STUDIA TROICA
Monographien 5

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## Monographien 5

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Teil 2

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### Einzelstudien zur Besiedlung der Troas

İlhan Kayan*

# Geoarchaeological Research at Troia and its Environs

## Abstract

Sedimentological and stratigraphical data obtained by core drillings on the alluvial plains and at the foot of slopes encircling the Troia ridge have provided an important source to illuminate changes of geographical environment during the Holocene. The stratigraphical sequence of the Holocene sediments consists of three main units which represent three different paleogeographical periods. They are (1) Early-Middle Holocene (in general, corresponds to the Neolithic and Chalcolithic period) marine environment, which extended as a long bay along the lower valley of the Karamenderes river; (2) Middle Holocene (Bronze Age) deltaic progradation, which was a period of faster development because of small sea level fall; and (3) Late Holocene slower deltaic progradation and aggradation, and alluvial-colluvial sedimentation period (formation of the present flood plain). It is possible to develop these interpretations by means of more detailed sedimentological and paleontological analyses. However, the data obtained from 318 core drillings and paleogeographical evidences are in good concordance, and they are quite sufficient for the present geoarchaeological interpretations.

## Zusammenfassung

Sedimentologische und stratigraphische Daten, die aus Bohrkernen in den Schwemmlandebenen und Abhängen rund um den Troia-Rücken gewonnen wurden, dienen als wichtige Quelle, um Veränderungen der geographischen Umgebung während des Holozäns sichtbar zu machen. Die stratigraphische Abfolge der holozänen Sedimente besteht aus drei Haupteinheiten, die drei verschiedene paläogeographische Perioden repräsentieren. Das ist 1. die marine Umgebung des Früh- und Mittel-Holozän (entspricht ganz allgemein dem Neolithikum und Chalkolithikum), die sich als lange Bucht entlang des unteren Karamenderes-Tales erstreckte; 2. die Progradation des Deltas im Mittel-Holozän (Bronzezeit), die eine Periode schnellerer Entwicklung wegen eines geringen Abfalls des Meeresspiegels war; 3. eine langsame Delta-Progradation und -Aggradation und alluviale Ablagerungsperiode (Entstehung der gegenwärtigen Flußebene). Diese Interpretation kann man durch detaillierte sedimentologische und paläontologische Analysen verfeinern. Jedoch stimmen die Daten, die wir aus 318 Bohrungen gewonnen haben, und die paläogeographischen Zeugnisse gut überein; sie reichen für die gegenwärtigen geoarchäologischen Interpretationen aus.

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* Acknowledgements: This paper has been compiled from my previous publications on paleogeographical, geoarchaeological research at Troia. This means that all knowledge here is also based on our research which had been performed under favour of continuous support and encouragement of Prof. Dr. Manfred O. Korfmann since 1983. The Troia Project, under his management, contributed greatly on my scientific life and experience. By this way, also many students and assistants of me from our Geography Department in Ege University had training chance in Troia. In addition, he greatly supported us to develop our laboratory in our Department. I will remain grateful to him forever for his friendly interest and support. Prof. Dr. William Aylward has read the paper and corrected it for better English. Mrs. Erdmute Koppenhöfer and Prof. Dr. Dietrich Koppenhöfer also worked patiently on the paper to improve it during the course of editing. I thank them for their kind cooperation and contribution.

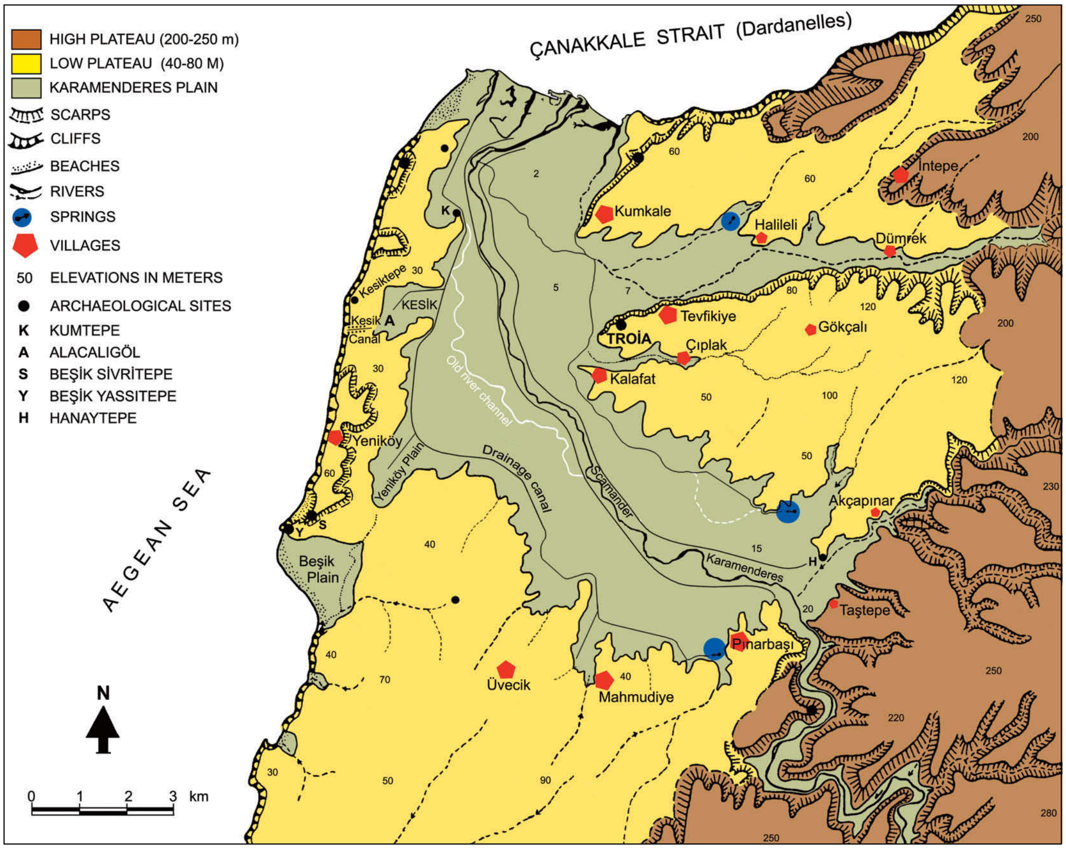

Fig. 1 Geomorphological outlines of the Troia area.

## Introduction

Important in archaeology and the history of culture, Troia is a very special site concerning the geographical changes in the surrounding area, and has been the subject of great interest and scientific research. Of course, the most important reason for this interest is the detailed description of the geographical environment made by Homer as he narrates events occurring in Troia and its surroundings. However, suspicions as to how much Homer's descriptions represent reality have provoked much discussion. Nevertheless, descriptions of the geographical environment of around 2700 or 3250 years ago – depending if one assumes Homer describes the landscape at his own lifetime, or at the supposedly earlier time of the Trojan War – which have reached the present day as written text are an important original feature of Troia offered by Homer.

It is obvious that the geographical environment of about 2700 years ago, described in the Iliad, has greatly changed in the course of time. Moreover, archaeological research at Troia has revealed that the settlement history of this area goes back to 5000 years before present. There are even earlier Chalcolithic settlements near Troia, especially along the edges of the Karamenderes delta-flood plain, including settlements at Kumtepe, Beşik-Sivritepe, and Çıplak (Fig. 1).[1] An-

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[1] Gabriel 2000; Gabriel 2001.

other Chalcolithic site, Alacalıgöl, has been found by our paleogeographical investigations on the Kesik plain, about 4 km west of Troia.[2] This means that such a long time span includes more environmental changes than the history of Bronze Age Troia. Concerning these changes, the most prominent events are the formation of a long bay along the lower part of the Karamenderes (Scamander) river according to sea-level rise in the Holocene, then the continuous change of the shoreline and coastal environments of the developing delta due to alluvial deposition. Deltaic progradation was contemporary with Trojan cultures and greatly affected their development. Therefore, environmental characteristics have always been considered important for the studies of Troia and comparisons between Homer's descriptions and the present geography.[3] Thus, in one respect, Homer has constituted a basis for environmental approaches in modern archaeology and the rise of geoarchaeology.

Travellers in the 19 th century curious to find the site of Troia carefully followed and interpreted the descriptions of Homer. The most outstanding subject of interest were the changes of coastline. The idea that Troia was a coastal settlement during its early stages is generally accepted. However, major curiosity was concentrated on the location of the coastline, naval harbours and battlefields during the supposed Trojan War in the Late Bronze Age. This requires that environmental characteristics and landscape changes in Troia should be taken into account and correlated with archaeological interpretations. Thus, the importance attached to the landscape by Homer has given impetus to the present scientific research in Troia.

After a long break of archaeological research in Troia and its environs, Manfred Korfmann started a new project in 1982. His first topic was the Beşik Bay on the western coast of Troia. Beşik-Yassıtepe and Beşik-Sivritepe were the main prehistoric sites he excavated. Beşik cemetery was also another interesting excavation site on the southern slope of Beşik- Yassıtepe. In 1988, Korfmann started new archaeological research, excavation and restoration on the main site of Troia. He kindly invited us to join these projects for research on the formation of the present geographical environment, its past progress and changes, and interrelations between landscape changes and cultural periods of Troia and its environs.

In the Troia Project, different research techniques and methods were applied by many experts from various countries. In this paper, we intended to explain our studies in terms of applied research methods and results. This is mainly based on our core drilling works. However, general geological and geomorphological characteristics of the area are essential to understand the development of present geographical environment. Therefore, these topics will be explained briefly, then the main topic, that is sedimentological and stratigraphical characteristics of the Holocene sedimentary environments of the Troia area and landscape changes and their paleogeographical-geoarchaeological interpretations will be emphasized.

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[2] Gabriel et al. 2004; Kayan 2009.

[3] Luce 1998; Kraft et al. 2003.

## Geological structure and geomorphology

Troia is located at the northwestern corner of a wide peninsula (Biga peninsula) which extends between the Aegean and Marmara seas in the northwest of Anatolia. The geological structure of this peninsula evolved on an old crystalline basement. Various sedimentary and volcanic units, which were added over the base in the following geological periods, formed a ground for development in younger geological periods (Neogene).

The formation of the present geographical appearance of Troia and its surroundings should be considered in terms of two phases. The first phase is the formation of the geological structure and its development. The succeeding phase is the shaping of the present geomorphology on this geological structure. The last part of the second phase is the period in which prehistoric settlement began in the Troad. Therefore, this stage is of major importance to archaeology and the history of culture.

When examining the geological structure of the Troia area, account must be taken of the Biga and Gelibolu peninsulas and their formation over a long period of geological time. The Biga peninsula consists of various sedimentary and volcanic rocks underlain by an older igneous and metamorphic base.[4] During the Neogene period, depressions were formed between raised mountain blocks. What was once a lake in what is now the Bayramiç-Ezine Basin, for instance, filled up in the course of aeons with material washed down from the surrounding slopes. Moreover, to the northwest, in the place where today the Gelibolu Peninsula and the Çanakkale Strait (Dardanelles) are situated, the Black Sea extended from the north into a basin where it formed a broad but shallow gulf. The low ridges around Troia were formed from sediment laid down on the bottom of this sea. During this time the Aegean was essentially land with several lake basins. This paleogeography existed mainly during the geological time of the Late Miocene, that is about 12–5 million years ago.

While the land continued to rise, layers of sedimentary rocks consisting of sand, clay and limestone which had been deposited on the bed of the shallow Neogene sea broke into three main blocks in the environs of Troia. These have formed the present Yeniköy Ridge to the west, and the Kumkale and Troia ridges to the east (Fig. 1). The Karamenderes (Scamander) river and its tributary, the Dümrek (Simois), settled in the depressions between the ridges and filled them with alluvial deposits, which formed the plain around Troia. Because this region is situated on the southern flank of the North Anatolian Fault Zone, tectonic movements have taken place, and recent earthquakes indicate that the region still has remarkable tectonic activity.

The surface of the ridges around Troia is at an elevation of 40–50 m and to the east rises to an elevation of up to 100 m. This brings about a low plateau formation (Fig. 1). A fault zone with a steep slope, running from northeast to southwest, bounds the low plateau area to the south. In this zone there are geologically rather young lava flows and rich springs of water. Above this rise, that is, on the igneous and metamorphic bedrock and other geological formations, there extends a slightly undulating higher plateau surface at an elevation of 200–250 m. The Karamenderes

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[4] Bilgin 1969.

river has incised this surface and opened the Araplar Gorge which connects the Bayramiç-Ezine basin to the south and lower Karamenderes delta flood plain to the west of Troia.

The Quaternary period, as we know, is much shorter than the preceding geological times (about 2 million years). During this period of geological history, tectonic movements had less influence on geomorphology, yet climate changes shaped the environment more strongly. Unlike in Europe, there was no ice age in Turkey because it is so far south. However, the fall in sea level during the glacial periods brought about changes in coastal regions all over the world, including Turkey. Low-lying coastal areas, especially delta-flood plains, underwent a great deal of geomorphological-environmental changes. This included the alluvial plain on the lower part of the Karamenderes river, west of Troia.

In the Quaternary period during the glacial ages the sea level fell appreciably. In the interglacial ages, however, the seas of the world reached approximately their present level. In deeper drilling holes on the Karamenderes plain some older marine sediment units were encountered below the Holocene marine sediments. Their $^{14}C$ dates are older than 20,000–30,000 years ago, that is older than Holocene, probably late Pleistocene. At the end of the Late Glacial Maximum, about 20,000–18,000 years ago, the sea level was about 100 m lower than today. Then, the **Dardanelles** and the Bosporus were river valleys and the Karamenderes (Scamander) was a tributary of the main river in the Dardanelles. Sandy-gravely alluvial sediments at a depth of about 30–40 m, which were encountered by drilling studies in the plain west of Troia, indicate the bottom of the valley at that time.

The last 15,000–10,000 years of geological history, that is the Holocene epoch, is more significant for the formation of the present environment and development of the human history. There are various methods to investigate this development from the view of natural and cultural sciences. The main ones applied in the Troia project obtained valuable data for understanding human-environment inter-relations and inter-actions. Our approach from the natural environment point of view is mainly based on sedimentological studies and paleogeographical interpretations of data obtained from core drillings on the Karamenderes delta-flood plain and its indentations in the surroundings of Troia (Fig. 1).

## Environmental research methods and their contribution on the Troia investigations

Including the Troia settlement site, high areas are generally subject to erosional conditions, and investigations made only in such areas are not enough to interpret all environmental developments. For example, soil characteristics on the slightly undulated low plateau surface in the surroundings of Troia have been supposed as indicators of environmental changes in recent periods. However, new research has shown that soil erosion has accelerated following anthropogenic destruction of natural vegetation, upper horizons eroded deeply, and important features which represent natural conditions of soil formation disappeared greatly. In contrast, vertical and horizontal variety and distribution of sediments which deposited into surrounding low areas, are the most reliable evidence for understanding the changing geographical environment. Therefore, it is necessary also to examine alluvial and colluvial sediments which are deposited in the surrounding lower areas, and data obtained from both erosional and depositional areas should be evaluated comparatively. In this way, it can be understood how the environment has changed over thousands of years in an archaeological site and in which way these changes have affected the land use pattern of people who lived there. For example, the pattern of life and food habits of the people who lived in Troia may have changed greatly from the time when the area surrounding the ridge was sea to when the same area changed into arable land due to alluvial deposition. At this point, in order to illuminate the man-environment interrelation, it was necessary to determine what were the former environmental characteristics or paleogeography of the present alluvial plains surrounding Troia. The sedimentary units deposited on the bottom of depressions in various environmental conditions are the best tools to bring out the environment during their formation, and the dynamic effects under which they were worked, transported and deposited.

Actual sediments in the environs of Troia consist of alluvium from the Karamenderes river and colluvial deposits washed down from the surrounding slopes. However, the variety of sedimentary environments increases by depth below the surface. Anthropogenetic material in old colluvial deposits (such as pot-sherds, pieces of brick and tile, fire remaining material like charcoal and ash, burned food remains like bones and shells) indicate humans being in this area or on the near slope. As to the alluvial places, the variety of sedimentological characteristics (like sediments of river floods, deltaic environments, coastal swamps, shoreline and marine environments) provide to determine geographical environments. For example, it is revealed that the area surrounding Troia was covered by sea and a culture depending on marine sources was influential through the Chalcolithic period. As to the Bronze Age, the fact that the surrounding area of Troia changed into arable land by alluviation caused a new position of Troia away from the prograding delta coast and the development of a culture based on land-side sources.

This indicates that useful information on human-environment interactions can be obtained by examination of sedimentary units deposited in low areas surrounding Troia. To reach different sedimentary units below the present alluvial surfaces and interpret what kind of geographical environment they represent is only possible by core drillings. Horizontal and vertical distribution of sedimentary units and three-dimensional geometry of the changing environments can only be deliniated using a sufficient number of drill-hole profiles.

Since 1977, more than 300 core drillings have been made on the colluvial and alluvial depositional areas in the surrounding of Troia using various techniques and equipment (Fig. 2). The aim was to reach old ground and sedimentary environments below the present surface to determine their distribution and changes, and to make paleogeographical reconstructions for some specific periods. At the same time, geological characteristics of the source area of sedimentary material, as well as geomorphological, climatological and biogeographical characteristics and processes of the sedimentation, have been investigated and mapped in detail.

Troia is situated at the western tip of a low plateau ridge which was formed by the last tectonic breakup of the youngest geological formations (Fig. 1). Therefore, the sources of alluvium in the region are sedimentary rocks which were repeatedly eroded from older uplands and deposited

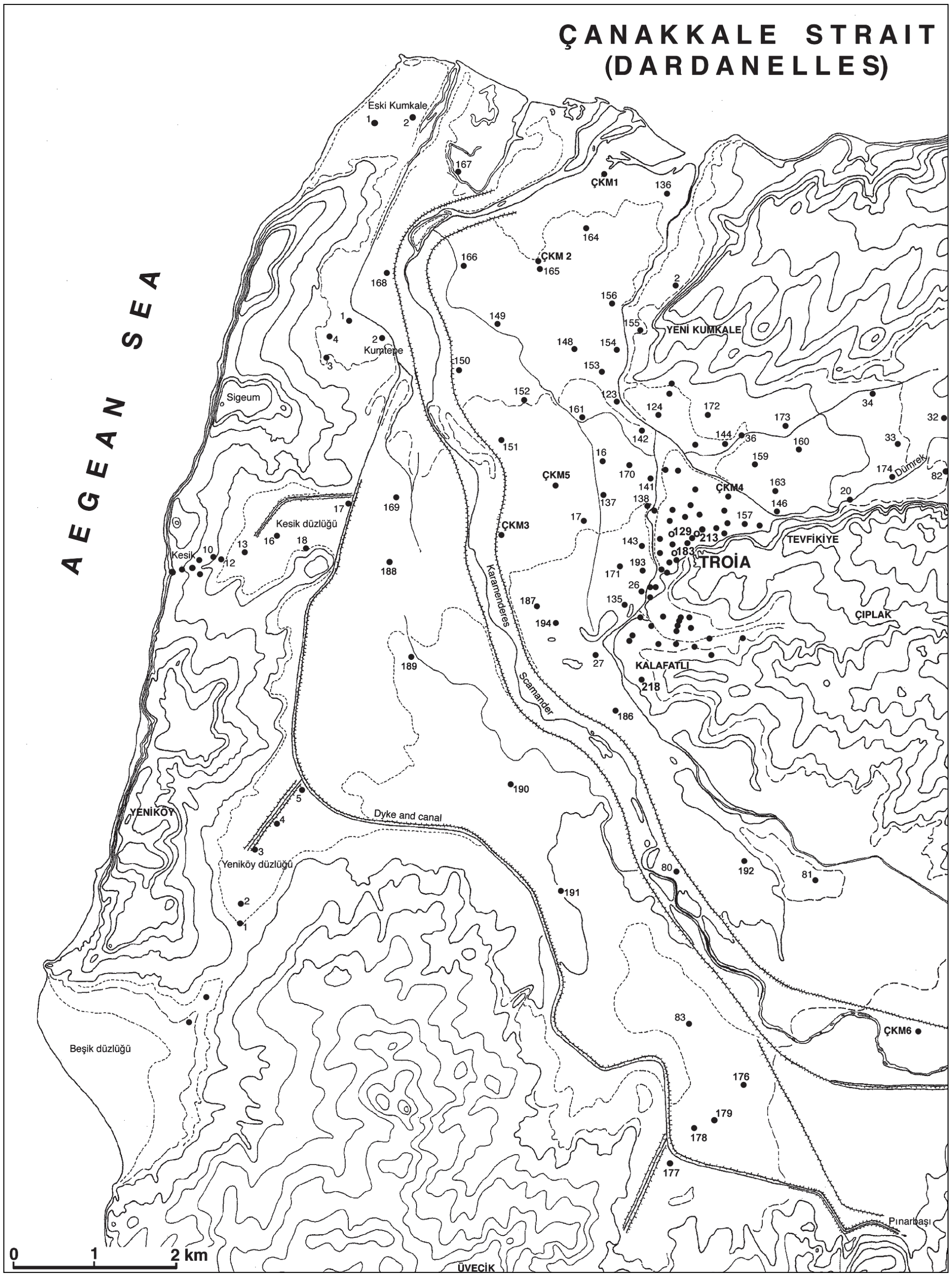

Fig. 2
Locations of core drilling points. Since the scale of the map is not suitable, most of the numbers and some points which are close to each other, can not be shown. ÇKM indicates MTA (Mineral Research and Exploration Institute) supported 7 drillings. 100 drillings were performed on the Beşik plain and Yeniköy-Sigeion ridge to the west. Numbers between 1–100 are Unimog drillings and 101–218 are the drillings made by Cobra gouge corer. Thus, the total number of the drillings reached 318 in 2006.

in low areas. Thus, alluvium is generally fine sandy, and causes difficulties to distinguish morphodynamic effects and types of sedimentary environments. For example, grain size of alluvial deposits indicates power and nature of torrents and river floods, whereas the grain size distribution in the Troia area is not enough to separate various former sedimentary environments in alluvium, like old river channels, because the source lithology is generally fine sandy. Some other characteristics of the region have also sometimes limited data sources for environmental investigation for the Troia Project. Some examples of this limitations are below.

On archaeological sites, geophysical prospection provides very important and valuable data. Geophysical investigations at Troia have been very successful and appreciated.[5] A detailed city plan of the Troia Lower City was created using this technique, and this result in Troia is one of the best examples of the application of geophysic methods for archaeological sites. This successful result suggested that geophysical methods might also be helpful to identify and delineate different subsurface sedimentation units and their environments (like identifying changes to river channels and the existence of former shorelines) on the Karamenderes alluvial plain and its extensions. However, geophysical methods cannot be used on alluvial plains surrounding Troia to explore the variety of natural sedimentation, even in different sedimentary environments, because the alluvium is all fine sandy, ground water is high, and the depth of geophysical measurements are set for archaeological prospections. However, geophysical examinations along the foot of slopes around Troia did reveal some significant anomalies related to differences between alluvial and colluvial sediments. For example, a coarser sandy fill of an old river channel, which had formerly been determined by core drillings at the foot of the northwestern slope of Troia, was confirmed by geophysic measurements too.[6]

Pollen analyses are another important tool of paleogeographical investigations. Vegetation properly represents geographical environment, and changes in pollen population in sediments indicate changes in vegetation. Thus, it can help to interpret climatic or anthropogenetic effects on changing vegetation and geographical environment. [7] Therefore, from the beginning of our drilling works and sedimentological analysis, we have needed to include a comprehensive pollen study into our research on the Troia area. Wet environments like swamps or lakes are suitable places for pollen accumulation and preservation. Sandy terrestrial deposits are not convenient for pollen accumulation because of their corrosive effects, nor to preservation because of their porous structure. Therefore, proper pollen profiles have not been found everywhere in the alluvial deposits surroundings Troia. In the course of time, our knowledge about the subsurface sedimentary distribution has increased. It is now understood that some sedimentary units promising good preservation can be found in some places. The most convenient area for pollen study is the Kesik (Alacalıgöl) plain which is located to the west of the Karamenderes plain, far from its floods. This area was a swamp area before a drainage system was established about fifty years ago (Fig. 1). However, because the sediment layer of the swampy environment is thin above the former marine sediment section, the represented period is short, and data is not enough for a complete paleogeographic interpretation in this area.

While pollen population provides data to interpret terrestrial environments, macro and micro fossils are the best tool for marine environments. As macro fossils, *Cardium* (*Cerastoderma edule*) shells are found almost everywhere connected with former marine environments. They are also

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[5] Jansen – Blindow 2003.

[6] Kayan 1996.

encountered in core drillings most frequently. However, they are adaptable to different physical conditions of coastal environments and they are therefore not useful for determining the environment in detail. On the contrary, oyster shells represent more special living conditions, for example, wavy water of a coastal zone with plenty of oxygen. They are abundant in coarse sandy sediments at the base of the Holocene marine transgression.

Micro fossils are another important subject of study. Some of them indicate certain specific environments (for example some species of *ostracods* definitely represent marine environment), and they are significant indicators for distinguishing paleogeographical changes to coastal environments. Such different environments to the west of Troia developed along a very shallow coastal zone of the prograding delta of the Karamenderes river. Therefore, the coastal environments are not easily separated from each other along definite boundaries (like coastal swamps, distributary channels, foreshore or swash-zone). Here, most of the marine organisms consist of species which are easily adaptable to slightly changing physical conditions like salinity, temperature, and changing low wave energy. Therefore, like macro forms, most of the marine microfauna is not sufficient to distinguish different paleo-coastal environments in this area.

Dating is another important part of paleogeographical interpretation. Chronological correlations are also essential in order to construct an interrelation between archaeology and the environment. From this point of view, one of the sources of data are potsherds which are generally found in drill-holes in colluvial deposits. They can sometimes be dated by archaeologists. However, a small piece of potsherd taken out from a small drill-hole often does not have characteristic features sufficient for dating.

In completely natural sediment units, away from archaeological sites, plant remains and especially shells of marine and coastal environments can be dated by $^{14}C$ method, which is generally applied in the surroundings of Troia to date paleogeographical environments. Since the beginning of our research program in the Troia area in 1977, a great number of $^{14}C$ dating analyses have been made in different laboratories in the USA and Germany. In particular, $^{14}C$ analyses made by Bernd Kromer at the *Institut für Umweltphysik der Universität Heidelberg* in Germany have made great contributions to our paleogeographical interpretations.[8] During our rather long research period, techniques for analysis, calculations and calibrations have changed. In general, shells (mostly *Cerastoderma edule*) and plant or total organism (in lesser number) that were taken from former shallow marine or coastal environments were used for $^{14}C$ dating analyses. *Cerastoderma* shells have a wide range of living conditions. They can survive in shallow marine environments in deltaic outlets and lagoons. They could have been worked and transported by waves of the rising sea during the Holocene, and especially the middle Holocene, when sea level was closer to present day level. Only complete bivalve shells represent their original living location, but these occur in very limited number. Consequently, although chronological data obtained by $^{14}C$ were carefully evaluated, paleogeographic reconstructions have not been done on these data alone. It seemed to us that a more reliable source for paleogeographical reconstructions is the sub-

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[7] See contributions by Riehl – Marinova and Riehl et al., this volume.

[8] Korfmann – Kromer 1993.

surface distribution of sedimentary units and their physical characteristics, such as color, texture, structure, faunal and floral remains, and some special formations like concretions, and lithological-mineralogical compositions. Also, $^{14}C$ dates are all used as rounded values and all dating evidence from around Troia has been taken into consideration as a whole. In fact, very precise dates are necessary in archaeology, but not generally for environmental changes.

Together with the $^{14}C$ method, the OSL (Optically Simulated Luminescence) technique is also applied for dating in the Troia area. In our experience, OSL is a suitable way for dating in colluvial deposits, while fluvial deposits are less suitable because of various reasons, particularly high ground water.[9]

## Core-drilling studies in Troia

After a long period of research and gaining experience in the surrounding of Troia, it is perceived that the most suitable method for paleogeographical reconstructions is interpretation of sedimentological-stratigraphical data obtained by core drillings. Thus, paleogeographical maps could be drawn according to vertical and horizontal distribution of delineated environments. It is also seen that data obtained by examination of various contents of different sediment units, such as pollen or macro-microfossils, do not change the main determination of geographical environments, but only supply more special and detailed interpretations. Therefore, since 1977, 318 core drillings performed in the surroundings of Troia using different techniques and equipments have progressed over time (Fig. 2).[10]

Our first paleogeographical studies in the environs of Troia started with J. C. Kraft and O. Erol in 1975. In 1977, seven rotary core drillings were made on the Karamenderes and Dümrek alluvial plains, surrounding Troia, with the support of the Mineral Research and Exploration Institute of Turkey (MTA) (Figs. 2–3). In most of these drill holes, of which the deepest went down 75 m to pre-Holocene bedrock, Neogene sediments were reached. This work revealed that following sea-level fall during the last glacial stage, the Karamenderes river incised a deep channel on a surface about 30 m below the present plain. In the earlier stages of the post-glacial sea-level rise, marine water intruded into this incision (about 10,000 years ago according to $^{14}C$ datings), then gradually covered the entire older floor of the valley. By 7,000–6,000 years ago, a ria type bay in the present lower Karamenderes valley west of Troia, extended southwards as far as just north of Pınarbaşı-Mahmudiye (Fig. 4). The sea-level rise peaked about 6000 years ago. Since then, the present alluvial plain began to prograde to the north, presently reaching about 4 km northwest of Troia.[11]

In 1982, Prof. Korfmann began an archaeological research and excavation project on Beşik-Sivritepe and Beşik-Yassıtepe north of the Beşik plain on the Aegean coast to the west of the Karamenderes plain (Fig.1). I was invited to join this project to bring out the geomorphological

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[9] Göbel et al. 2003.

[10] Kayan et al. 2003; Kayan 2006.

[11] Kraft et al. 1980; Kraft et al. 1982.

Fig. 3
An operation of a rotary core drilling (ÇKM 4) to the north of Troia. This drilling performed by MTA in 1977 obtained a good stratigraphical profile. The Miocene bedrock surface was encountered at a depth 37 m below present surface, which is about 7 m above sea level. Lower 15 m of the sediment profile indicates marine environment. Above this, about 8 m deltaic and then 7 m fluvial-terrestrial sediment units ensue each other vertically (see also Fig. 15).

evolution of the Beşik plain and especially to understand whether or not this plain was in a bay during the Bronze Age. Thus, we intended to interpret paleogeographical evidence for the possibility of a natural harbour in the Beşik Bay. 80 hand drillings were performed to a maximum depth of 8 m, using an Eijkelkamp hand-drilling tool (Fig. 5), and some $^{14}$C dates were obtained. We showed that the present Beşik plain formed as a small bay about 6,000 years ago. Afterwards, around the period of Troia VI, a coastal barrier separated a small lagoon (Figs. 6–7).[12] There is no major stream behind the Beşik plain to bring any great amount of alluvium. Therefore, coastal landforms developed here only under the control of marine processes. This made it possible to delineate small relative sea-level changes during the middle and late Holocene, in particular, that the sea fell about 2 m in the Late Bronze Age and caused widening of the coastal barrier and reduced the lagoon. This implies that no Bronze Age natural harbour with an open water surface seems to have been possible here (Fig. 8).[13]

A new project at Troia led by Prof. Korfmann started in 1988. A multi-purpose »Unimog« vehicle was granted to the project by Daimler-Benz for the heavy excavation works. In particular, it has a hydraulically-powered screw drilling rig, providing powerful, fast and productive drilling capabilities down to 20.50 m (Fig. 9). Using this equipment, tens of drill-holes were bored every year, especially on the alluvial plain around Troia.

The Unimog was also used to excavate trenches down to 2.5 m in some places, especially on the colluvial deposits along the foot of the slopes, in order to carry out detailed examinations of

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[12] Kayan 1991.

[13] Kayan 1991.

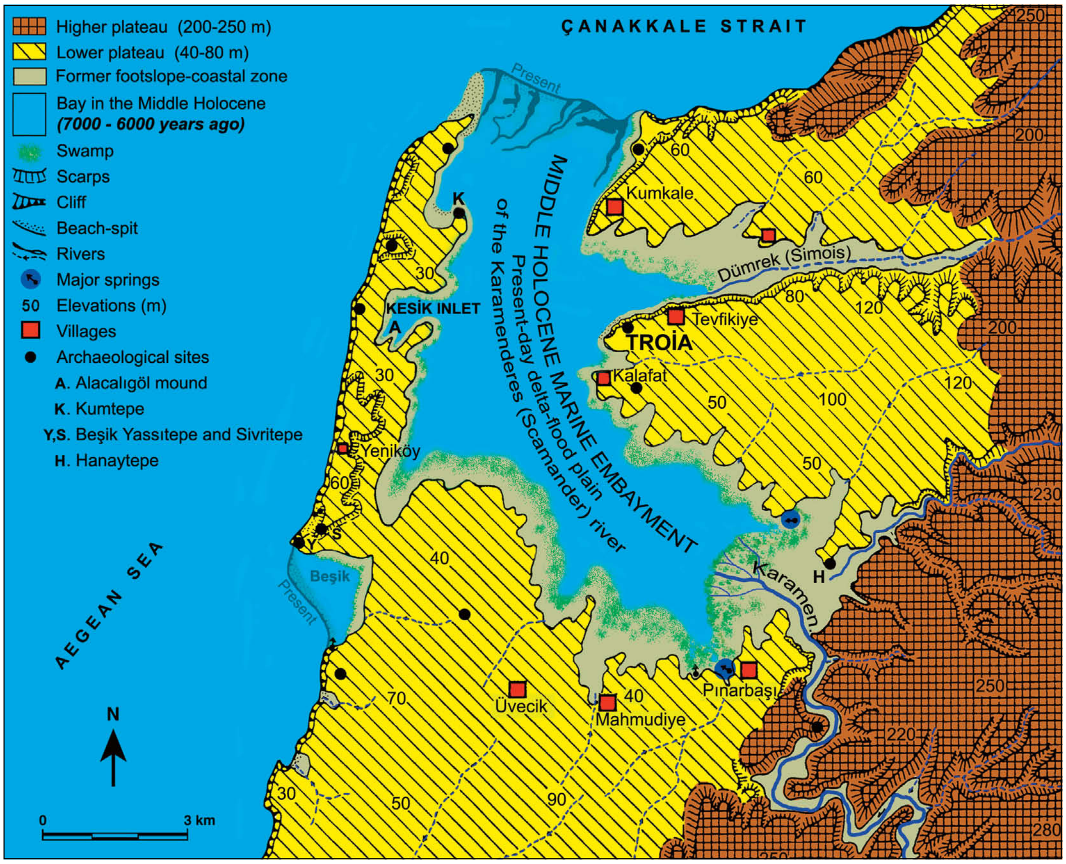

Fig. 4
Paleogeographical reconstruction of the lower parts of the Karamenderes (Scamander) and Dümrek (Simois) valleys in the Middle Holocene, about 7000–6000 years ago. In this period, the lower Karamenderes valley was completely covered by the rising sea and formed a marine embayment. A Troia settlement did not exist yet. However, the Alacalıgöl and Kumtepe Neolithic settlements were already established on the shoreline of the embayment.

soil formations and dispersion of archaeological material from the mound (Fig. 10). In addition, an Eijkelkamp hand-drilling tool was also used here in places where it was more convenient. Down to a depth of 8–10 m the Eijkelkamp is quite good for examining surface sediment layers which formed during historical or even prehistoric times (Fig. 5).

In 1992–1994, our research concentrated on the Yeniköy ridge (Sigeion ridge in archaeology), which separates the Karamenderes plain from the Aegean Sea to the west, and its eastern foot which slopes gently towards the plain (Fig. 1). Here, geomorphological characteristics along the western edge of the Karamenderes plain suggest some old inner harbour locations, and there is some discussion in the literature about this. New data were obtained from our study on this area, and they have made it possible to clarify some speculations.[14]

Although the number of our drilling holes, most of which were made by the Unimog after 1988, reached 200 in 1996, the great variety of marine, coastal, deltaic, flood plain and swampy environments in the research area, in addition to colluvial and archaeological deposits, and their vertical and horizontal changes in short distances, brought out the necessity to increase the number of drillings and the variety of techniques. The Unimog provided very useful data by means

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[14] Zangger 1992; Zangger et al. 1999; Kayan 1995; Kayan 2009.

Fig. 5
Sample profile of an Eijkelkamp hand drilling equipment, which was used on the Beşik plain generally. Sinking about 8–10 m deep is possible with this tool. As it is seen on the photograph, sediment samples could not be taken under undisturbed conditions. However, it is possible to separate different recent sediment units and soil horizons. The equipment on the photograph is not original. Corer-ends are handmade by a smith and extension rods are water pipes. Our first studies were performed using this simple tools.

of its great hydraulic power. It was a great advantage to be able to sink drill-holes down to 20 m in a short time, cutting through all kinds of sediment sections. However, the samples could not be taken as undisturbed cores because of the mixing effect of rotaryscrew drilling. In addition, due to the large volume of the screw-rods (Fig. 11), sediments climb upward under high pressure during the operation and samples cannot be located to their real depths. This was a great disadvantage for precise correlations, and for this reason percussion drilling equipment has been preferred in more recent studies. Our suggestion to obtain percussion drilling equipment was accepted by Korfmann, and the Troia Expedition provided a set for our studies. Using this equipment, one metre of gouge-corer rod is driven into the ground by an engine-powered drill (Cobra), and then is driven deeper with extension rods of 1 m each (Fig. 12). Thus, it is possible to have fairly undisturbed sediment samples, though they are slightly compressed. The diameter of the corer may be 60 mm, 50 mm or 35 mm, and it is possible to reach down to 30 m in suitable sediments. However, 15–20 m is a good depth under normal conditions. In addition, deeper test drillings are also possible using thinner rods of 25 mm diameter. This is useful in order to find bottom depth or bedrock surface below marine sediments. After we obtained a hydraulic lifter in 1997 to take out the gouge-corer and extension rods, our drilling work reached very productive conditions for data collection (Fig. 13). In 2006, the number of Cobra core-drillings reached 118 and the total number of the Troia drillings 318 (Fig. 2).

Sediment samples taken from the drilling-holes are first analysed in our laboratory in the Department of Geography, Ege University. These are simple grain size, pH and calcimetric analyses. Then, if necessary, we prepare samples for $^{14}$C or other analyses and send them to the relevant laboratories. In 1997 and 1998, OSL (Optically Simulated Luminescence) analyses were tried and good results were obtained by a research team from Heidelberg.[15]

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[15] Forschungsstelle Archäometrie der Heidelberger Akademie der Wissenschaften am Max-Planck-Institut für Kernphysik. Göbel et al. 2003.

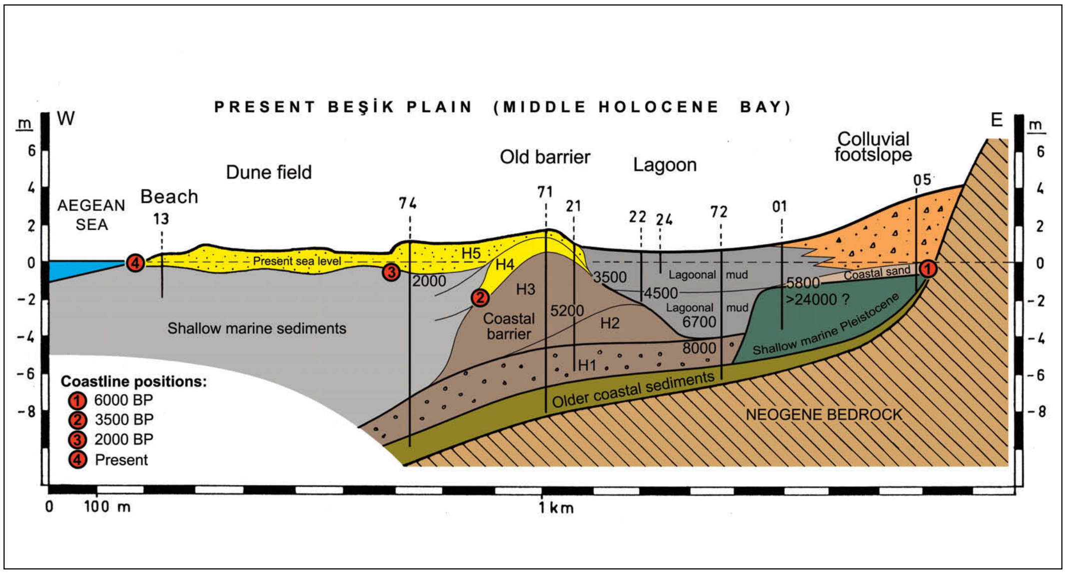

Fig. 6
The west-east cross-section of the Beşik plain, displaying subsurface Holocene sedimentary environments and geomorphic evolution periods. Based on 80 shallow hand-drilling sediment samples, a coastal barrier system separating a laggon has been outlined in several periods (H1–5). Four digit numbers indicate $^{14}$C dates in proper positions. See also Fig. 7. (Modified from Fig. 4 in Kayan 1991).

Finally, drilling data are evaluated by computer in a standard format (Fig. 14) and prepared for drawing along desired cross-sections (Fig. 15). Based on a great number of cross-sections in various directions, paleogeographical maps can be drawn and geographical reconstructions of coastline positions for various times are possible (Fig. 16).

Knowing the precise topographical elevations of the drilling points from the present sea level is especially important for stratigraphical correlations between the drilling holes. This matter has always created great difficulty for our drilling works. Topographical measurements have been performed in the same system since the time of Dörpfeld's research at Troia to keep all data and interpretations consistent. In the new period of research led by Korfmann, geodetic experts have continued to use Dörpfeld's system to provide continuity. This system is 60 cm lower than the Turkish National Geodetic System, which is being used in all Turkish topographical maps and engineering works today.[16] We had new topographical measurements made in 1992, based on the present mean sea level to the west of the Kesik canal. Besides, very precise measurements have been possible in recent years using GPS electronic devices. Here the important point is to know which global system is being used. Consequently, topographical maps at a scale of 1/25000 and 1/5000 (generated from 1/25000) we used for our measurements in general, and GPS measurements in recent years have provided different data. This incompatibility causes great difficulty for the correlation of subsurface sedimentary units in cross-sections. Because the vertical scale is exaggerated, about 20 cm difference of altitude, for example, can cause an abnormally inclined view of the surfaces of sediment units on cross sections. This may imply tectonic deformation (like tilting), but this is not intentional. To minimize such misinterpretations, some regulations have been made by multi-directional crosschecks and comparisons.

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[16] See contributions by Messmer and Cieslack, this volume.

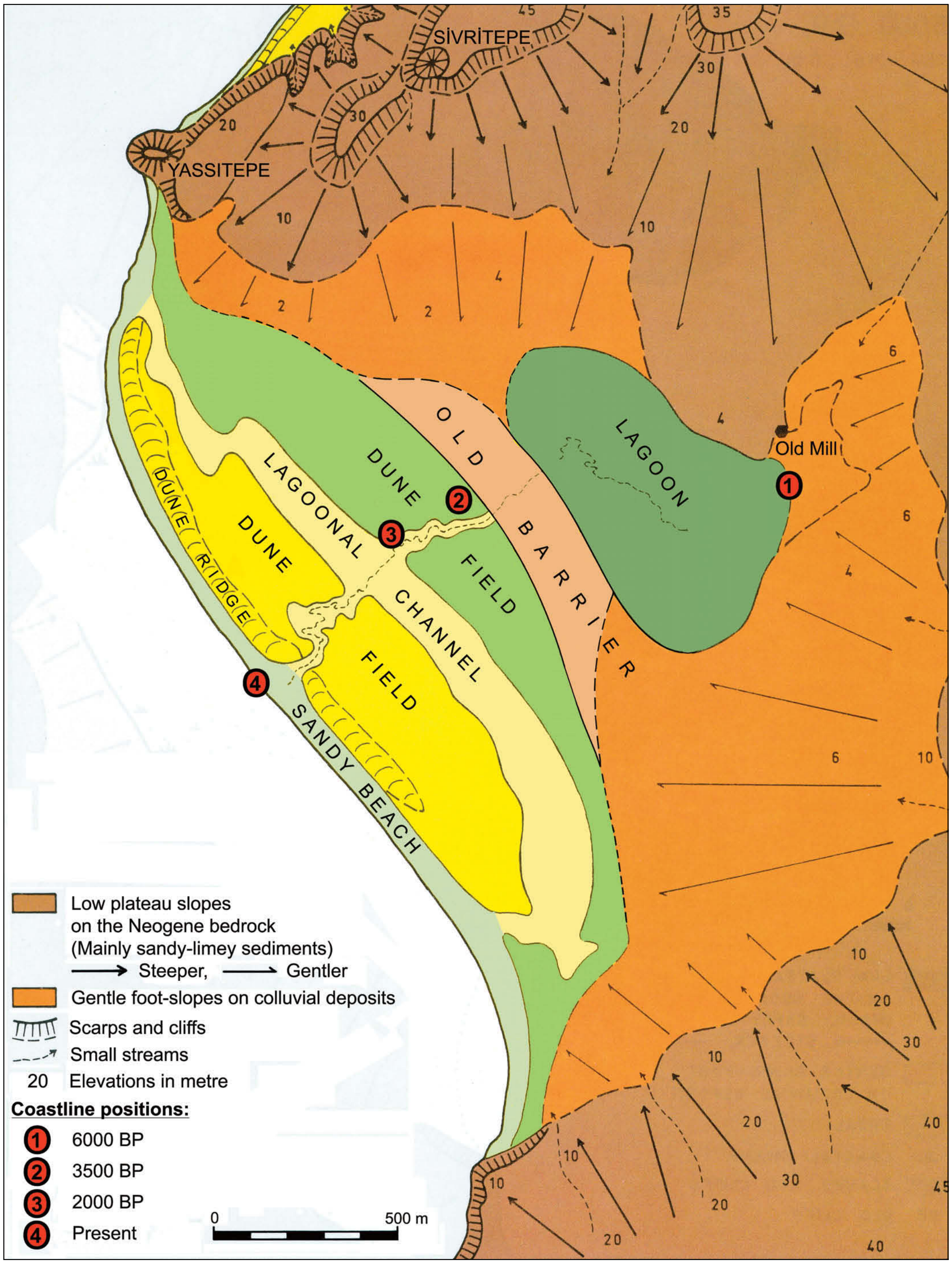

Fig. 7
Geomorphological development periods of the Beşik plain. See also Fig. 6. (Modified from Plate 5 in Kayan 1991).

On the other hand, in recent years, new agricultural development of the entire Karamenderes plain, especially levelling works have changed the surface elevations of drilling points. Therefore, in some places, vertical shifts of up to 50 cm must be taken into account in certain drill-hole correlations. Also locations of old drilling points are difficult to find because all of them had been

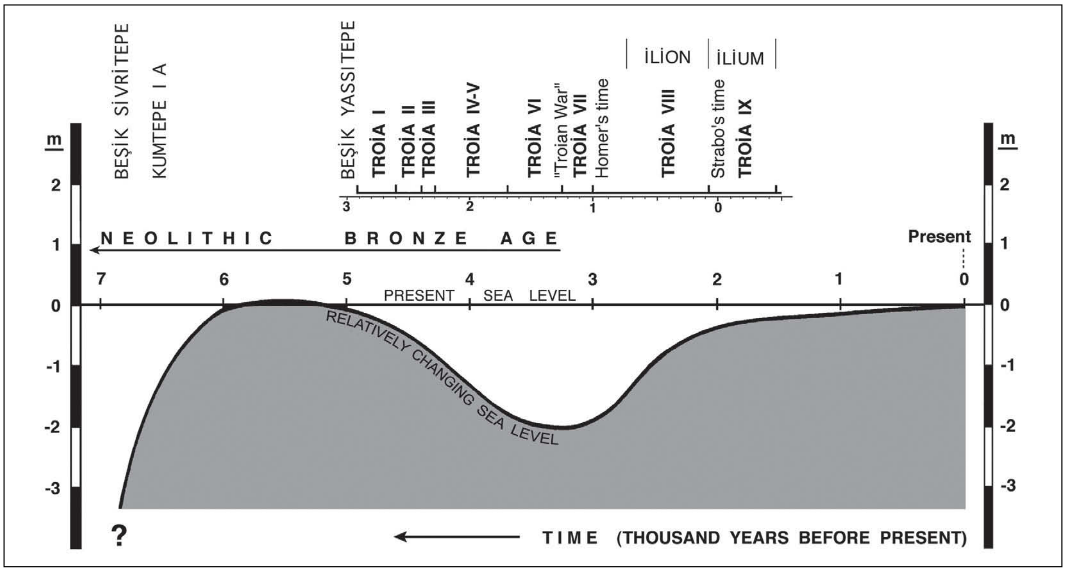

Fig. 8
Middle-Late Holocene relative sea level changes in the Troia area (Kayan 1991).

located according to old field roads or boundaries which have disappeared by the new levelling works. However, all drilling points can be transferred precisely on to new plans using GPS techniques from our original 1/5000 maps and plans.

Our studies in the Troia area have been summarized above. Results of the studies have been published in various places, but were first published in Studia Troica, which is the annual journal of the Troia Project. A brief summary of the important results of sedimentological and stratigraphical data obtained by drilling studies and their geoarchaeological interpretations are given below.

## The Holocene stratigraphy and geoarchaeological interpretations

The rough surface of the Neogene bedrock formations, which had been broken up by the neotectonic movements, is found at the bottom of the alluvial plains in the surroundings of Troia. Above this, the Pleistocene marine sediment formation was reached by drillings in some places, which $^{14}$C dates indicate is older than 20,000–30,000 years ago. Also, drilling evidence indicates that towards the end of the last Glacial period about 15,000 years ago, when sea level was about -100 m, the bottom of the lower part of the Karamenderes valley was a slightly undulated erosional surface on older (Pleistocene) marine and terrestrial (alluvial and colluvial) sediments. $^{14}$C dates of marine sediments and OSL dates of terrestrial deposits support this interpretation.[17] The bottom of the valley at that time was about 30 m below the present plain to the west of Troia. The ancestral Karamenderes river had an incised bed close to the western slope of Troia ridge (Fig. 17).[18]

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[17] Göbel et al. 2003.

[18] Kayan 1996.

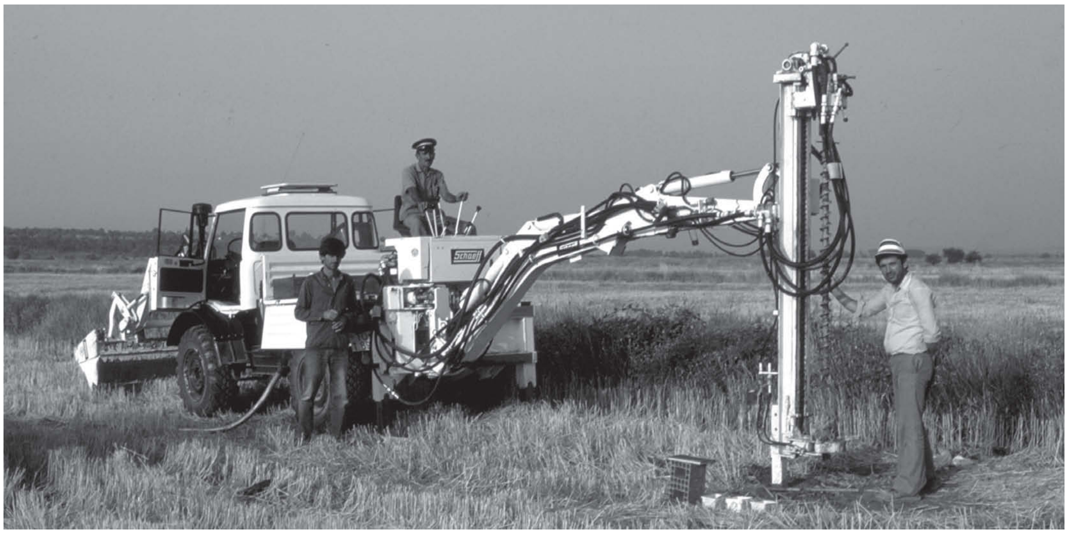

Fig. 9
A screw-drilling operation with Unimog to the north of Troia.

Sedimentological data obtained from core drillings made on the alluvial plains surrounding Troia show that the Holocene stratigraphical sequence consists of three main units. These units and their paleogeographical environments are summarized below in chrono-stratigraphical order, from bottom to top (Fig. 15).

## Early Holocene paleogeography and marine transgression

The rapidly rising sea during the Early Holocene, firstly intruded into the incised channel of the ancestral Karamenderes river at the bottom of the valley which is about 40–50 m below the present surface to the west of Troia. $^{14}$C dates of large marine shells (especially cardium and ostrea shells) taken from about 50 m below the present surface were dated to 10,000 years ago (Fig. 17). By 7,000 years ago, the old valley bottom was completely covered by sea water and the shoreline was near Pınarbaşı-Mahmudiye to the south (Fig. 4). In drill holes which reached the Neogene bedrock, marine sediments start with coarse lag deposits (gravely and coarse sandy transgression facies). Large oyster shells are generally abundant in this bottom deposits. Overlying fine grained and generally very homogeneous marine mud is the main sediment unit of the Holocene transgression (Fig. 15). This has varying sedimentological characteristics from place to place, from well sorted very fine sand to very sticky black mud. Sticky black mud is related to organic colloids. However, marine shells are very rare because of anoxic and acidic conditions. Some small methane explosions were experienced during the drilling operations in the south.

Although the bay at the mouth of the Karamenderes river was of a ria type inlet, neither gravely-coarse sandy old river channels nor clean sandy beach sediments are encountered in the fine grained marine sediments. This is related to the bedrock types. The bedrock in the surrounding area consists completely of sandy-silty-clayey carbonaceous Miocene shallow marine sediments. In addition, the Karamenderes leaves most of the coarser alluvium in the Bayramiç-Ezine basin behind the Araplar gorge and brings generally finer grained material to its lower

Fig. 10
Digger equipment of Unimog vehicle also used to open some trenches about 3 m deep. This is very useful in some places to see recent sediments and man-made deposits. Here, for example, two periods of fill in the defence ditch around Troia is clearly separated. 1) Miocene limestone bedrock, 2) Older fill in the ditch, 3) Younger fill in the ditch.

delta plain. The homogeneously fine grained nature of the Holocene sediments causes difficulties of detailed interpretation of the morpho-dynamic characteristics of the sedimentary environments, such as delineating old river channels or old shoreline positions.

Archaeological material (for example any piece of sherd carried by water into this old marine environment) was not encountered in this unit. In fact, $^{14}$C dates of marine-coastal shells obtained from coastal deposits at about present sea level below the present surface along the foot of the Neogene slopes are always found to be close to 6,000 years ago. This means that the sea level rise stopped at its present level about 6,000 years ago. However, maximum extension of the sea to the south may be a little earlier, about 7,000 years ago, because of the balance between alluviation and sea level rise. Towards the end of the transgression period, the sea level rise slowed down and intrusion was now more than compensated by alluviation, so that in the period 7,000–6,000 years ago, the shoreline must have prograded northward in spite of the slow sea level rise.

## Middle Holocene deltaic progradation

The top surface of the marine sediment unit extends for a few metres, generally 2 metres, below the present sea level under almost the whole surface of the present plain (Fig. 15). On this very flat surface, there is no clear change in the physical characteristics of the sediments through the wider middle part of the plain. They are still blackish dark grey silty, fine-very fine sandy somehow marine or marine connected sediments. Organic colloids and marine shells are generally less frequent than in the underlying true marine sediments.

These sediments vary from place to place. For example they are homogeneous in some places but laminated in others. Towards the lower parts of the lower tributaries, such as the Dümrek or

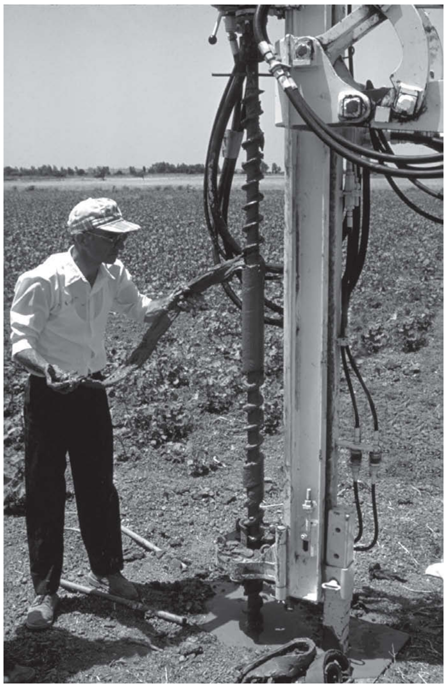

Fig. 11
Sediment examples on screw-corers taken by Unimog. These are disturbed because of compression and driven upward during the operation in the hole. Cohesive sediments can be taken from the corer as in a block shape, while loose sandy sediments unload and good sampling is not possible.

Çıplak rivers, they have a terrestrial content and show a hard block structure with carbonaceous concretions. Marine shells are rare and mixed with brackish-freshwater species. All of these characteristics indicate that this is a transition zone between lower marine and upper terrestrial units. The sediments must have been deposited in the very shallow coastal environment of a delta flood plain. There is no beach or lagoon formation. Instead, sediments indicate swampy or seasonally wet environments. The upper surface of this unit is almost at the present sea level. Thus, it is possible to interpret that the transition zone belongs to the most recent water zone which is filled with deltaic sediments following the end of the sea level rise.

One of the characteristics of the transition zone is a number of sediment belts which represent former deltaic distributary channels or inlets (»azmak« is the more specific term in Turkish). These are medium-coarse sandy, generally muddy and contain high amounts of organic colloids. While coarse sand implies water flow, their muddy nature and organic content represent stagnant conditions at least from time to time (or seasonally). Their depth below present sea level is concordant with the interpretation as »azmak« features.

Over such a very shallow coastal zone, a small sea level fall would cause a wide area to be turned into dry land. This interpretation is supported by sediment characteristics and $^{14}C$ dates which point to a regressive sequence in the period between 5,000–3,500 years ago. Thus, the transition surface represents an important change from a wet environment to dry land suitable for human use.

Two important characteristics of the transition zone are noticeable in the plain along the foot of the ridge to the west of Troia. One of them is a major deltaic sedimentation unit in various other sediments representing all wetland environments other than marine. The delta unit starts on a flat sea bottom about 2–3 m below present sea level, that is about 9–10 m from the present plain surface to the west of Troia. Then coarse sandy, gravely, clean and loose deposits fill the area up to about present sea level (Fig. 15). This is in concordance with the general geometry of the transition zone. In the horizontal dimension, the deltaic unit covers an area about 200 m wide to the north of Troia, then continues southwestward forming a wider belt.

The second important characteristic of the sandy unit is its geoarchaeological sense. Although normally no archaeological material like pot-sherds or pieces of brick and tile are found in this stratigraphical unit, some small pieces of potsherds can be found along the foot-slopes of Troia in deltaic sediments, which were washed down from the slopes into deltaic sediments. They are contemporaneous with the delta development. As an example, two potsherds which were found in the hole of drilling number 129, at 10–10.5 m below the present surface (about 3 m below

Fig. 12
A gouge-corer drilling operation. Percussion drilling gun (a), Cobra, provides driving 1 m gouge corer into ground. To go deeper, 1 m extension rods are attached each time. Then hydraulic lifter (b) provides to pull up rods and corer to obtain sediment core (see Fig. 13).

present sea level) are very interesting at this depth (Fig. 18).[19] It has not been possible to date them because they are transported and eroded. However, archaeologists who are experts on Troia ceramics are sure that they are very old, probably from the Bronze Age. This is also in concordance with our interpretations.

## Late Holocene deltaic progradation and alluvial-colluvial landform development

The uppermost unit of sedimentation is above present sea level and generally consists of fine sandy-silty floodplain deposits (alluvium) in the main part of the bottom of the Karamenderes-Dümrek valleys. Its colour varies according to the level of the ground water. Below the water table grey-dark grey sediments look like the lower units and sometimes it is difficult to separate them. However, they are different in their nature of hard block mud and carbonate content. As for the layers above the water table, these are generally brownish-olive colours. In the upper layers, grain size homogeneity is disturbed and some flow marks, coarser flood bands and pedogenetic horizons can be viewed. However, great stream channels, recognizable by coarser sediments, are rare. As stated above, this is because the bedrock in the area produces only fine grained sediments.

Towards the foot of the slopes along the edges of the alluvial plain, colluvial material mixes into flood plain sediments. These are also fine sandy and originate from the slopes, consisting of Neogene bedrock. In addition, they contain clayey soil material which has been produced by weathering on the slopes. Therefore they can be easily distinguished. They have great importance because of their content of archaeological material. For example in the near surroundings of Troia, colluvium contains potsherds, pieces of brick and tile, fire remains such as charcoal, ashes

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[19] Kayan 2002.

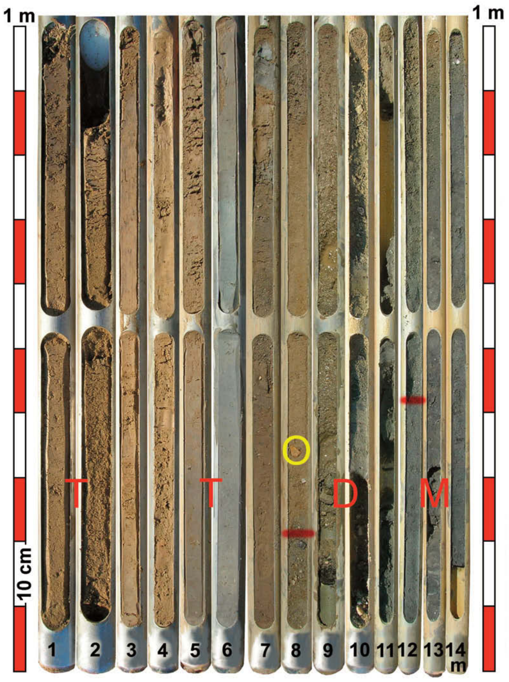

Fig. 13
An example for a set of sedimentological and stratigraphical core profile obtained by Cobra drilling equipment. Photograph belongs to drilling number 213, which is located to the north of Troia. Here, Neogene bedrock is not encountered because it is about 35 m deep. However, marine (M), deltaic (D) and terrestrial (alluvial-colluvial) (T) sediment units can be distinguished from bottom to top. Yellow circle points out a piece of sherd about 7,5 m below present surface, in the lower part of terrestrial sediments.

and burned soil, and food remains like bones and shells. The rounded shapes of potsherds imply that they were transported for some distance by water flow on the surface. Their abundance, shapes and ages all are very important tools for geoarchaeological interpretations. From this point of view, some interesting results have been obtained from the core-drilling studies performed on the northern and southern foot slopes of the Troia ridge.[20]

The present surface to the **north of the Troia ridge** is about 7 m above sea level. Based on data obtained from a great number of drilling holes which were made to the north of the Schliemann trench, there is a platform on the Neogene bedrock about 50 m wide, beneath the alluvial-colluvial sediments and just below the present sea level (Fig. 15).[21] The surface of the platform is covered with marine sediments up to the present sea level. $^{14}$C dates show that the coarse sandy coastal sediments belong to 5,800–5,200 years ago, which is consistent with other evidence in the region. The upper section, above sea level, consists of colluvial deposits containing archaeological material. These are generally related to fire: stone remains of fireplaces, burned bones and shells and ashy muds are abundant. Some potsherds have been dated as Troia IV, V, and VI by archaeologists. This deposit can be followed up to the old channel of the Dümrek river, which was located about 50 m north of the foot of the steep Troia slope. Because the Dümrek river later shifted northward, the old river course is covered by finer sediments at the top, and disappears. Thus, it is understood that the sea was right at the foot of the »Schliemann trench« during the earliest periods of Troia, i. e. Troia I and II. During Troia IV–VI, a strip of dry land suitable for human use formed between the slope and old Dümrek channel (Fig. 15).

To the south of Troia, another detailed study on the outskirts of the Lower City of Troia showed that a layer of earth about 1 m thick containing archaeological material spreads over a wide area about 2–4 m below the surface.[22] The archaeological material consists of densely packed pieces of potsherds, bricks and tiles, and burned material in colluvium. Pieces of archaeological material must have washed down by rain water from the old city and spread over the lower area following a great destruction including fire in the city. Here in the Çıplak valley, the lower marine sediments do not extend much to the east because the Çıplak valley is not deep on the Neo-

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[20] Kayan 1996; Kayan 1997a.

[21] Kayan 1996.

[22] Kayan 1997a.

gene bedrock and the river easily filled this small valley with alluvial-colluvial sediments originating from the lower plateau surface (Fig. 1). OSL dating of these sediments indicate that it is possible to correlate them with pre-Holocene (Pleistocene) marine sediments in the deeper parts of the Karamenderes valley, and to suggest them as their terrestrial equivalent.[23]

## Conclusions and discussions concerning environmental changes in the Troia Area

**Active tectonics** in the Troia area have been a focus of attention and dispute by earth scientists, especially following the Marmara earthquake of 1999. For Troia, earthquakes have special significance because of evidence for severe earthquakes responsible for the destruction of the prosperous city of Troia VI. The Troia area is located on the southern flank of the North Anatolian Transform Fault Zone and in a transitional region between this zone and Aegean tensional tectonics. Therefore, geological and geomorphological evidence of young tectonic activity is abundant everywhere. On a regional scale, it is not possible to explain geomorphological features without considering tectonic activities. However, time is a very important factor in terms of chronological sequence and duration of tectonic events. Earth scientists are accustomed to measure time in millions of years, while archaeologists, historians and even social geographers are accustomed to only thousands of years at most, and more generally only hundreds of years. They must be careful to respect this difference in order to understand each other. The geological structure and geomorphological formation of the ridge of Troia and its surroundings spans the last 10 million years. But inundation of the Karamenderes lower valley and its tributaries by rising sea in the Holocene, the alluviation of this region, and the estab-

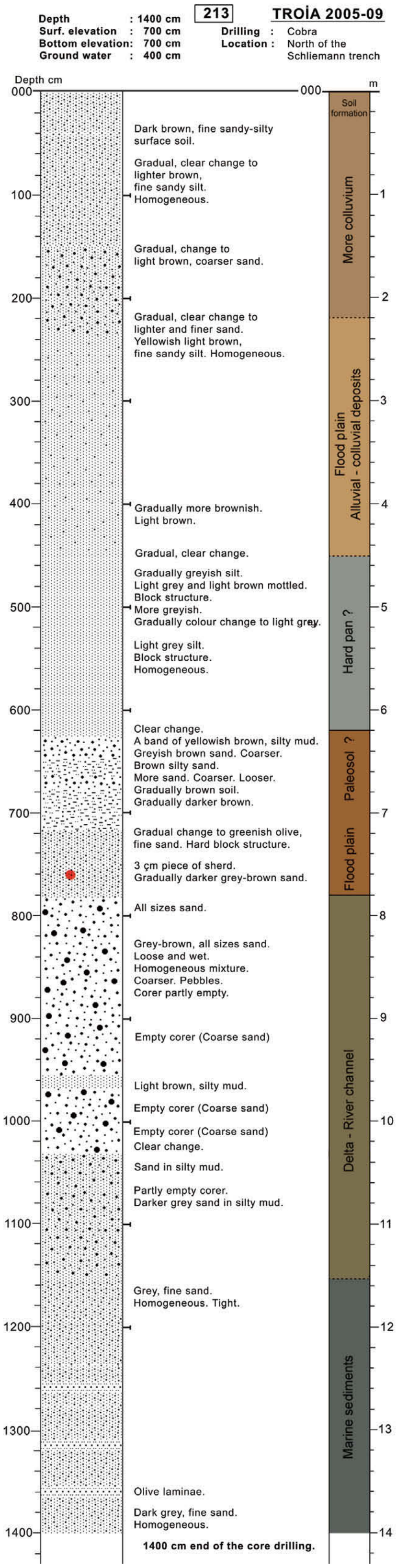

Fig. 14
As an example, sedimentological interpretation profile of drilling number 213 (Figure 13). All drilling logs have been evaluated in the same computer form and prepared a data collection. Different sedimentary units which are separated on Fig. 13, are shown here in a precise scale, and some special findings like pot sherds and shells with symbols.

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[23] Göbel et al. 2003.

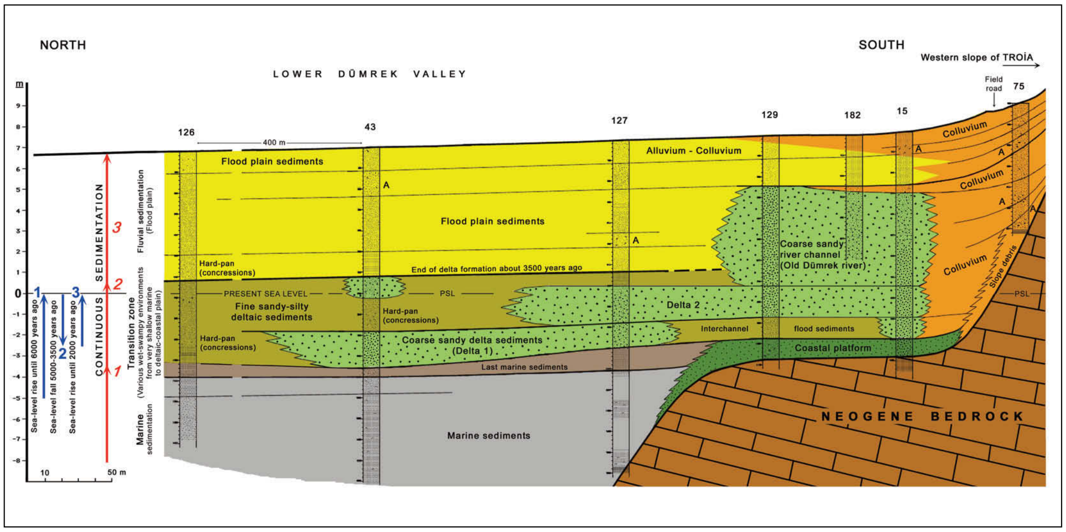

Fig. 15
North-South cross-section near the foot of western slope of Troia. On the right, a bedrock platform along the foot of northern slope of Troia, about 10 m below present surface was a narrow coastal environment in the Bronze Age. Deltaic shoreline in the Karamenderes valley reached here with various sedimentary facies, towards the end of this period. Finally, flood plain deposits and colluvium from adjacent slope covered all bottom of Karamenderes and Dümrek valleys. On the left of the figure, a red arrow indicates continuing sedimentation (Italic 1, 2, 3) in various environments through the middle-late Holocene. Blue arrows indicate sea level changes in the same period (1: 6000 BP, 2: 3500 BP, 3: 2000 BP). (A) represents abundant archaeological material, especially pot-sherds.

lishment and development of Neolithic and Bronze Age settlements occurred only in the last 10 thousand years. Differences between magnitudes and sequences of the events that have occurred across 10 million years and across only 10 thousand years must be realized correctly.

As stated above, structural lineations of landforms around Troia are very distinct as a reflection of the basement structure in NE-SW and the Neotectonic break up along the N-S and E-W direction. In fact, outlines of the Aegean coastline and lower part of the Karamenderes plain were formed as a result of these structural lineations. However, the subsurface geometrical configuration of the middle and late Holocene sedimentary units, on the Karamenderes plain and its indentations, has revealed that the sedimentary units have not been subjected to tectonic deformation. From this point of view, the very smooth and horizontal extent of the uppermost surface of the marine sedimentation unit of the Holocene transgression, generally a few metres below present sea level, is particularly remarkable. $^{14}$C dates from this surface are about 7,000–6,000 years old, and its plane morphology indicates that the surface was formed out of spreading sediments in marine embayment instead of terrestrial material washed down from the surrounding slopes. Any deformation, such as tilting, has not been detected on the surface, and this indicates that severe tectonic activity of a magnitude that could have had an effect on the morphology has not occured during the last 7,000 years. Of course, this is not evidence for the stability of the region during this period. Severe earthquakes are clear evidence for continuing active tectonics. The matter important to emphasize here is that tectonic activity during this period has not affected and deformed the geomorphology, at least in a recognizable magnitude. In other words, tectonic activity or deformations are not visible on the landforms and have not been a primary factor for the geomorphological development of the region since the middle Holocene.

In addition, evidence for tectonic deformation has not been detected in the sedimentation units above the upper surface of the marine unit, which was formed in the last 7,000–6,000 years. All local and secondary sedimentation surfaces also extend smoothly and horizontally. Only lateral transition between footslope colluvial deposits and the bottom sediments are evidently upwards. This is because the sediments were not deposited in the depression in a water environment as before. Instead, they were accumulated along the footslopes in a terrestrial environment and slowly washed down into the bottom of the depression.

Compaction of the sediments deposited at the bottom of the Karamenderes embayment is another matter that deserves consideration. In particular, the marine section of Holocene sediments that filled an embayment in a rather short time consists of loose silty-fine sandy mud with high organic content. Therefore, it is normal to expect some compaction in the mass of this sedimentation unit. Also, in general terms, a tectonic shock, something like a severe earthquake, might have brought about vibration and compaction effects on silty marine sediments. However, correlation of the core drilling logs has not revealed any evidence for such deformation in the marine or overlying terrestrial sediment units and their discernable top surfaces. This may be explained by the inadequate thickness of the Holocene sediment units.

In defining tectonic deformations in young tectonic movements in the Troia area, one aim of earth scientists is to detect evidence for severe earthquakes which are often proposed as a cause of destruction, especially for Troia VI. Some earth scientists attempt to dig trenches and examine their profiles to find signs of recent earthquakes. However, these trenches only reach depths of about 4–5 m. Ground water presents problems for deeper trenches. According to sedimentological evidence obtained by core drillings and $^{14}$C dating, 6 to 7 m of sediment has been deposited on the bottom near environs of Troia since Troia VI (over the last 3,250 years). Obviously, it makes no sense to try to find marks of tectonic deformation from supposed earthquakes in the Troia VI period in these younger sediment layers.

In conclusion, there is no doubt that geomorphological outlines of the Troia plain and its surroundings were drawn by young tectonic movements. However, geomorphological effects of these movements on the sedimentary units that began to be formed in the Middle Holocene are not verified. Therefore, it seems that earth science research techniques alone are not enough to obtain evidence to prove one way or the other if earthquakes destroyed Troia VI. Archaeological evidence must be taken into account too.

A **supposed tsunami** or tsunamis that may have affected Troia in the Holocene is another topic of interest in recent years. Some scholars postulate that Troia and the surrounding area may have suffered tsunamis in the Holocene. There is no specific evidence in favor of this argument, which became popular following the dreadful tsunami disaster in southeast Asia in 2005. In our core drillings, which reached 318 in number on the valley bottom of the Karamenderes-Dümrek rivers, on the Beşik coastal plain, and in small indentations along the inner edge of the Yeniköy ridge, we have never encountered any evidence of a tsunami. Of particular concern is the magnitude of a tsunami wave that might have developed in the northern Aegean sea, as well as the possibility of a wave's intrusion from the Çanakkale Strait into the Karamenderes valley or over the lowest parts of the Yeniköy ridge. It is hard to postulate such an occurrence in the present day or in the Holocene geographical configuration given the topographic-batimetric features of the region, the distances and directions for travel of waves, and magnitudes of Holocene tectonic activities.

A great deal of marine shells in the earth around Troia have been presented as evidence for a severe tsunami event by some earth scientists. But shells are found at all archaeological sites on coastal regions, and Troia is no exception. Even, in archaeological surveys, shells are normally interpreted as evidence for archaeological sites in the same way as pot sherds. Shells are generally

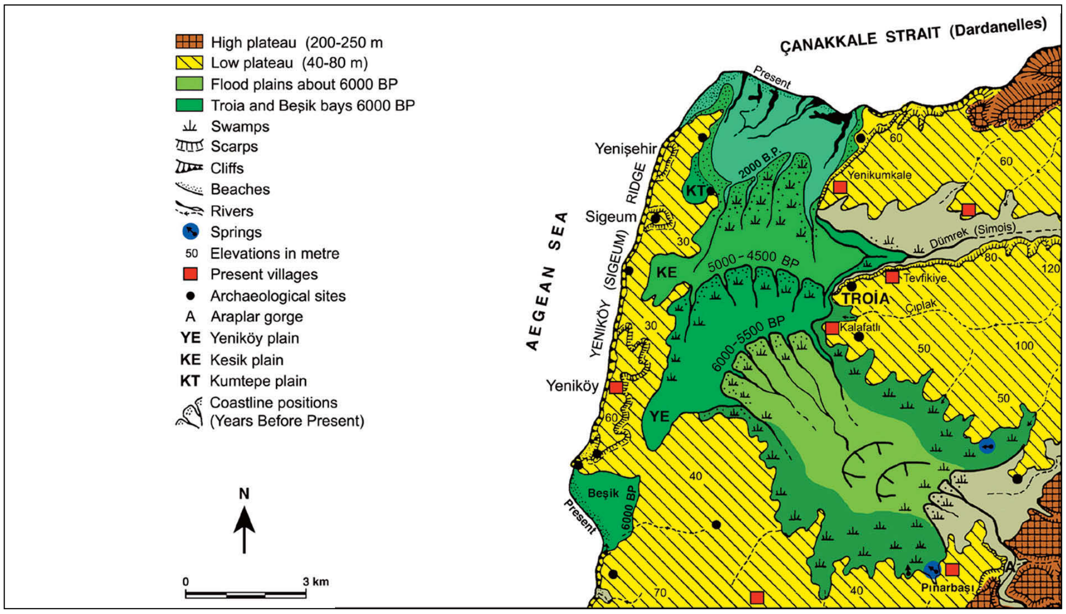

Fig. 16
Geomorphological development of the Karamenderes (Scamander) plain (Kayan 2000).

remains of marine gastropods (mostly Cerastoderma edule) which were consumed as food. In addition, shells can be transported in mud taken from deltaic swamps to produce mud bricks. They are also found at settlements as remains of personal ornament or other domestic usage. Therefore, the existence of shell remains at a site about 30 m above sea level like Troia is not an evidence of an inundation caused by a tsunami.

**Holocene sea-level changes** and their effects on the Troia area are also a subject of discussion. Some evidence and interpretation on this matter has been pointed out in our previous publications.[24] Accordingly, about 10,000 years ago the rapidly rising sea reached into the lowest parts of the lower Karamenderes flood-delta plain. It can be assumed that, even during the time the sea inundated it, the Karamenderes continued to bring alluvium, and deposited it in the bay. Thus, the position of the coastline in the bay changed continuously depending on the balance between the rise of the sea level and alluvial sedimentation. During the period of more rapid sea level rise, until about 7,000 years ago, the coastline continued to advance south, covering former delta plains and reaching the vicinity of Pınarbaşı (Fig. 4).

It is known that the rise in the sea level slowed down and that by about 6,000 years ago the sea reached today's level (Fig. 8).[25] During this time the coastal zone began to be filled with alluvium which the Karamenderes brought from the Bayramiç-Ezine depression, and the new deltaic coastline prograded northward. Drilling studies have shown that swampy areas of vast dimensions stretched south of Troia during that time.[26]

Geomorphological investigations on the Aegean coast of Anatolia have shown that the sea level has also changed during the last 6,000 years.[27] The first perceptible evidence of small sea level

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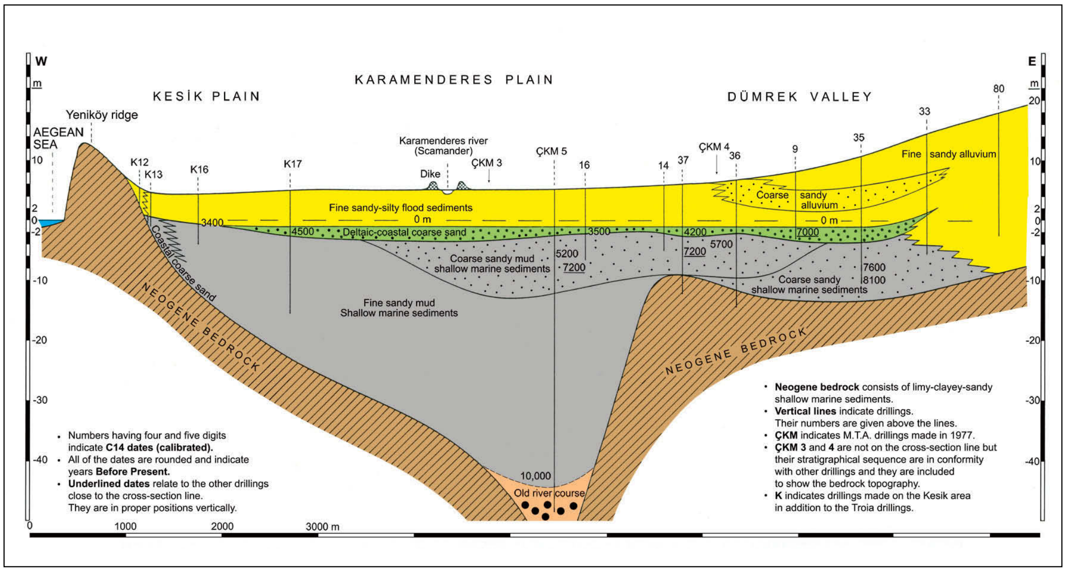
[24] Kayan 1991; Kayan 1995.
[25] Kayan 1991.
[26] Kayan 1995.



- Numbers having four and five digits indicate **C14 dates (calibrated).**
- All of the dates are rounded and indicate years **Before Present.**
- **Underlined dates** relate to the other drillings close to the cross-section line. They are in proper positions vertically.

- **Neogene bedrock** consists of limy-clayey-sandy shallow marine sediments.
- **Vertical lines** indicate drillings. Their numbers are given above the lines.
- **ÇKM** indicates M.T.A. drillings made in 1977.
- **ÇKM 3** and **4** are not on the cross-section line but their stratigraphical sequence are in conformity with other drillings and they are included to show the bedrock topography.
- **K** indicates drillings made on the Kesik area in addition to the Troia drillings.

Fig. 17
Simplified west-east cross-section of the lower Karamenderes-Dümrek delta-flood plain to the north of Troia (Kayan 1995).

changes was obtained from our core drillings in the Beşik coastal plain, which was formed by marine processes. Here, coastal sediments with plenty of shells were encountered when drill-holes reached down to present sea level along the footslopes surrounding the plain. In general, $^{14}$C dates from these coastal sediments produced dates about 6,000 years old. Similar features and results have been found in the vicinity of Troia. In the following time, the sea level first fell about 2 m between 5,000–3,500 years ago, and rose again to its present level around 2000 years ago (Fig. 8).[28] This slight sea level fluctuation influenced the development of the alluvial plain of the Karamenderes and the Dümrek around Troia, and consequently also had a bearing on the activities of the Trojans in the Bronze Age.

Although we have enough evidence for small sea-level changes during the last 6,000 years, there is no proof for the cause of these events. In the Troia-Karamenderes area, Holocene (or the late Pleistocene) sediments belonging to marine or coastal environments have never been encountered above present sea level. On the contrary, in our former, deeper drilling holes in the Karamenderes plain, some marine sediment formation older than 30,000 years ($^{14}$C dates) were bored in deeper levels.[29] Accordingly, there is no indicator denoting any uplift of the pre-Holocene surface on which Holocene marine sediments accumulated. In addition, the middle-late Holocene sea-level changes can be followed in the same order and magnitude all along the Aegean coast of Anatolia.[30] The Aegean coastal region has faulted-blocky structure and tectonic reasons are not convincing explanations for uniform sea-level changes. Thus, an eustatic reason concerning a climatic effect must be taken into account for sea-level changes, otherwise new evidence must be produced if any different explanations are to be considered.

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[27] Kayan 1997b; Kayan 1999.

[28] Kayan 1991.

[29] Kraft et al. 1980.

[30] Kayan 1988.

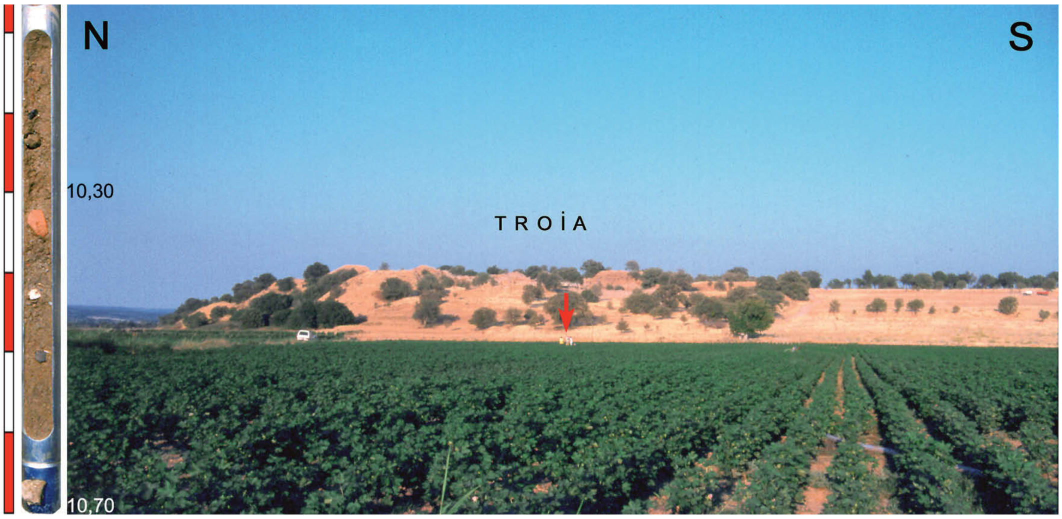

Fig. 18
A view towards the western slope of Troia. A red arrow indicates the location of drilling work for number 183. Here, the surface of the cotton field is about 8 m above present sea level. In the drill hole, the Miocene bedrock surface was encountered at a depth 11 m below present surface. Left inset is a part of another core sample, number 129, at a depth of 10,20–10,70 m. Its location is almost in exact place, that is left end of the picture. Some pieces of sherds in fluvial coarse sandy deposit interpreted by Troia archaeologists as older periods of Troia (Troia IV?). Sherds are not well rounded. This means that they were washed down from the adjacent slopes and Troia was occupied in this time. Then, obviously the sea was lower than its present level (see Fig. 8 and 15).

## About the potential harbour sites

Since the Karamenderes plain was a long bay for several millennia after 7,000 years ago, Troia must have had a harbour or harbours in different places following changes of coastline positions during deltaic progradation. An important question then arises as to where the Troia harbours were. This is one of the main topics of discussion related to the paleogeographical changes in the Troia area.

As stated above, three low plateau ridges, which consist of uplifted Miocene shallow marine sediments, delineate the geomorphological outlines of the Troia area. One of them is the Yeniköy ridge (or Sigeion ridge in archaeology) in the west, which separates the Karamenderes plain from the Aegean Sea (Fig. 1). This north-south trending ridge is about 40–80 m high and 1 km wide. Its western slope forms a steep cliff line, cutting almost horizontal Miocene beds of carbonaceous sandstone and claystone. In contrast to the straight shape of the western cliff line, the eastern slopes descend gently to the Karamenderes plain and then give way to alluvial deposits. On this eastern side, the line between the alluvial surface and the Miocene bedrock slopes is greatly indented. Three particular indentations on this side have been interpreted by Troia visitors and explorers as possible ancient harbour sites. These are, from south to north, the Yeniköy, Kesik and Kumtepe indentations as extensions of the Karamenderes plain.

There are very shallow thresholds between the Yeniköy and Kesik plains and the sea. In addition, there are small canals or ditches across the thresholds, which have caused some speculations about water passages between the Aegean sea and supposed inner harbours in the Bronze Age.[31] We carried out detailed geomorphological research including drilling studies in this area in order to elucidate this matter under the light of new evidence.[32]

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[31] Cook 1973; Zangger 1992; Zangger et al. 1999.

[32] Kayan 1995; Kayan 2009.

## Yeniköy plain

The Yeniköy (Sigeion) ridge is interrupted towards its southern end by a structural depression extending NE-SW. The Beşik plain is situated on the coastal part, while the Yeniköy plain extends from the Karamenderes plain on the inner part of this depression. The Beşik and Yeniköy plains are separated from each other by a very flat threshold only about 10 m above sea level (Fig. 20). The bedrock, which consists of Miocene marine sandstone here, is open to the surface. This geomorphology has been interpreted by some explorers to show that the sea overflowed this threshold at one time and intruded into the Yeniköy plain, and thus the Yeniköy ridge formed as an island. Sandy cover and some shell fragments supported this idea. However, there is no true evidence for such a marine connection.

There is a simple man-made trench a few metres deep across the threshold. This implied to some explorers that even if there was no natural marine connection over the threshold, a man-made canal might have connected the Yeniköy and Beşik inlets. Thus, it was supposed that the Yeniköy inlet would have been a very convenient harbour site in ancient times. Our drilling evidence clearly showed that Beşik and Yeniköy embayments were covered by sea water when the sea reached its present level about 6,000 years ago. However, there is no evidence to indicate any natural or artificial connection between the two bays. On the contrary, detailed investigations showed a 2 m sea level fall about 5,000–3,500 years ago, that is, during the Bronze Age, causing wide areas to dry up and change into land in both embayments.[33] No doubt that sandy cover and shell fragments on the surface of the threshold originate from disaggregation of the bared bedrock which consists of shallow marine Miocene sediments.

Although it is not known when the ditch on the Yeniköy threshold was dug, it is almost certain that the purpose was to take fresh water from Pınarbaşı springs to people who lived on the Beşik plain in historical times. It was last cleaned and used in the 1950s. This usage was limited to running a water-mill (Hanımdeğirmeni) which was located at the point where the canal reaches the Beşik plain. This was subsequently abandoned. The Yeniköy plain was covered with swamp until the 1960s because it was the natural area where the waters of Pınarbaşı springs spread. With various improvements and the digging of some new canals over the past decade, the swamp has dried up and the plain has been made arable.

## Kesik plain

The Kesik plain is the middle indentation along the western edge of the Karamenderes plain to the north of the Yeniköy plain. It is situated just to the west of the site of Troia, across the Karamenderes plain (Fig. 1). It is also formed on a NE-SW structural line similar to the Yeniköy plain, and it extends toward a low gate between two horizontal limestone platforms, Yeniköy and Subaşı, on the Yeniköy (Sigeion) ridge (forming a threshold between the plain and the sea). The Kesik

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[33] Kayan 1991; Kayan 1995.

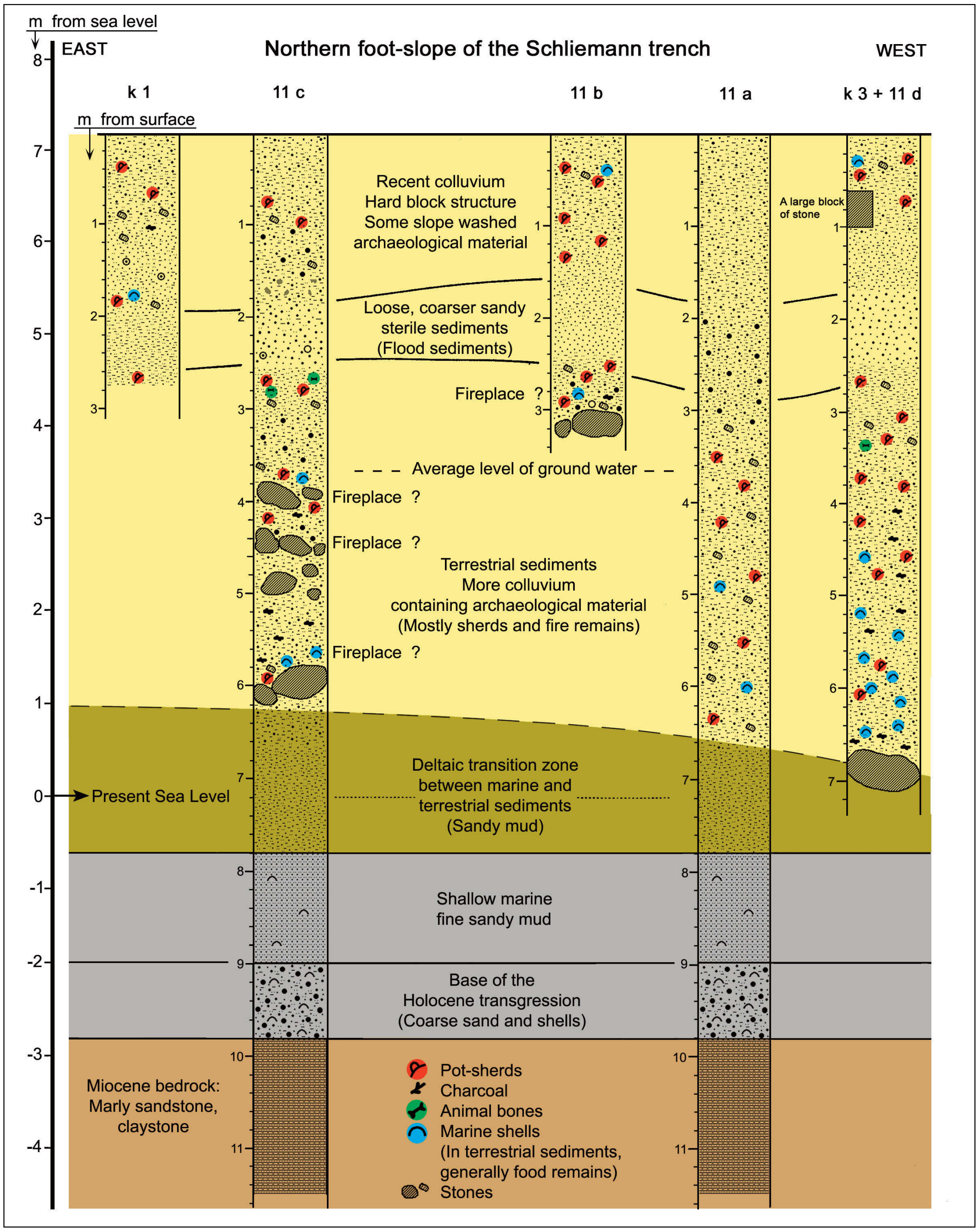

Fig. 19
Details of drilling holes along the foot of the northern slope of Schliemann's N–S trench, looking south from the Dümrek plain (Kayan 1996).

plain, like the Yeniköy plain, was covered by swamp until the 1960s, but then it was drained and made into an arable area.

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 is a steep cliff. A dry canal-like feature cuts straight across the lowest part of the Yeniköy ridge in an east-west direction. »Kesik« means »cut« or »cleft« in Turkish and the name of the area comes from this feature. The lengthwise profile of this cleft-like feature is asymmetric in accordance with the shape of the ridge itself (Fig. 20). The highest point in the bottom is 13.7 m above sea level at a distance of about 150 m from the sea, but the inner side profile is gentle and opens on to 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 there is only an earth road at the bottom which is used by people walking between the plain and the coast. Drilling holes and trench profiles on the bottom of Kesik »canal« clearly showed that the Neogene bedrock (sandy marl here) is covered by 2 m of colluvium. No archaeological material was encountered in the many drillings which were made in the bottom of the cut.

If the geomorphological characteristics of the Kesik plain and Kesik »canal« are interpreted together with the Holocene marine transgression, in which the rising sea covered the Kesik plain to form a small inlet, one can easily imagine that the Kesik plain could have been an excellent harbour which was connected to the Aegean Sea by the Kesik »canal.« Concerning this idea, there are various interpretations in the literature,[34] and the Kesik »canal« has been the subject of great interest in this respect. It is thought that the canal was opened by man to connect the harbour of Kesik inlet, which was an extension of the Holocene Karamenderes bay, as a short-cut to the Aegean Sea to the west. Although the canal is too high for direct water connection, there are some ideas that it could have been used as a dry slipway to transport ships between the Aegean Sea and the Kesik bay.[35]

The origin of the Kesik canal between the Kesik depression and the Aegean Sea is a subject of discussion. Our interpretations on this matter have been explained in former publications.[36] In the new stage of our research we have obtained no evidence to change our former interpretation. In brief, the Kesik canal appears artificial with its very straight direction. However, no evidence has been discovered to suggest that it was dug out, nor has any trace of dumped material been found in surrounding fields. The canal is very narrow and the bedrock forms a threshold in the middle at a height of about 13 m above sea level. Therefore, the canal cannot possibly be used as a waterway between the Kesik depression and the sea. In addition, any archaeological material or any trace of human impact were not found in colluvial deposition about 2 m thick in trenches which we dug across the canal with the Unimog digger.

On the other hand, there is some evidence implying that the canal depression is naturally formed on a fault line. This is based on differences in elevation between two sides (north and south) of the canal, and the morphology of the bedrock along the eastern extension of the canal on the surface (Ballıkaya ridge) and underlying alluvium (drilling data). However, sedimentological and stratigraphical features of the Holocene deposits in the Kesik depression do not support such tectonic activity for the Holocene.[37] According to available data, the most probable explanation may be as follows:

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[34] Cook 1973.
[35] Zangger et al. 1999.
[36] Kayan 1995; Kayan 2009.
[37] Kayan 2009.

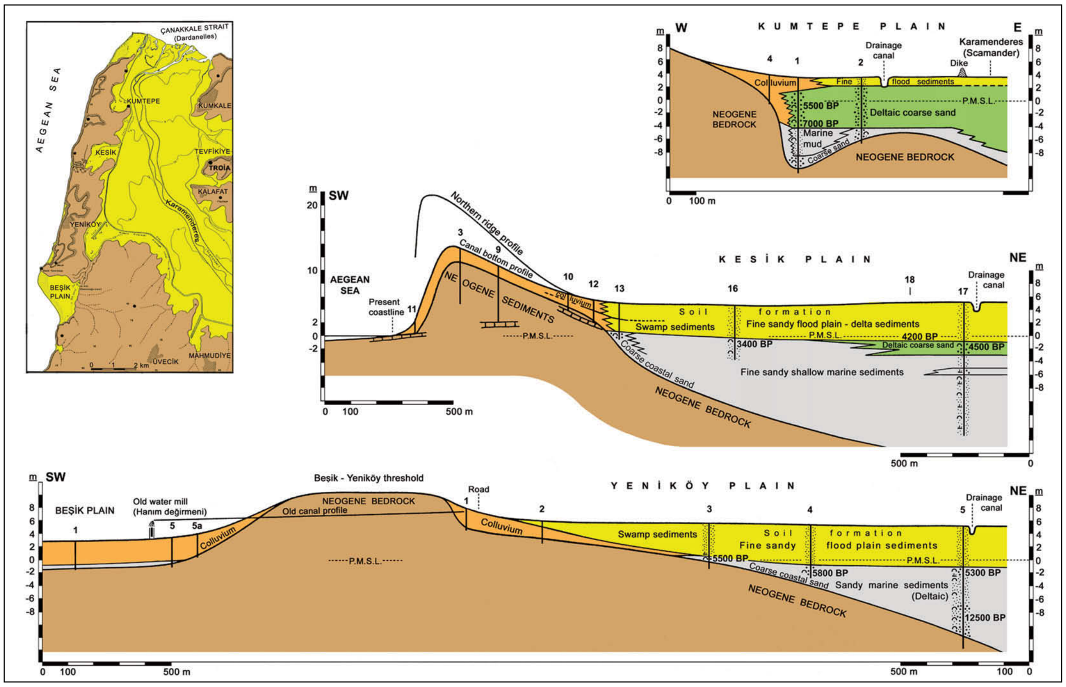

Fig. 20
Cross-sections of the Yeniköy, Kesik and Kumtepe indentations along the western edge of the Karamenderes (Scamander) plain, West of Troia (Kayan 1995).

The Kesik canal may have originally formed on a fault line before the Holocene, long before human activity in this area. In prehistoric times, inhabitants had no need for a canal here. Although the bottom of the Kesik depression was a marine environment in the Neolithic, humans living in this area, such as at Alacalıgöl mound, were not able to attempt such a big project, so this period is not included in the following discussion. But the Bronze Age, especially the period of Troia VI/VIIa, remains under discussion as a period of possible canal construction. During this period the Kesik depression was not a marine embayment; instead, it was covered by a swamp. Therefore, a harbor is not a subject of discussion for the Kesik depression and a canal was not necessary for a waterway connection with the Aegean Sea. In fact, there is no archaeological evidence later than the Chalcolithic period in this area. It seems that the Kesik area lost its convenient nature and was abandoned because of its swampy formation. In recent historical times, the Kesik plain became more valuable because of agricultural necessities. The development of Sigeion to the north may be one of the reasons to use the Kesik plain for agriculture. On the other hand, the stratigraphical sequence of the upper sediments in the plain indicates that the plain was not covered by a swamp completely and continuously during historical times.[38] Only in recent centuries did the swampy area expand again because of alluvial development on the Karamenderes plain. Then, people attempted to drain excessive water from the Alacalıgöl part of the plain in order to create arable land. It is also possible that they tried to dig some small trenches to accomplish this, but nothing as large as the Kesik canal. It seems that such attempts could not been successfully completed. The canal has been used continuously for land passage between the Kesik plain and the coast of the Aegean Sea. This usage may have been more important during the wars of the last century.

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[38] Kayan 2009.

## Kumtepe plain

Kumtepe plain is the northerly indentation of the Karamenderes plain of the Yeniköy ridge (Fig. 1). It has the same geomorphological characteristics as Yeniköy and Kesik plains, that is, it is formed in a NE-SW secondary structural depression. To the west of the Kumtepe plain, the Yeniköy ridge is lower (35 m) between higher (70 m) limestone platforms to the north and south. These are the sites of the ancient Sigeion and later Yenişehir settlements. A very low and flat secondary ridge extends eastward, then bends to the north from the Yeniköy-Sigeion ridge. One of the oldest known settlements of the area, Kumtepe mound, is situated at the northern tip of this low ridge. The small plain separated from the Karamenderes plain by this low ridge is named Kumtepe plain here after the Kumtepe mound. Because of its geomorphological configuration, the Kumtepe plain has also been interpreted as an old harbour site.

This lowest part of the Karamenderes plain was described by Strabo at the time of Christ, and mapped by Leake based on his descriptions.[39] No marine indentation was shown on this map. Also, there is no evidence indicating that Kumtepe indentation was used as harbour. Since it has similar characteristics to the southern indentations, we made several drilling-holes in this area to determine this matter. Based on core interpretations, there is no difference on the stratigraphical sequence (Fig. 20). Colluvial deposition is widely spread along the inner edges of the embayment. On the bottom, a coarse sandy, thick deltaic deposit is dominant. The reason for coarse sandy deposition is that the Karamenderes river first filled the western edge of the bay during the final stage of deltaic progradation, keeping its original direction as in the south. When the coastline was in the Kumtepe indentation, strong northerly winds might have worked alluvium to form a coarser sandy beach. Later, deltaic progradation stopped in front of the northern extension of the Yeniköy ridge, and during the last stage, the Karamenderes river and its deltaic progradation shifted NE to the present position.

Today, the amount of water and sediment which the Karamenderes river can carry down to the coast and eventually to the sea is considerably reduced because of a dam (Bayramiç dam) which has been constructed in the upper basin, and because of the extraction of large amounts of ground water for agricultural irrigation. Thus, the surface flow has greatly decreased. Furthermore, the strong current in the Çanakkale Strait hinders the formation of a deltaic promontory. The very little sediment reaching the sea (Çanakkale Strait) today is carried towards the Aegean Sea by the current, and accumulates partly at the northern tip of the Yeniköy ridge and partly in various places along the western coast of the Yeniköy ridge such as the Beşik coast.

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[39] Leake 1824; Kraft et al. 1982.

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