Aegean Sea and Troia bay before the Beşik and Yeniköy plains were filled with alluvium.

In addition to the surface investigations, a series of borehole-studies was made to determine the relation between the Beşik and Yeniköy plains and the geomorphological effect of the threshold. There is enough borehole evidence to elucidate the sedimentological sequence and the geomorphological development of the Beşik plain.[13] It has been shown that the rising sea during the Holocene intruded up to the site of Hanımdeğirmeni. Surface-elevation is about 2–3 m here. Coarse sandy coastal sediments with plenty of marine shells were encountered when the boreholes penetrated down to the present sea-level. $^{14}C$ dates of the shells taken from here were found to be about 6000 years B.P. Toward the threshold, these coastal sands cover the Neogene bedrock beneath the recent colluvium. Toward the Beşik plain there is a lagoonal muddy sediment unit below the coastal sand. This time, only two trenches about 3 m deep were dug near Hanımdeğirmeni down to the bedrock to examine the colluvial cover.

During our latest investigations, new boreholes were made on the Yeniköy plain (Fig. 2). Borehole No. 5 was made on a site where the Yeniköy plain opens onto the Karamenderes plain. This borehole penetrated down to 20.5 m and encountered Neogene bedrock at 17.2 m below the surface (or −11.8 m). A typical Holocene transgressive sequence of sedimentation was found here (Fig. 6). The sequence starts with coarse sandy, shallow marine sediments on the bedrock surface and changes to a finer sandy-silty mud further up. The marine sediments come to an end with coarse coastal sands including many marine shells at 7 m below the present surface (−2 m). This means that the sea, which previously had intruded into the Karamenderes valley, retreated over this surface of −2 m which was then covered by fine sandy delta flood-plain sediments up to the present surface. Here in the Yeniköy plain, flood-sediments were deposited in a swampy environment which was formed by the waters of the Pınarbaşı springs. In the other boreholes, coastal sediments were found up to the present sea-level toward the edge of the Yeniköy plain. This is clearly seen in borehole No. 3 (Fig. 7). Coastal sediments have never been found above the present sea-level. This indicates that the sea was never higher than its present level during the Holocene, or even during the entire Quaternary. Marine sediments were not encountered in boreholes Nos. 1–2, but bedrock was found beneath the 2–3 m of colluvium on the surface.

| Laboratory number | Borehole location, date, number | Sample depth (cm) from surface | Cal. BC 95.4 (2σ) | Cal. Age BC 400 yrs reservoir correction | Used age (BP) before present |
|---|---|---|---|---|---|
| 16296–15665 | Yeniköy 1992-03 | 540–560 | 3970–3690 | 3510–3340 | 5500 |
| 16297–15703 | Yeniköy 1992-04 | 750 | 4120–4087 | 3890–3750 | 5800 |
| 16293–16091 | Yeniköy 1992-05 | 660–680 | 3580–3530 | 3335–3155 | 5300 |
| 16298–15664 | Yeniköy 1992-05 | 1480–1500 | 11190–10680 | 10680–10390 | 12500 |
| 16294–16156 | Kesik 1992-16 | 550–600 | 1920–1620 | 1480–1285 | 3400 |
| 16299–15674 | Kesik 1992-17 | 600–650 | 2530–2500 | 2610–2255 | 4500 |
| 16295–15682 | Kesik 1992-18 | 540–560 | 2697–2473 | 2200–2100 | 4200 |
| 16291–16118 | Kumtepe 1992-01 | 450–500 | 3966–3795 | 3530–3455 | 5500 |
| 16292–15688 | Kumtepe 1992-01 | 800 | 5349–5236 | 4920–4815 | 7000 |

Table $^{14}C$ dates of marine shells, datings by Dr. B. Kromer, Institut für Umweltphysik der Universität Heidelberg. Dates are rounded for ease of paleogeographical reference. Precise determinations are given in the table.

Marine shell-samples were taken for $^{14}C$ dating from boreholes Nos. 3–5 (see Table and Fig. 7).[14] The samples were taken from various levels to determine when marine sedimentation began and ended. Yeniköy plain is a typical site for this purpose, and the results were found to be in accord with our previous evidence and interpretations. In borehole no. 5 shell-samples taken from the coarse sandy marine sediments at a depth of 15 m, just above the Neogene bedrock, were found to be from 12,500 years B.P. (Fig. 6). In the same borehole, shell-samples from the upper end of the marine sediment unit were found to be from 5300 B.P. This means that marine sedimentation at the entrance of the Yeniköy indentation started about 13,000 years ago (?) and ended 5300 years ago. The coastline of the maximum extension of the sea, when the sea first reached its present level, was encountered in borehole No. 3. Marine shell-samples taken from the coarse coastal sand covering the Neogene bedrock about 5–6 m below the present surface (just at the present sea-level) gave a date of 5500 B. P. Further toward the center of the plain, in borehole No. 4, coarse sandy sediments from a slightly deeper level were also dated to 5800 B. P. On the other hand, towards the slope, boreholes Nos. 1–2 did not cut through any marine sediment.

From this borehole-evidence and from the $^{14}C$ dates it is clear that the rising sea in the Holocene covered the front of the Yeniköy embayment about 12,000 years ago. We know from earlier borehole-evidence that the sea intruded farther South through the Karamenderes plain near to the Pınarbaşı area during the time of its maximum extension about 8000–7000 years ago. At that time the sea-level was lower than it is at present. Since the plain (or, at that time, the estuarine bay) was not yet filled with alluvium, the sea was able to intrude farther inland despite the lower sea-level.

As sea-level begin to rise more slowly, sedimentation had an increasingly large effect in the bay, and by 6000–5500 years ago the coastline had moved to the East of the Yeniköy embayment (Fig. 8). By about 5500–5200 years ago there remained only a small bay roughly 1–2 m deep in the central part of the Yeniköy plain. Then, around 5000 B. P., the sea started to retreat and the present plain began to be formed. But the area remained under water, without interruption, because of the Pınarbaşı springs. Although the source of the material sedimented in this area was the Karamenderes river, little sediment, generally of a fine size, reached here; but this had a high organic content because of the swampy conditions.

According to all this evidence, there is no doubt that both the present Beşik and Yeniköy plains formed as marine embayments during the Holocene transgression. The sea intruded toward the Karamenderes valley from the Northeast (from the

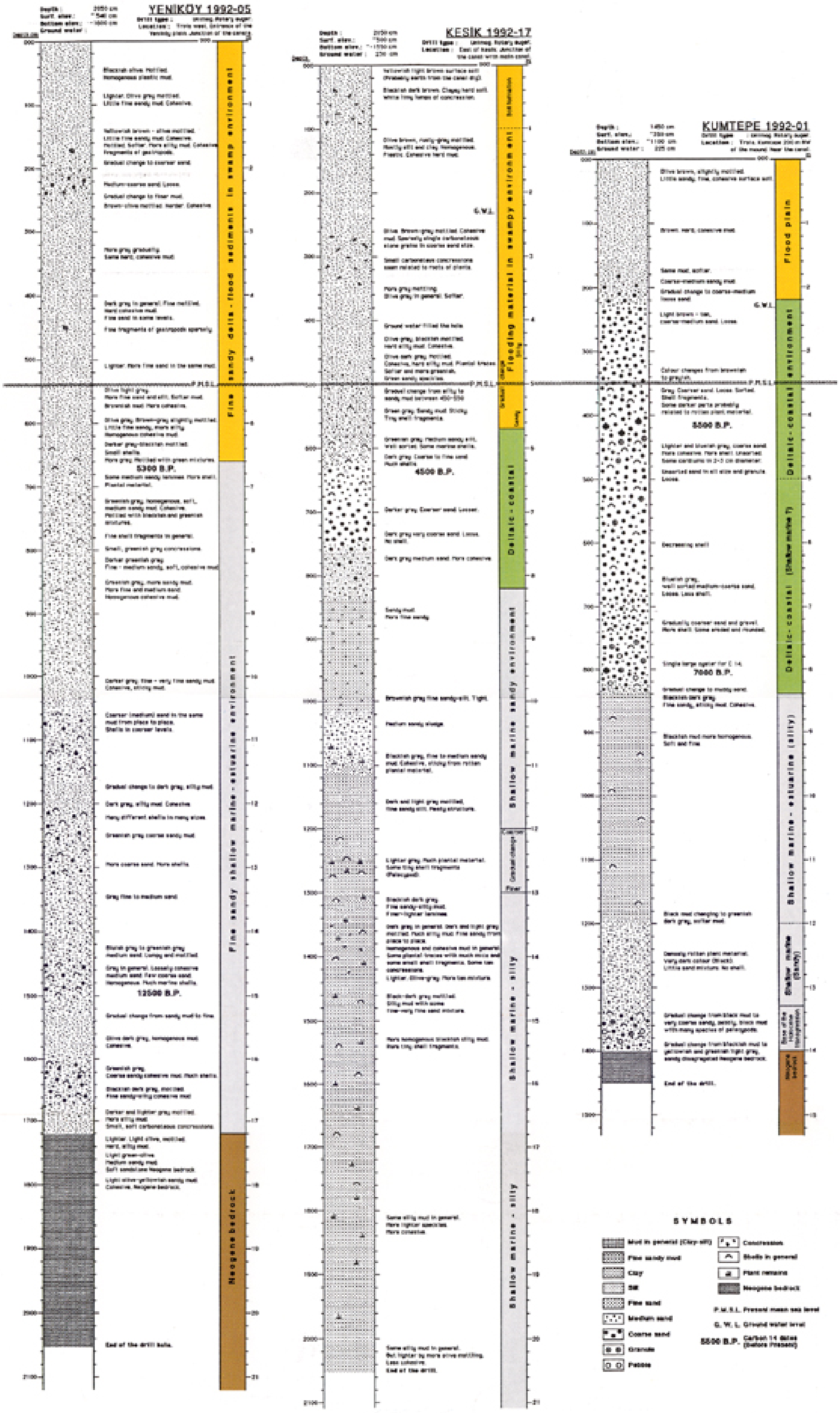


Fig. 6 Borehole-profiles from the entrances of the Yeniköy, Kesik and Kumtepe embayments. Vertical positions of the subsurface sedimentary units are adjusted to the present sea-level. In general, finer sediments are dominant in the South (Yeniköy borehole). Towards the North, coarser deltaic-coastal sediments gradually form increasingly thick sections (especially in the upper parts of the Kesik and Kumtepe boreholes). This is because of the coarser alluvium of the Dümrek river (see text). Real marine sediment-units generally come to an end a few meters below the present sea-level. $^{14}C$ dates from these levels were found to be earlier in the South. However, this level is also early in the Kumtepe profile in the North. This is because the borehole lies close to the coast where coarser sediment has been reworked on this lower plain over a long time (see Fig. 2 for the locations of the boreholes).

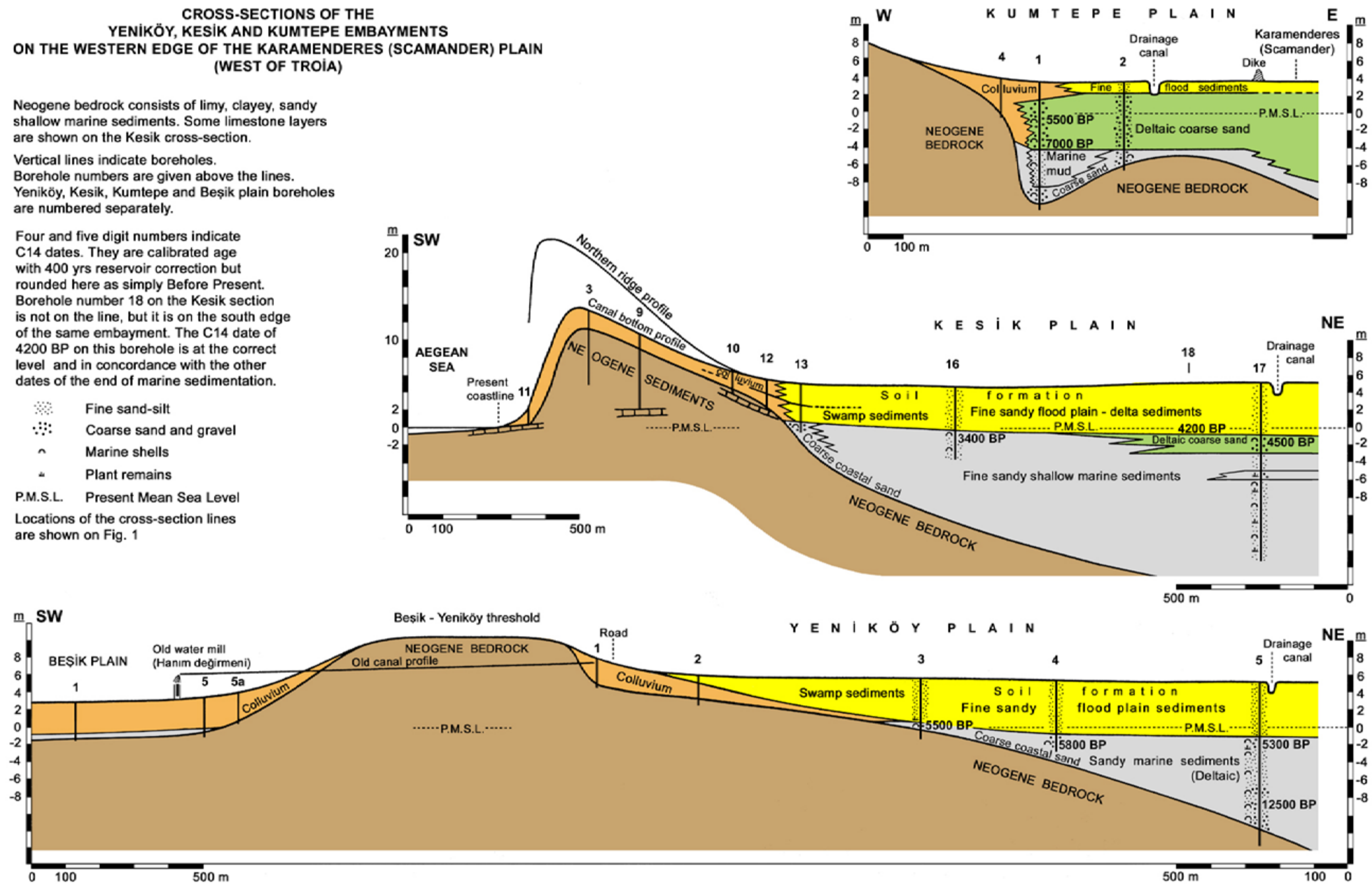


Fig. 7 Lengthwise cross-sections of the Yeniköy, Kesik, Kumtepe embayments.

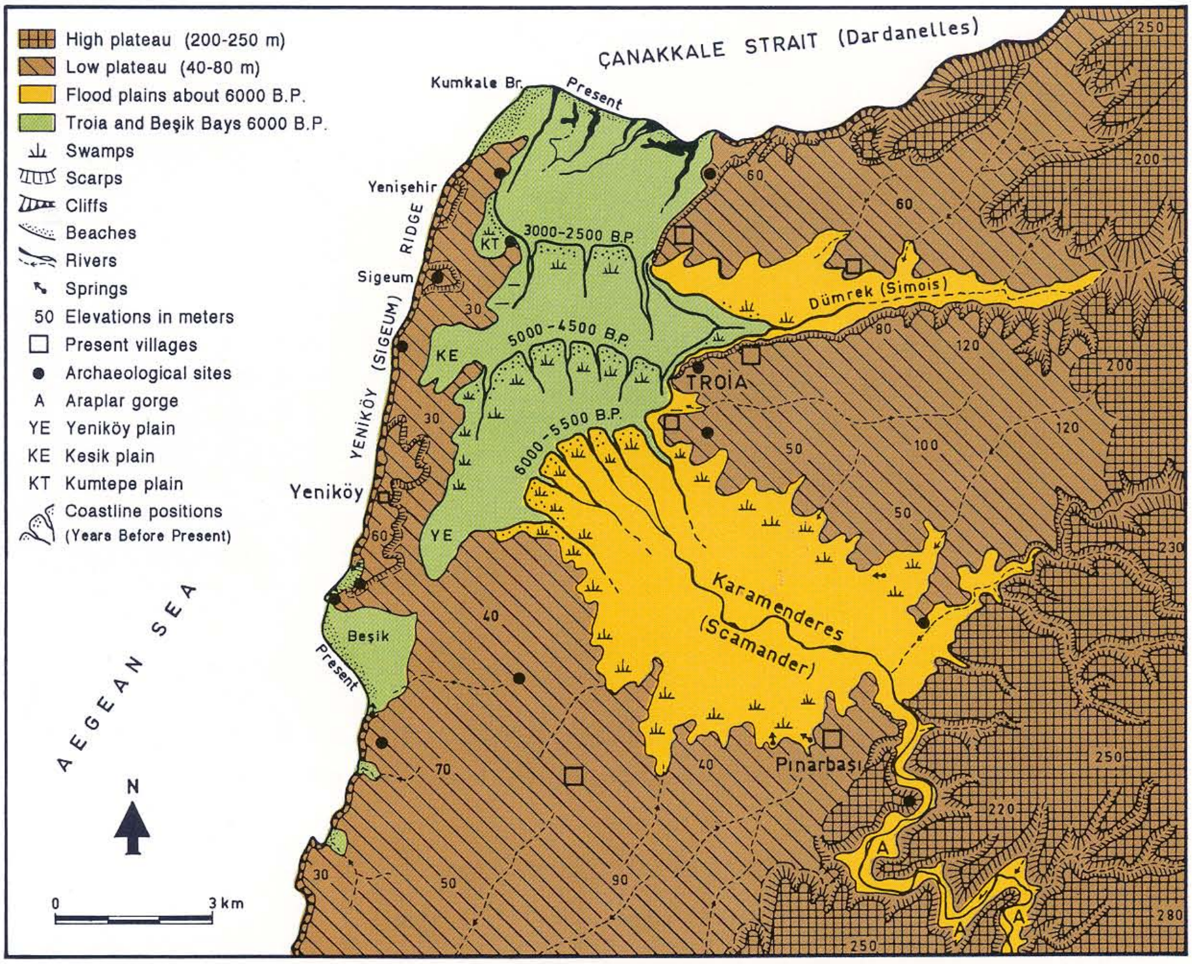


Fig. 8 Paleogeographical reconstructions of the Karamenderes plain.

Çanakkale Strait) and toward the Beşik embayment from the Southwest (the Aegean Sea). But it is definite that these two bays were separated by a low threshold and were never joined naturally or artificially. Also there is no evidence to indicate that the Beşik and Yeniköy bays were used as major harbours. The ditch through the threshold was not dug to make a naval gate, but to bring fresh water to the Beşik plain.

## Kesik Plain, Kesik Canal and Kesiktepe

The Kesik plain lies in another indentation along the western edge of the Karamenderes plain to the North of the Yeniköy plain (Figs. 2 and 9–10). It is situated due West of the site of Troia, across the Karamenderes plain. Like the Yeniköy plain it too is formed on a Northeast-Southwest structural line, and it extends towards a low gate in the Yeniköy (Sigeum) ridge situated between the two horizontal limestone platforms of Yeniköy and Subaşı. This gate forms a threshold between the plain and the sea. Like the Yeniköy plain the Kesik plain was covered by a swamp until the 1960s when it was drained and turned into arable land.

To the West of the Kesik plain, the Yeniköy ridge is only about 600 m wide. The elevation is a little more than 20 m at the top. The eastern slope is gentle, but the western slope has steep cliffs. Outcrops of limy-marly-sandy layers of Neogene sedi-

Fig. 9 Kesik plain, Kesik canal and Kesiktepe from the East. The Aegean Sea is just behind the Yeniköy (Sigeum) ridge.

Fig. 10 The Kesik plain from Kesiktepe. A dirt road extends towards the Kesik canal and connects the plain to the sea on the right. A very low, hook-like secondary ridge separates the plain from the main Karamenderes plain in the South and East. Small cliff-like slope features are noticeable at the tip of this ridge.

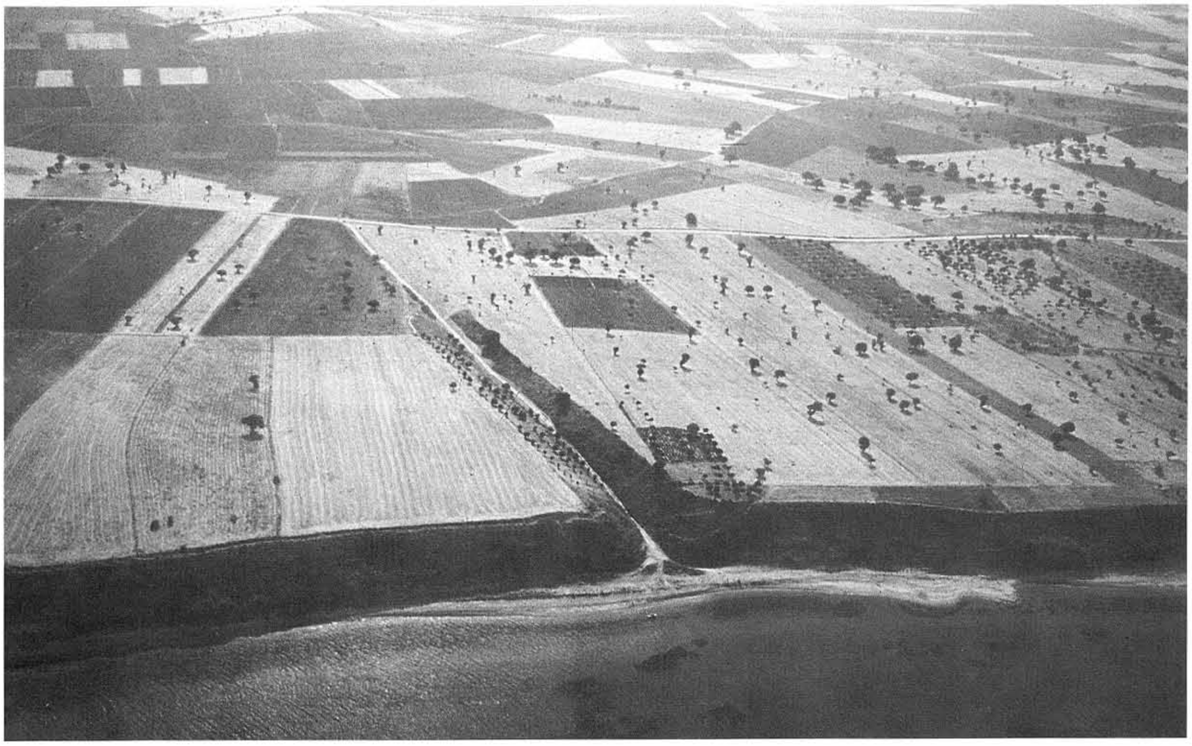

Fig. 11 Aerial view of the Kesik canal from the Northwest. The Kesik canal cuts the asymmetrical profile of the Yeniköy ridge transversely. The Kesik plain extends behind the junction of the roads.

ments can be seen along the steep cliff-line. There is a dry canal-like feature cutting straight across the lowest part of the Yeniköy ridge in an East-West direction (Fig. 11). "Kesik" means "cut" or "cleft" in Turkish, and the name of the area comes from this feature. The East-West profile of this cleft-like feature is asymmetrical, as is that of the ridge itself. The highest point in the bottom is 13.7 m above sea-level at a distance of about 150 m from the seaward mouth, but the profile towards the interior is gentle and opens onto the Kesik plain at an elevation of 6.3 m about 400 m East of the top. The crosswise profile of the Kesik "canal" is also asymmetrical. The southern slope is steeper and higher than the northern slope because of the geological structure. The Kesik canal has no floor. It looks like a V-shaped valley, but at the bottom there is only an earth road which is used by people walking between the plain and the coast (Fig. 12). The surface of the Yeniköy ridge rises gently to the North of the Kesik canal and reaches an elevation of 40 m in about 500 m. Here there is a tumulus-like hill roughly 12 m high (52 m above sea-level) and about 100 m in diameter at its base. The hill is shaped like a regular cone, but with the top cut off. Hence the name "Kesiktepe" which means "cut hill" in Turkish. Thus, there are three features with the name "Kesik": Kesik plain, Kesik canal or passage and Kesiktepe (Figs. 2 and 9). Supposing that the Kesik plain was once covered by sea-water, one can easily imagine that it could have been an excellent harbour. When the canal feature is included in this picture, it would seem very logical to suppose that this harbour was connected to the Aegean Sea by a canal. The idea can be developed further. The Kesik area is just to the West of Troia and lies on the shortest direct line between Troia and the Aegean Sea. Bozcaada (Tenedos), the entrance of the Çanakkale Strait (Dardanelles) and Troia are easily seen from Kesiktepe. It is an excellent site from which to inform Troia of ships coming from the southern Aegean and sailing toward the strait (Fig. 13). If the site of the present Kesik plain were to be a harbour, it

Fig. 12 Inner profile of the Kesik canal, seen from the East at the highest part. The asymmetrical crosswise profile of the canal is noticeable: steeper to the South (left), gentler to the North (right). The Aegean Sea is visible just at the end of the "canal".

would make very good sense to join this harbour to the sea in the West by a canal 600 m long. It would be very useful, because it would be possible to pass into the west harbour of Troia directly from the Aegean Sea, instead of entering the Çanakkale Strait and coping with the difficulties of its currents. Also it would be advantageous for the hiding of ships and for their defence when attacked from the sea. All these ideas find expression in the various hypothesis in the literature.[15] They may be tested by examining the geomorphological formation and natural characteristics of the Kesik plain, Kesik (canal) and Kesiktepe.

The stratigraphical sequence and environmental characteristics of the subsurface sedimentary units of the Kesik plain were examined by a number of boreholes as in the Yeniköy plain (Fig. 2). One of the boreholes, No. 17, was taken down to 20.5 m by the Unimog, and the others were drilled to about 8 m by hand-operated boring. The Neogene bedrock was encountered in the westernmost borehole at 3 m deep, but was not reached in the others (Fig. 7). This means that in the Kesik plain the bedrock surface lies deeper than in the Yeniköy plain. The stratigraphical order of the Holocene sedimentary units is the same as in the Yeniköy plain. In borehole No. 17, which is situated at the entrance of the Kesik plain, the deepest unit is a fine mud deposited in an estuarine environment (Fig. 6). It has much organic content and it is more silty in the lower part. But from 12 m below the surface upwards, it becomes more sandy. It can be deduced that during the silting-up of the Karamenderes (or Troia) estuarine bay, the coastline came gradually closer to the Kesik plain, and coarser sandy sediments started to reach the site of borehole No. 17. In this borehole the grain-size of the sand becomes coarser about 7 m below the pre-

Fig. 13 Panoramic view to the Northwest from the top of the Kesiktepe. Limy strata of the Neogene bedrock at the top indicate that the hill is originally natural. In the middle distance the horizontal limestone platform of Sigeum can be seen on the long Yeniköy ridge. In the far distance (North) is the entrance of the Çanakkale Strait.

sent surface (–2 m), and marine sediments come to an end. At this level the sand contains plentiful marine shells. Their $^{14}C$ dates were found to be 4500 B. P. In the other boreholes of the Kesik plain the continuation of the same unit was dated to around 4000 B. P. For example in borehole No. 18, the coastal sand unit was encountered 5.5 m below the present surface. This is exactly the present sea-level. Marine shells from this level were dated 4200 B. P. Marine sediments were found at almost the present sea-level in borehole No. 16 again with coarse sands including shells which were dated to 3400 B. P. (Fig. 7).

From this evidence it is clear that during the Holocene the Kesik plain was an indentation of the Karamenderes estuarine bay. This bay existed here until 4500–4000 B. P. At this date, the coastline of the Karamenderes delta will have lain between the Kesik plain and Troia (Fig. 8). This means that the marine environment lasted later here than in the Yeniköy plain. This makes good sense. Deltaic progradation caused the coastline to recede northwards. 5500 years ago it lay to the east of the Yeniköy plain; by 4500 B. P. it lay between Kesik and Troia. Presumably this deltaic progradation was facilitated by the fall of about 2 m in the sea-level which occurred during the Bronze Age and which is revealed in the Beşik plain (Fig. 3).[16]

The Kesik is another interesting feature on which we concentrated our attention during this research (Figs. 10–11). It looks as though it was dug by man. We took precise topographical measurements to delineate the morphometry of this feature, and made twelve boreholes to examine the sediments covering the bedrock. A cross-section based on these data is given in Fig. 7.

There is no running water in the bottom of the Kesik. The drainage-area is limited only by two low side-slopes. This means that the Kesik is not a stream valley, and river-erosion has not affected the formation. Although we did not expect any fill in the Kesik, twelve boreholes were made along the bottom. Six boreholes and two trenches were opened at the highest part. All the evidence showed that there is in fact no fill in the bottom of the Kesik canal, either marine or fluvial. In none of the boreholes was any more than a thin layer of colluvium found (Fig. 7). This is not more than 2–2.5 m thick. This unit passes gradually to a disaggregated bedrock surface. Bedrock here is mostly sandy-limy marl and claystone, outcrops of which are seen along the cliff-line in the West. Thus the highest part of Kesik, which is at 13.7 m above sea-level, is almost directly on the bedrock and it is impossible for it ever to have served as a water-channel linking the Kesik plain and the sea.

Other possible natural reasons for the opening of the Kesik were checked. For example, there is a difference of about 2 m between the two sides of the Kesik-canal. When it is viewed from a distance (Fig. 9), this suggests that the Kesik canal opened on a structural line like a fault. This is consistent with some other tectonic characteristics of this area. For example, some small faults can be seen along the cliff profile cutting the Yeniköy ridge crosswise. Also there are some small scarps on the eastern extension of the Kesik canal, along the northern slope of the secondary hook-like lower ridge to the East of the Kesik plain. Also the bedrock is not strong in the bottom of the Kesik-canal, and it has a mylonitic nature. This all implies that the Kesik probably formed on a fault line. However, structural lineation may have affected the Kesik canal only in the initial stages of its formation; it need not be a tectonic feature in its completed form. In particular the theory that the Kesik-canal was opened by an earthquake is completely unsupported by any evidence.

In fact the morphology of the Kesik canal looks artificial. However there is another important question: If the Kesik was opened by digging, where is the spoil from the excavation? There is no additional heap of earth in the area. Boreholes Nos. 14 and 15 were made to examine possible areas (Fig. 2), but the bedrock was found very close to the surface. The absence of such an amount of earth could only be explained if it were assumed that it had been transported to the coast and then dispersed by the waves in the course of time. However, there would be no logical reason to carry a great volume of excavated earth to the coast.

The shape of the Kesik implies that it was opened by man. To connect the inner harbour (the Kesik plain) to the Aegean Sea with a short cut might be thought the only reason for digging such a canal. However, there is no evidence that this canal was dug and used during the Early Bronze Age when the Kesik plain was definitely a marine embayment. Also an important point is that the sea has never risen up to the Kesik canal and no water connection has ever occurred. However, some archaeologists and philologists[17] declare that such a canal might have been used in the Bronze Age even without its making a direct connection by water; the small ships of that time could have been carried by 15–20 men between the sea and the Kesik harbour. This is possible; but in that case the canal's bottom surface, where the sailors would frequently have walked and carried their boats, should be easily recognizable. From various small finds (artefacts, especially sherds) and soil characteristics, such surfaces can in fact easily be recognized in our hand operated boreholes as for example to the North of Troia. It proves that people used the area, or walked around there. But nothing has been found in the Kesik which indicates such a surface. Thin colluvial surface-cover changes gradually as one penetrates deeper, and passes naturally into disaggregated bedrock. There is no clearly delineated stratification. During our careful examination of this area no significant potsherds or other traces of artefacts were found on or in the thin colluvium except for two small and insignificant sherds which were found very close to the surface.

Moreover, there is no definite evidence to indicate that the old Kesik bay was used as a harbour. According to sedimentological evidence and $^{14}C$ datings the Bronze Age saw a slight fall in sea-level of about 2 m in this area. It is evident that during the same period the marine environment in the Kesik plain changed to that of a delta flood-plain. Therefore we suppose that the Kesik canal has been used since the Bronze Age as it is used today – only as a passage for walking between the plain and

Fig. 14 The Kumtepe plain from the West. Geomorphic outlines of the Kumtepe plain are very similar to those of the Kesik plain (Fig. 5). There is a low, hook-like, secondary ridge here too. Kumtepe mound is situated at the northern tip of this ridge.

the coast. The Kesik canal may not have been opened all at one time. Possibly it began as an indistinct structural depression, a natural gate used by man as a convenient passage. Then, especially during wars, this passage may have became more important, more frequently used and more extensively dug out. Thus perhaps it took shape slowly rather than in one planned excavation. On the steep cliff-line to the North there are some other, smaller cuts which have been opened by rain-water acting on the weak structural lines. It is obvious that these lower and less steep sites provide convenient routes for crossing the steep cliff wall. We suppose that the Kesik canal started to be formed in this way.

Finally we must consider the Kesiktepe to the North of Kesik canal. A point for discussion is whether the mound is natural or artificial and, if artificial, whether or not it is a tumulus.[18] There is a small hollow in the cut-off top which was obviously dug as a shelter. In the hollow it can be seen that the hill consists of natural limestone or marly limestone bedrock strata (Fig. 13). The strata dip slightly toward the sea. Limy-marl layers can be seen on the East-facing slope, but the sea-facing western slope is covered in rubble. Illegal excavations have opened a profile in the rubble cover.

On the Yeniköy ridge there are, as stated above, almost horizontal limy strata of the Neogene sediments which form small platforms (mesas) and which are encircled by steep slopes. These are the site of several settlements: in the South Yeniköy, in the middle ancient Sigeum, in the North Old Yenişehir (Fig. 2). Structurally, Kesiktepe is one of these platforms between Yeniköy and Sigeum, but is separated from them by the lower parts of the ridge. It is a remnant of the uppermost limy strata on the Yeniköy Neogene ridge after a long time of erosion. As one might expect from its limy lithology, it was formed by steep slope retreat and was finally shaped into a "butte" resembling a tumulus. The size and shape of this hill are very similar to genuine tumuli in the area. This gives the impression that Kesiktepe is a tumulus. But it is a natural hill originating as a remnant of hard strata on the surface of the Yeniköy ridge.

However, the thickness of the rubble cover on the west-facing slope of the hill is too great to be natural. Thus it may be a natural hill which has been shaped artificially by man. As stated above, the site of the hill is important strategically as a watch-point. The hollow at the top indicates that it may have been used during the last great wars for this purpose.

On a superficial view it would seem quite logical to define the Kesik plain as a harbour, the Kesik passage as a canal connecting the harbour to the sea by a short route, and Kesiktepe as a tumulus. However, we found no clear evidence to prove these theories during our careful examinations there. The $^{14}C$ dates show that the marine embayment in the Kesik plain changed into land about 4000 years ago. So this embayment could only have been used as harbour during the Early Bronze Age. But it could not have been so used in the Late Bronze Age, during the period of Troia VI. On the contrary, the Kesik plain has since then and until recent years been a swamp environment fed by spring waters coming from Pınarbaşı. This area was not easily filled by the alluvium of the Karamenderes river due to its sheltered position. Therefore for a long time after becoming swampy land the Kesik swamp might have been reached by boats through some inlets (Turkish "azmak") for hunting and fishing (Fig. 8).

## Kumtepe and Kumtepe Plain

Kumtepe plain is situated in the last indentation of the Karamenderes plain in the North of the Yeniköy ridge (Figs. 2 and 18). It too is shaped by a structural depression like the Yeniköy and Kesik plains. It extends from the Karamenderes delta plain toward a low gate (35 m) between the limestone platforms (70 m) of Old Yenişehir and Sigeum. The Kumtepe mound is situated at the northern tip of a secondary low Neogene ridge extending from the Yeniköy ridge at first toward the East, then bending to the North. The small plain which is separated from the Karamenderes plain by this secondary ridge is named Kumtepe plain here after the Kumtepe mound. The mound is one of the known oldest settlements in the Troia area. Its earliest levels go back to 6500 B. P.[19]

Like the Yeniköy and Kesik plains, the Kumtepe plain has been formed by deposition of the alluvium of the Karamenderes river. Surface elevation is lower than 4 m today. The stratigraphical order of the sedimentary units, which was examined in four boreholes, is similar to that of the plains to the South. The Neogene bedrock was encountered at 14 m below the surface in borehole No. 1 in the entrance of the plain (Figs. 6–7). It is covered by coarse sandy coastal sediments which were deposited at the bottom of the rising sea in the Holocene. Grain-size becomes gradually finer higher up, and changes into the blackish mud of a shallow marine environment. But in the Kumtepe plain the nature of the sediment changes here at –4 m and a coarse sandy-gravelly loose sediment unit overlies the mud. There are plentiful marine shells, especially in the lower levels of the coarse sandy unit. They are dated to 7000 B. P. by $^{14}C$. Also at –1 m marine shells are again abundant. Their age is found to be 5500 B. P. The coarse sandy unit continues up to 1–2 m above the present sea-level. Then a fine sandy flood deposit, about 2 m thick, forms the present plain.

The bedrock surface was found a little higher, at 9.5 m below the present surface, in borehole No. 2 to the Northwest of the Kumtepe mound near the drainage canal (Fig. 7). Here the coarse sandy-gravelly unit continued down to the bedrock surface, and marine mud was not found. The reason for the higher bedrock surface is the extension of the secondary low ridge beneath the alluvium. Boreholes Nos. 3–4 were made along the inner edge of the plain. Marine sediment units were not found, but disaggregated bedrock surface was encountered under a 4–4.5 m thick colluvium. This means that the rising sea during the Holocene could not have intruded all over the Kumtepe embayment because it is not wide and deep enough. If the sedimentological characteristics of the Kumtepe plain are taken into account together with those of the Yeniköy and Kesik plains, some conclusions can be drawn relating to the geomorphological development of the entire Karamenderes plain. The transition-surface between the marine and fluvial sediments beneath the Yeniköy plain in the South is at about –2 m, and is dated to 5300 B. P. In the Kesik plain, the level is again –2 m but the date is 4500 B. P. These figures show that the coastline advanced toward the North in the course of time (Fig. 8). At this rate the change from marine to fluvial sediments in the Kumtepe plain would be expected to lie just below the present sea-level, and to have occurred at a date not earlier than 4000 B. P. But the change from shallow marine sediments to coarse sandy deltaic ones is in fact observed at –4 m and occurred c. 7000 B. P. This indicates that other factors affected the formation of the delta (Fig. 6). When the Karamenderes plain was an estuarine bay, coarse sandy sediments from the Karamenderes river could not reach down to the middle and lower parts of the bay. But the lowest tributary, the Dümrek river, poured coarse sandy sediments into the lower part of the bay because at that time it had no preceding alluvial plain to hold them. This is why there is no coarse sediment in front of the Yeniköy plain at lower levels, while toward the North coarse sediments start to be found at higher levels, as they are in front of the Kesik plain. Farther to the North, a coarse sandy deltaic sedimentary unit forms a thick unit below the recent fine sandy flood-plain sediments (Fig. 7). This means that the source of the coarse sediments is not the Karamenderes river, but the Dümrek river coming from the East into the lower plain. In fact, even today, it is noticeable that the course of the Karamenderes river is shifted westward at the west end of the Dümrek valley: the great amount of alluvium brought down when the Dümrek river is in flood has pushed the bed of the Karamenderes river to the West (Fig. 2).

Another dynamic factor in the formation of the lower delta plain of the Karamenderes is the currents at the mouth of the Çanakkale Strait. During the time when the delta coast lay to the East of Kumtepe, sedimentation started to be affected by the currents of the Çanakkale Strait and more sediment accumulated in the West. Thus, a coastal spit formed toward the North as an extension of the Yeniköy ridge. This area became the site of Old Kumkale village. Later the spit caused a change in the direction of the current at the mouth of the Çanakkale Strait, and a counter-current started to affect the formation of the youngest delta and delta coast to the East of the sandy spit.[20] This in turn affected the direction of the lowest course of the Karamenderes river which it shifted again toward the East and formed a small, new, bird's-foot type of delta (Fig. 2).

Finally, two additional boreholes were made on the Old Kumkale coastal spit to examine the distribution of the subsurface sedimentary environments. The bedrock was reached at –18 m in the first hole. There were 4 m of coarse sandy-gravelly sediments at the base of a marine unit on the bedrock. Fine sandy shallow marine sediments were extracted from –14 m up to the present sea-level. On the surface, there is a coastal dune formation up to 1–2 m above the sea-level. The depth of borehole No. 2 was 14 m. The bottom of the fine sandy marine sediment unit was not reached in this hole. There is no $^{14}C$ dating from these boreholes. The fact that the coarse sandy upper Kumtepe unit is not found here can be explained by assuming that less of the coarse sandy Dümrek alluvium reached this area (Fig. 2).

The Karamenderes river has not flooded in recent years because of dam constructions in the upland area, and because of falling ground-water throughout the plains caused by pumping for irrigation. Therefore sediment-transport to the coast has decreased and delta formation almost stopped. Only a little sediment reaching the Çanakkale Strait is being transported West of the Old Kumkale spit, and a sandy shoal is being formed toward the West.

The shape of the Kumtepe plain is very similar to that of the Kesik plain. This could be thought to imply that it was another harbour site. But this indentation is smaller, and it was filled up at an earlier period by coarse sandy deltaic-coastal sediments. According to the $^{14}C$ dates, the Kumtepe indentation was a marine embayment for a certain time before 7000 B. P., but after 7000 B. P. became land. Our boreholes are not yet sufficient to elucidate the paleogeography of the Kumtepe area in every detail. However, we expect to find that a coastal spit or barrier first closed the Kumtepe bay, and that a lagoon then formed which became an excellent environment for the Kumtepe people to collect plentiful shell-fish. On some old maps based on Strabo's descriptions, the coastline is set between Kumtepe and Yenikumkale around the time of Christ, and the Greek camp of the much earlier Troian War is shown to the East of the low Kumtepe ridge.[21] However, no coastal indentation toward the Kumtepe plain is shown on these maps. There is also no evidence that the Kumtepe plain was used as harbour during ancient times.

## Conclusions

The Karamenderes delta flood-plain has formed in a structural depression between low plateau ridges which consist of Upper Miocene stratified limy-sandy sediments. Over a hundred borings were made in the plain by several techniques to test how the subsurface sedimentary environments changed during the Holocene. According to the sedimentological, stratigraphical and chronological evidence obtained by the boreholes, the rising sea during the Holocene formed an estuarine bay in the place of the present plain. $^{14}C$ datings of marine shells show that the bay started to be formed over 10,000 years ago. The rising sea reached its present level for the first time about 6000 years ago. There is no evidence that the sea has ever risen to a level higher than the present. In the period later than 6000 years ago, alluviation had a greater effect on the formation of the Karamenderes embayment, and the coastline retreated toward the North until it reached to the Çanakkale Strait (Dardanelles). Various sedimentological units were found by the borehole studies which document this process. Coarse sandy-gravelly sediments with many shells cover the bottom as a base of the Holocene transgression. Then a marine mud unit fills the embayment. It is mostly fine sandy-silty mud of a blackish colour. This is overlain by coarse sandy deltaic-coastal sediments which form a transition-level from the marine mud. The uppermost fluvial sediments mostly consist of fine sandy flood-plain deposits.

The transition-surface between the lower marine and upper deltaic-fluvial sediments lies a few meters below the present sea-level. It is a rather flat surface except in areas near to the river beds and slopes. Sediments on the surface generally represent a coarse sandy deltaic-coastal environment. They contain plentiful shells, sometimes eroded by wave activity. Coastal sediments are found at almost the present sea-level along the edge of the embayment. These coastal formations are of course below the present surface of the plain and are covered by the younger sediments. They can only be reached by boreholes.

These are two possible explanations for the fact that the transition surface is below the present sea-level:

1. Since the Karamenderes delta flood-plain has formed in a structural depression, it is possible to suppose that the bottom of the depression subsided or down-faulted again during the last 6000–5000 years. Such a hypothesis could be supported by the location of the area, which is near the active North Anatolian Fault Zone. However, there is not enough geomorphological-sedimentological evidence to prove it. The fact that the transition-surface is very flat, and that the coastal sediments along the edge of the plain are always at the present sea-level, would indicate that if there was such a tectonic movement it should have been regular, and of the same intensity all over the area. But since the region has a mosaic character structurally, it is difficult to envisage an enbloc movement. Furthermore the same characteristics are seen in other delta-plains on the Aegean coast of Turkey.[22] Consequently, there is not enough evidence to indicate a tectonic subsidence or even sediment compaction in the lower Karamenderes depression.

2. On the other hand, there is evidence to show that the sea-level fell a few meters after it had reached its present level about 6000 years ago, and stood for a time at that level. Studies on the Beşik plain and $^{14}C$ dating show that the sea-level fell about 2 m in the period 4000–3000 B. P.[23] These changes mean that while the Karamenderes estuarine bay filled up with alluvium after the sea-level ceased to rise, a few meters' fall in the sea-level would have accelerated deltaic progradation. In addition, climatic changes which caused these more general changes in sea-level might also have affected the dynamic, flow and regime of the river. For example, more frequent floods could have caused the Karamenderes river and its tributaries

to bring down more and coarser alluvium. Although there is not enough evidence on this matter, a sharp change in the nature of the sediment is noticeable.

There are three structurally low indentations along the inner edge of the western ridge which separates the Karamenderes plain from the Aegean Sea. In this study they are named as Yeniköy, Kesik and Kumtepe from South to North. There are discussions in the literature concerning their possible use as natural harbour-sites in the Bronze Age; it has even been postulated that there were artificial canals connecting the Yeniköy and Kesik harbours to the sea. Our borehole-tests have shown that the indentations were really small bays opening onto the main Karamenderes estuarine bay. However, our observations have shown that the thresholds to the West of the Yeniköy and Kesik plains are higher than the sea, that the sea has never risen up to the thresholds, and that there has never been any water connection with the sea, whether natural or artificial. A small ditch on the Yeniköy threshold was dug to bring fresh water from the Pınarbaşı karstic springs to the Beşik plain and for use at a water-mill. As for the Kesik canal, there is no evidence to show that it has ever been used other than as a footpath by man.

$^{14}C$ dates of the shells taken from the transition-level between the marine and fluvial sediment-units show that the Yeniköy bay filled up with sediments about 5000 years ago and the Kesik bay 4000 years ago. Both were therefore bays during the Early Bronze Age, and it is possible they were used as natural harbours. However, there is no definite evidence indicating such usage. Indeed, while to the North of Troia much artificial material (sherds, pieces of charcoal, ash, burned shells and bones) was found in boreholes at the same transition-level, proving that people used this surface, such finds have never come to light in the supposed western harbour sites. The same $^{14}C$ dates show that in later times the small bays of Yeniköy and Kesik could not be used as harbours because they were land. In fact water from the Pınarbaşı springs caused these areas to be covered with swamps. So the most that can be said is that they may have been accessible via inlets (azmaks) from the sea which covered the northern part of the embayment.

It is obvious that the coastline, which lay between the South of Troia and the Yeniköy plain about 6000 years ago, has changed position, continuously retreating to the North. It is quite possible that on the changing coast some convenient sites were used as civil or military harbours as necessary in the course of the various cultural periods of Troia. However, no clear evidence has been found up to now to show that the natural indentations along the western edge of the "Troia Bay" were organized and used as main harbours. Therefore we believe that it is not necessary to discuss ambitious theories concerning the harbours of Troia.

## Discussion

The paleogeography of the Troia area, and especially the discussion of past changes in its coastline, has an important place in the literature. However, almost all studies are based on the present topography, on environmental descriptions by ancient authors, or on comparison between the two. Homer and Strabo are the most important ancient sources on this subject; but their descriptions are not based on their own observations. Furthermore all later interpretations are based on previous ideas and generally repeat them without including new evidence. Paleogeographical interpretations have mostly concentrated on alluvial geomorphology and especially on coastal changes. It is therefore sedimentological-stratigraphical data, especially those concerning the alluvial deposition of the Karamenderes and Dümrek rivers, that should now be taken into account as the most valuable or trustworthy evidence. Dating is also very important. It is not enough simply to express the idea that the sea formed an estuarine bay in the lower Karamenderes valley and that the present plain was formed by the deposition of alluvium. From the geo-archaeological point of view, it is more important to know where the coastline was when, what were the effects of its position on land-use, and what was the relation between the changes in natural environment and the cultural stages of the site Troia. For this purpose alluvial stratigraphy must be examined and dated systematically. Such research has been performed only by

R. Virchow and, later, by O. Mey and W. Dörpfeld.[24] Their examinations, however, were limited to the surface layers, and their test-drills were not deep enough to elucidate the full alluvial development of the area.

It was for these reasons that in 1977 Professors Dr. J. C. Kraft, Dr. O. Erol and I first planned a drilling programme in order to obtain subsurface data on the alluvial plains in the environs of Troia. I subsequently continued the study in two other projects, one in the Beşik plain in 1983–1988, and the other in 1988–1993 in the Karamenderes and Dümrek alluvial plains, especially close to the site of Troia. This research was carried out within the Troia Archaeological Expedition led by Prof. Dr. M. Korfmann. Some of the interpretations in our earlier papers[25] relating to sea-level changes gave rise to criticism. Before replying I have waited a long time to obtain more evidence from boreholes and more experience with which to interpret it. We now have data from about 200 boreholes from this area, including the Beşik plain.

In this paper, I do not attempt to discuss older interpretations because they are mostly hypothetical.[26] Instead, subsurface sedimentological environments have been examined and an attempt has been made to produce a chronological sequence. In recent years, however, E. Zangger has produced some new interpretations in his publications on Troia.[27] He postulates that the alluvial plains in the environs of Troia are the site of the lost Atlantis of mythology. This theory has sparked off great interest in the press, and Zangger himself has given many interviews. He bases his theory on mythological sources. This is out of our field and I cannot discuss this aspect of the subject. But I would like to express my disagreement from the geomorphological point of view.

Zangger believes that the Troia plain was never covered by sea and that, except for a narrow coastal part, it was always an alluvial plain like today.[28] He thinks that the plain was covered by the canals of a well-developed city especially during the stage of Troia VIh, and that this city was Atlantis. In addition, he refers to our drilling-holes of 1977 and suggests that the marine mud-units may be canal-fills, arguing that the holes could have struck some of the many canals by chance.[29] This suggestion can not be accepted. First, I now have

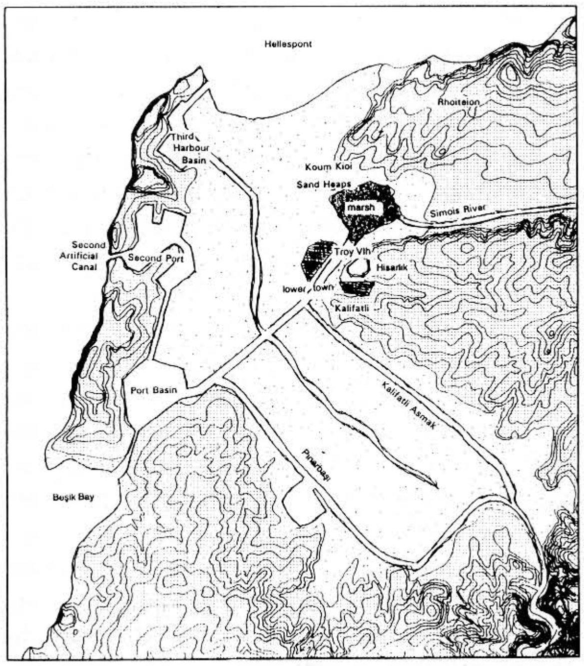


Fig. 15 Zangger's hypothetical map of Troia VIh. Along the inner edge of the coastal ridge (the Yeniköy or Sigeum ridge) the map shows a number of port-basins, connected by channels to the Aegean, to the Çanakkale Strait, and to one another. Frequent flooding and the large amount of alluvium brought down by the Karamenderes river would in fact have made it completely impractical to channel the natural river-courses into artificial canals. And the harbours (ports) have never been connected by canals with the sea (see text).

over 100 boreholes in this area, and it is impossible that every single one should by chance have struck the canals of Atlantis. Secondly, a marine sediment can be distinguished from a channel-fill. Therefore the plain was definitely a marine embayment, and in fact $^{14}C$ dates indicate that during the Late Bronze Age the area to the West of Troia was still covered by a wide swamp.

On the reconstruction map for the Bronze Age, Zangger shows our Yeniköy, Kesik and Kumtepe indentations as harbours and connects them to one another, to the sea, to Troia and to the South of the Karamenderes plain by many canals (Fig. 15).[30] These canals are connected to the Karamenderes river in the South, at the mouth of the Araplar gorge. Such a river, which transports a lot of sediments and has frequent floods, could not reach the sea by flowing in artificial canals. This area is not a tidal flat or tidal marsh. If the river were forced to keep to artificial canals, a great amount of alluvium would soon fill the canals, the river would flood and would itself open new natural courses. This could not be prevented. Besides, nothing has so far been found to indicate the existence of such constructions.

Following the descriptions of ancient writers, and Schliemann's interpretations, Zangger argues that the courses of the Karamenderes and Dümrek rivers were taken into artificial canals, that the sand from excavation of the canals was heaped up to change the course of the rivers, and that these heaps of sand can still be seen on the present surface. There are in fact sand-covered areas to the Southwest of Yenikumkale and Kalafatlı villages (Fig. 2). Both have very similar positions in the topography. They were formed by wind directed by topographical lineaments. These sand-covered areas are, in addition, the sites of deserted villages and cemeteries. They have been covered because the rough surface of the ruins held the blowing sands. Zangger, following Schliemann, says that below the sand covers lie flood-sediments of the Karamenderes river and, at deeper levels, marine sediments. As a matter of fact, the course of a flooding river cannot be changed by a loose sandmass. The attempt would be unsuccessful.

Even if it is accepted that the supposed canals were sufficient for natural flow, thick deltaic fills should have been found in the harbour sites and on the coastline at the mouths of the "canals". It is obvious that the Karamenderes river has transported a great amount of alluvium in the period between 5000–3000 B. P. and since, and that there are no means by which this can have disappeared. Yet there is no evidence of such sediments in the supposed harbour-sites or along the coast. As may be seen in Figs. 6–7, deltaic-coastal coarse sandy sediments form a thicker bed in the lower part of the Karamenderes plain. They become thinner toward the western edge. There is no coarse sandy flood-sediment beneath the Yeniköy plain. There is only a coarse sandy coastal deposit at the entrance of the Kesik plain as an extension of the thicker deltaic sediments in the middle part of the Karamenderes plain. This means that the main area of the deltaic formation was the axis of the plain along the natural course of the river. Coarser flood-sediments reached to the western edge of the embayment only in the North, and that during the environmental change from marine to fluvial.

In addition, there is no deltaic formation along the coast at the mouths of the supposed canals. The Beşik plain was formed by coastal sedimentation.[31] The coastline in the region of the Kesik canal is straight and cliffy and no trace of deltaic formation can be seen there. Indeed no such formation could ever have been possible because, as the evidence given above has shown, there never exist any direct connection by water between the supposed harbour sites (Yeniköy and Kesik) and the Aegean Sea. Given the geomorphological characteristics of the area, such connections are impossible.

Consequently it is my opinion that, from a geomorphological point of view, Zangger's theory that the plain of Troia is the site of Atlantis does not have the necessary proof.

## Notes

1 *Acknowledgement:* This research has been made possible by Prof. Dr. M. Korfmann's kind invitation to join his team, and by his offer to provide support for my work in his camp since 1983. Without his support, especially for drilling-works and $^{14}C$ datings, interpretation of the paleogeography of the area would not have been possible. I am greatly indebted to him. $^{14}C$ datings have been carried out by Dr. B. Kromer. In 1991 I had the good fortune to discuss the ancient authors with Prof. Dr. E. Pöhlmann in the field. He gave me new ideas concerning their interpretation. Ahmet Kader, who is operator of the hydraulically-powered Unimog drilling-rig, has worked for me with much effort, patience and friendship. I am grateful to him. Also I thank all my workers, especially Mehmet Özbudak who has worked for me most frequently, and my assistants and students who have joined me occasionally. This paper has been read and corrected by Mr. Alec Rylands and Dr. Donald Easton. I thank them for their hard work and friendly patience.

2 Korfmann and Kromer 1993.

3 In the earliest stage of our research at Troia, 7 bore-

holes were made across the Karamenderes plain down to 30–75 m deep by the Mineral Research and Exploration Institute of Turkey in 1977. An interpretation of the findings was published together with J. C. Kraft and O. Erol (1980 and 1982). Thanks to M. Korfmann, I joined his projects first in the Beşik area and made 76 hand-operated borings down to 8–10 m in the years between 1983 and 1988. In the following period, between 1988 and 1993, 83 boreholes were made in the area near Troia, and a further 29 related to this paper were made on the western edge of the Karamenderes plain. Their locations are shown on Fig. 2. Different techniques were used in these boreholes depending on the aim and on the characteristics of the areas. A hydraulically-powered Unimog drilling-rig bored down to 20.5 m by augerpoint. In addition, 8–10 m boreholes were made by means of an Eijkelkamp hand-operated boring device, and some trenches were opened to a depth of 2.5–3.0 m.

4 "Yeniköy ridge" does not appear as an official name on the maps. In this paper we needed a name to describe the long ridge which extends from the Beşik plain in the South to Kumburnu at the entrance of the Çanakkale Strait in the North, separating the Karamenderes plain from the Aegean Sea. For this purpose "Yeniköy" is preferred because it is well known in this area as the largest settlement. In the archaeological literature this ridge is called the "Sigeum ridge" on account of the ancient city of Sigeum (Kraft et al. 1980 and 1982).

5 "Yeniköy plain", "Kesik plain" and "Kumtepe plain" are also not official names and will not be seen on the maps. However, we needed particular names for particular geomorphological units. These are preferred as the most suitable and representative (see Figs. 1–2).

6 Cook 1973.

7 Bilgin 1969.

8 Erol 1992.

9 Kraft et al. 1980 and 1982.

10 Kayan 1991.

11 Kraft et al. 1980 and 1982.

12 Leake 1824. For example a map produced under the name of J. D. Barbié *[du Bocage]*, printed in Paris 1819, and another map under the name of Leake, printed in London 1824 (Kraft et al. 1982).

13 Kayan 1991.

14 Precise figures of the $^{14}C$ datings are given in the Table. However, round figures are used in the text and in the figures in order to simplify the chronological sequence of the paleogeographical periods. Precise dates are of course important for archaeology, but for much slower environmental changes, such as are studied in this paper, round dates should be enough. We trust that this will not cause any serious misunderstanding.

15 Cook 1973, 166–167 summarizes them.

16 Kayan 1991.

17 For example Prof. Dr. E. Pöhlmann, oral discussion.

18 Cook 1973, 165–166.

19 Sperling 1976, Korfmann and Kromer 1993.

20 Bilgin 1969.

21 Leake 1824, Kraft et al. 1982.

22 Kayan 1988, 1991 and 1994.

23 Kayan 1991.

24 Virchow 1879 and Mey 1926.

25 Kraft et al. 1980 and 1982.

26 Cook 1973, Bintliff 1991, Luce 1984.

27 Zangger 1992 and following.

28 Zangger 1992, 201–216, Chapter 7: Reconstruction of Troy.

29 Zangger 1992, 203.

30 Zangger 1992, 211.

31 Kayan 1991.

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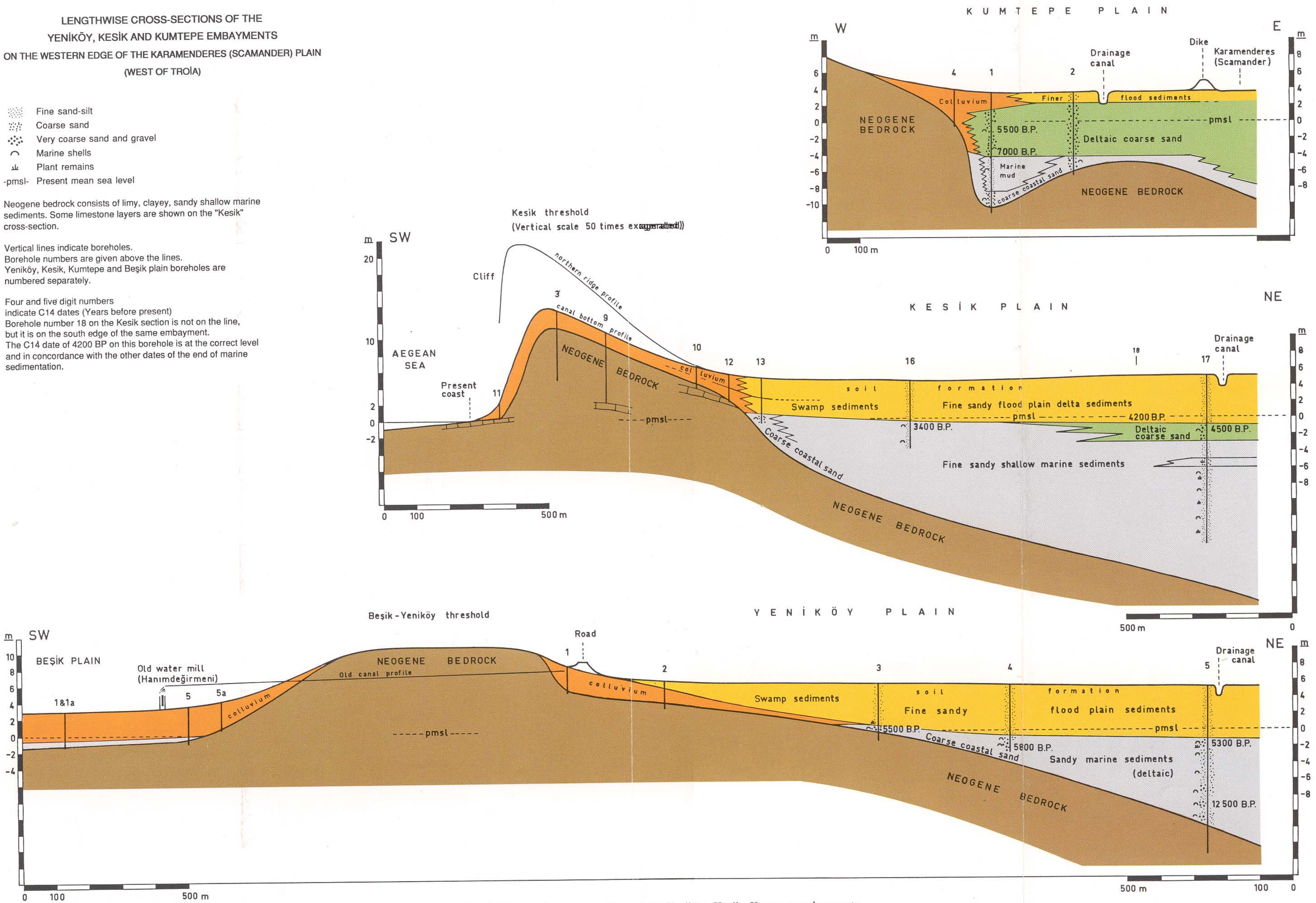


Fig. 7 Lengthwise cross-sections of the Yeniköy, Kesik, Kumtepe embayments.