MATER, B –TUROĞLU, H. 2009. "Outlines of the Holocene Geomorphology of Anatolia". *Prehistoric Economies of Anatolia: Subsistence Strategies and Exchange*. Workshop at the Austrian Academy of Sciences, 13–14.11.2009, Vienna.

Outlines of the Holocene Geomorphology of Anatolia

Baris Mater, Hüseyin Turoğlu

Abstract

During the Holocene (10,000 yr BC to present), which corresponds also with the prehistoric periods, rapid geomorphological changes occured in Anatolia. Despite representing an interglacial period, climate changes or changes caused by oscillations in lakes, rivers and in seas led to significant changes in the environment and thus societies.
Spatial changes are documented for several lakes in Anatolia such as the Salt Lake (Tuz Gölü), the former Konya Lake, the Akşehir Eber Lakes and others. The large Anatolian streams (Tigris, Euphrates, Kizilirmak, Yesilirmak) have attracted settlers and agriculture, though occasional floodings and have caused disasters. The deposits of the Kizilirmak, the Yesilirmak, the Göksu, the Seyhan and the Ceyhan rivers formed large deltas along the Anatolian coast. The Gediz, the Kücük and the Büyük Menderes rivers saw rapid aluvial changes on the coasts and the plains in their hinterlands. Climate changes during the Holocene have led to sea level changes. Thus, the Anatolian coastal marine terrace formed, and provided together with a number of terraced fields, new space for settling. Tectonic movements have played a crucial role in shaping the rich Anatolian landscape until recently.
The geomorphological features and changes were fundamental in determining the living conditions, subsistence strategies and welfare levels of the inhabitants of the Anatolian peninsula.

Introduction

Anatolia is a peninsula roughly in the shape of a rectangle which lies between 26 and 45 East meridians and 36-42 North parallels. It acts as a natural bridge between Asia and Europe (Fig. 1). Its surface area is approximately 780.000 kilometer squares; its coastal length approximately 8350km; and its average height 1132 meters. ¼ of its total area is between 500-1000m level and almost half of it appears between 1000-2000m of elevation step. The remaining ¼ is between 2000 - 4000m of elevation. The country is a land of rugged terrain which is significantly rich in terms of surface form variety. The drainage and biogeographic characteristics have adapted to this rich surface variety. Due to these geographical properties, Anatolia has always been a favorable settlement since the beginning of humanity. The most important proofs to this are the settlements of several prehistoric and historical civilizations and rich archeological findings.



Fig. 1: Location map of Anatolia (Google Earth-2009).

The geographical, especially geomorphologic character of Anatolia has been a significant reason for every phase of human history to choose this place as settlement. The main focus of this study is the fundamentals of geomorphologic characteristics of Anatolia in the Holocene Era. This geomorphologic character has always been in constant change and development with both tectonic and volcanic activities and changes in climatic qualities. Anatolia has continued this characteristic during the Holocene as well. The indicated evolvements sometimes led to the occurrence of new life for Neolitic and later settlements; sometimes resulted in disasters that brought devastation or migration. Therefore, the importance of the geomorphologic character of Anatolia within the Holocene is remarkable in terms of history of humanity. The topic to be outlined has been enriched by typical examples. However, fundamentals have been emphasized rather than details since the content is too broad.

The causes on the changing of geomorphologic environment

The rapid climatic changes that took place in a time span of 11.500 years back from today and their direct and indirect impacts, the activities of surface drainage, tectonic movements and volcanic activities are the basic geographic factors that determine the fundamentals of Holocene geomorphology of Anatolia.

Although there are 6 significant climatic cycles which show a fast intercalation of cold polar and arid tropical climactic conditions (9000–8000, 6000–5000, 4200–3800, 3500–2500, 1200–1000, and 600–150 years BP), the Holocene (11,500 cal yr BP to the present) represents generally interglacial climatic conditions. It has been accepted that from the beginning of the Holocene, the climatic conditions of Anatolia have explicitly changed and the present climatic conditions have started to occur. In the period of 9000–6000 years BP, hot climatic conditions had an influence in Anatolia in general. The melting of glaciers due to humid and warm-hot climatic conditions resulted in a rise of +2m from -40m in sea level compared to the existing level (Flandrian transgression). This hot period has been determined by names such as "Climatic Optimum, Holocene Optimum, and Holocene Thermal Maximum". Although this period was a hot period in general, in some time spans such as 8200–8100 years BP, cold conditions were effective. The periods of 6000–5000 and 3500–

2500 years BP passed under the dominance of cold climatic conditions. It is accepted that there was a second change in climatic conditions and "The Iron Era" was a cool period. The periods of 4200–3800 and 1200–1000 years BP are considered as hot periods. During the period of 4200–3800 years BP, temperatures increased by 2-3ºC more than the existing level. The period of 1200–1000 years BP has been titled as the second "Climatic Optimum" or "Medieval Warm Period" by some researchers. In this period, the withdrawal of the glaciers at high latitudes by melting and the settlement of the Normans to Iceland and Greenland have been identified by research. The period of 600–150 years BP, however, was the last cold period belonging to pre-history and has been identified as Little Ice Age. At high latitudes, the cold climatic conditions erased the necessary circumstances for human life, leading the emigration of settlements to low latitudes. Afterwards, a new hot era when temperatures gradually increased took place. The end of the 19th century and the 20th century is a period when hot climatic conditions dominated again (ATALAY 1998, ATALAY 2005, ERİNÇ 1979, EROL 1979-a, DAVIS at al 2003, HOUGHTON vd. 2001, KAZANCI 2005, MAYEWSKI et al 2004, STAGER and MAYEWSKI 1997).

In the formation of Anatolia's existing geomorphologic character, the young tectonic movements had a deterministic and directive role. These tectonic movements are still effective today even though they started at the end of Miocene. Therefore, tectonic movements and their impacts are seen in the Holocene as well. These movements are transformed faults (Within the North Anatolian Fault Zone and East Anatolian Fault Zone) or normal faults (West and mid-west Anatolian Fault Zone). The traces of the earthquakes that these faults caused can be seen both in natural surroundings and on manmade structures. Due to this, cities that moved place, rivers that changed their creek bed or topographic dislocations are the significant results of tectonic movements occurred within the Holocene. From the Neolitic era when agriculture began to the present, the places chosen as settlement have usually been tectonically active. Indeed, these places both have an arable land structure and are accessible for irrigation. This natural attraction has driven human beings from the start to these tectonically active areas for settlement. Tectonic mobility has always been observed all through Anatolia in every period of history.

The volcanic centers in western Anatolia, especially in Kula and its surroundings; in central Anatolia in the Argaeus mountain; volcanic activities in Eastern Anatolia in Nemrut, Süphan, Tendürek and Agri (Ararat) Mountains and in Southeast Anatolia in the Karacadağ basic volcanism have all continued their activeness within the Holocene. Volcanic activities have caused significant changes on the geomorphology of their surroundings and drainage system by spreading lava, volcanic dust and piroclastic materials. The Anatolian Holocene volcanism occurred in a basic character in general. Therefore, basalt lavas that keep their liquidity for a long time have spread to a wide area under the control of natural slope conditions as seen in the basalt nozzles in Karacadağ and Kula regions in Southeastern Anatolia. Basalt lavas have usually caused the deterioration of the existing drainage systems by using drainage channels to flow and spread as seen in the Gediz Valley.

Coastal zone

The changes in sea level within the Holocene have played a major role in the occurrence of delta development and flood plain problems on the coast and its immediate surroundings. Since the Holocene was a hot period, due to the melting of glaciers in especially the climactic optimum period, the 2-3m rise in sea level caused the sea water to flow into hinterland for kilometers and therefore the submerging of the area especially in bottom coastal regions. The decrease of sea level, terrace systems, deltas and coastal plain developments are other

geomorphologic changes that took place on the coastal areas in the Holocene. The developments, especially in the Western Anatolia coast and in the deltas of major rivers that flow into the Black Sea and the Mediterranean, have caused a displacement of Neolitic and other antique settlements to translocate from time to time (ATALAY 1998, ATALAY 2005, BENER 1967, ERİNÇ 1979, EROL 1963, EROL 1981, EROL 1983, KAYAN 1996-a, KAYAN 1988, KRAFT et al 1980).

The coast of Western Anatolia attracts attention with its rivers that are located in the rift zone through the east-west direction, sinuous coast lines and the deltas that move fast by being filled with alluviums carried by these rivers. This geomorphology has always been preferable by settlements since the Neolitic Era besides showing a fast metamorphosis within the Holocene. The Karamenderes (Skamander) River and plains of Gediz, Kücük Menderes, and Büyük Menderes show an interconnected development with the continuation, and historical and local preferences of archeological settlements together with the Holocene geomorphologic development.

The Karamenderes (Skamander) River has moved the coast line of its delta plain by approximately 4 km during a 3000-year's time. In the early Holocene, sea transgression is seen as an important phase in delta development. Marine sediment stratigraphy which is supplied by the drillings, have done in the delta and flood plains is accepted as the proof of this transgression. Alluvial and colluvial sedimentation form the latter phases of flood plain development (Fig. 2). The archeological findings within the vertical section of the delta, marine shells, sand, and river sediments sometimes appear consecutively, sometimes interlocked. The results of drilling applied to the flood plain of the Karamenderes (Skamander) River in the southeast of the prehistoric town of Troia approve the sea transgression and thick sea sediments. The marital shells and sediment samples show 7000-5000 years BP but no archeological findings have been gathered inside these sediments. In the drillings carried out in the further west, archeological findings such as food remains and pieces of coal have been found. The dates of these findings show that the coast line of the Middle Holocene was 13m below the surface (ERİNÇ 1979, KAYAN 1996-a, KAYAN 1996-b, KAYAN 1997, KAYAN 1988, KRAFT et al 1980).

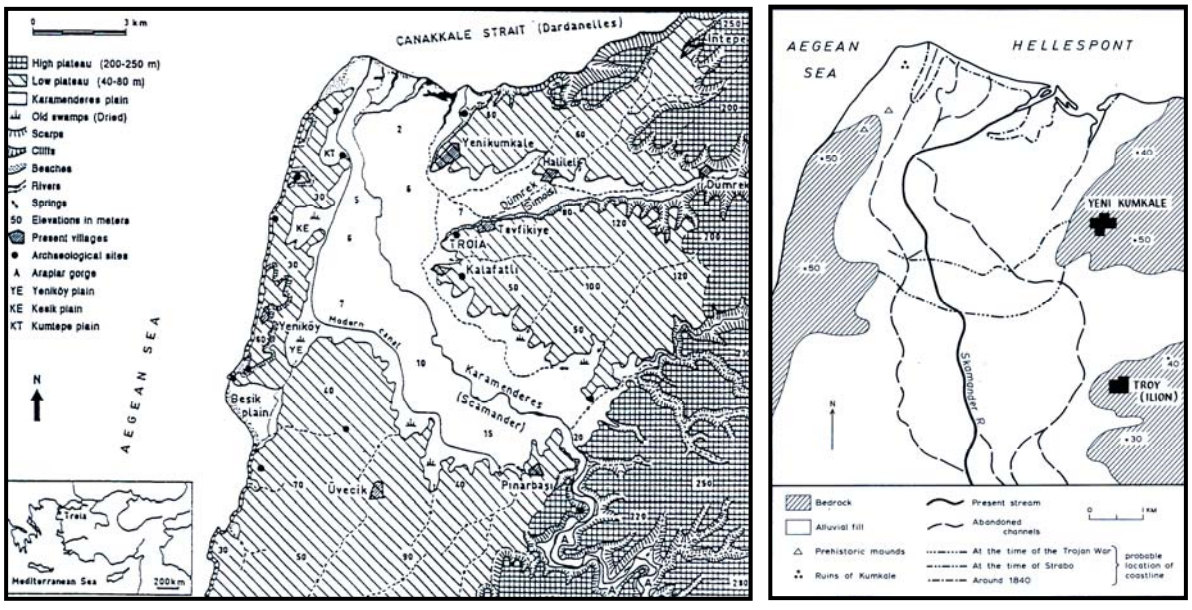


Fig. 2: Geomorphological outlines of the Karamenderes (Skamander) delta-flood plain and shoreline changing (ERİNÇ 1979, KAYAN 1996).

The rivers of Gediz, Kücük Menderes and Büyük Menderes are situated inside the tectonic grabens which flow into the Aegean Sea and show an approximate parallelism to one another (Fig. 3). The activities of each three rivers and caused their geomorphologic changes show parallelism. Besides the similarities between the Holocene alluvial geomorphologies inside the grabens and geomorphologic developments of the delta-coast plain, they show the same characteristics in terms of original factors.

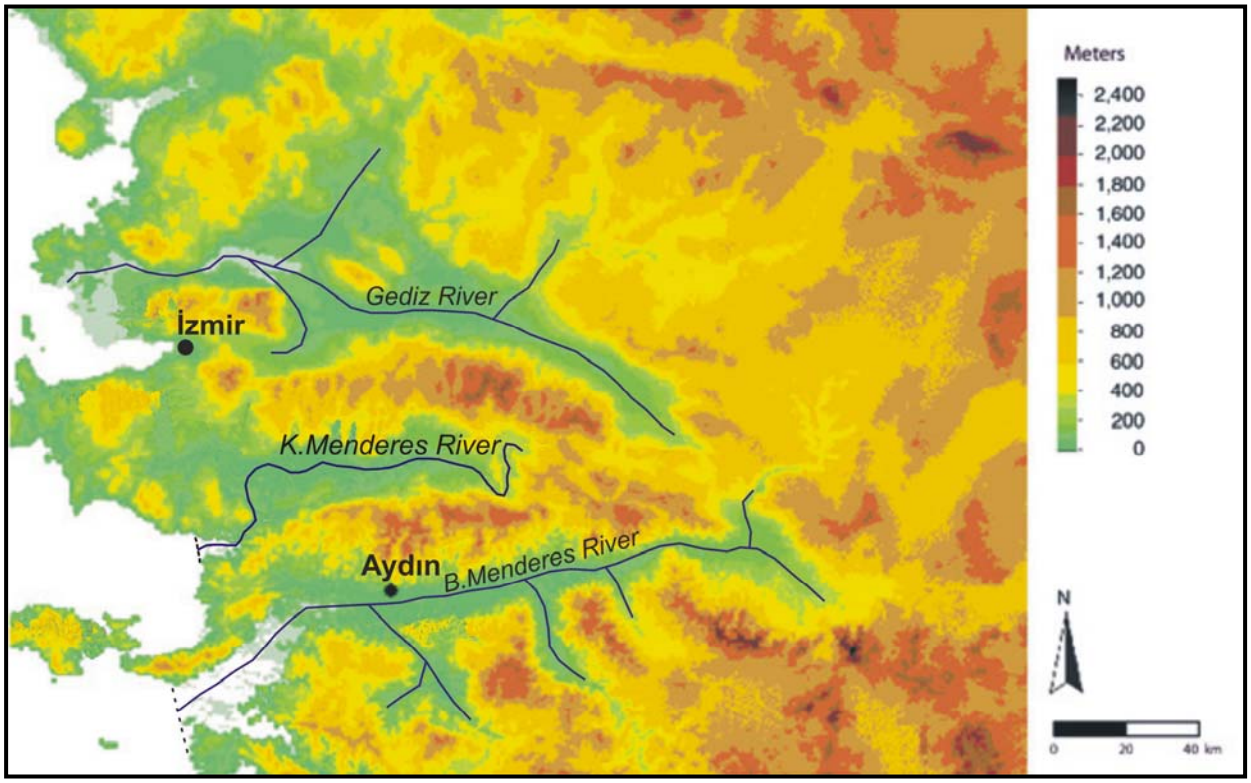


Fig. 3: The general topographic features of coastal and inland Agean Region, Western Anatolia.

The Gediz Delta is a 400 km^2 coast plain which is formed by the alluviums carried by the Gediz River in the north of the Izmir Bay (ERİNÇ 1955, ERİNÇ 1979). The Gediz River has caused the delta to develop in a wide range by changing its bed many times within the Holocene (Fig. 4). This development occurred most probably in the Holocene. In addition, the low plains of the Gediz Delta and the sea transgression caused by climatic optimum were invaded by the waters of the Aegean Sea. The old abandoned riverbeds of the Gediz and the abandoned meanders show the closeness of the wide areas of the delta plain to sea level and the formation of these areas in the Holocene in a period close to the present.

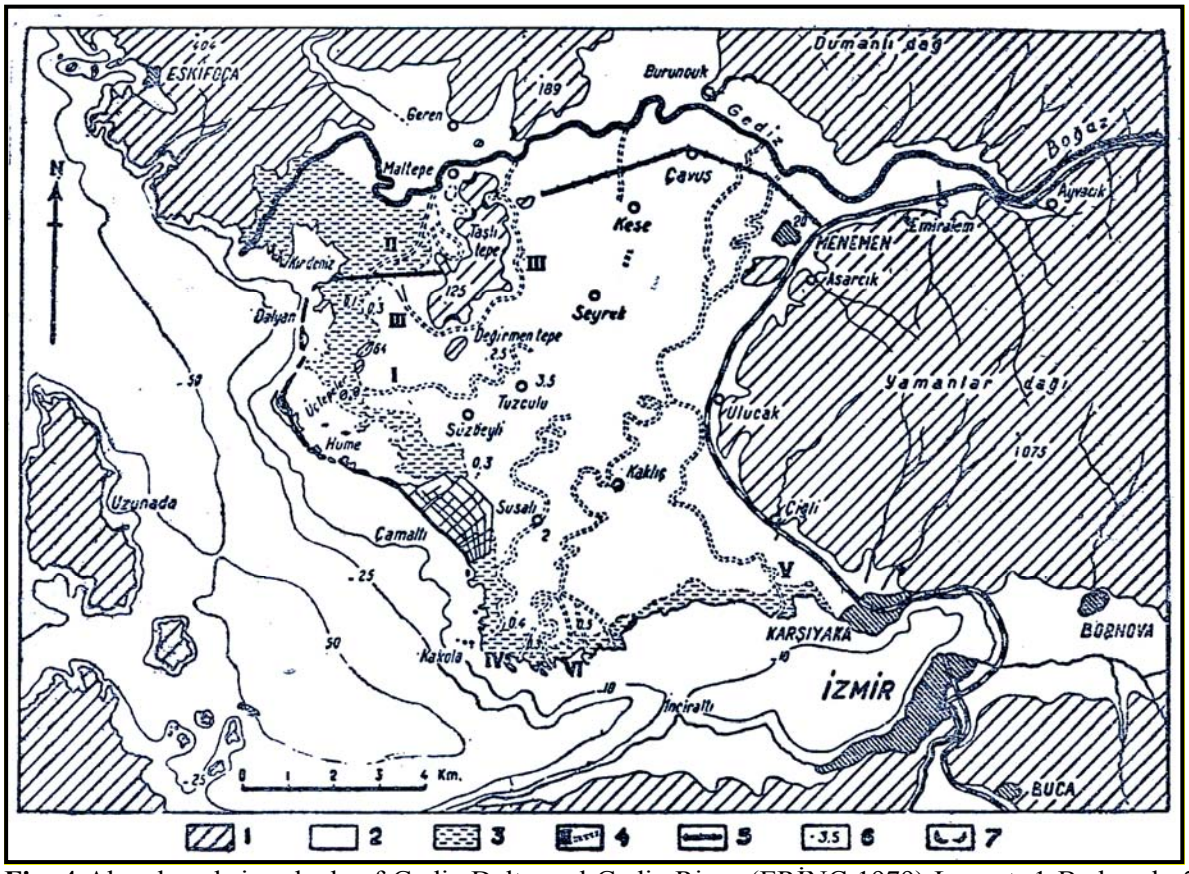


Fig. 4: Abandoned river beds of Gediz Delta and Gediz River (ERİNÇ 1979) Legent: 1-Bed rock, 2-Alluvion, 3-Marshes, 4-Old river beds, 5-Berm crest, 6-Altitude (m), 7-Eroding bank.

Another similar delta-coast plain development on the coast of the Western Anatolia has occurred in the mouth of the Kücük Menderes River where it flows to the Aegean Sea. The evolution of the Delta and of the coast line happened much more slowly in the beginning. Still existing rush-beds, marshes, relict lakes and lagoons are evidence of the fast continuation of the development of the delta-coast plain. The date of the settlements on the coast of the Lesser Meander River goes back to the Neolitic Era. Arvalia and Cukurici tumuli are Neolitic settlements going back to approximately 8000 years from the present (about 6000 BC). The remains of several settlements belonging to latter periods take place in these surroundings. Their dispersion show that the delta-coast plain of the Kücük Menderes River is in close contact with the geomorphologic development. The city of Ephesus, which is located on the coast of this bay, was one of the major economic, social and cultural centers of its time (Fig. 5) (BRUCKNER 2005, BRUCKNER vd. 2005, ERİNÇ 1979).

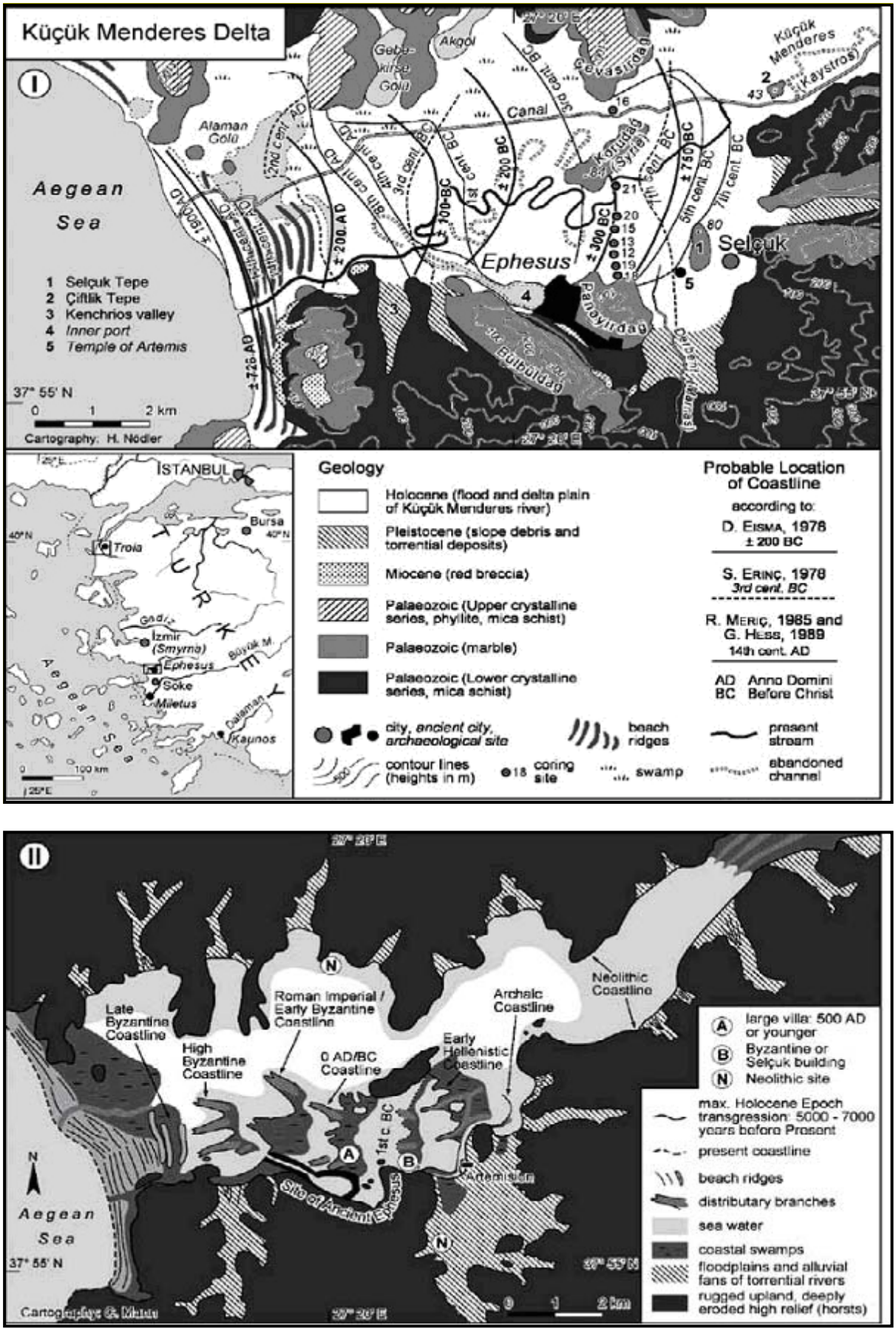


Fig. 5: Progradation scenario of the K.Menderes Delta (BRUCKNER 2005).

Approximately 3000 years ago, the coast line of delta-coast lowland was in front of Selçuk and Korudag (Syrie) was an island in the bay. However, with a rapid progradation, these places transformed to land and the coast line reached Ephesus approximately 2200 years ago (± 200year BC). Progradation continued speedily and the coastline started to take its present form in the 1900s (BRUCKNER vd. 2005, ERİNÇ 1979).

The development of the Büyük Menderes Delta shows similarity to the other delta-coast lowlands of Western Anatolia. The Aegean coastline which snuggled into hinterland in Quaternary remounted to the hinterland approximately by 30km compared to the present and reached the frontier of Söke city in the beginning of the Holocene (Fig. 6). Rapid progradation continued in Holocene as well; so the coast line of the delta-coast plain reached the frontier of Myus antique city (ERİNÇ 1979). Myus, Priene, and Miletos were the seaports of the period. The establishment of Miletos is accepted to be 5500 years ago (3500 years BC). Holocene marine transgression caused this city (Miletus I) to submerge (BRUCKNER 1997).

Rapid accumulation of the alluviums carried by the Büyük Menderes River, the sea reached to Myus coastline in 2500 years BP (± 5th century BC), to Bafa cape in 2100 years BP (± 1 th century BC), and to Miletus in 1450 years BP (± 550 years AD) in this bay by being regressed (Fig. 7). The Myus, Priene, and Miletos seaports lost their socio-economic activity and function by being left in the hinterland. The antique port of Miletos was in the hinterland by 2km from the coast in the 17th century. At present, it is far from the coast by more than 5km. The alluviums of the Büyük Menderes River caused the occurrence of an alluvial lake (the Bafa Lake) by blocking the front of the Latmos Bay (ERİNÇ 1955, ERİNÇ 1979, BRUCKNER 1997).

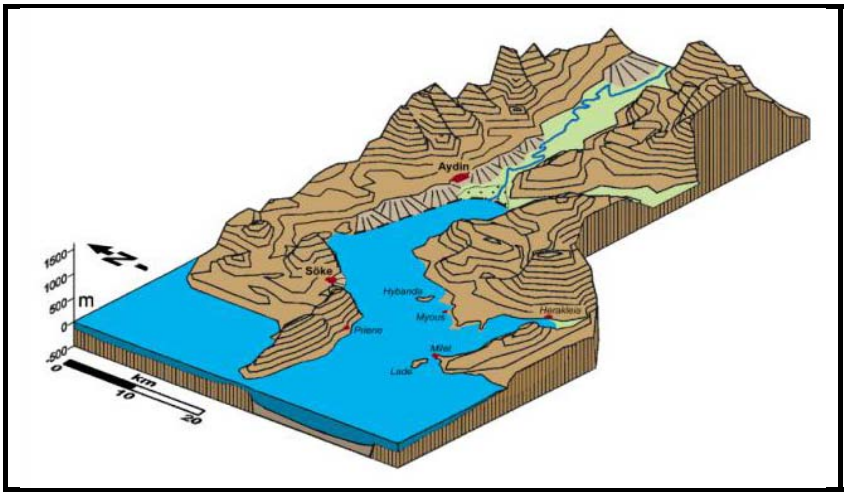


Fig. 6: The inland shores of Quaternary period of Aegean Sea has receded in the early Holocene and moved to 30 km inland from today's position near Söke. Quick progradation continued within Holocene, delta-coastal plain shoreline came up to the front of the ancient city Myus (BRUCKNER 1997).

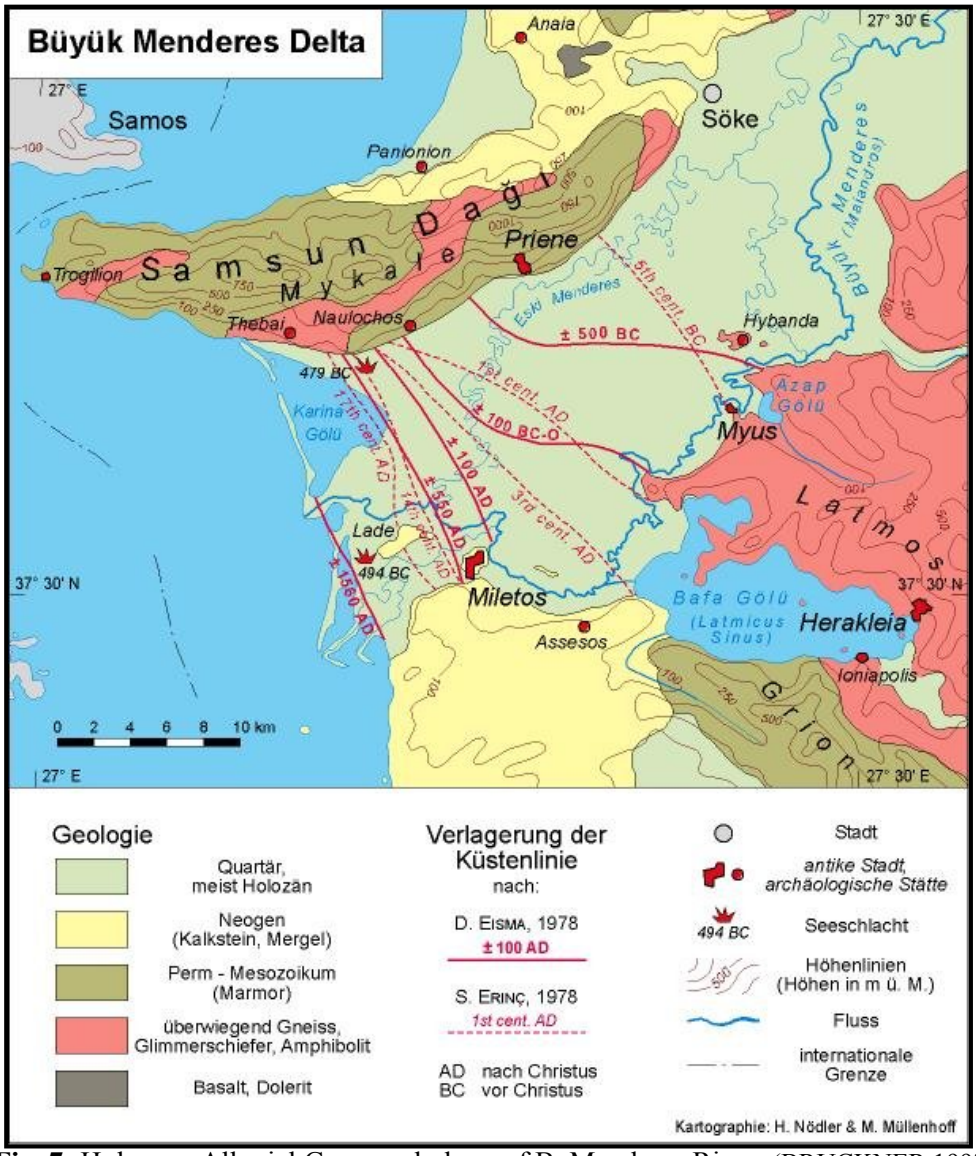


Fig. 7: Holocene Alluvial Geomorphology of B. Menderes River (BRUCKNER 1997).

The development of the Black Sea coast in Quaterner is mostly related to the differences in climatic features. Not only the increase of the sea level in the Black Sea but also the flowing of Mediterranean waters to the Black Sea by means of the straits were effective in this differentiation. The Holocene geomorphology on the Black Sea coast mostly developed under the control of climatic conditions of climatic optimum period. 2-5 m Nis terraces belong to the transgression of this era (ERİNÇ 1954). Due to the structure of Black Sea coast, low lands, bays and gulfs are not very common. Consequently, it is possible to see the Flandrian Transgression and its Nis terraces in limited dimensions. Only the deltas of Kizilirmak and Yesilirmak allow the distinct view of the traces of these sea level changes in the Holocene. The Kizilirmak Delta (The Bafra Plain) is a geomorphologic unit where these developments in the Holocene are clearly observed on the Black Sea coast. In Fig. 8, the section labeled as GD represents the Holocene Era progradation of the delta. The İkiztepeler excavation belonging to a settlement that dates back to 3200 years BC continues over the former delta level. Archaeological findings show that this settlement had an economic structure depending on fishery and agriculture. Archaeological and archaeogeographic research indicate that this settlement was near the old coast line and that the inhabitants dealt

with agriculture on the former delta plain besides benefiting from the Black Sea for the purpose of fishery (TUROĞLU 2005). It is seen that a similar situation is valid for the Yesilirmak Delta and that the delta progradation is almost the same as Kizilirmak Delta progradation (ERKAL 1991).

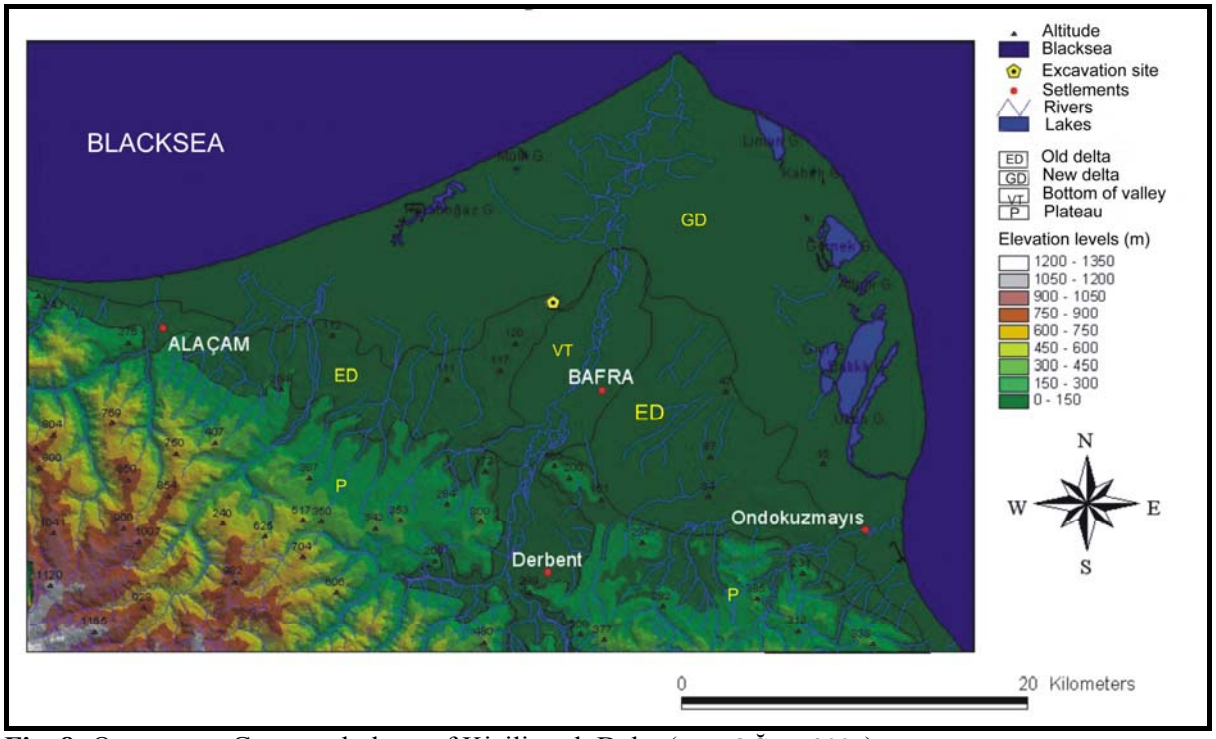


Fig. 8: Quaternary Geomorphology of Kizilirmak Delta (TUROĞLU 2005).

The character of Çukurova and its surrounding can be summarized as terrace systems and plain base. The terrace systems belong to Pleistosen. On the other hand, today's delta is new and its formation coincides with the Flandrian transgression. Especially, the delta progradation within the last 2500-year period occurred very rapidly.

As a consequence, one of the rapid coastline changes occurring in the Holocene took place in the Çukurova Delta (Fig.9). This delta, where the Rivers of Seyhan and Ceyhan flow into the Mediterranean, continued its development in the Holocene. Although there are no prehistoric tumuli in this delta-coast plain, several Epi-paleolitic and Neolitic settlements are encountered when proceeding to hinterland especially through the Seyhan River and to slopes in the direction of the east, west, and north. This situation explains why delta development is so up-to-date and rapid and why ancient settlements are left in the hinterland (ERİNÇ 1953, ERİNÇ 1979, ÖZDOĞAN 1997). A similar situation is valid for the Göksu (Silifke) Delta as well. A large segment of the Göksu Delta, which represents the Flandrian Transgression in the Holocene, is 5m high in altitude. In the middle of the Holocene, a regression occurred due to the sea recession of a few meters. For the last 3000 years, a continuous rise (1mm/year) has been in progress. The wide delta plain has developed as a structural form of this period. The significant role of the alluvial material carried by the river is distinctly observed in the delta development.

Furthermore, the geomorphological units which are developed by the waves and currents have also contributed to this delta development. As a consequence, a large segment of the Göksu Delta developed under the control of the river and coast dynamics besides the sea level change in the Holocene Era (BENER 1967, EROL 1983, EROL 1993).

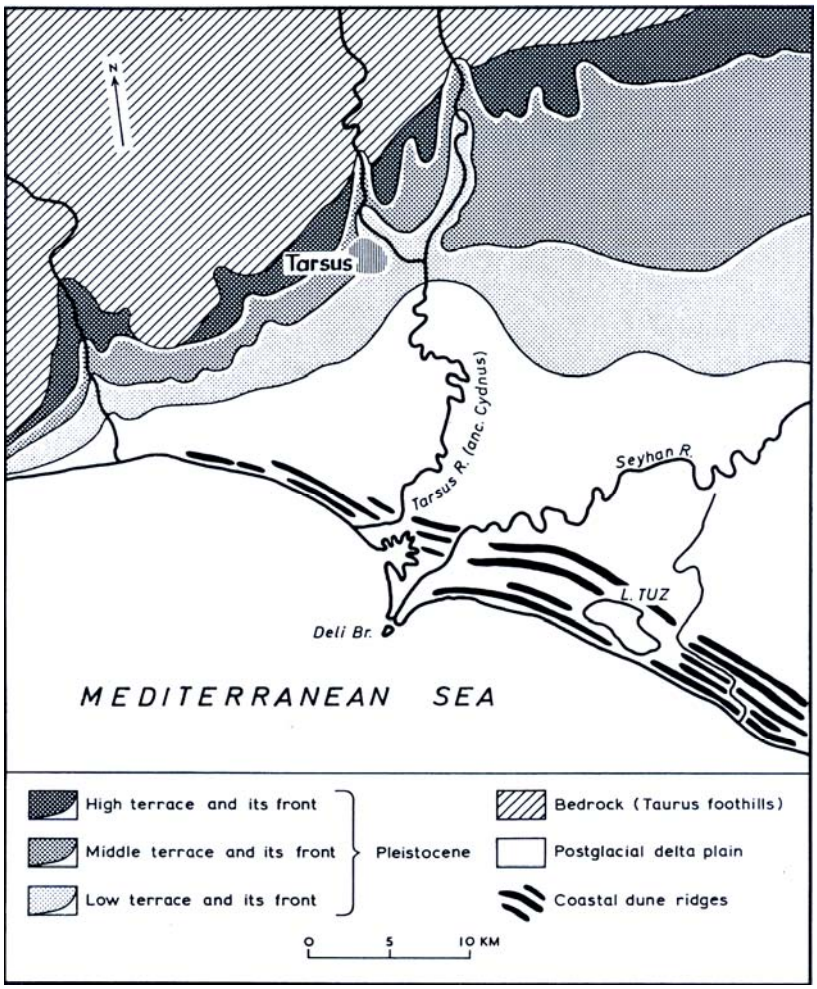


Fig. 9: Çukurova Delta (ERİNÇ 1979).

Lake Environment

The climatic changes in the Holocene in the form of cooling have been effective on the hydrologic balance by means of decreasing evaporation. This has resulted in high water level of lakes in the hinterland of Anatolia such as Van Lake, Tuz Lake, Burdur Lake, İznik Lake, Acıgöl, and Hazar Lake as well as the formation of some pluvial lakes such as the Konya Pluvial Lake (Fig 10). On the other hand, the climatic changes in the Holocene in the form of increase in temperature have resulted in low water level in lakes, decrease in lake sites and the occurrence of low lake bases as high slopes or lake terraces around the lakes. Especially, the spatial changes in the Konya Lake, Tuz Lake, Burdur, Acıgöl and Akşehir Lakes have been in remarkable magnitudes (Fig. 10). The difference in the level of the altitudes of pluvial lake terraces is caused by the effect of regional tectonic activities. As on the sea coast, especially the lowest terraces on the coast of pluvial lakes are the proofs of the change in water levels due to climatic fluctuations that occurred in the Holocene. The Holocene terraces on the coast of lakes belong to the middle and late Holocene Era and are recognized with their erosion forms and sand deposits (ERİNÇ 1979, EROL 1979-b, EROL 1981).

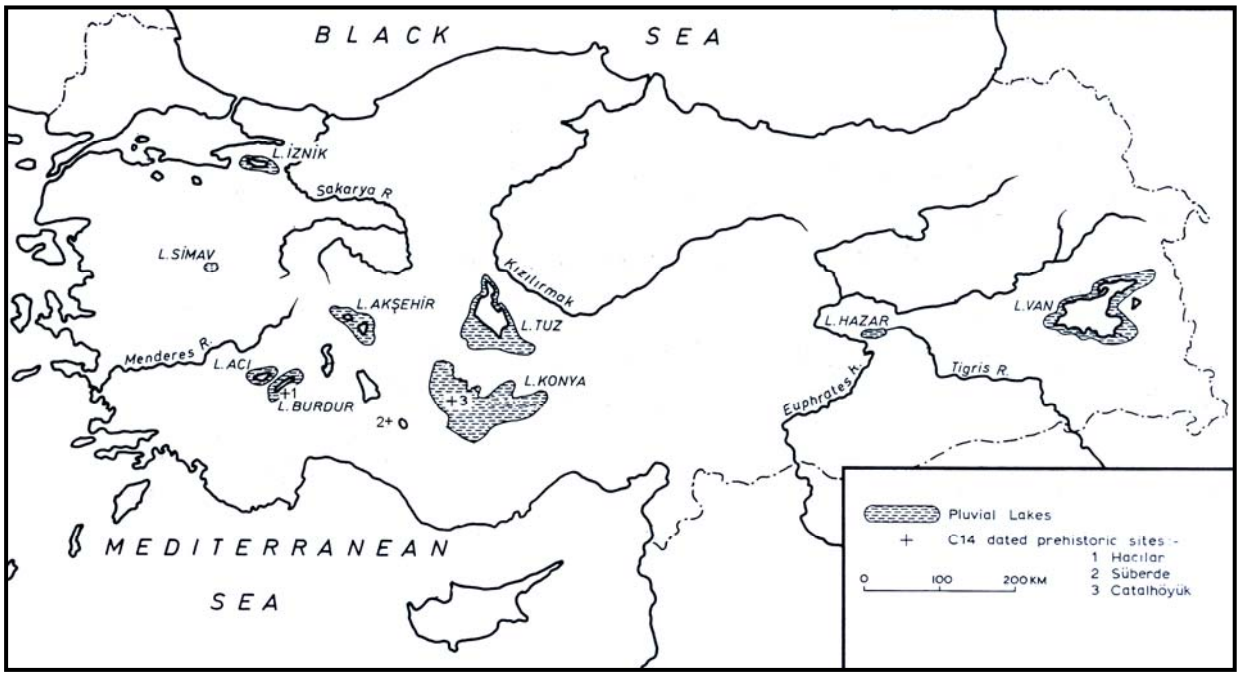


Fig. 10: Anatolian's pluvial lakes and their current shorelines after the last glacial maximum (Modified after ERİNÇ 1979).

The fluctuation in the levels of pluvial lakes in Anatolia in the Holocene Era caused the decrease of lake water and the highness of former lake bases by forming terraces. These lands have been favored for Neolitic, Mesolitic and late period settlements. The Holocene terraces in the north of the Burdur Lake, the Konya Valley and the findings gathered by archaeological excavations around Karapınar constitute important data on this topic. The climatic optimum period was an era when the areas of pluvial lakes in Anatolia such as Konya, Tuzgölü, and the Burdur Lake partially expanded. It is understood from archaeological findings that the old settlements on the lake coasts changed place parallel to this ebbing and expansion in lakes. It is seen that the Burdur Lake is in a general trend of decrease, although it showed several natural cycles within the Holocene era. In addition, the dispersion of tumuli around the lakes of Suğla and Beyşehir provide important data about the former lake coasts. Similar coast characteristics have been determined in the surroundings of the Sultan Sazliği (Kayseri). The evidence of climatic oscillations within the Holocene Era has preserved the present time as lake terraces (EROL 1979-b, EROL 1980, EROL 1999).

These changes in lake levels have had a direct impact on the prehistoric settlements. Lake coasts and their surroundings are very suitable for agricultural activities that started in the Neolitic Era. In fact, these lands both have arable land and reachable water. The increase in lake levels caused the submerging of these settlements. Moreover, the decrease of water made their lives difficult due to a distancing from water; thus, causing them to alter their lives significantly in both situations. It is not a coincidence that Çatalhöyük, an important center of prehistoric settlement of Anatolia, is in the pluvial lake of Konya. The Çatalhöyük settlement was affected by the period of stretching and enlargement of the lake area due to climatic changes.

The River system

The Flandrian transgression caused by the optimum climatic conditions made the sea level increase by 2-2,5m compared to existing levels; thus, submerging the deltas, coastal plains and other low areas on the Anatolian coast. This situation caused the drowning of the lower course of the rivers flowing from the Anatolian coast, the changing of drainage systems and activities of erosion and accumulation (ERİNÇ 1979).

The general impact of short-time and fast changes on the climatic characteristics of Anatolia on drainage has been in the direction of a decrease in the streams. This general character has been cut due to short oscillation. Hot and semiarid climatic conditions have reinforced the development of closed basin drainage systems (ERİNÇ 1979).

Another characteristic of the Holocene drainage system of Anatolia is the often occurring floods and overflows which are caused by precipitation and snow melts that are a natural result of climatic properties. Especially the settlements of the Neolitic and Post-Neolitic Era on the fruitful alluvial plains of the Euphrates and Tigris Rivers have often been affected by these disasters (ERİNÇ 1979, KRAFT et al 1980, ÖZDOĞAN 1995).

Conclusion

The Holocene geomorphologic characteristics of Anatolia have had an impact on the control of regional tectonic motions, volcanic activities, and climatic changes that had a global effect. The effects of these factors can be seen in their direct transformative role still existing today on the coasts, plains, lakes and rivers of Anatolia. This has both been an advantage and a disadvantage for people who found a suitable settlement on this dynamic geomorphology. Despite the occasional problems, its inhabitants could not abandon the advantages of its geomorphologic advantages and therefore Anatolia has always been a preferable site in every period of history.

Bibliography

B. A. S. DAVIS - S. BREWER - A. C. STEVENSON - J. GUIOT, -Data Contributors, "The temperature of Europe during the Holocene reconstructed from pollen data". Quaternary Science Rewiews, Volume 22, Issues 15–17, 2003, 1701–1716.

H. BRUCKNER –A. VOTT, –A. SCHRIEVER, –HANDL, et M., "Holocene delta progradation in the eastern Mediterranean". Méditerranée N° 1.2, 2005, 95–106.

H. BRUCKNER, - M. MULLENHOFF - M. HANDL - K. VAN DER BORG, "Holocene landscape evolution of the Büyük Menderes alluvial plain in the environs of Myous and Priene (Western Anatolia, Turkey)". Z. Geomorph. N.F., Suppl.-Bd. 127; Berlin/Stuttgart 2002, 47–65.

H. BRUCKNER, "Coastal changes in western Turkey - Rapid delta progradation in historical times". In: Briand, F., Maldonado, A. (eds): Transformations and evolution of the Mediterranean coastline. CIESM Science Series 3, 63–74 (Bulletin de l'Institut océanographique, numéro spécial 18. Musée océanographique, Monaco), Monaco 1997.

H. BRUCKNER, "Delta Evolution and Culture - Aspects of Geoarchaeological Research in Miletos and Priene". In: Wagner, G.A., Pernicke, E. & H.-P. Uerpmann (eds.): Troia and the Troad. Scientific Approaches. Springer-Verlag Berlin 2003, u.a., 121-144.

H. BRUCKNER, "Holocene shoreline displacements and their consequences for human societies: the example of Ephesus in western Turkey". Z. Geomorph. N. F., Suppl. Volume 137, 11–22, Berlin-Stuttgart 2005.

H. TUROĞLU, "Kizilirmak Deltası ve yakın çevresinin jeomorfolojik özellikleri ve insan yaşamındaki etkileri". İstanbul Üniversitesi İkiztepe Kazılarının 30. Yılı Sempozyumu, 01–04 Eylül 2005, Samsun 2005.

İ. ATALAY, "Kuvaterner'deki İklim Değişmelerinin Türkiye Doğal Ortamı Üzerindeki Etkileri". Türkiye Kuvaterner Sempozyumu TURQUA-5, Bildiriler Kitabı, 121-128, ITU Avrasya Yer Bilimleri Enstitüsü, İstanbul 2005.

İ. ATALAY, "Paleoenvironmental conditions of the Late Pleistocene and Early Holocene in Anatolia, Turkey". In: Alsharhan, Glennie, Whitte & Kendall (eds.), Quaternary Deserts and Climatic Change, ISBN 9054105976, 227–237, Balkema, Rotterdam 1998.

İ. KAYAN, "Geomorphological Evolution of the Çıplak Valley and Archaeological material in the alluvial sediments to the South of the lower city of Troia". Studia Trioca, ISBN 3–8053–2357–3, Bant 7, 1997, 489–507.

İ. KAYAN, "Geomorphological Outlines of Turkey", In: Demirci, Ş.-Özer, A. –Summers, G (eds), Archaeometry 94. The Proceedings of the 29th International Symposium on Archaeometry, 365–374, TUBITAK publications, Ankara 1996-a.

İ. KAYAN, "Late Holocene Sea-Level Changes on the Western Anatolian Coast", Paleogeography, Paleoclimatology, Paleoecology, Volume 68, 1988, 205–218.

İ. KAYAN, Holocene stratigraphy of the lower Karamenderes-Dümrek plain and archaeological material in the alluvial sediments to the North of the Troia ridge. Studia Trioca, ISBN 3–8053–2357–3, Bant 6, 1996-b, 239–249.

J. C. KRAFT –I. KAYAN –O. EROL, Geomorphic Reconstructions in the Environs of Ancient Troy. Science, Volume 209, no 4458, 1980, 776–782.

J. C. STAGER and P. A. MAYEWSKI, "Abrupt Early to Mid-Holocene climatic transition registered at Equator and Poles", Science, Volume 276, 1997, 1834–1836.

J. T. HOUGHTON –Y. DIGY, –D. J. GRIGGS, –M. NOGUER –P. J. VAN DER LINDEN, –X. DAI –K. MASKELL –C. A. JOHNSON, Climate Change 2001: The Scientific Basis, Cambridge University Press, ISBN 052180767 0 Hardback, ISBN 0521 01495 6, Paperback, Printed in USA at the University Press, New York 2001.

M. BENER, "Göksu Deltası". İstanbul Üniversitesi Coğrafya Enstitüsü Dergisi, Sayı:16, 86–100, İstanbul 1967.

M. ÖZDOĞAN, "Neolitik in Turkey". The Status of Research. Readings in Prehistory, Studies Presented to Halet Çambel, Graphis Publications, 41–59, İstanbul 1995.

M. ÖZDOĞAN, "Anatolia from the Last Glacial Maximum the Holocene Climatic Optimum: cultural formations and the impact of the environmental setting". Paléorient, Année, Volume 23, Numéro 2, 1997, 25–38.

N. KAZANCI –S.A. LEROY –S. ÖNCEL –Ö. İLERİ – M.C. ALÇİÇEK –F. UYSAL, "Gölsel Verilerle Kuzeybatı Anadolu'nun Geç Holosen'deki İklimi". Türkiye Kuvaterner Sempozyumu TURQUA-5, Bildiriler Kitabı, p.304, ITU Avrasya Yer Bilimleri Enstitüsü, İstanbul 2005.

O. EROL, "A geomorphological study of the Sultansazliği lake, central Anatolia". Quaternary Science Reviews, Volume 18, 1999, 647–657.

O. EROL, "Anadolu kıyılarının Holosendeki değişmeleri hakkında gözlemler. Coğrafya Araştırmaları Dergisi, Sayı:2, Ankara 1963.

O. EROL, "Historical Changes on the Coastline of Turkey". In: Brid, E. and Fabbri, P. (eds), Coastal Problems in the Mediterranea Sea, Proceedings of the Venice Symposium, 95–107, Bologna 1983, .

O. EROL, "Neotectonic and Geomorphological Evolution of Turkey". Z. Geomorph. N. F., Suppl. Bd. 40, 193–211, Berlin-Stuttgart 1981, .

O. EROL, "Quaternery pluvial and interpluvial conditions in Anatolia and environmental changes especially in south-central Anatolia since the last glaciation". Annals of the Geographical Research Institute, Publication of the Geographical Research Institute, Facullty of Letter, University of Ankara, Volume 9, No:9, 1980, 5–16.

O. EROL, "The Late Quaternary History of the Lake Basin of Central and Southern Anatolia". In: Brice, W.C. (ed.), The Environmental History of the Near and Middle East Since the Last Ice Age, p.140-, London, Academic Press 1979-b.

O. EROL, "Türkiye kıyılarındaki bağıl deniz düzeyi değişmeleri ve bunun Göksu Deltası ile diğer deltaların evrimine etkisi". Uluslar arası Göksu Deltası Çevresel Kullanma Semineri, 06–09 Ekim 1992, Bildiri Metinleri, DHKD yayını, 1993, 128–138,

O. EROL, Dördüncü Çağ (Kuaterner) Jeoloji ve Jeomorfolojinin ana çizgileri. A.Ü.D.T.C.F. Yayınları Sayı:289, Ankara 1979-a.

Ö. EMRE - T. ERKAL –A. TCHEPALYGA –N. KAZANCI –M. KEÇER –E. ÜNAY, "Doğu Marmara Bölgesinin Neojen - Kuvaternerdeki Evrimi". MTA Dergisi, Sayı:120, s. 233–258, Ankara 1998.

P. A. MAYEWSKI - E. E. ROHLIN - J. C. STAGER - W. KARLE - K. A. MAASCH, - L. D. MEEKER - E. A. MEYERSON - F. GASSE -S. v. KREVELD -K. HOLMGREN -J. L. THORP - G. ROSQVIST - F. RACK - M. STAUBWASSER - R. R. SCHNEIDER -E. J. STEIG, "Holocene climate variability". Quaternary Research, Volume 62, 2004, 243– 255.

S. ERİNÇ, "Changes in the Physical Environment in Turkey Since the End of the Last Glacial". In: Brice, W. C. (ed.), The Environmental History of the Near and Middle East Since the Last Ice Age, 87–139, London, Academic Press 1979.

S. ERİNÇ, "Çukurova'nın alüviyal morfolojisi hakkında". İstanbul Üniversitesi Coğrafya Enstitüsü Dergisi, Sayı: 2, Cilt:3–4 s. 147–159, İstanbul 1953.

S. ERİNÇ, "Karadeniz ve Çevresinin morfolojik tekâmülü ile pleistosen iklim tahavvülleri arasındaki münasebet", İstanbul Üniversitesi Coğrafya Enstitüsü Dergisi, Cilt: 3, Sayı: 5–6, s. 46–94, İstanbul 1954.

S. ERİNÇ, Gediz ve K.Menderes Deltasının morfolojisi, Türk Coğrafya Kurumu Yayını No:2, İstanbul 1955.

T. ERKAL, Çarşamba Ovası (Yeşilırmak Deltası) ve çevresinin jeomorfolojisi. Basılmamış Doktora tezi, İ.Ü. Deniz Bilimleri ve İşletmeciliği Enstitüsü, Jeomorfoloji Anabilim Dalı, İstanbul.1991.