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Holocene Coastal Development and Archaeology in Turkey

by

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with 8 figures

Zusammenfassung. Die Türkei hat eine Küstenlinie von etwa 8300 km Länge, die im weitaus größten Teil hohe und steile Kliffe aufweist. Dabei verläuft die Schwarzmeerküste im Norden und die Mittelmeerküste im Süden parallel zu den geologischen und morphologischen Einheiten, so daß niedrige Küstenebenen oder Deltas hier selten sind. Im Gegensatz dazu verläuft die ägäische Küste quer zu den Strukturelementen. Die Flüsse liegen in tiefen Depressionen (Gräben) und haben in den küstennahen Teilen dieser Depressionen auch Deltas aufgeschüttet. In Übereinstimmung mit der Küstenkonfiguration war der Kulturaustausch zwischen Küste und Hinterland im Norden und Süden der Türkei in prähistorischer Zeit behindert, während im Westen die tiefeingreifenden Ebenen und Täler Leitlinien für die Verbindung verschiedener Kulturen waren. In dieser Arbeit werden die geomorphologischen Charakteristika der türkischen Küste im allgemeinen beschrieben, mit besonderer Berücksichtigung der Küstenveränderung und des Einflusses auf die Landnutzung im jüngeren Holozän. Die Region Tuzla und Klaros werden dabei als Beispiele für die Küstenveränderungen und die geo-archäologischen Entwicklung der ägäischen Küste besonders intensiv behandelt.

Summary. Turkey has a long coastline of about 8300 km. Its greater part has high steep cliffs because the entire country has a high and massif morphology. The Black Sea coast in the north and the Mediterranean coast in the south run longitudinally to the geological and geomorphological trends, and low coastal or deltaic plains are not much seen along these coasts. However, the Aegean coast in the west runs transversely to the structural trends and the rivers occupying the tectonic depressions (grabens) have formed wide delta plains on the coastal parts of these depressions. In accordance with the coastal configuration, cultural interrelations between the coastal and interior regions have been relatively limited since the prehistoric times on the north and south of Turkey, while in the west the alluvial plains extending inland from the Aegean coastal plains has been more conducive to contact between different cultures. In this paper, the geomorphological characteristics of the coasts of Turkey are described in general, and coastal changes and their effects on the coastal land use especially in the late Holocene have been stressed. Tuzla and Klaros have been used as two examples of coastal change and geo-archaeological development on the Aegean coast.

1 *Introduction*

Turkey is surrounded by seas on three sides. The total length of the coastline is 8333 km. The shape of the country looks like a rectangle of about 1500 by 600 km, with its longer dimension in an east-west direction (Fig. 1).

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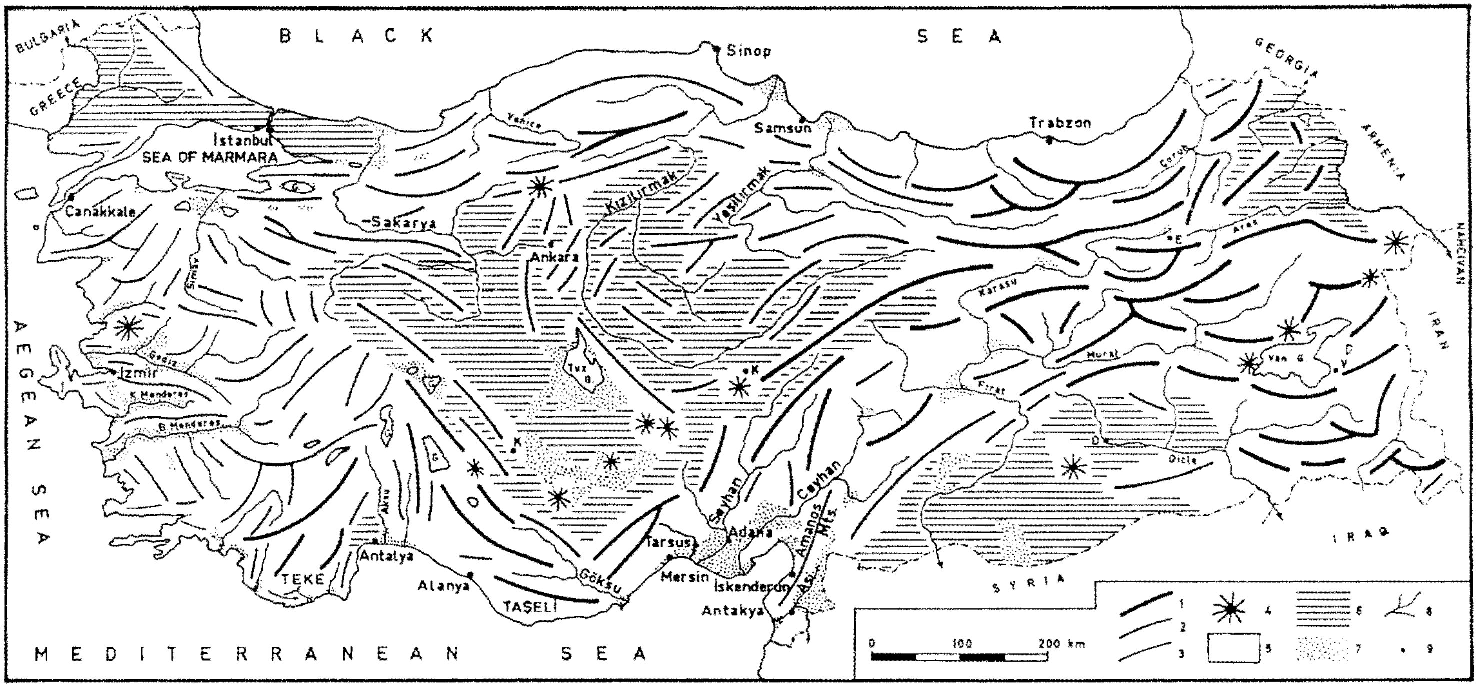


Fig. 1. Geomorphological outlines of Turkey and coastal configuration. 1) Mountain ridges higher than 2,000 m. 2) Mountain ridges 2,000–1,000 m high. 3) Mountain ridges lower than 1,000 m. 4) Volcanic mountains. 5) Rough, mountainous land (steep slopes generally). 6) Plateaus (low undulating land included in some places). 7) Main alluvial plains. 8) Rivers. 9) Cities. G: Lake (Göl, gölü).

The Black Sea coast in the north and the Mediterranean coast in the south run parallel to the structural trends and are not much indented. Therefore their lengths are each about 1700 km. On the contrary, the Aegean coast in the west extends transversally to the structural trends and is very indented. Although the direct distance is less, the actual coastline length is about 2800 km. The Sea of Marmara and the straits, Istanbul (Bosphorus) and Canakkale (Dardanelles), have a total coastline of 1200 km, and the islands about 1000 km. Because Turkey has such a long coastline, coastal studies must be given important consideration.

The geomorphological characteristics of the present day coastline of Turkey have been determined by the general geological and geographical characteristics of the country, eustatic sea-level changes, and alluvial development during the Holocene.

Turkey is located in the alpine orogenic belt. It is in the form of a huge block because the whole country has been raised by neotectonic movements after the mountain ranges were shaped between older plates. The average altitude is 1032 m. More than half of the approximately 800,000 km^2 total area of Turkey is above 1000 m. Broadly curved high mountain belts with peaks of over 3000 m run in an east-west direction along the northern and southern regions: the North Anatolian Mountains and Taurus Mountains, respectively. Their coasts are generally straight, high and steep. In the west on the other hand, there is a mosaic-like block structure between fault lines running in different directions. The most striking elements of the morphology are the east-west trending faults and associated faulted mountains (horsts) and long depressions (grabens) between them. Therefore, the coastline in the west is very indented (Fig. 1).

Turkey is a country which has a great variety of lithological units. Various kinds of landforms have appeared on units with different lithological-tectonic characteristics, and have been subjected to processes present during the various climatic conditions of the latest geological times. Thus, a wide variety of landform types can be seen along the coastlines. Marine dynamic effects, particularly the last Holocene sea-level rise and accompanying alluvial deposition and delta formation are other reasons for the variety of the coastal landforms.

Turkey lies roughly between latitudes 36° and 42° north and longitudes 26° and 45° east, and is located at the meeting of the Old World continents. In spite of its location far from the oceans and close to the arid subtropical regions, it has more humid climatic conditions than would otherwise be expected because of the Mediterranean Sea. Its high and massif shape also increases the variety of the climate.

Turkey is a country which has been heavily settled and used by man since prehistoric times due to its suitable environmental conditions related to its geographical location. However, high mountain ranges along the coastlines in the north and south caused different cultural developments in the interior, as opposed to the coastal regions. The coastal areas of Turkey have some remains of cave settlements which go back to Paleolithic times; of small coastal settlements whose number is seen to have increased during Neolithic times; and of big and magnificent harbour cities which were established in Classical times and extensively developed during the Hellenistic and Roman periods. Suitable physical conditions had an important effect on the continuous development of culture through the ages along the coastal area of Turkey. Although they have changed in the course of time, the climate and vegetation have always been within limits suitable for human life. At the same time, rapid geomorphological changes along the coastlines have affected the settlements, cultures, and type of land use since Neolithic times, which is when the relationship between man and his natural environment began to develop. Consequently, cooperation is necessary between the geomorphological and archaeological fields of research, especially along the Aegean and Mediterranean coastal areas of Turkey. During recent years, much research has been performed as successful examples of such cooperation. For example Troia, Ephesos, Miletos, Kaunos, Limyra are some of the major archaeological sites where geomorphological-environmental investigations have been continuing parallel to the archaeological research and excavation projects. Publications related to these investigations are in preparation yet.In this paper, the relation between the cultural development of various archaeological sites and changes in the coastline, and their effects on each other will be stressed, with some examples from the Aegean and Mediterranean coasts of Turkey. However, general characteristics of the Black Sea and Marmara coasts will be mentioned first for comparison.

2 *The Black Sea and the Sea of Marmara coasts of Turkey*

The Black Sea coast of Turkey runs along the foot of the North Anatolian Mountains in conformity with their wide curves (Fig. 1). There are no remarkable indentations or projections, or islands along this coast. The continental shelf is generally narrow and the sea quickly becomes deep. In the east there is a vertical range of about 6000 m over a very short distance, between mountains which rise to 4000 m, and the sea floor which is about 2000 m deep. The middle part of the coastline forms a wide curve toward the north. Three main projections of the Black Sea coast are situated along the eastern part of this curve. Two of them are the deltas of the Kizilirmak and Yesilirmak rivers. The third one in the west is the Sinop peninsula which consists of Tertiary formations. The North Anatolian Mountains descend toward the Sea of Marmara in the west and become an undulating plateau.

The Black Sea coast of Turkey is generally high and steep along the foot of the mountains. Northerly winds prevail. Thus, waves coming from the deep and open sea work vigorously on the coast. In addition, the lithology of the North Anatolian Mountains generally consists of weak detritic formations such as flysch and conglomerates. Therefore, landslides along the coast facilitate cliff retreat. Because the mountains run parallel to the coast, rivers have rather small catchment areas on the steep slopes. However, precipitation is high in this region (about 2500 mm in the east and more as altitude increases) and flow rates of the rivers are high. Therefore, alluvium carried by the rivers to the coast has a great deal of coarse sediments such as pebbles and boulders but nevertheless wide delta plains do not develop. The deltas of the Kizilirmak and Yesilirmak rivers are the exceptions. They are big rivers gathering water from wide inland basins and reach the sea through gorges in the middle part of the North Anatolian Mountains where the altitude is relatively low. They have formed great delta plains only because of the much greater quantity of alluvium which they transport. Other deltas create small coastal plains formed generally of coarser alluvium at the mouths of smaller rivers. A prominent delta plain has not formed at the mouth of the Sakarya river in the west, despite its wide catchment region behind the mountains. This river has formed only a sandy coastal strip rather than a delta projection because most of its alluvium has been deposited in the inland basins, and coastal dynamics preclude for delta formation (Fig. 1). Because of all these geomorphological characteristics, there are no wide coastal plains sufficient for intensive settlement and agriculture, nor are there any sheltered bays or coastal indentations which could be used as natural harbours (EROL 1988). Therefore archaeological remains of well developed ancient cities as seen on the Aegean and Mediterranean coast of Turkey are not found on the Black Sea coast.

The Sea of Marmara is a small inland sea which is connected to the Black Sea in the north and the Mediterranean Sea in the south by the straits known as the Bosphorus and the Dardanelles, respectively. It has been formed by ingression of sea water through a transversal structural depression in the North Anatolian Mountains. High and steep cliffy coastal features are dominant between the western extensions of the North Anatolian Mountains. The coastline is also generally cliffy in the western and southern coast of the Sea of Marmara, along the edge of a plateau. However, there are a number of large deltas formed on the shallow continental shelf by rivers coming from wide valleys between plateau ridges, especially on the south coast (Fig. 1).

The straits have great importance for the Black Sea and the Sea of Marmara. Connection of these inland seas with the open sea is only possible through these two natural gates. Therefore the straits have affected the coastal formation of the Black Sea and the Sea of Marmara by controlling the sea-level and water characteristics during the Holocene.

It is known that the Marmara and Black Seas were closed lake basins and that the straits were river valleys during the last glacial period, when the sea-level was lower than the present day because the deepest part of the Bosphorus is about 50 m and the Dardanelles 60 m. There is evidence that the level of Black Sea rose faster than the Mediterranean, and water exchange started from Black Sea towards the Sea of Marmara about 12,000 years B.P., and from the Mediterranean to the Marmara and Black Seas about 9500–7000 B.P. (STANLEY & BLANPIED 1980). Also, MERIC (1990) has used Bosphorus sediments to show that the Sea of Marmara became to be a marine basin about 7500 B.P. and attained marine characteristics about 6000 B.P. The coast of the Sea of Marmara resembles the Black Sea coast from the archaeological point of view. The remnants of some Neolithic settlements are found on the high and steep plateau edges along the coast. On the other hand, the absence of big ancient city remnants indicates that a pattern of coastal land use was dominant along the Marmara coast similar to that along the Black Sea. According to ÖZDOGAN (1990) and ARSEBÜK & ÖZBASARAN (1994) the Yarimburgaz cave to the west of Istanbul is the earliest settlement site of the region. The Fikirtepe culture to the east of Istanbul is dated at 7000 B.P. During this earliest known cultural period of the region, some nomadic communities lived in this area consuming a great deal of sea-food. During the following Chalcolithic period the number of settlements increased but interest in sea-food decreased. Agricultural activity became more important especially on the coastal plains in the south. From the time of Bronze Age, small settlements developed into cities with central organization (ÖZDOGAN 1990).

3 *The Aegean coast of Turkey*

The Aegean coast of Turkey is distinguished by its very indented shape and numerous islands. The reason for this characteristic is the faulted structure of the region. On the alpine mountain belt, when the Anatolian land-mass was uplifted by neotectonic movements, the area of the Aegean Sea was downfaulted, and the faults extending NE-SW and NW-SE delineated blocks which formed the zigzag shape of the coast. However, the east-west fault lines and horst-graben systems are more important for the formation of the Aegean coast of Anatolia. Some of the long grabens extend far inland. They have been traversed by rivers collecting surface waters from great areas and wide fluvial plains have formed on their floors (Fig. 2). Deltas and low coastal features have developed on the coastal parts of the plains. The Büyük Menderes, Küçük Menderes, Gediz and Bakirçay rivers are examples of this geomorphological model. On the other hand, some depressions remained as long bays because there were no rivers to fill them with alluvium. Edremit Bay in the north and Gökova bay in the south are examples of this type. Thus, the Aegean coast of Anatolia has a rich geomorphological variety.

One of the other important events which affected the formation of the Aegean coast of Anatolia is the Holocene transgression. Rapidly rising sea-level after the last glacial period emphasized the zigzag feature which already existed. Thus, intrusion of the sea toward the coastal embayments, grabens, and the mouths of rivers formed bays and estuaries of different sizes and shapes. Horizontal change in the coastline depended on the relation between the previous topographical inclination, the rate of sea-level rise and the volume of alluvium reaching the coast.

No evidence has so far been found that Holocene sea-levels on the Aegean coast of Anatolia were ever higher than at present (KAYAN 1988b). Submerged features along the high coasts and slopes drowned by alluvium along the edges of the delta plains are predominant. It might be thought that the reason for this submergence is a general tectonic subsidence of the Aegean coastal region. However, it is difficult to see how such a general movement of the same order could have taken place in this region which has a mosaic nature consisting of fault blocks and formed by recent tectonic movements.

Sedimentological and stratigraphical evidence obtained from borehole studies on some of the alluvial plains of the Aegean coast of Anatolia have been useful in illuminating this subject. The progress of the marine transgression, the period of marine sedimentation, deltaic and coastal sedimentation after the sea-level rise, and the period of flood plain sedimentation have been clearly separated by our borehole studies on the plains of the Troad in the north, Ephesos in the middle, and Datça in the south (KAYAN 1988a, 1988b, 1991). Dating of these sedimentological phases has been carried out using C14 and archaeological data. According to these data, the rapidly rising sea during the early Holocene intruded into the embayments of the topography along the coast. The

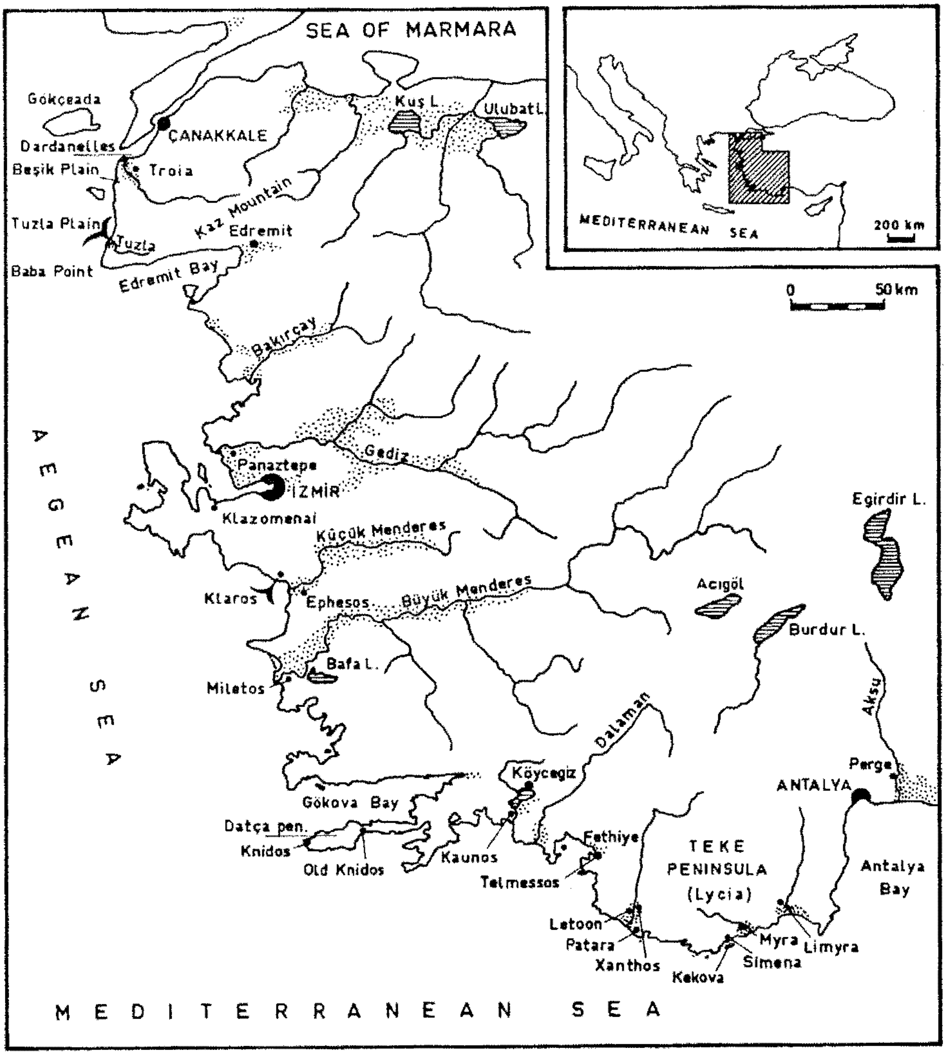


Fig. 2. Aegean and south-western coastal regions of Turkey. Only the locations mentioned in the text are shown. Dotted areas indicate main alluvial plains. Hatched areas are the major lakes.

sealevel rise stopped at its present level about 6000 B.P. (Fig. 3). During the following time, the sea-level was stable for a certain time and coastal landforms developed according to this sea-level. For example coastal barriers formed in places where there was enough alluvium. It can be interpreted that the sea-level fell a few meters (it seems generally about 2 m) in the period between 5000 and 3500 years B.P. This change caused a widening of the barriers and reduction or drying out of the lagoons behind them. In many places, archaeological findings of the Geometric and Archaic periods such as the

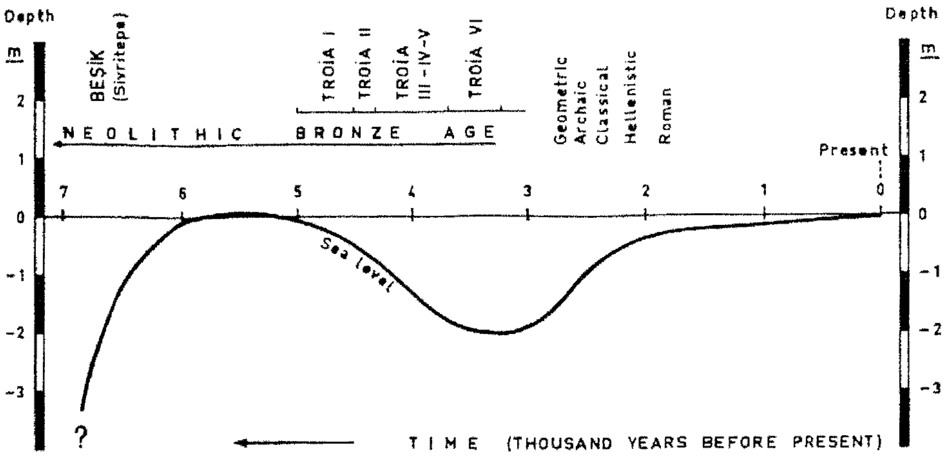


Fig. 3. Relative sea-level changes along the Aegean coast of Turkey during the last 7000 years (after KAYAN 1991). The curve is plotted based on the sedimentological and archaeological evidence, including C14 dates, obtained from the Besik plain to the west of Troia. The horizontal line represents the present sea-level with thousand year intervals. It is noticeable that the rising sea during the Holocene first reached its present level about 6000 years ago (B.P.), then descended about 2 m between 3500–3000 B.P., and finally approached its present level again around the time of Christ.

bases of walls are found about 1 m below the present sea-level. In the Roman period, it seems that the sea reached the present level once again. However, this rise was not caused by any new ingression on the coastline, because the size and speed of this second sea-level rise was much smaller. There is some sedimentological evidence which indicates that soil erosion was faster than before and the amount of alluvium reaching the mouths of the rivers increased during this period.

These relative sea-level changes in the late Holocene can be compared with the sea-level curve drawn by KELLETAT (1975) for the Eastern Mediterranean. His curve was also drawn based on coastal geomorphological and archaeological evidence, mostly from Italy and Greece. On this curve, sea-level is a little above the present about 5500–5000 years ago, then it falls to −5 m about 3500 B.P., and finally it rises again to the present level as an unsteady transgression. Small differences on the vertical scale and the manner of the last rise can be explained by regional variations.

The environmental changes related to sea-level change during the late Holocene are in accordance with the archaeological evidence. Most of the Neolithic settlements on the Aegean coast are found on low hills near coastal plains which have been filled with alluvium, such as the Troad in the north, Panaztepe and Klazomenai near Izmir, and the Ephesos area in the south. At these sites, large quantities of marine shells are found as middens. They indicate that the shallow bays and estuaries which formed during the first rising of the sea and the lagoons which formed later were important food reservoirs for the Neolithic people (KAYAN 1991). The reduction in size of the lagoons during the Bronze Age may have negatively affected this source. However, accelerated deltaic progradation following the falling sea-level during this period may be an important environmental reason for the cultural change tending towards more extensive agricultural development.

The archaeological importance of the sea-level changes derives from their effect on the horizontal shifting of the coastline. However relative sea-level change (by reasons of eustatic, tectonic or deltaic compaction) is only one of the reasons for the changing locality of the coastline. Another is alluvial deposition on the coast. A great deal of borehole evidence is necessary to interprete the relation between these two factors and the horizontal change of the coastline on the major delta plains. On the other hand, this relation can be described in a short time with a small number of boreholes on smaller coastal plains. The resulting model of geomorphological development in relation to sea-level changes can be applied to larger and more complex delta plains. Such an approach has been applied in the Troia and Ephesos research. These two examples are given below to explain how the paleogeography was constructed. One of them, to the south of Troia (present Biga peninsula), is the Tuzla coastal-delta plain of the Tuzla river (KAYAN 1994). The other, to the north of Ephesos, is Klaros in the Ahmetbeyli valley (KAYAN 1995) (Fig. 2). The Tuzla and Klaros plains were first investigated geomorphologically from the surface. The subsurface data of the old sedimentary environments was then obtained from borehole studies and used for the Holocene paleogeographical reconstructions.

4 *Example 1: Alluvial geomorphology of the Tuzla plain and Holocene coastal changes*

The Tuzla plain is situated about 10 km north of Baba Point on the west coast of the Biga peninsula, which is a large rectangular extension of Anatolia toward the west between the Sea of Marmara and the Aegean (Fig. 2). It is a delta-flood plain formed by the alluvial fill of the Tuzla river in a structural depression crossing a narrow coastal strip of land with low hills. The length of the plain is about 6 km and the coastline of the delta is 4 km. The name "Tuzla" indicates the hot, salty springs on the northeastern portion of the plain. Although salty spring water was worked for salt production in ancient times, today it is only used for thermal therapy. The structural units of the Biga peninsula are varied and constitute a heterogeneous mosaic. The base of the peninsula consists of crystalline rocks and granitic intrusions. Kaz Mountain (1774 m high) in the southeast, which is the peak of the peninsula, was formed on an uplifted part of this basement. Structural directions of the crystalline basement including the Mesozoic limestone and serpentine formations generally run NE – SW. The peninsula was an erosional upland during the Tertiary period. However, severe volcanism occurred along fault lines especially related to the tectonic break at the beginning of the Miocene. Thus, mostly andesitic lava formations covered wide areas and have an important place in the structure of the peninsula. In addition, two major sedimentary depressions were formed on the peninsula by neotectonic movements. One of them was a terrestrial inland basin, the other one was a marine basin which was an extension of a shallow gulf of the Paratethys basin in the north. High threshold areas between the basins eroded extensively and a wide erosional surface formed during the Late Miocene. This low

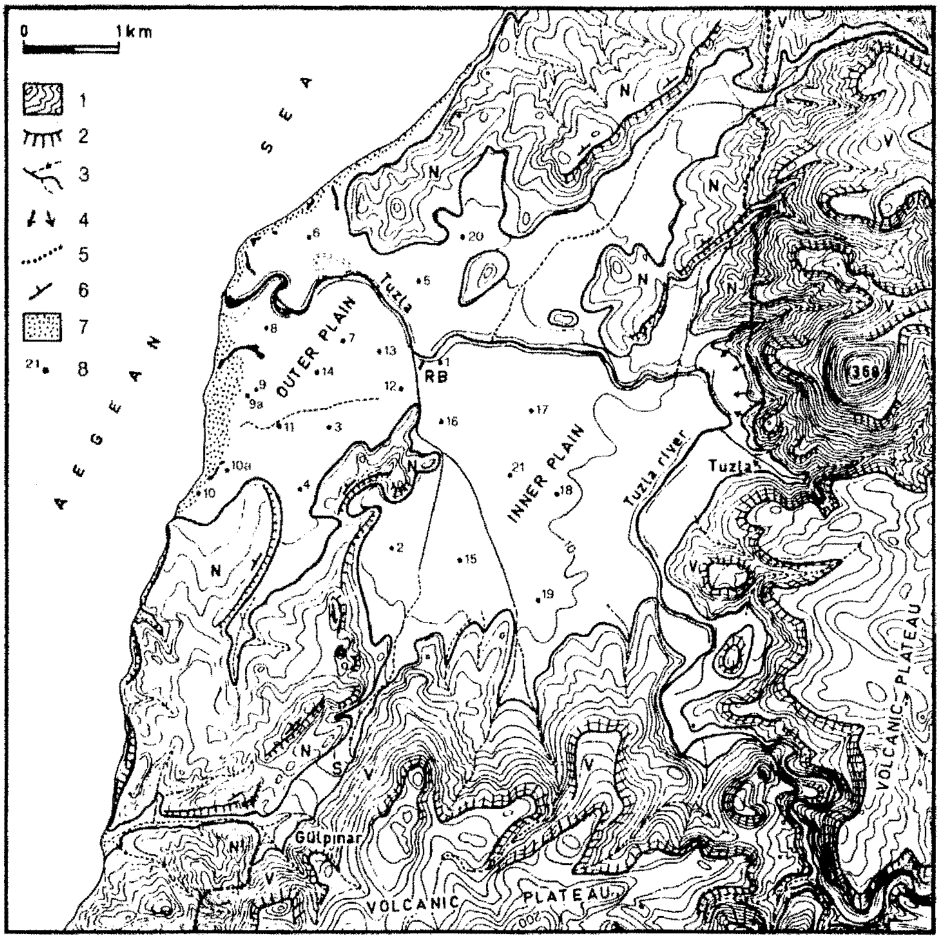


Fig. 4. Geological-geomorphological outlines of Tuzla plain and its environs. 1) Contour lines with 10 m interval, 2) escarpments, 3) rivers (dashed lines intermittent), 4) springs (hot, salty), 5) geological boundary, 6) dip and strike, 7) beach and coarse sandy dune cover, 8) borehole locations and numbers. V: Volcanic rocks (mostly andesitic, and Oligo-Miocene age), N: Neogene shallow marine sediments (limy and detritic). S: Temple to Apollo Smintheus, RB: Roman bridge.

undulating surface can be observed at about 200 m in the southwestern portion of the peninsula. Here, it is deeply dissected by Tuzla river and its tributaries. Therefore the southwestern part of the Biga peninsula is a wide plateau on the volcanic formation.

The Late Miocene shallow marine formation, which consists mostly of limy-detritic sediments, extends along the western coastal strip of the Biga peninsula. It is stratified on the volcanic baserock and was uplifted together with the base after the Miocene. Therefore, bedding is almost horizontal near the coastline and is bent up toward the inland volcanic base. These monoclinal strata constitute some cuesta ridges and hills, and the Tuzla plain was formed transversely between these ridges and hills. Therefore it has irregular indentations along its edges. A main hilly-ridge belt in the middle of the plain separates the plain into an inner and an outer or coastal plains (Fig. 4).

During the investigation of the alluvial geomorphology of the Tuzla plain, in addition to the present surface features, subsurface sedimentological characteristics were also examined. 21 hand auger boreholes were made to obtain data on the old sedimentary environments. The boreholes penetrated to a maximum of 10 m below the surface. Also some information was collected from the farmers who have private water wells on the plain. As a result, different subsurface sedimentary environments were determined and the progress of the alluvial geomorphology of the plain can be described as below.

During the Early Holocene when the sea-level was lower and the coastline was far from its present location, the inner and outer or coastal parts of the present Tuzla plain were covered with coarse sandy-gravelly alluvium in just the same way as a larger flood plain. According to the post-glacial transgression, the rising sea reached its present level in the Middle Holocene, and the coastline advanced to the west of the inner plain. The surface elevation of the inner plain was very close to the sea-level at that time and it was about 8 m below the present surface in the middle part (Fig. 5 and 6).

In this geographical environment, the Tuzla river deposited its alluvium mostly in the middle of the inner plain and the surface was elevated. However, the northeastern and southwestern parts of the plain were lower and swampy because little alluvium reached these distant parts from the main course of the river. On the other hand, the length of the Tuzla river in the plain became shorter because the coastline was farther inland. Therefore alluvial deposition increased and an elevated coastal barrier (or beach ridge) developed along the narrow part of the present plain. This barrier affected the water run-off from the inner plain and alluvium from the Tuzla river was deposited as muddy sediments. The transition surface between the coarse sandy lower alluvium and the muddy upper alluvium is recognizable in the borehole profiles (Figs. 5 and 6).

During the following periods, while the inner plain was being filled with muddy alluvium, new sandy deltas developed on the site of the present outer plain, first towards the south and later towards the north. In the course of time the northern delta formed a small projection toward the sea. This change in the alignment of the coastline caused erosion along the older delta coast in the south. Particularly fine material was transported north by a slow littoral drift to create a narrow strip of coastal plain in front of the older cliffs in the north. The cliffs farther south however are under severe wave erosion today.

It has not been possible to obtain any absolute dating, such as C14, for the alluvial formation of the Tuzla plain. However, there are some C14 dates and archaeological evidence to explain sea-level changes and paleo-geographical periods of the Besik (Besige) plain near Troia in the north, and it is possible to apply this evidence to the Tuzla plain because geomorphological formations of the Besik and Tuzla plains are parallel in time and order (KAYAN 1991, KORFMANN & KROMER 1993). Applying this similarity, it can be said that the rising sea first reached its present level about 6000 years ago and later extended inland on the previous flood plain of the Tuzla river as far as the western margin

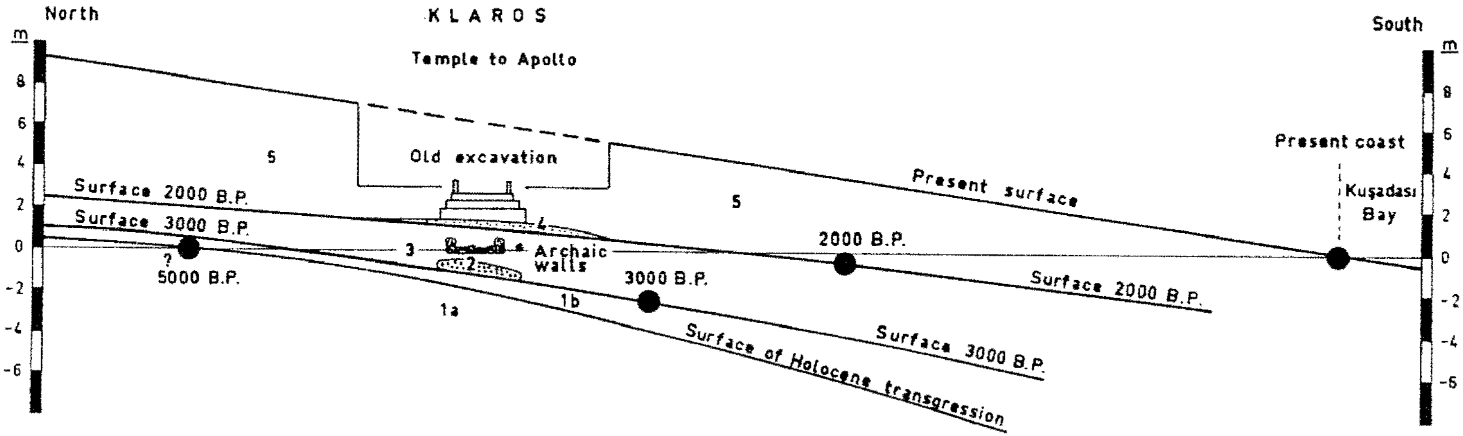


Fig. 5. Two cross-sections of the Tuzla plain along the west-east direction. The main parts of the plain, the inner and outer (coastal) parts, are separated by a narrower part between the low Neogene hilly-ridges (see Fig. 4). This narrow part affected the geomorphological development of the plain during the mid-Holocene by the formation of a wide coastal barrier (see Fig. 6). 1) Early Holocene coarse sandy alluvium, 2) mid-Holocene coastal barrier which formed following the first sea-level rise up to the present level in mid-Holocene, 3) lagoonal and coastal swamp deposits to the west of the inner plain, 4) mid-Holocene muddy alluvium of the inner plain, 5) first delta formation to the south of the outer plain, 6) lagoonal and backswamp deposits to the north of the outer plain, 7) last flood-plain deposits covering the entire plain, 8) coarse sandy coastal beach formations. c: Colluvium, b: Neogene bedrock. Double figures indicate the borehole numbers (see Fig. 4)

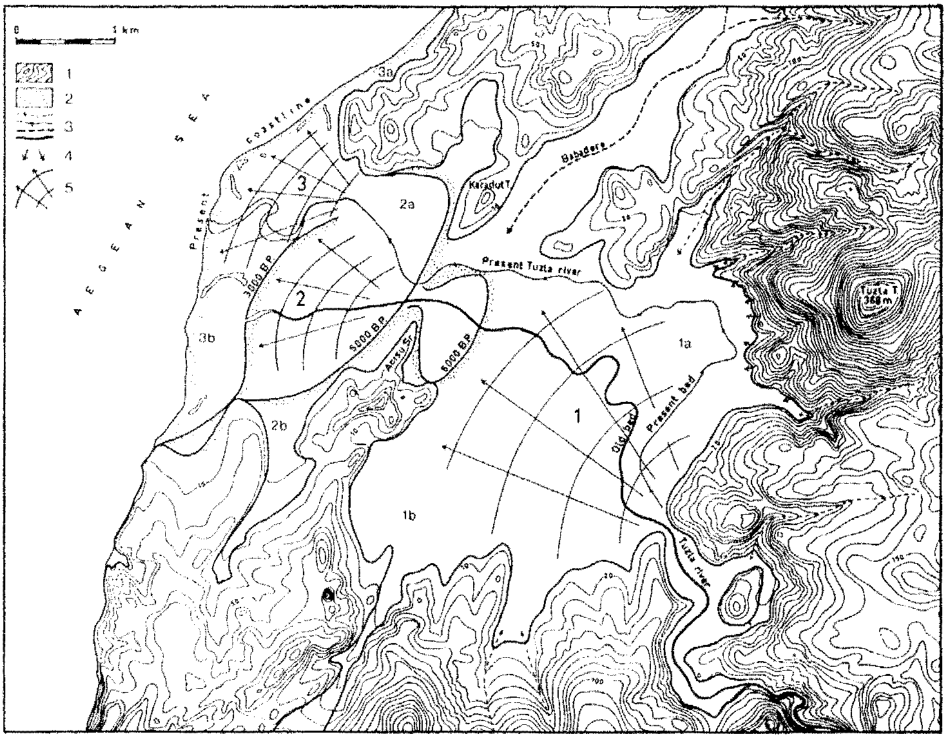


Fig. 6. Holocene geomorphological development of the Tuzla plain and coastline changes. 1) Contour lines with 10 m interval, 2) beaches, 3) rivers, 4) springs (hot, salty), 5) morpho-dynamic progression of river-mouth deposition in different periods. Numbers 1, 2, 3 indicate the main stages of the alluvial deposition, and a, b subdivisions of the main morphological units.

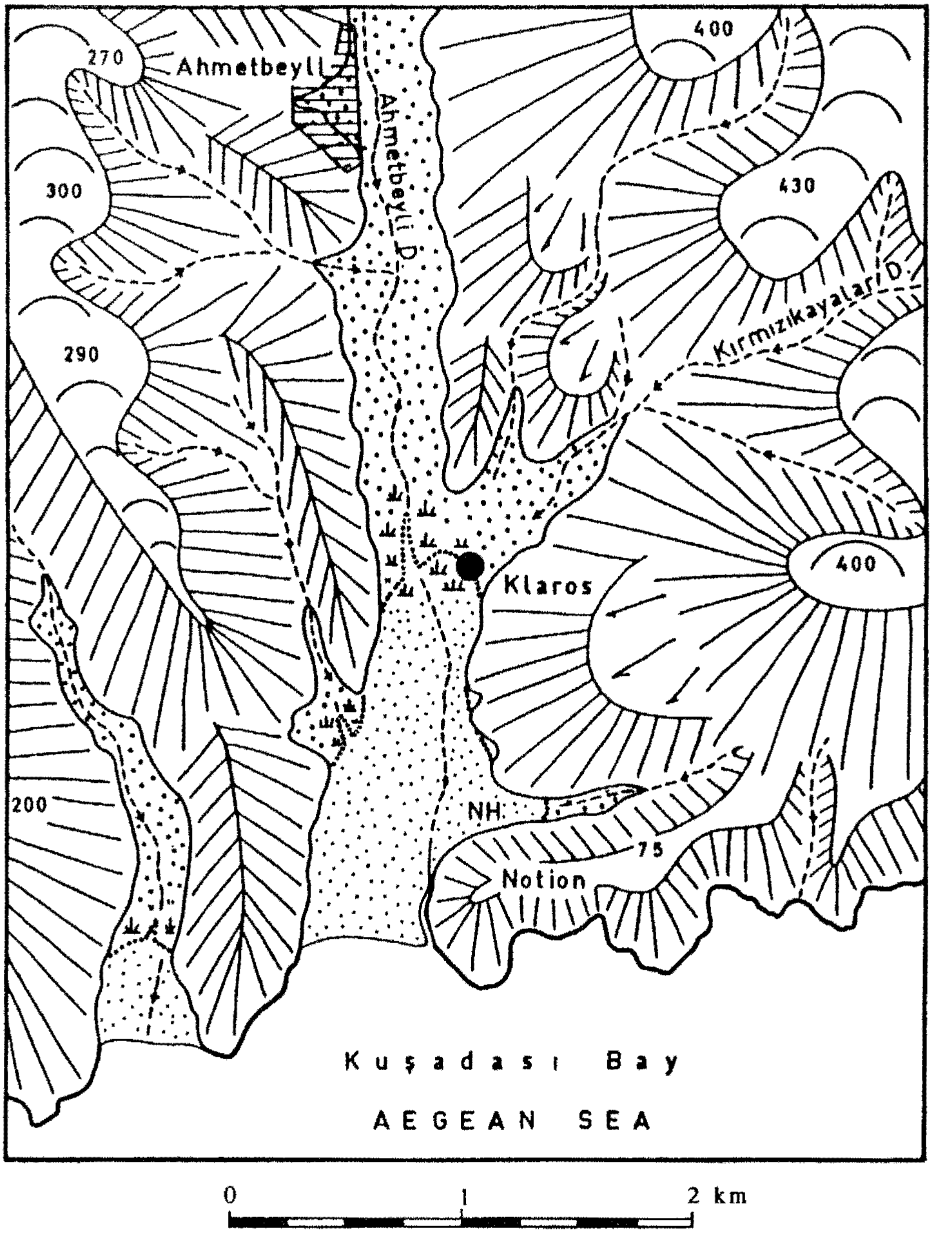
of the inner plain. On the other hand, according to this comparison, any important tectonic movement which may have occurred, such as tilting to the north or northwest as seen on previous (pre-Holocene) morphology, is not visible on the landforms of the last 6000 years. This conclusion is significant because the Biga peninsula is a structural block situated near the active North Anatolian Fault and its extensions toward the North Aegean Basin. The Tuzla plain is situated in a region settled since prehistoric ages. Convenient natural conditions and the strategic importance of the Canakkale Strait have made the region attractive through the ages and various cultures have fought and mixed there. Some settlements have been identified in the environs of the Tuzla plain dating back to the 3rd and 2nd millennium B.C. Liman tepe in the north and Besik tepe in the south (as distinct from the northern Besik area near Troia) are sites of pre-Hellenistic settlements, though there are no architectural remains visible today (Cook 1973). Their locations are on small low structural platforms extending toward the sea. It is supposed that the present day low coastal plains in both sides of the platforms were small coastal indentations used by sailors as natural shelters, or shallow lagoonal waters in these areas used for fishing, especially for shell-fish. Moreover, the most remarkable archaeological remains of the area are the Hellenistic temple to Apollo Smintheus at Gülpinar and the stone arches of a Roman bridge on the Tuzla plain (Fig. 4).

The present position of the Roman bridge on the narrow middle part of the plain gives some impression of the geomorphology and physical conditions of the plain during the Roman period. It is known that the bridge was constructed on an ancient road between Alexandria Troas to the north and the temple of Apollon Smintheus to the south. It is clear that the former beach ridge on the narrow part of the plain was used to cross the Tuzla plain and the bed of the Tuzla river at that time. This implies that the surface of the plain was muddy and swampy at least during the rainy seasons. This surface can also be recognized in the borehole profiles a few meters below the present surface between muddy alluvium and overlying fine sandy-silty final flood plain sediments (Fig. 5). The beach ridge which had formed during the earlier period was inland and not on the coast at that time, but it was still a little higher than the plain and its sandy material easily drained surface water. Therefore this high, dry threshold between the two parts of the plain was more suitable for the construction of the bridge. The feet of the bridge arches have been drowned by recent alluvium from the Tuzla river. The present course is to the north of the bridge, as the Tuzla river has since changed its course.

The Tuzla plain has been secluded and inactive during recent centuries except for saltworks. However, it has greatly improved in agriculture since the 1950's. Tomato production especially has increased because of its greater profitability. The necessary irrigation water is supplied from ground water. Over-drawing of ground water during recent years has caused serious problems. Penetration of salt water into the aquifers from springs in the inner plain and from the sea in the outer plain have made the ground water and soil salty. Therefore, it is necessary to grow other products which need less irrigation. A gorge in the Tuzla valley before it reaches the plain suggests that the water of the river can be captured and collected in a dam and used before it reaches the salty ground.

5 *Example 2: Geomorphological-geoarchaeological investigations on the Klaros excavation area*

Klaros is situated on the floor of the Ahmetbeyli valley about 1600 m from the present coastline (Figs. 2 and 7). This valley is a small gorge leading from the Cumaovasi plain in the north to the Kusadasi gulf in the south. It has been formed in a rift type structural depression by the Ahmetbeyli stream which has a rather small watershed but brings a great deal of alluvium from the detrital deposits in the south of Cumaovasi basin. It is clear that the sea formed a narrow estuarine bay in the lowest part of the valley during the Holocene transgression. Data obtained by archaeological excavations and sedimentological borehole studies show that the site of Klaros was covered by the shallow water of an estuarine bay before the first construction of the temple. It is obvious that the coastline in the bay shifted rapidly from north to south with the deposition of



Erosional surfaces and ridges

Shoulders

Steep slopes

Intermittent rivers

430 Elevations (m)

Coastline 3000-2500 B.P.

Alluvial plains 3000-2500 B.P.

Swamps 2500 B.P.

Alluvial plains formed during the last 2500 years

NH Probable harbour site of Notion

Fig. 7. Geomorphological outlines of the Klaros area.

alluvium from the Ahmetbeyli stream and its tributaries. However, the data acquired by this study is not enough to say how far the bay had extended inland during the sea-level rise of the Holocene.

According to the archaeological (DE LA GENIÈRE 1990, DELATTRE 1992) and sedimentological evidence, the site of the temple to Apollo at Klaros was covered by a coastal swamp close to the coastline at the beginning of the first millennium B.C. Coarse sandy beach sediments and a cemented section or beachrock layer in the beach sand just below the first structure of the temple (? Archaic) indicate that the sea-level was about 1–2 m lower than the present at that time. The sedimentological data show that a coastal swamp formed and extended gradually towards the south following the changes to the coastline caused by alluvial deposition. Another reason for the formation of this swampy environment was a karstic spring with a large supply of fresh water.

The earliest artefacts were found in the lowest levels of the swamp sediments just above the coastal sand and a beachrock formation. This level is about 0.5 m below the present mean sea-level. The findings especially related to fire (ashy mud, burned wood, etc.); food remains such as bones, shells, and sherds are plentiful. A piece of firewood from here has been dated by C14 to the 6th century B.C. which is in concordance with the dates of the archaeological findings. Thus, the coastal swamp was a place covered by reeds and other hygromorphic plants where man moved around, made fires and cooked food. It may be supposed that these people had settled just behind the swamp on the slightly higher and drier parts of the alluvial fan of the Kirmizikayalar stream (a tributary of the Ahmetbeyli stream), which is to the north and northeast of the site of Klaros (Fig. 7). The pre-Hellenistic (? Archaic) Klaros sacred structures may have been situated in such an environment. This place may also be the harbour of the ancient city of Kolophon to the north.

The coastline must have extended farther to the south of Klaros by the beginning of Hellenistic times. By that time the swamp had been filled and raised by the alluvium of the Ahmetbeyli stream and its tributaries, and formed a drier surface. This new surface was also filled and levelled artificially for the construction of the Hellenistic temple to Apollo and other sacred structures (Fig. 8). According to archaeological sources, the ancient city of Notion on the coast to the south is younger than the city of Kolophon to the north of present Ahmetbeyli village. It may be supposed that the area between Klaros and Notion was filled by alluvium during Hellenistic times. This made the road connection between the two sites more convenient. In addition, a small bay just to the north of Notion was probably the site of the inner harbour of Notion. It means that the coastline was situated a few hundred meters inland from its present position with an extension to the east and to the north of Notion. Many boreholes are necessary to prove this hypothesis. In the same region, related to the ancient city of Ephesos, detailed geo-archaeological investigations and borehole studies were made by KAYAN & KRAFT (not published yet) on the delta plain of the Küçük Menderes river which like the Ahmetbeyli stream flows into the Kusadasi gulf of the Aegean Sea. Preliminary results of the sedimentological borehole evidence show a geomorphological development parallel to that of Klaros. For instance, marine sediments were encountered a few meters below the present sea-level to the north of the temple of Artemis, on the present surface of the

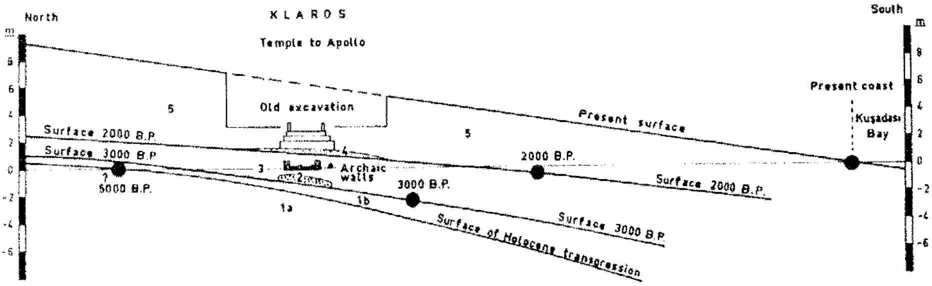


Fig. 8. Coastal changes and coastline positions at Klaros on a schematic cross-section along the bottom of the Ahmetbeyli valley. The horizontal scale is proportional. The distance between the temple and the present coast is about 1600 m. The vertical scale is over-exaggerated to emphasize the relation between the position of the temple and sea-level fluctuations. The vertical scale is precise at the site of the Temple. The horizontal position of the coastlines and related surfaces at given dates are conceptual. 1a) Fluvial fill of the valley before the Holocene transgression, 1b) Muddy sediments with marine shells, overlying the transgression surface, 2) Coarse sandy coastal sediments and beachrock layer, 3) Sediments of the coastal swamp, 4) Artificial fill over the swamp sediments to level the surface for the construction of the Hellenistic temple to Apollo, 5) Flood plain deposits. Heavy dots indicate coastline positions for given dates (B.P.: Before Present). * C14 date of a piece of wood, about 2500 B.P.

plain. At the temple site, the base of the first Archaic construction is also about 1 m below the present sea-level. It is understood that the base of the first walls stand directly on the coastal sediments. Although all of the C14 dates of the Ephesos samples are not ready to use and the final interpretations have not yet been done, there is a good concordance between Ephesos and Klaros on the coastal changes, and this development is quite similar to the Troia and Tuzla plains in the north Aegean along the bottom of the Ahmetbeyli valley. The horizontal scale is proportional. The distance between the temple and the present coast is about 1600 m. The vertical scale is over-exaggerated to emphasize the relation between the position of the temple and sea-level fluctuations. The vertical scale is precise at the site of the Temple. The horizontal position of the coastlines and related surfaces at given dates are conceptual.

On the Datça peninsula, which is situated at the southwest corner of the Anatolian peninsula between the Mediterranean and Aegean seas, a similar study was carried out at the site of the ancient city of Old Knidos (Fig. 2) (Kayan 1988a). Here also, some geomorphological and archaeological evidence indicates a similar development of sea-level changes and ancient use of the coastal strip. For instance, some beachrock layers extending about 2 m below the present shallow sea water were interpreted as evidence of a regressive period, and some remains of the base of stone walls extending 1 m below the present sea-level as proof of the last sea-level rise. As a result, it is understood that all of the Aegean coast of Anatolia has had a uniform geomorphological development during the Holocene epoch. The rising sea in the post-glacial period reached its present level about 6000 years ago and formed the coastline into a very indented shape by drowning all along the coast which already had a structurally zigzag shape. Neolithic settlements were established on the edges of the bays at that time in order to acquire sea-food from the shallow bays and lagoons. Later, the sea-level fell about 2 m during the Bronze age (between 5000 and 3500 B.P.). This event accelerated alluviation and receding of the coastline on the delta plains. Such an environmental change would have affected the development of agriculture. In the beginning of the first millennium B.C., the colonists who came to these coasts by sea used as natural harbours the bays and lagoons, which were not completely filled with alluvium at that time. Agricultural products obtained from the fertile plains behind the bays, especially olive oil and wine, became the most important elements of marine trade and resultant affluence. In the following period, during the first millennium B.C., the sea-level rose slowly again and reached its present position around the time of Christ (KAYAN 1988b). However, alluviation was probably faster than before because of human impact. Therefore, no clear coastal ingression occurred in connection with this small rise in sea-level. In addition, remains of Archaic and Classical building bases on the coast are to be found about 1 m below the present sea-level. In alluvial areas, remains from these periods are also found below the present sea-level under alluvial cover. Archaeological evidence shows that the sea has been around its present level since the Roman period; any fluctuations have been very small and impossible to distinguish.

6 *The Mediterranean Coast of Turkey*

The Mediterranean coast of Turkey runs parallel to the structural trends, as does the Black Sea coast in the north (Fig. 1). The coastline follows the high and steep southern slopes of the Taurus mountains, which consist of various geological formations. Although the Taurus mountains run west-east in general, they can be separated into major sections which are different from one another in shape and structure. These are, from west to east, Teke, Taseli and Amanos high mountainous regions. The Antalya and Mersin-Iskenderun bays are situated between them as wide structural embayments. The Teke region in the west is a high mountainous wide and massif peninsula. The mountain ranges with peaks of up to 3000 m generally run in a north-south direction. Between the ridges, there are two longitudinal depressions in the west and east in which two main rivers of the region occur. Therefore the southern coast of the Teke peninsula has a transversal feature. However, in the middle part of the southern coast, structural trends are in a west-east direction and the coastline exhibits also a Dalmatian type of submerged features. The coast on the west of the Teke peninsula is very indented but the coast facing the Antalya gulf in the east is relatively straight (Figs. 1 and 2).

Submerged high coastal features are dominant on the Teke peninsula. Steep rocky slopes plunge into the sea without any wave-cut cliff or even any well developed notches. This is evidence for the young morphology of the coast. The lithology of the mountainous area behind the coast mostly consists of carbonates and these cannot provide enough alluvium to fill the bays, but greater wave energy and littoral drift have formed large coastal barriers and lagoons in front of some embayments which are not seen on the Aegean coast in such a size.

The Teke peninsula is the area of ancient Lycia. Great embayments on the Lycian coast were very convenient harbour sites in ancient times. However they are mostly encircled by high and steep mountain slopes and the hinterland is not wide. Therefore the harbour cities which were established in these embayments developed mostly based on maritime trade. Kaunos, Telmessos, Patara and Simena are the examples of these ancient harbour cities (EROL 1991).

Kekova is an island on the southern coast of the Teke peninsula near Simena, one of the impressive Lycian cities and it is well-known for its submerged wall ruins extending right down into the sea. Although they give the impression that the land has subsided recently, the drowned position of the Lycian (starting 7th century B.C.) wall bases about 1 m deep implies that the relative sea-level change is not much different from that on the Aegean coast.

In the middle part of the Mediterranean coast, the Taurus mountains draw a wide arc towards the south (Fig. 1). The mountainous Taseli plateau rises behind the coast, up to 2000 m high at its peaks. The coast is again longitudinal structurally, and high and steep. The mountains mostly consist of carbonate rocks and alluvial deposition of rivers on the coast is not enough to form wide coastal plains. Therefore, instead of delta projections, even fairly large rivers have been able to form only relatively small coastal plains, merely straightening the coast. However, the Göksu delta is an exception in the east, because the river Göksu which drains a wide area between the mountain ranges has formed a delta projection on the coast.

The Antalya and Cukurova plains and their low coasts in the west and east of the Taseli plateau are situated behind the two wide bays. These embayments have formed at the junctions of the main structural parts of the Taurus mountains. The western part of the Antalya bay-head coast has been shaped along the edge of a wide travertine formation. Therefore the coast is steep, with cliffs about 40 m high, and the city is situated on the travertine platform which rises in steps up to 300 m high at the foot-slope of the high mountains about 30 km north. This wide travertine formation is produced by karstic spring waters which worked the carbonate formations of the Taurus mountains by karstic solution processes.

On the NW-SE extending eastern coast of the Antalya bay, alluvial plains cover wide areas among low hills and ridges of the Neogene formations along the foot of the high mountains. This low coastal strip becomes gradually narrower toward the southeast and high mountain slopes reach to the coast to the west of Alanya.

Cukurova in the east is the largest coastal delta plain of Turkey. There are two structural depressions here running in a NE-SW direction. The Adana depression in the west has been filled up with alluvium from the Seyhan and Ceyhan rivers and the Cukurova plain has been formed at the bottom. However, the Iskenderun depression in the east does not have such big rivers. Therefore, it has not been filled with alluvium and is still a bay today. However the Ceyhan river has recently changed its mouth to the Iskenderun bay and has started to construct a new delta in the southwest of this bay (Fig.1). The eastern coast of the Iskenderun bay is a narrow piedmont coast along the mountain ridge, which runs NE – SW. In the south, the delta plain of the Asi river is situated in another structural depression. It has not been able to form a delta extension, but the delta coast has only straightened out the embayment. The coastline farther south runs in a north-south direction into Syria.

From the geo-archaeological point of view, many of the important ancient cities on the Mediterranean coast of Turkey are found on the coastal delta plains of relatively big rivers. However, they were not established on the coast, but instead they were situated on a river and a little inland. Since the coastline is mostly straight along the alluvial coasts, the inner parts of the river mouths were used as sheltered natural harbours (EROL 1988, 1991). Letoon, Myra, Limyra, Perge, Aspendos and Tarsus are examples of this locational characteristic (Figs. 1 and 2).

Along the eastern part of the Antalya bay of the Mediterranean coast some raised coastal landforms are seen. These are different from features on the western part and the Aegean coast. Pleistocene coastal terraces can be found in some places even up to 20–30 m above present sea-level. In addition, there are some biogenic features on the rocky coasts which are interesting formations indicating the Holocene coastal development. These are bio-erosional notches and benches which are formed by gastropods such as *Patella* and *Littorina*, and rims just the outer edges of the notches, formed by calcareous algae (*Neogoniolithon notarisii*) and vermetids (*Dendropoma petraeum*). Notches and rims are found almost everywhere at the present sea-level along these coasts, where the tide range is only about 10–20 cm, but there are also uplifted notches and rims in some places. In recent years, some of these to the west of Alanya and near the Asi delta in the east have been examined and dated by C14. Two platforms 1.3 and 0.5 m above the present sea-level were observed at Figla Point and near coasts to the west of Alanya (KAYAN, KELLETAT & VENZKE 1985). On Figla Point, stromatolithic calcareous algae at a 0.5 m high platform were dated by C14 and it has found that they had lived in the period from 2700 to 1550 years ago (KELLETAT & KAYAN 1983). On the rocky coast near the Asi delta the coastline trace at 2.5–3.0 is dated by organisms which lived in the period from 5000 to 2500 years ago, and at 0.7–0.8 m from 3000 to 1400 years ago (PIRAZZOLI et al. 1991).

This evidence indicates that two sudden tectonic uplifts affected these coasts about 2500 B.P. and 1400 B.P. The second one coincides with a regional earthquake which is known from historical records to have happened in July A.D. 526. Examination of how this tectonic event affected the ancient Seleucia Pieria harbour on the Asi delta coast have shown that the last sudden tectonic uplift accelerated the alluvial fill of the harbour which was already silting up like the ancient Aegean harbours (EROL 1992).

The scale of recent tectonic uplifts increases toward the east along the east of the Antalya bay of the Mediterranean coast of Turkey. These tectonic movements have not affected the western part of the Mediterranean coast and the Aegean coast. On the contrary, there is a general submergence in the west because of a regional tectonic subsidence or eustatic rise. Therefore it can be stated that the two regions which have different relative sea-level changes are separated from one another by an axis or a hinge on the Antalya bay which runs in a north-south direction. The western part was submerged, and the eastern uplifted by tilting toward the Antalya bay in the west.

7 *Summary and results*

The structural characteristics of Turkey have had a greater effect on the pre-Holocene geomorphological formation of the coasts. Turkey as a whole is a high massif country. Therefore, high steep cliffy coasts run longitudinally in an east-west direction along the northern and southern mountain ranges. Wide alluvial plains and deltas have not developed on these coasts. On the contrary, rivers which settled in the long depressions running in an east-west direction in the west have formed delta plains on the coast. Through the Holocene, post-glacial sea-level rise has had a major effect on the geomorphological development of the coasts, and coastal alluvial plains have formed following the changing coastline. Different coastal parts of Turkey with different characteristics have affected cultural development in many ways since prehistoric times. The Black Sea and Mediterranean coasts with their high steep mountain slopes had a negative effect on the contact between different cultures on the sea coast and in the interior. However, on the Aegean coastal region in the west, the transverse morphology of the coastline facilitated cultural relations between different communities. In general, only small trading harbours were established on the narrow coastal strip of the Black Sea and Mediterranean coasts, while wealthy and magnificent harbour cities developed on the wide plains of the Aegean and Mediterranean coasts. Alluvial deposition in their harbours in the late Holocene was a matter of great importance.

A general submergence is one of the important characteristics of the Aegean and western Mediterranean coasts of Turkey. The rising sea during the post-glacial period reached its present level about 6000 years ago, but in the period between 5000 to 3500 years B.P. it fell by about 2 m. Then it rose again to its present level around the time of Christ. All geomorphological, sedimentological, and archaeological evidence shows that this sea-level change is almost uniform in scale and order along this long coastal strip. It is difficult to imagine this uniformity, without any tectonic distortion, in such a region formed by neotectonic movements, but there is no definite evidence of any tectonic distortion or separate block tilting during the late Holocene.

Coastal indentations especially along the Aegean coast were longer during the first sea-level maximum 6000 years ago because the present volume of alluvium had not yet been accumulated at that time. The coasts were convenient places to settle for the Neolithic people, and the shallow waters of bays and lagoons were rich sea-food reservoirs. The small scale of sea-level fall during the Bronze Age accelerated deltaic progradation and facilitated agricultural development. However, the last sea-level rise has not given rise to any coastal encroachment on the alluvial plains, because the vertical scale and speed of this change has been small and alluvial deposition has easily balanced the ingression. On the other hand, there are some uplifted features along the eastern part of the Mediterranean coast of Turkey. Some of these are coastal terraces which seem to be of Pleistocene age, but C14 dates of some bio-erosional notches and bio-constructive rims show that two major uplifts happened in the late Holocene: the first one about 2500 years ago was about 2 m, and the second one 1400 years ago was 0.8 m on average. The scale of uplifting increases toward the east. This may mean that the uplifting movement tilted the eastern part of the Mediterranean coastal region of Turkey toward the Antalya bay.

References

Arsebük, G. & M. Özbasaran (1994): Yarimburgaz magaralari Pleistosen'den bir kesit. – XI. Türk Tarih Kongresi. 17–27. Türk Tarih Kurumu. Ankara.

Cook, J.M. (1973): The Troad. An archaeological and topographical study. – Oxford University Press, London.

Delattre, L. (1992). Autel D'Apollon, Le sondage 1a. – Cahiers de Claros **1**: 19–50. Contributions réunies par Juliette de La Genière. Éditions Recherche sur les Civilisations. A.D.P.F. Décrets Hellénistiques, Paris.

Erinç, S. (1993): Türkiye fiziki cografyasinin ana çizgileri. – Bulletin. Istanbul Univ. Insti. Mar. Sci. Geogr. **10**: 1–10, Istanbul.

Erol, O. (1988): Turkey. – In: Walker, H.J. (Ed.): Artificial structures and shorelines. – 241–252, Kluwer Acad. Publishers.

– (1991): Türkiye kiyilarindaki terkedilmis tarihi limanlar ve bir çevre sorunu olarak kiyi çizgisi degismelerinin önemi [Abstract: Abandoned historical harbours on Turkish coastline and the impacts of coastal changes as an environmental problem]. – Bull. Istanbul Univ. Insti. Mar. Sci. and Geogr. **8**: 1–44, Istanbul

– (1992): Seleucia Pieria: An ancient harbour submitted to two successive uplifts. – Internat. J. Naut. Archaeol. **21**, 4: 317–327.

Flemming, N.C. (1978): Holocene eustatic changes and coastal implications for tectonics in the northeast Mediterranean: implications for models of crustal consumption. – Phil. Transact. Roy. Soc. London **289** (1362): 405–458, The Royal Society, London.

De la Geniere, J. (1990): Le sanctuaire d'Apollon à Claros; Nouvelles découvertes. – Revue des Études Grecques. CIII, 490–491: 95–110, Paris.

Kayan, I., D. Kelletat & J.-F. Venzke (1985): Küstenmorphologie der Region zwischen Karaburun und Figlaburun, westlich Alanya, Türkei. – Beiträge zur Geomorphologie des Vorderen Orients. Beihefte zum Tübinger Atlas des Vorderen Orients, Reihe A (Naturwissenschaften) **9**: 17–70. Dr. Ludwig Reichert Verlag, Wiesbaden.

Kayan, I. (1988a): Datça yarimadasinda Eski Knidos yerlesmesini etkileyen dogal çevre özellikleri. – Cografya Arastirmalari Dergisi **11**: 51–70, Ankara Üniversitesi Dil ve Tarih Cografya Fakültesi, Ankara.

– (1988b): Late Holocene sea-level changes on the Western Anatolian coast. – Palaeogeogr., Palaeoclimat., Palaeoecol. **68**, 2–4: 205–218, Special Issue: Quaternary Coastal Changes. Ed. by Pirazzoli, P.A. & D.B., Scott (A selection of papers presented at the IGCP-200 meetings). – Elsevier Science Publishers B.V., Amsterdam.

– (1991): Holocene geomorphic evolution of the Besik plain and changing environment of ancient man. – Studia Troica **1**: 79–92, Verlag Philipp von Zabern, Mainz am Rhein.

– (1994): Tuzla ovasinin (Ayvacik- Çanakkale) alüvyal jeomorfolojisi ve Holosen'deki kiyi çizgisi degismeleri [Summary: Alluvial geomorphology of the Tuzla plain and Holocene coastal changes]. – Ege Üniversitesi Rektörlügü Arastirma Fonu Proje No: Edf. 1988–027, 74 pp, Izmir. (Unpubl. report)

– (1995): Klaros kazi alaninda jeomorfolojik-jeoarkeolojik arastirmalar [Summary: Geomorphological-geoarchaeological investigations on the Klaros excavation area]. – Aegean Geogr. J. **8**: 1–26, Ege University, Izmir. (In print)

Kelletat, D. (1975): Eine eustatische Kurve für das jüngere Holozän, konstruiert nach Zeugnissen früherer Meeresspiegelstände im östlichen Mittelmeergebiet [An eustatic curve for the Younger Holocene, constructed from evidence of former sea-levels in the Eastern Mediterranean]. – N. Jb. Geol. Paläont. Mh. **1975** (6): 360–374, Stuttgart.

Kelletat, D. & I. Kayan (1983): Alanya batisindaki kiyilarda ilk C14 tarihlendirmelerinin isiginda geç Holosen tektonik hareketleri. – Türkiye Jeoloji Kurumu Bülteni **26**: 83–87, Ankara.

KORFMANN, M. & B. KROMER (1993): Demircihüyük, Besik-Tepe, Troia Eine Zwischenbilanz zur Chronologie dreier Orte in Westanatolien. – Studia Troica **3**: 135–171, Verlag Philipp von Zabern, Mainz am Rhein.

MERIC, E. (1990): Istanbul Bogazi Güneyi ve Haliç'in geç Kuvaterner (Holosen) dip tortullari [Late Quaternary (Holocene) bottom sediments of the southern Bosphorus and Golden Horn]. – Istanbul Teknik Üniversitesi Vakfi, Istanbul.

ÖZDOGAN, M. (1990): Tarih öncesi dönemde Marmara Bölgesi. – In: MERIC, E. (Ed.): Istanbul Bogazi Güneyi ve Haliç'in geç Kuvaterner (Holosen) dip tortullari [Late Quaternary (Holocene) bottom sediments of the southern Bosphorus and Golden Horn]. – 107–111. Istanbul Teknik Üniversitesi Vakfi, Istanbul.

PIRAZZOLI, P.A., J. LABOREL, J.F. SALIEGE, O. EROL, I. KAYAN & A. PERSON (1991): Holocene raised shorelines on the Hatay coasts (Turkey): Palaeoecological and tectonic implications. – Marine Geology **96**: 295–311, Elsevier Science Publishers B.V., Amsterdam.

STANLEY D.J. & C. BLANPIED (1980): Late Quaternary water exchange between the eastern Mediterranean and the Black Sea. – Nature **285**: 537–541.

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