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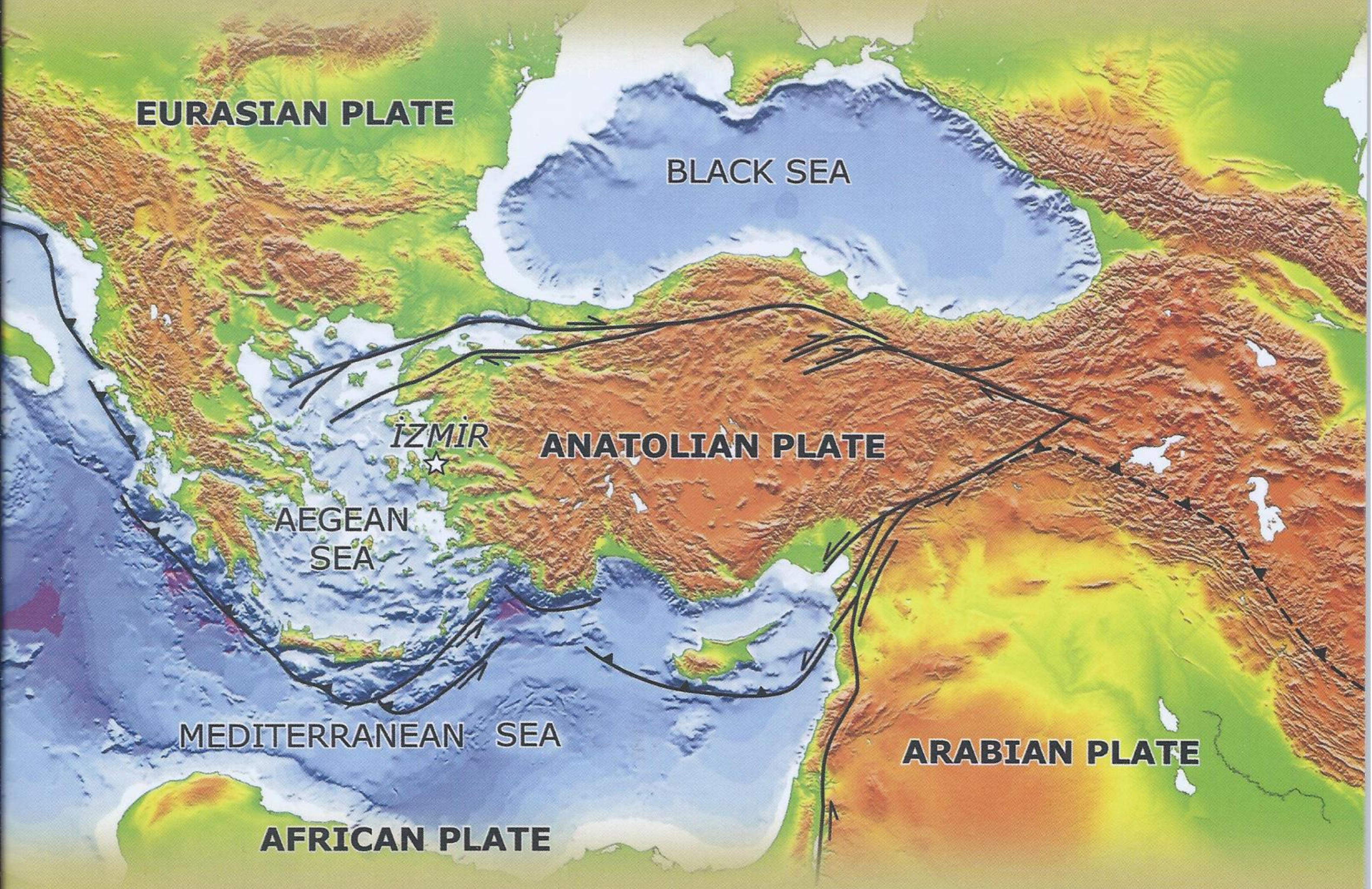

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OUTLINES OF WESTERN ANATOLIAN GEOLOGY

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The Western Anatolian region is characterized by a number of approximately E-W trending, sub parallel, normal fault zones which border a swarm of grabens and the intervening horst blocks (Fig. 1). As a consequence of this there is an intense seismic activity, as evidenced by a number of instrumentally recorded earthquakes, roughly encircling the active faults (Fig. 2). Motions on the faults confirm an extension approximately in N-S direction. Therefore the western Anatolian and Aegean regions have long been known to represent a broad zone of extension stretching from Bulgaria in the north to the Hellenic arc in the south (Yılmaz et al., 2000).

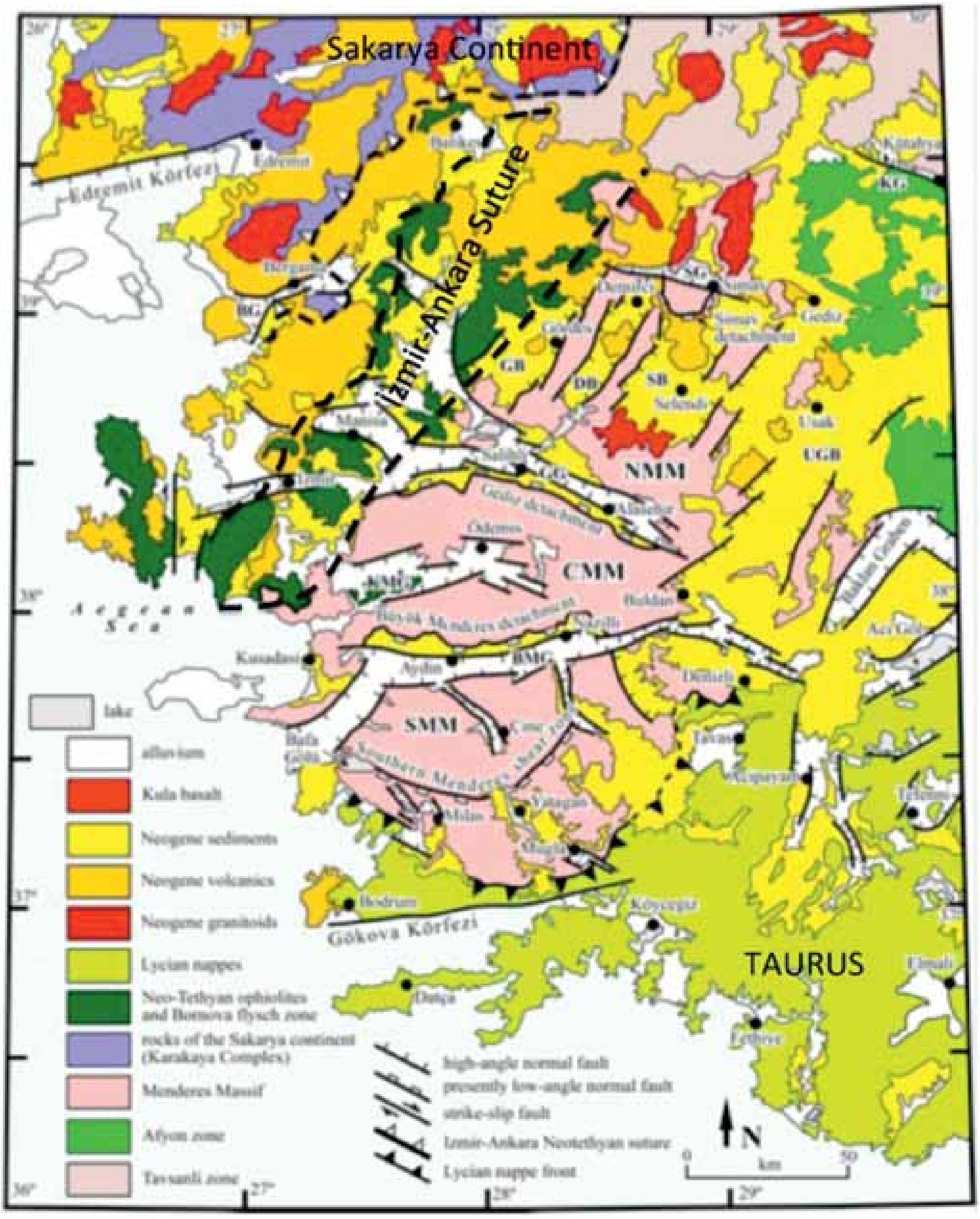

Figure 1. Geological map of western Anatolia (Modified after Hinsbergen et al., 2010).

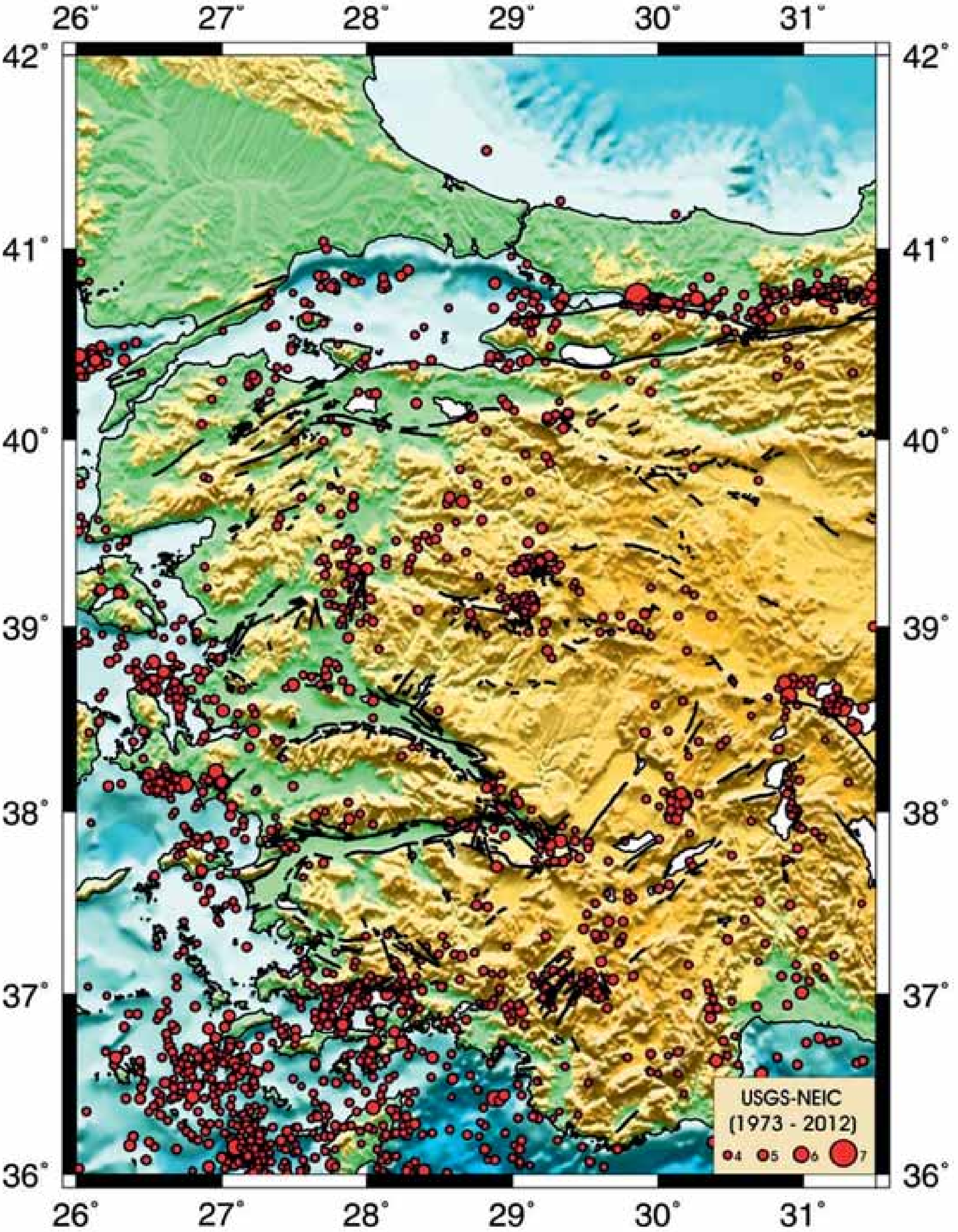

Figure 2. Seismicity map of western Anatolia (USGS-NEIC Epicenters during 1973-2012 with M > 4.0 and plot is courtesy of Prof.Dr. Tuncay Taymaz and Res.Assoc. Yeşim Cubuk of İstanbul Technical University.

In western Anatolia two groups of rocks may readily be distinguished; a) the Neogene and younger rocks and b) the older rocks. The former forms a common cover of nonmarine origin to the latter, which comprises a tectonic mosaic, developed prior to the deposition of the Neogene units (Fig. 1). The Neogene cover rocks consist of terrestrial sedimentary deposits formed from the Early Miocene to the present. Volcanic rocks also accompanied the sediment deposition extensively (Fig. 1). Among the tectonic mosaic the following tectonic zones are differentiated from the north to the south; the Sakarya continent, the İzmir-Ankara ophiolitic suture, the Menderes Massif and the Taurides (Fig.1). They were amalgamated as a result of total demise of the branches of the

Tethyan Ocean and the consequent collision of the bordering continents during the Late Cretaceous-Eocene period.

There appears to be an overall agreement on the geological evolution of the pre-Neogene tectonic mosaic of western Anatolia as outlined by Şengör and Yılmaz, (1981) and elaborated by Yılmaz (1989). According to these works, the following evolutionary history may be summarized as illustrated in figure 3. The late Cretaceous marked the beginning of convergent regime at all fronts in Turkey, and was particularly characterized by the emplacement of ophiolite nappes (Fig. 3B and C). These nappes moved onto extensive carbonate platforms that began subsiding "en masse" with the onset of obduction (Fig. 3B to C). The initial phase of metamorphism of the Menderes Massif may in part be ascribed to this subduction and the subsequent obduction events Fig. 3C and D).

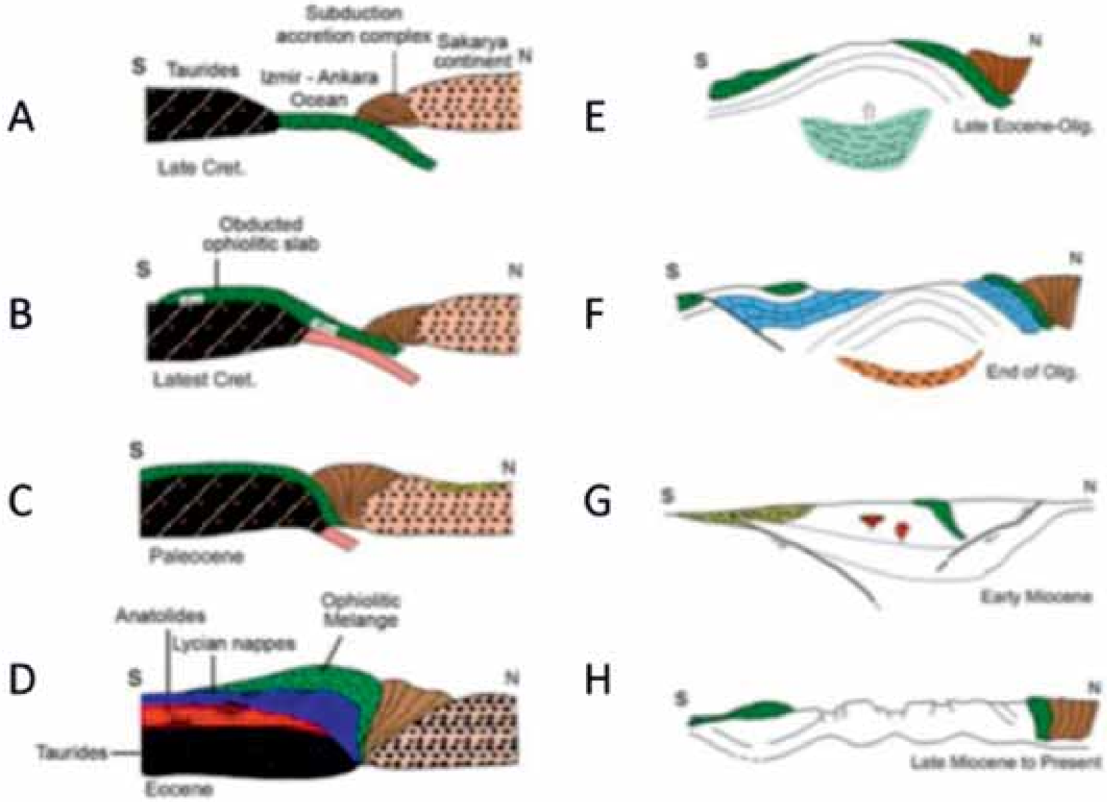

Figure 3. Schematic sections illustrating consecutive stages of tectonic evolution of Western Anatolia. (Modified after Yilmaz 1986).

Following the obduction of the ophiolitic nappes onto the Tauride- Anatolide platform, the Tauride Anatolide platform began to be internally imbricated. During the late Eocene-Oligocene the initial uplift the Menderes Massif occurred and it was partly unroofed (Fig. 3E).

During the Oligocene period the whole Aegean Region including Western Anatolia, the Aegean Sea area, and the Balkan Region became a high land and began to be effectively eroded (Fig. 3F). This elevated domain subsided near the sea level during the Late Miocene period. During this time, following a long absence, the sea incursion began into the region for the first time from the Central Aegean area. When the region represented a continental environment, the region wide denudation continued interruptedly to the Early Pliocene, and generated an extensively developed flat-lying erosional surface Fig. 3G). At that period the region was close to the sea level, because the Upper Miocene-Lower Pliocene sedimentary successions are represented by transitional units that formed in sea, lagoon and lake environments (Yılmaz et al., 2000; 2010; Yılmaz, 2008). Presently the erosional surface may be used as a key stratigraphic marker to identify the younger and older events, and the younger morphological features.

The following four major geological items of the region are still widely debated:

1. The Menderes Massif; its origin, mechanism of formation and age of development
2. The Magmatic Associations; ages and mechanisms of their generation

3. The Neogene Cover rocks; the tectonic regime under which they were developed and their tecto/stratigraphic divisions.

4. The N-S extensional regime; its time and mechanism of initiation.

A number of different views have been proposed on each one of these subjects.

The Menderes Massif is one of the main tectonic elements of Western Anatolia. Under the name of the Menderes Massif is included a variety of metamorphic associations which crop out in the central and southern parts of western Anatolia occupying a 250 X 120 kms region. It is roughly elliptical in shape with a north north-east-south south-west trending long axis, and is located between the İzmir-Ankara suture zone in the north and the Taurides in the south (Fig. 1).

Generally the following zones or units are regarded as commonly associated with the Menderes Massif: The Afyon and Tavşanlı zones; which consist essentially of a metamorphosed sequence which are made up of three distinct layers: A Paleozoic succession at the base, consisting of metaclastics, a thick carbonate sequence in the middle, which is Mesozoic in age, and it is overlain tectonically by an ophiolite nappe at the top.

These zones have suffered HP metamorphism during the late Mesozoic-Early Tertiary period, under the thick (> 6 km) nappe pile.

The Metamorphic rocks extending along the Dilek Peninsula, northwestern belt of the Massif, are regarded as the easterly continuation of the Cyclades Massif of the Central Aegean regions, because they both have similar successions, and both have suffered similar metamorphic events including the HP metamorphism.

The main body of the Menderes Massif consists essentially of a Pan African basement association and its cover sequence (Candan et al. 2001; Erdoğan and Güngör, 2004; Bozkurt and Oberhansli, 2001). The former consists essentially of augen gneisses (orthogneisses), metagranites and metagrabbros with eclogitic relicts (Bozkurt and Oberhansli, 2001). The latter is made up of schists, phyllites and marbles. The schist envelope includes quartzo-feldspatic gnesiss, pelitic and psammitic gneises, micaschists, amphibolite schists . These are followed upward by micaschist-limestone intercalation passing up onto the lower grade rocks, which are made up of graphite bearing micaschists, phyllite and marbles. Above a meta basal conglomerate, the marble envelope begins, and is dominated by meta limestones forming a thick succession. The schist-phyllite envelope is regarded as the Paleozoic in age; whiles the metalimestones are mostly Mesozoic. The marble envelope is small in the north and central parts, but large in the south.

The Menderes Massif suffered a complex metamorphic history; five phases of deformation have been identified (Bozkurt and Oberhansli, 2001); the blueschists and eclogites with strong greenschists overprint documented. The retrograde metamorphic evolution at greenschist facies condition was associated with the ascent of the Massif while mylonitic fabrics penetrating into the rocks along the major fault zones (Çemen et al., 2006). Synextensional genetic melts formed and intruded into the Massif using the zones of weaknesses (Bozkurt and Oberhansli, 2001).

Exhumation of the Menderes Massif has occurred in at least two main stages; (Bozkurt and Park, 2004; Catlos and Çemen, 2005; Ring et al., 2007; Çemen et al., 2006). The initial elevation occurred before the Early Miocene (Fig 3 E); the Early Miocene terrestrial sediments deposited directly on the high grade metamorphic rocks sealing their contacts with the surrounding rocks and its NNE elongated map pattern (Fig 1). However the high-grade metamorphic rocks of the central region were not yet elevated to their final position in this period. The Central part has been elevated once again individually during a later stage of exhumation, which occurred in the late Miocene (Gessner, 2000; 2004; Yılmaz et al., 2000; Çemen et al., 2006) and, this formed the Bozdağ dome.

The Bozdağ dome is separated from the north and the south parts of the Menderes Massif by extensional detachment faults, which display ductile to brittle deformation, along and across the fault zone. Its elevation became the source of thick, red lateral fan deposits of upper Miocene age, which wrap round the Massif (Fig. 6B). During this period the Central part of the Massif was possibly the main morphological high of the western Anatolia, because going away from the Bozdağ horst the red clastics transit gradually to the low energy lacustrine deposits, which cover the entire western Anatolia during the late Miocene-Early Pliocene period (Yılmaz et al., 2000).

With respect to the centrally located Bozdağ horst; three geographic domains are usually distinguished in the Menderes Massif: the Northern, Central, and Southern domains (Fig. 1). The Central domain and the surrounding Northern and Southern domains share common lithological characteristics and metamorphic histories. All of the zones or units, which form the Menderes Massif, and its border zones may be regarded as belonging to the same entity, the Taurides, because of their litho-statigraphic similarities and their ages. They may be viewed as representing the northerly equivalent of the Tauride passive margin, facing the Tethyan Ocean, located in the north (Fig 3A-D) (Şengör and Yılmaz, 1981). Following the total consumption of the Tethyan ocean floor, the collision occurred between the Taurides and the Sakarya continent (Fig. 3A-D). The underplated northern part of the Taurides underwent regional metamorphism (Fig. 3D and E), and formed the Menderes Massif when elevated (Fig3E). Above the Menderes metamorphics, the southward transportation of the nappes took place from the late Cretaceous till the late Eocene (Fig. 3D), as evidenced by the deposition of the olistostromes, derived from the Nappes, which accumulated in front of the Nappe package (Şengor and Yilmaz 1981; Candan et al., 2001). They were later overridden, and themselves underwent different degrees of metamorphism under the Nappes.

The southern zone is alternatively known as the Lycian Nappes and is commonly regarded as representing slices of the Taurus sequence, which were transported southward as thrust sheets (Şengor and Yilmaz 1981;Ring et al 2001) above the Menderes Massif during the development of the Orogeny (Şengör and Yılmaz, 1981). With the present outcrop pattern, being buried under the nappes, the Menderes Massif may thus be regarded as a tectonic window (Şengör and Yılmaz, 1981).

Three partly coeval metamorphic events have been recorded in the Menderes Massif.

A. HP metamorphism ranging in age from 25 to 80 million years (Gessner et al 2001; Candan et al., 2005; Ring et al., 2007; Whitney et al., 2008).

B. HT metamorphism ranging in age from 20 to 62 million years (Şengör et al., 1984; Bozkurt & Satır, 2000; Bozkurt & Oberhansli, 2001; Gessner et al 2001; Catlos & Çemen, 2005; Thomson & Ring, 2006).

C. The cooling age of the metamorphic rocks, ranging from 5 to 50 million years (Gessner 2001; Lips et al 2001; Gessner et al., 2004; Catlos and Çemen, 2005; Purvis et al., 2005). The three age groups get broadly younger toward the South. Collectively the age data indicate that, synorogenic events that affected the Menders Massif continued well into the Miocene period (Yilmaz et al 2000; Rimmele et al., 2005; Yılmaz, 2010).

According to the present structural ordering. The central part of the Menderes Massif as exposed in the Bozdağ horst; which is the structurally lower tectonic unit with respect to the hanging wall rocks of the detachment low angle normal faults in the north and the south, may thus be regarded as the also lowest tectonic entity of the Menderes Massif. However these high-grade metamorphic core rocks are observed to have thrust over much younger rocks, such as Rudist bearing meta sediment. This simple correlation indicates that the Menderes Massif has undergone multiple structural rearrangements during a rather long history of evolution (Şengör et al., 1984; Ring et al., 2001; Gessner et al., 2004).

The Magmatic rocks cover large areas in western Turkey from the Thrace Region and the Marmara region in the north down to the Bodrum Peninsula in the south. They were formed in two phases, the early phase and the late phase (Yılmaz, 1989; Yılmaz et al., 2000; 2001). During the early phase, granitic stocks and small plutons, and intermediate and felsic volcanic rocks were extensively developed. The plutonic and volcanic rocks are closely associated in time and place. Together they commonly formed in a collapsed caldera environment, in which the granites, which are surrounded by the intimately related volcanic suits, above the granites, occupy the centrally located, deeper part. These rocks are high K, calc-alkaline in composition, and their compositions form a cluster displaying a common character and origin. The early phase of magmatic associations displays magmatic arc geochemical signatures; the mantle-derived magmas were enriched including the crustal components and later underwent AFC processes. (Yılmaz et al., 2000, 2001; Aldanmaz et al., 2000; Altunkaynak and Dilek, 2006; Canticelli et al, 2009).

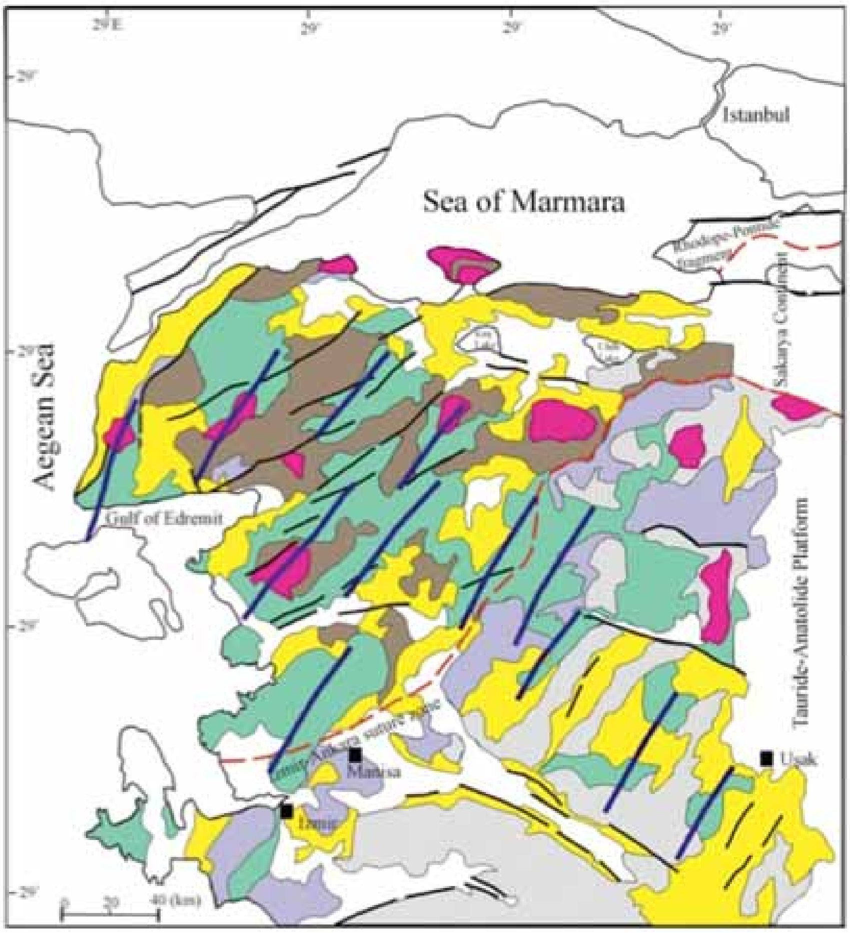

Figure 4. Geology map of NW Anatolia illustrating main magmatic axes (modified after Yilmaz, 1989).

The magmatic centers of this early magmatic phase are aligned in NNE directions (Fig. 4). The granitic magmas reached shallow levels in the crust along these trends and the volcanoes, erupted along the faults and fissures defining the trend. A number of caldera type granites and associated volcanic centers have been mapped and identified in the region as exemplified from the Ezine, Kozak and Bodrum areas.

The late phase of the magmatic events produced mainly basic rocks, which were missing during the early phase. They are sporadically developed and much less extensive. They form a distinctly different compositional cluster from the chemical composition of the early phase. Geochemically, the latter is commonly alkaline in character, and displays similar affinities to the magmas that formed under extensional regimes. The late phase of magmatic rocks began to form during the late Middle to late Miocene, around 15-10 million years ago, and have continued till the present time. There is a time gap between the developments of the two magmatic phases. The gap is large in the northern regions where the initial phase began during the Eocene-Oligocene period. It narrows toward the south, and may briefly be overlapping in the southern volcanic centers (Helvacı et al .,2009 ;Prelevic et al., 2012).

The gradual migration of the volcanic front of the early phase displaying the arc magmatic affinities leads to the following assumptions:

1. They were formed in association with the subduction along the Hellenic trench. This subduction is assumed to have been continuing since at least the Cretaceous period. This assumption is based on the length of the subducting slab, which is more than 600 kms, and the seismic tomography displays a single slab below western Turkey (Spakman et al., 1998; Hinsbergen et al., 2010).

2. The southward migration of the arc magmas may be regarded as linked to the rollback of the subducting slab; at least two stages of rollback are observed along the length of the slab (Spakman et al 1998; Altunkaynak & Dilek, 2006; Hinsbergen et al., 2010).

The late magmatic phase, which is closely related with the E-W trending faults and the associated structures, is considered to be the magmatic products, which have formed under the extensional regime, when the N-S extension began.

High Mg ultrapotassic volcanic rocks also occur partly associated with these two groups of volcanic rocks. They crop out mostly in the eastern part of the western Anatolia from the Kütahya -Afyon region in the north to Isparta in the south (Ersoy et al., 2012; Prelevic et al., 2012), overlying preferentially metamorphic rocks of the Menderes Massif. They were derived from the initially highly depleted, subsequently enriched mantle, favorably in a supra subduction environment.

The Neogene cover rocks of western Anatolia are terrestrial deposits, and form three tecto-stratigraphic units separated by unconformities (Fig. 5) (Yılmaz et al., 2000; Yılmaz, 2008). The Lower Unit is Early to Middle Miocene in age, and was commonly deposited within NNE trending structural depressions lying sub-parallel to the volcanic axes (Figs. 4 and 6). Away from the volcanic axes this unit is represented commonly by fine-grained detrital rocks, such as claystone, marl and fine-grained sandstone with some alternating coal seams (Yilmaz et al 2000). Due to the proximity to the volcanic centers, the sediments alternate with, and include, increasing amounts of volcanoclastics, pyroclastics and lava layers.

The Middle Unit is Late Miocene-Early Pliocene in age, and is represented primarily by lacustrine white limestones and marls. They are the most extensive Neogene rocks in western Anatolia, and apparently were formed in interconnected lake basins (Helvacı and Yağmurlu, 1995). These shallow lakes appear to have covered whole western Anatolia during this period. This was followed by a phase of denudation, which formed a regionwide flat lying erosional surface.

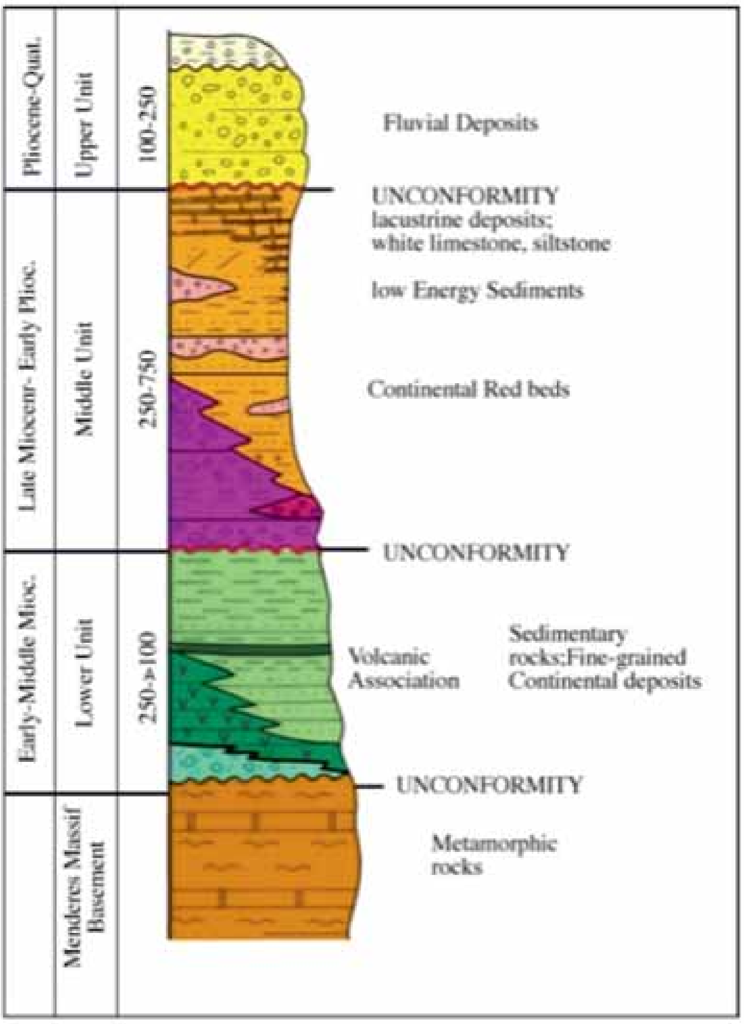

Figure 5. Neogene Generalized stratigraphic section of western Anatolia (modified after Yilmaz,et al 2000).

The Upper Miocene-Lower Pliocene limestone sequence and the erosional surface above it are fragmented by E-W trending faults formed after the early Pliocene period, when the present horst-graben system began to form (Fig. 6). The infill of these grabens is fluvial sandstones and conglomerates. They cut the Early N-S trending grabens, which have been elevated above the newly developed horst blocks. Under the graben depressions where the N-S grabens superimpose with E-W grabens the thicknesses of the graben fill reach up to 3000 m. Otherwise the graben fill is less than 1000 m in thickness.

There are about ten approximately E-W oriented grabens in Western Anatolia. The best-developed grabens are Büyük Menderes, Gediz, Edremit and Kerme grabens. They are about 100-150 km long, and 5-15 km wide. The grabens are asymmetrical. In each graben one margin is characterized by steeper topography, associated with surface breaks. On the footwall margins block bounded, listric, normal faults are readily observed.

The Western Anatolian grabens close eastward and enlarge westward. Some of the grabens is onshore some others extend into the offshore Aegean Sea. The geomorphology associated with the grabens and the horst dominates the landscape of western Anatolia and controls the major west flowing drainage system. The intervening horsts (>1000 m) control lateral subsequent streams.

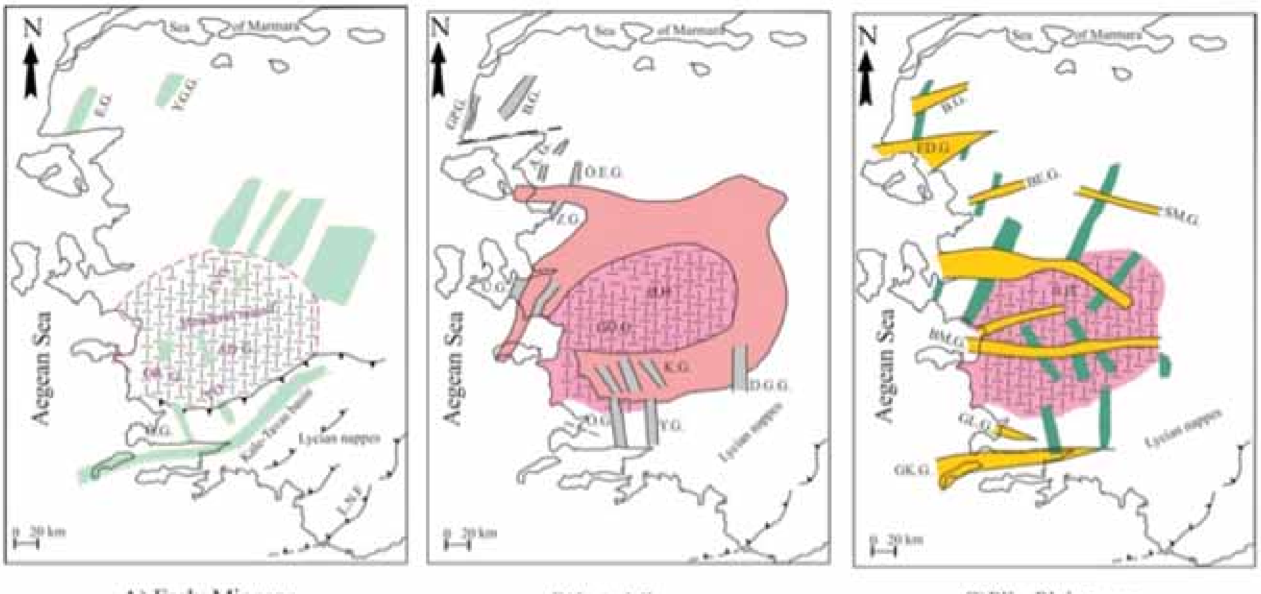

Figure 6. Schematic Neogene tectonic map of western Anatolia (After Yilmaz et al 2000).

The data documented on the timing and histories of development for the E-W grabens are conflicting. There is an on-going debate on the two major problems associated with the cover rock geology and the related graben structures;

1. When did the grabens begin to develop?
2. What is the mechanism, which triggered their development?

Extensional regime often follows development and then the collapse of the orogenic belts, and the extensional driving forces are known to be related to the pre-extensional history of the orogenic belt. In many cases the area of extension invading the area of shortening in time. Therefore the two problems appear to be intimately associated to one another and require a fuller understanding of the geology of the region, together with the detailed geology of the grabens areas.

On the timing of the development of the E-W grabens two different views have been variously proposed; according to the one group of views the grabens are relatively old. They began to develop during the Late Oligocene-Early Miocene. The N-S extension, which caused their generation, has been continuing ever since (Seyitoğlu, 1997). To the other group of views the present grabens are young structures; not older than the Late Middle Miocene, and the region has suffered more than one phase of extension intervened by a compressional episode, (Yılmaz et al., 2000).

The northern part of the western Anatolian region is structurally more complex, because the N-S extensional regime of the Aegean Region and the North Anatolian Transform Fault Zone (NAFZ), as the northern plate boundary of the Anatolian Plate, intersect (Yılmaz et al., 2010).

The Anatolian Plate is the major, wedge shaped lithospheric entity (Şengor and Yilmaz 1981). It is bounded by two transform faults. Of these, the NAFZ, represents the northern fault. The Anatolian Plate is escaping westward from the point of convergence in the Karlıova junction in the East Anatolia. The escape began, following the complete elimination of the Tethyan oceanic realm between the collided Arabian and Laurasian plates, during the Pliocene-Pleistocene. From eastern Anatolia, the NAFZ stretches to the west for more than 1000 km.

The entrance of the NAFZ into the northwestern Anatolia post-dates the development of the late Miocene-early Pliocene erosional surface, because the NAFZ cuts and displaces this marker. In fact, two different morphological features dominate the western Anatolian morphology a) flat-lying erosional surfaces, and b) narrow and long ridges, and depressions.

The narrow ridges correspond commonly to closely developed horsts; they have steep, normal-fault-bounded slopes. The remnants of the erosional surfaces have been elevated above these horsts; therefore, commonly they have flat tops (Yılmaz et al., 2000; Yılmaz, 2010).

A major structural axis, a hinge line is recognized in northwest Anatolia. It is a tectonic bend, which formed as a result of the westerly motion of the Anatolian Plate. This induced an E-W shortening deformation when it met resistance in the Greece-Balkan Domain. This obstacle prohibited further westerly advance of the Anatolian Plate, and caused its anti-clockwise rotation to move in a southwesterly direction above the Hellenic Trench. The anti-clockwise rotation is a relatively young event, confined to the last 2-3 ma periods.

In the eastern and western parts of the western Anatolia the GPS vectors display different directions and rates of motion. The eastern part moves from east to west, while the western part moves from northeast to southwest. These are reflected also in the trends of the changes in the strikes of the faults and the associated major morphological features such as the hills that are clearly linked with the anti-clockwise rotation of the Anatolian Plate in the Aegean Region, and the related stress regime that such changes have generated.

The NAFZ is the major structural element of the Marmara Region. In the eastern part of the region, the NAFZ splits into two major branches. The northern branch follows a trend along Sapanca Lake. Entering into the İzmit Gulf, it is buried under the waters of the Marmara Sea. The southern branch extends along the Dokurcun valley, and the southern side of İznik Lake as one segment before entering the Marmara Sea, through the Gulf of Gemlik. In the southern part of İznik Lake, the southern branch splits to form a third segment. Further west there is not one continuous strike-slip fault. Instead, there are a number of short segments dispersed into the Biga Peninsula.

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GENERAL GEOLOGY AND TECTONIC SETTING OF THE WEST TURKEY*

Cahit Helvacı & E. Yalçın Ersoy & Ökmen Sümer

The western Anatolia forms the easternmost part of the Aegean Extensional Province (Figure 1). The region is characterized by Aegean subduction system along which the African Plate is subducted under the Anatolian Plate that is tectonically escapes toward the west along the strike slip North Anatolian Fault Zone (NAFZ) in the north and South Anatolian Fault Zone (SAFZ) in the south. The western Anatolia is also characterized by a number of approximately east-west trending, subparallel, normal fault zones bordering a set of grabens and intervening horst blocks. Seismic activity is intense and has been recorded by a network of instruments roughly encircling the active faults. Motions on the faults confirm that extension is in a north-south direction. Western Anatolia and the Aegean regions have long been known to represent a broad zone of extension (Phillipson 1918) stretching from Bulgaria in the north to the Hellenic arc in the south (McKenzie 1972). The N–S-directed extensional tectonics in the region has resulted the nearly E–W-trending grabens such as Gediz, Küçük Menderes and Büyük Menderes grabens. In each graben, one margin is characterized by steeper topography, associated with surface breaks. On the footwall margins of the grabens, planar faults are readily observed. Another feature of the region is the presence of the NE–SW-trending strike-slip faults which are newly though to be belong to the İzmir-Balıkesir Transfer Zone (İBTZ). The İBTZ represents a weakness zone that was operated an accommodation zone since the Cretaceous (Okay & Siyako, 1991; Ring *et al*. 1999; Sözbilir et al. 2003; Erkül *et al*. 2005; Uzel & Sözbilir 2008).

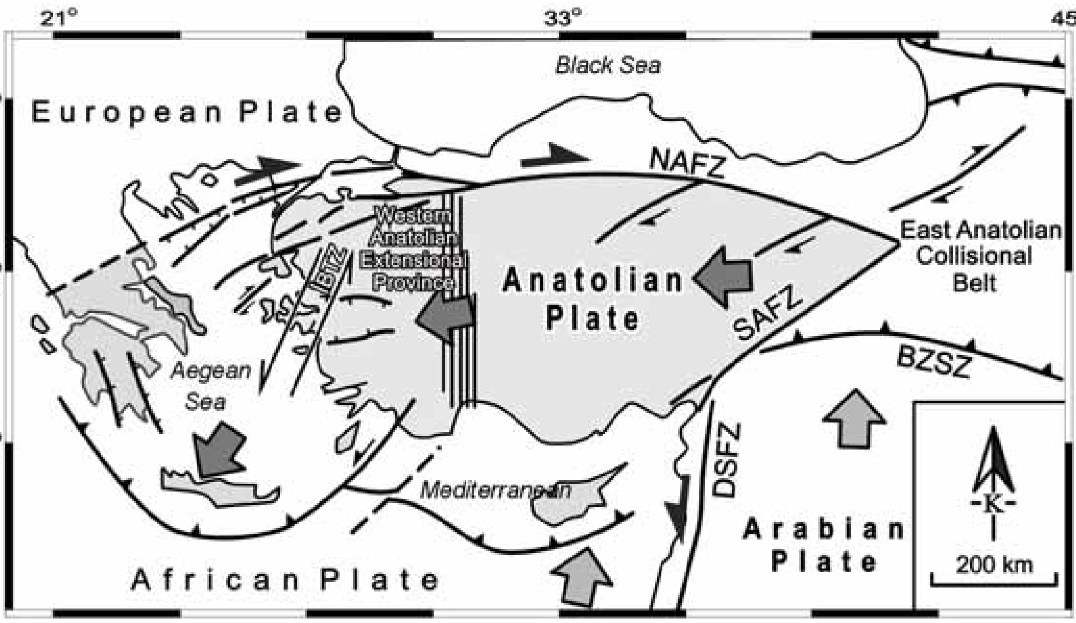

Figure 1 Regional tectonics structures of Turkey and surrondings.

**This section is from Helvacı et al. (2009)*

The pre-Quaternary geological background of the region is made up of several tectono-stratigraphic units and covering Oligo-Miocene sedimentary and volcanic rocks. The tectono-stratigraphic units are the Menderes Massif

and Cycladic blueschists representing the parts of the several continental fragments which were amalgamated by pre-Neogene continental collisions; and the Bornova flysch zone and Lycian nappes representing the oceanic remnants of the Neo-Tethys oceans (Figure 2).

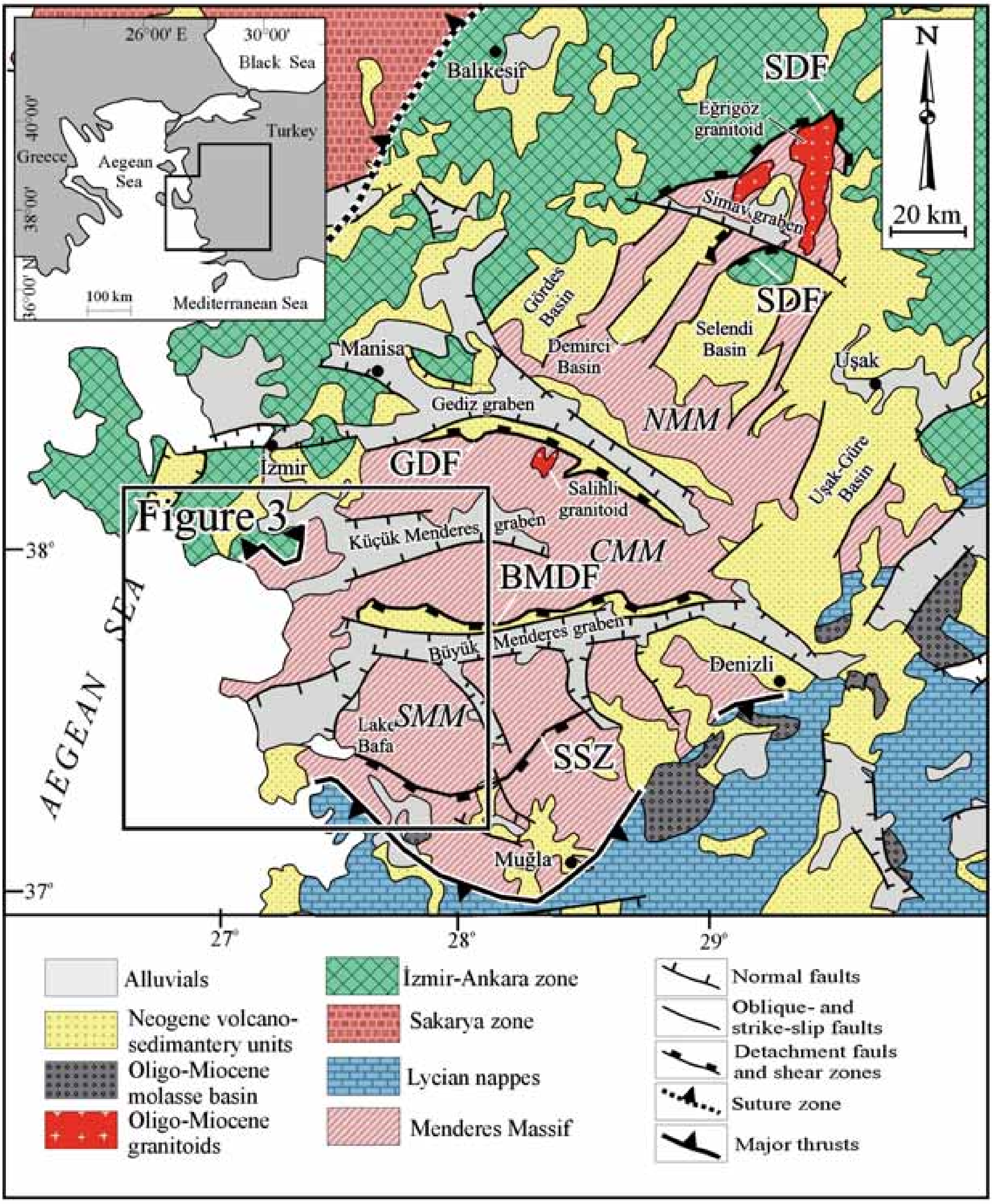

Figure 2 Generalized geological map of western Anatolia showing major tectonostratigraphic units on which Neogene and Quaternary sedimentary basins developed. SDF–Simav detachment fault, GDF–Gediz detachment fault, BMDF–Büyük Menderes detachment fault, SSZ–Selimiye shear zone, NMM–Northern Menderes Massif, CMM–central Menderes Massif, SMM–Southern Menderes Massif. Modified from Sözbilir (2005).

The Menderes Massif, with its northeasterly oriented elliptical shape, has lift significant imprint on the geological evolution of western Turkey. From north to south the Neogene grabens Simav, Gediz, K. Menderes, and B. Menderes divide the Menderes Massif into four sections (Dora et al. 1995; Figure 2). The Menderes Massif is composed of lower- to mid-crustal metamorphic rocks, such as augen gneisses, schists and marbles which were exhumed during the Neogene extensional events. The Cycladic bulueschists consists of high-pressure supra-crustal metavolcanic and meta-volcaniclastic and thick marbel units.

A part of the Vardar-İzmir-Ankara suture, the Bornova flysch zone (or Bornova mélange) is composed of greywacke-shale alternations in which giant blocks of limestone an ophiolite occur as olistolithes (e.g. Şengör & Yılmaz 1981; Okay *et al*. 1996). The nonmetamorphic Mesozoic carbonates and Bornova melange that were deposited in flysch facies rest along a thrust fault on the top of the Menderes Massif. The Bornova mélange rocks are composed of the shale and sandstone, which form the matrix and limestone mega blocks, mafic volcanic intervals and ophiolitic rocks. The age of the sandstone and shale and the other components of the Bornova mélange rocks vary from Upper Cretaceous to Paleocene (Erdoğan 1990).

The North Anatolian Fault System

The North Anatolian Fault Zone (NAFZ) is a nearly 1500 km long, having dextral strike-slip component that extends from eastern Turkey in the east to Greece in the west (Figure 1). It is predominantly a single zone of a few hundred meters to 40 km wide. This transcurrent Fault zone forms the part of the boundary between the Eurasian Plate to the north and Anatolian Plate to the south (Bozkurt 2001). The age and cause of dextral motion along the NAFZ is controversial and there are basically four different views: (1) The right-lateral motion commenced by the Middle Miocene and it was resulted from the westward motion of Anatolia away from the collision zone in the eastern Turkey where the Arabian and Eurasian plates had collided (McKenzie 1978). (2)The activity of the NAFZ did not commence until the latest Miocene or Early Pliocene because of the deformed Miocene sedimentary rocks or nearly 25 km offset is recorded by any studies (Barka *et al*. 2000). (3) The initiation of the activity along the NAFZ in the eastern Anatolia had occurred during the Late Miocene and propagated westwards reaching the Sea of Marmara region during the Pliocene (Okay *et al*. 1999). (4) The initiation of the activity along the NAFZ was ~16 Ma or older in the eastern parts but less than 3 Ma in the western parts of the region (Gautier *et al*. 1999).

The Aegean Subduction System

The African Plate is subducted along the Aegean subduction system underneath the Anatolian Plate. The Aegean arc system performs an important role in the geodynamical evolution of the Aegean region. In the literature, two locations have been proposed for the location of the subduction zone (Figure 1). This disagreement is due to the presence of two major thrust zone, spaced 50-100 km apart. The southern tectonic line takes place where the African Plate starts to go down below approximately 200 km wide wedge of accreted sediments. This wedge is termed as the Mediterranean Rise and is composed of sediments resting on the African Plate. The latter zone is marked by a trench known as Hellenic Trench. The contact between the sediments of the Mediterranean Rise and the thrust units above the Hellenic Trench is well defined to the south of the Crete. The Hellenic Trench is characterized by dip focal earthquakes which are characterized by fault plane solutions of thrust mechanism. There are several studies on the age and start the collision from Aegean arc system. It is suggested that the initiation of the subduction has taken places approximately 13 Ma ago (Le Pichon & Angelier 1979). Some authors have also favored a late Miocene/Pliocene age for the initiation of the subduction (e.g., McKenzie 1978). Le Pichon & Angelier (1979) calculated an age of 13 Ma on the basis of the oldest rocks of island arc affinity. However, others claimed that the age of the Aegean subduction zone is at least 26 Ma (Meulenkamp *et al*. 1988). Seismic tomography, on the other hand, indicates that the subducted slabextents to >800km depth and assuming between 200 and 400 km of stretching in the upper crust and a subducting rate of 15 km/Ma.

Late Cenozoic Basins in Western Anatolia

Western Anatolia forms one of the most seismically active and rapidly extending regions in the world and it is currently experiencing an approximately N–S continental extension at a rate of 20–60 mm year (Reilinger *et al*. 1997). Basin- bounding active normal faults of the grabens are the most prominent neo-tectonics features of western Anatolia (e.g., Şengör *et al*. 1985) (Figure 2).

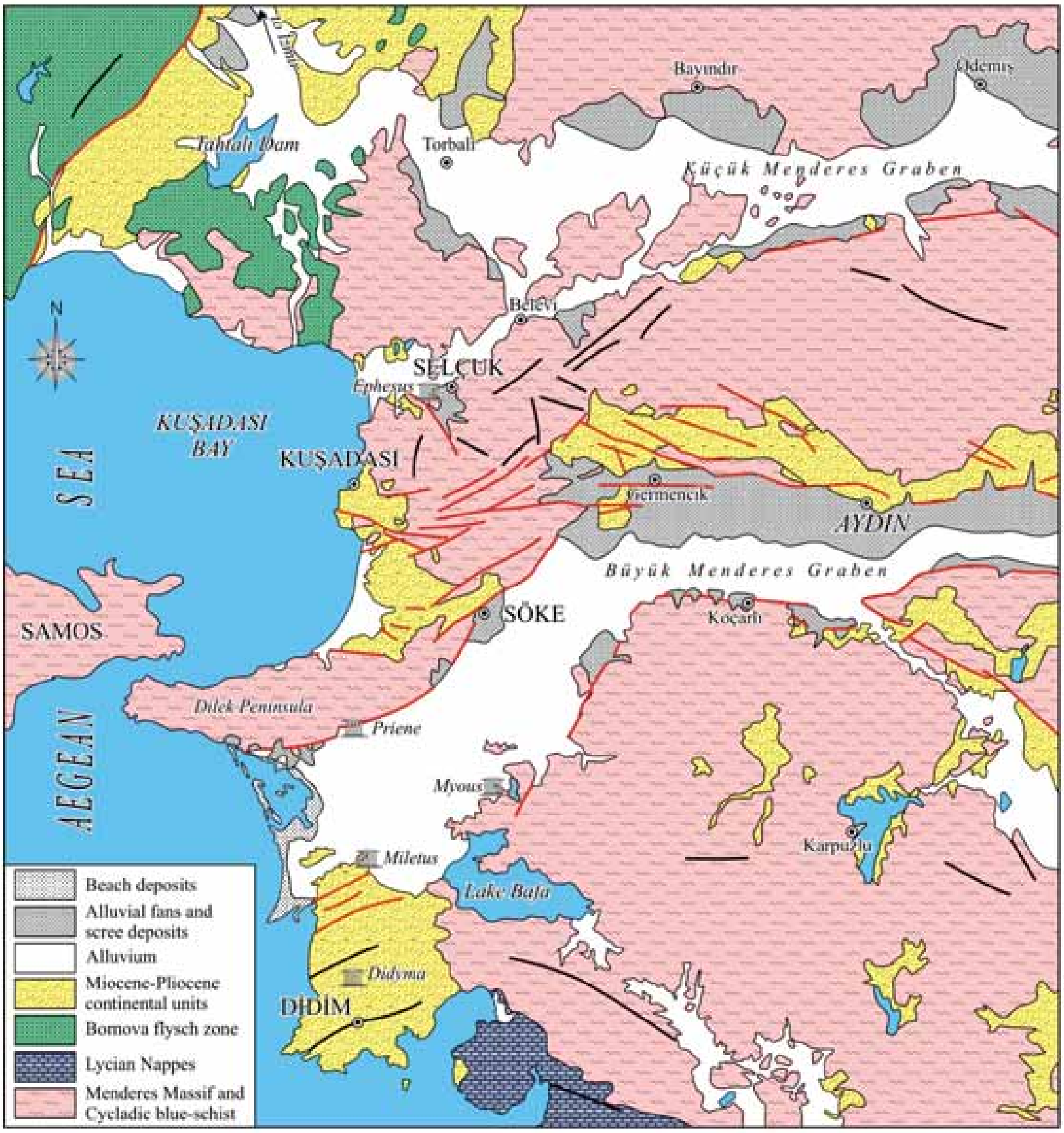

Figure 3 Generalized geological map of the Büyük and Küçük Menderes grabens (Modified from MTA geological map).

The late Cenozoic crustal extension in the region has resulted in (1) NE–SW-trending volcano-sedimentary basins, and (2) E–W-trending grabens. The NE–SW-trending basins are, from west to the east, Soma basin (İnci 1998), Gördes basin (Seyitoğlu & Scott 1994; Purvis & Robertson 2004), Demirci basin (Yılmaz *et al*. 2000), Selendi basin (Seyitoğlu 1997a; Purvis & Robertson 2004; Ersoy & Helvacı 2007) and Uşak-Güre basin (Ercan *et al*. 1978; Seyitoğlu 1997a; Westaway *et al*.

2004). The E–W-trending Neogene basins are cut by still active Plio–Quaternary E–W-trending grabens, such as Edremit graben (Yılmaz & Karacık 2001), Simav graben (Seyitoğlu 1997b), Gediz graben (Koçyiğit *et al.* 1999; Sözbilir 2002; Bozkurt & Sözbilir 2004; Westaway *et al.* 2004), Küçük Menderes Graben (Rojay *et al.* 2005; Bozkurt & Rojay 2005; Emre *et al.* 2006; Emre & Sözbilir 2007), and Büyük Menderes Graben (Seyitoğlu & Scott 1992; Cohen *et al.* 1995).

The NE–SW-trending basins generally consist of early and middle Miocene volcano-sedimentary successions, late Miocene volcanics and sediments, which are separated by basin-scale unconformities. The early-middle Miocene volcano-sedimentary successions are thought to be deposited in response to extensional detachment faulting in the region that exhumed the Menderes Massif (e.g., Purvis & Robertson 2004; Ersoy & Helvacı 2007). The E–W-trending grabens are characterized by deposition of alluvial fans and alluvium in recently deforming basins which are bounded by active normal-faults

Büyük and Küçük Menderes Grabens

Büyük Menderes Graben is a E-W trending depression, 150 km long and 10-20 km wide, bounded by active normal faults (Paton 1992). The graben changes its direction in Ortaklar, extends NE-SW through Söke, intersects with Gediz Graben in the east of Buldan and turns to Denizli basin from Sarayköy (Figures 2 and 3; Westaway 1993). Sarıkemer Bridge and Didyma are located at the southwest of the NE–SW-trending part of the graben (Figure 3). The historical earthquakes occurred in B.C. 31, 26 and D.C. 2, 1653, 1895, 1899 and 1955 along the graben bounding faults show that the region is seismically active.

Four units divided by unconformities overlie the metamorphic basement in the Büyük Menderes Graben around Sultanhisar-Nazilli-Kuyucak.

I. Unit: The unit crops out in the northeastern part of Dereağzı, around Hasköy and between Sultanhisar and Güvendik, and consists of conglomerates containing abundant boulder size clasts. This clastic facies bounded by N-S trending fault in the west, turns into sandstone-mudstone and bituminous shales. In the farther east, the unit is characterised by sandy limestone facies. The unit deposited in a basin consisting of alluvial fan deposits, fan delta and lacustrine deposits from west to east. The unit includes economic coal seams being mined recently. According to palynological data, the unit is Early-Middle Miocene (Figure 4; Sözbilir 2001; Seyitoğlu & Scott 1992).

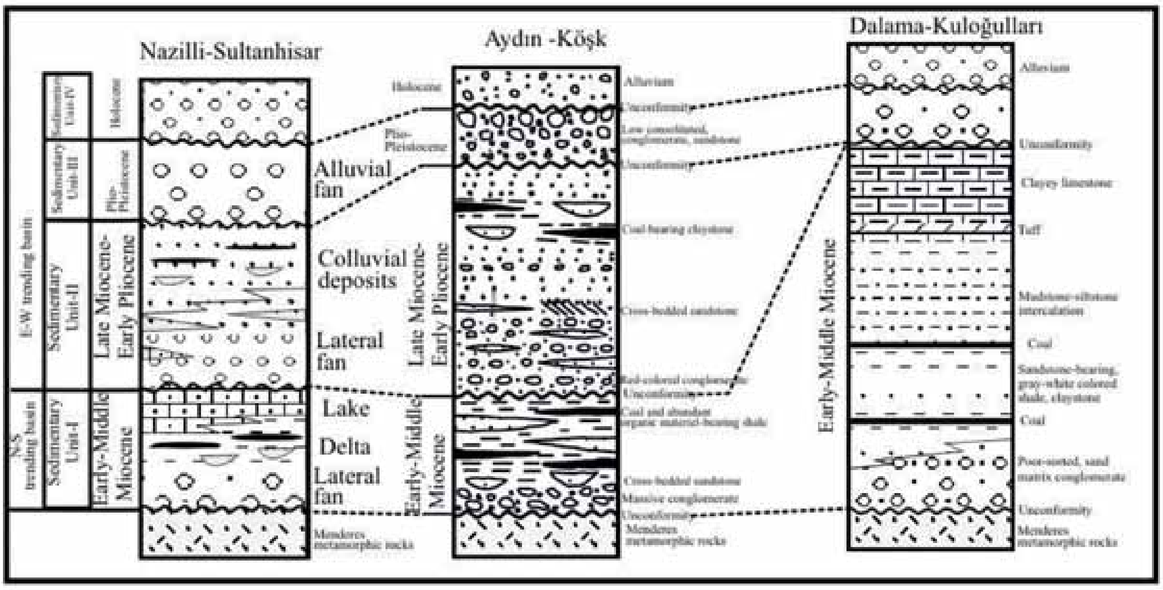

Figure 2. Stratigraphic correlation of Cenozoic sediments which developed in the southern margin and the northern margin of Büyük Menderes Graben (after Sözbilir 2001).

II. Unit: The sediments of the unit are characterised by reddish terrestrial conglomerates and sandstones. They crop out around Gökkıran tepe, in the southeast of Güvendik and between Bayındır and Gediz. Sandstone-claystone intercalation with coal lenses is abundant between Bayındır and Gediz (Figure 4).

III. Unit: The unit consisting of abundant conglomerate and sandstone intercalation extends longitudinally E-W in direction from Sultanhisar to Kuyucak. The unit crops out in the north of Nazilli along with dramatic change in topography, and continues 2 km wide to the north. Facies characteristics of the unit indicate that it is related to alluvial fans controlled by the E-W trending faults. Fossil findings around Şevketin Dağı show that III. Unit is Late Pliocene-Pleistocene (Ünay *et al.* 1995) (Figure 4).

IV. Unit: The sediments of the unit consist of alluviums filling Büyük Menderes depression and are formed by fine-grained river deposits transported by Büyük Menderes River and perpendicular alluvial fan deposits. The unit is still forming recently.

The E–W-trending Küçük Menderes Graben was developed at the centre part of the Menderes Massif. Ephesus is located at the westernmost edge of the southern border of the graben. At the eastern part of the graben, uppermost Middle Miocene-Upper Miocene sedimentary rocks occur on a basement of metamorphic rocks and Middle Miocene andesitic volcanic rocks (Figure 5). Emre & Sözbilir (2007) have showed that these sediments were deposited in an N–S-compressional tectonics that produced nearly N–S-trending strike-slip faults and associated reverse faults. These sedimentary rocks are unconformably overlain by Plio-Pleistocene sediments that were deposited in extensional tectonics. This phase of extension has widened the basin and continued up to present. The Küçük Menderes Graben is recently deformed under N–S-directed extension.

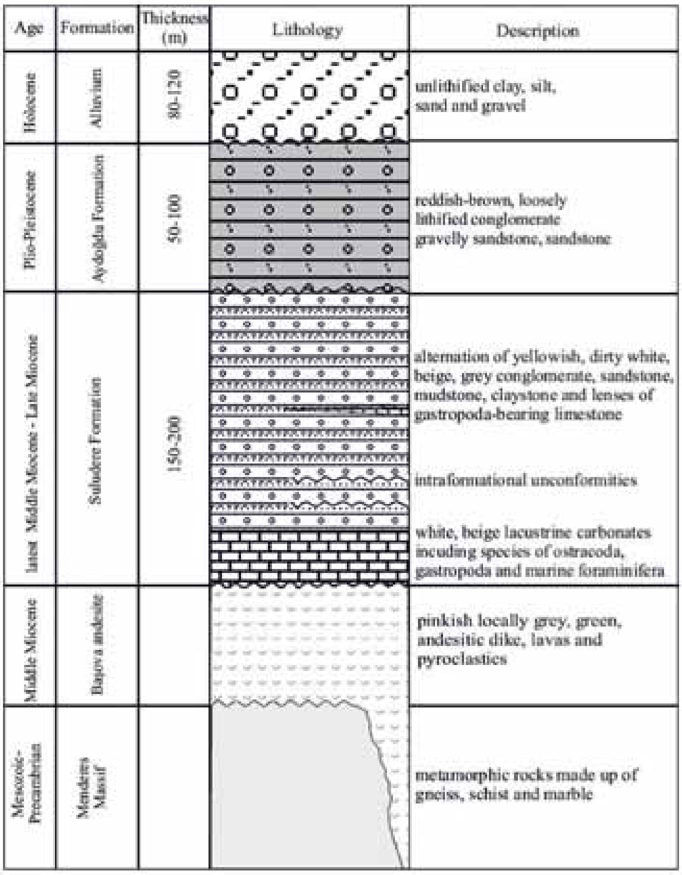

Figure 5 Stratigraphic section of the Neogene units in the eastern edge of the Küçük Menderes Graben.

Proposed Models for Extensional Tectonics and Basin Formation in the Region

The cause and origin of crustal extension in the region fall into five different models. The ***cross-graben model*** of Şengör (1987) predicts the NE-trending Early Miocene basins began to develop as "palaeotectonic Tibet-type cross-grabens" under N-S Palaeogene compression and shortening, and then, they were replaced by neotectonic Aegean-type cross-grabens (*replacement structures*) under the following N-S extensional regime commencing in the Tortonian (Figure). Tortonian and younger basins belong to the N-S extensional regime related to the tectonic escape of Anatolian block along the North Anatolian Fault (NAF) zone since the late Serravallian (ca. 12 Ma).

The ***orogenic collapse model*** of Dewey (1988) considers that the both NE–SW- and E–W-trending depressions began to develop coevally during latest Oligocene–early Miocene times, in a neotectonic N–S extensional regime that was resulted from the orogenic collapse of the over-thickened crust.

According to the ***back-arc spreading model***, the post-Oligocene extension in the Aegean region was governed by subduction zones triggered by gravitational instability of old, dense oceanic lithosphere (e.g., McKenzie 1978). This caused an extension in the overriding plates as a result of slow convergence rates combined with rapid subduction rates.

The ***two-stage, episodic extensional model*** has been proposed for the extensional tectonics in western Anatolia, which consider that two or more of the above mechanism played role in the Late Tertiary extensional tectonics in the region. According to this view, Late Cenozoic basins and grabens in western Anatolia have developed as a result of two-stage (episodic) extensional tectonics; the fist one is related to the orogenic collapse and second one is related to the present neo-tectonic extensional phase commenced during the Pliocene (Koçyiğit *et al*. 1999). In this view there is a compressive phase in the late Miocene–early Pliocene interval, separating the two periods of extension, and hence, extensional tectonics in this region is episodic rather than continuous style. The closuring of the Bitlis-Zagros suture zone in late Serravalian (~12Ma; Dewey & Şengör 1979) was followed by late Serravalian–early Pliocene compressive phase. In the late early Pliocene the Anatolian plate started to escape westward.

Recently the ***pulsed extension model*** have been proposed for the Late Tertiary extensional tectonics of the western Anatolia, which presumes that neither continuous-style nor two-stage, but has a rather complex history showing at least three different phase of extension (Purvis & Robertson 2004). This model predicts that the first "pulse" of the N-S extension took place in late Oligocene giving rise to low-angle normal faulting that created N-S trending "scoop-shaped" depressions in which sediments accumulated during Early-Middle Miocene (e.g., Gördes and Selendi Basins). This phase of extension was droved by roll-back processes of Aegean subduction system. The second "pulse" of extension occurred in Early Miocene–Late Miocene which gave rise to E-W trending basin formation related to the exhumation of the Menderes Massif, similarly was droved by roll-back processes. The last "pulse" of the extension responsible to again the E-W- trending grabens, which controlled by tectonic escape of Anatolian plate.

ARCHEOLOGİCAL SİTES İNFORMATİON AND CHRONOLOGİCAL DATA, İNCLUDİNG CİTY PLANS AND BUİLDİNG SPECİFİCATİONS WİTH FİELD AND SİTE PHOTOGRAPHS*

Şükrü Tül (Dokuz Eylül University/ Türkiye),
translated by Ahu Selin Erkul (Dokuz Eylül University/ Türkiye)

EPHESOS

Ephesos, known as Efes in modern Turkish, is one of the oldest and most important cities of the world. The area surrounding Ephesos especially the southern part of Selçuk near Çamlık hill was already inhabited during the Neolithic Age as was revealed by the excavations carried out nearby Çukuriçi mound. The area continued to be inhabited in the Bronze Ages and the finds excavated in the mound revealed that the obsidian sharp blades were coming from Melos island. The most important period in Ephesos' history is the period when the city became the capital of the Arzawa civilization in the 2nd millennium BC. The city in this period was called Abasa (Apasa) in the Hittite texts. Excavations in the recent years have unearthed Abasa and its settlements and the city walls at the Ayasuluk Hill. Abasa's power seemingly decreased in 1315 BC after the campaigns and attacks of Mursili II, the Hittite King. A burial ground from the Mycenean era with ceramic pots was discovered close to the ruins of the Basilica of St John. This was the period of Greek expansion and growing trade activities when the immigrants settled in the area.

The city of Ephesos itself was founded by the Attic- Ionians migrants who were settled in the west of the present stadium. The mythical founder of the city was Androklos who had to leave his country after the death of his father king Kodros. Large populations of the Ionians who were formerly living in Koressos moved to Ephesos and settled in the area surrounding the Artemis Temple during the reign of Croesus, the Lydian King. The city in this period was rather disorganized with its outer district Smyrna, other districts and the Temple of Artemis located at the center. The magnitude of the Temple of Artemis which was reconstructed during Croesus' reign made Ephesos a center of attraction, visited by merchants, kings, and sightseers, many of whom paid homage to Artemis in the form of jewelry and various goods. Its splendor also attracted many worshipers. In 356 BC, the Artemis temple was burned down. After Alexander the Great defeated the Persian forces, the Greek cities of Asia Minor were liberated. Alexander the Great contributed to the reconstruction works of the temple. After Alexander's death, Ephesos came under the rule of Lysimachus who moved the city to a new settlement in its new location between the mountains of Panayır and Bülbül. The new city which was built on the former Smyrna district was covering the pilgrimage road (embolos) between Preon and the Pion mount (Figure 7).

The city which may be visited today reflects the traces of the settlements between 3rd century BC and 6th century AD. Ephesos was an important center for early Christianity. The arrival of the Virgin Mary together with John, one of the chief apostles, John's attempts to work with congregation and to send messages to other Anatolian cities and the visit of Paul to Ephesos, "the most important city in the second province of the God" as it was known, strengthened the city's importance for the Christians.

**This section is from Helvacı et al. (2009)*

Later, the city was centered on the Basilica of St John which was built in the 6th century AD. In this period trade activities were moved to Neapolis near modern Kuşadası due to the silt accumulated in the ancient harbor. Attacks and sackings by the Arabs first in the year 654-655 and later in 700 and 716 hastened the decline further. The city was abadoned in the coming years and the Episcopacy of Ephesos was diminisned into the Basilica of St John on the Ayasuluk Hill. In 1304, the town was conquered by Aydınoğulları principality. The town was rebuilt again a short period of flourishing and Isa Bey Mosque was constructed in 1375.

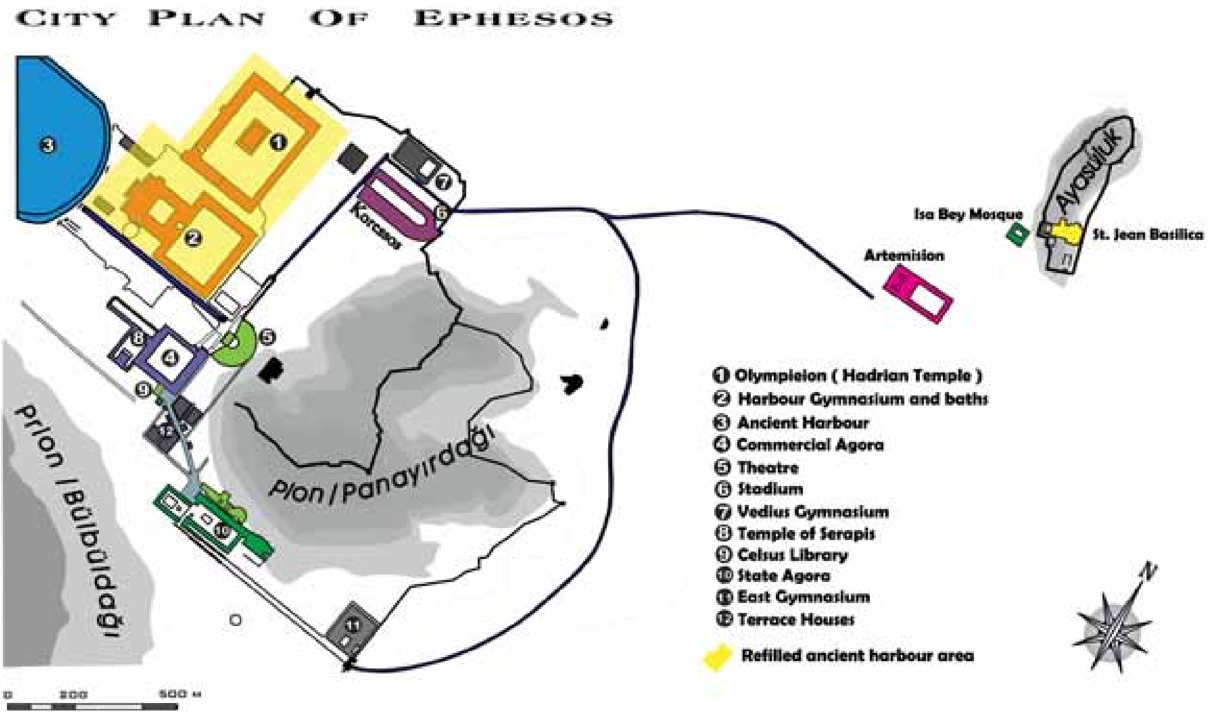

Figure 6 Ephesos city plan (modified by Ökmen Sümer and Şükrü Tül after Cambridge, MA: 1995).

Artemision

The Temple of Artemis which was first built in the 8th century BC or earlier hosted many votive objects coming from various parts of the world in its early phases. It is known that the goddess was worshipped in a very large area covering Spain in the west and the Caspian Sea in the east. The oldest temple was a clay-floored peripteral temple surrounded by colonnades. Anton Bammer notes that although the flood-prone site was raised by silt deposits about two metres between the eighth and sixth centuries. Hogarth identified a new complex called C temple and dated the constuction of this new temple to the 7th century BC. The new Archaic temple of 24 m high, now built of marble with its 127 peripteral columns doubled to make a wide ceremonial passage round the cella, was designed and constructed around 560- 550 BC by architect Chersiphron and his son Metagenes from Knossos and Theodoros from Samos. A new ebony or grapewood cult statue was sculpted by Endoios and a naiskos to house it was erected east of the open-air altar.

This enriched reconstruction was built at the expense of Croesus, the wealthy King of Lydia. The rich foundation deposit of more than a thousand items has been recovered. Fragments of the bas-reliefs on the lowest drums of Croesus' temple, show that the enriched columns of the later temple, of which a few survive were versions of the earlier feature. Today, the remains of this temple may be seen underwater (Figure 8 and 9). Some stone parts with meander figures may be seen in the western side of the Isa Bey Mosque.

Figure 7 Artemis Temple, 8th century shrine at the hearth of the Naos; restored column Late Classical temple (at bellow) (Photo Sükrü Tül).

The Temple of Artemis at Ephesos was destroyed in 356. Then the temple, which was considered one of the Seven Wonders of the World, was rebuilt to same measurments as the old temple. Skopas, a famous carver, worked carved reliefs into the temple's columns. These reliefs are now exhibited in the British Museum. It is also known that the temple was then transformed into a church and the stones were reused in the construction of the Basilica of St John on Ayasuluk Hill. After sixty years of patient searching, the site of the temple was rediscovered in 1869 by an expedition sponsored by the British Museum led by John Turtle Wood, the discovery of the temple made Ephesos once more a tourist attraction. Thousands of voyagers and tourists have come of visit the site. Ephesos may be considered the earliest archaeological site to be visited by mass groups The places to visit in the ancient Ephesos beginning with the main entrance gate can be listed in the following pages.

Figure 8 A schematic illustration of the Temple of Artemis in a coastal harbor setting by E. Falkener (~1850) (Kraft at al., 2007).

Remains Situated in the Northern Part of the City The Vedius Antoninus Gymnasium

The construction of the gymnasium dates around the second century AD, funded by Publius Vedius Antoninus and his wife Flavia Papiana. They dedicated the gymnasium to Goddess Artemis and to Emperor Antoninus Pius. In Ephesos, gymnasiums were the schools for young people in which one could take lessons for art, sports, literature, drama and speech. The most important and beautiful of these gymnasiums was the Gymnasium of Vedius. The entrance of the gymnasium is on the east, and when entering there is a palaestra surrounded by columns. The hall of emperors is also on the east, with statues and floors covered with mosaics.The gymnasium included a bath, with a tepidarium, a caldarium, and a frigidarium. There was a pool at the frigidarium, with the statue of the god of the River Kaistros in the north end, pouring water into the pool from the amphora that the god was leaning on. Today, the statute is displayed in Izmir Kültür Park Tarih ve Sanat Museum. Since it is not included in the regular visit itinerary, the Vedius Gymnasium may be visited by a special permission.

Harbour Street

This street is situated between the Harbour Baths and the Theatre. Entering from the port, traders and sailors would first arrive in this street. It was designed as a great road with marble slabs and colonnades. It was constructed in the Hellenistic Period, but then was renovated during the reign of the Emperor Arcadius in the 4th century AD, from whom it takes its present name, the Arcadian Street

The street was 530 meters long and 11 meters wide, and on both sides of the street there were shops and galleries, and gates in the form of monumental arches. There were four higher columns with the statues of four apostels on the top. Excavations have revealed that the street decorated with statues was illuminated by candle-like street lamps at night. Sewerage channels ran beneath the marble flagstones. Excavations in the street furthermore provided evidence on the events that caused the harbour to be silted up and modified due to its inconvenience during Hadrian's reign. .

At the entrance of the port there were the Harbour Baths. They were built in the year 2 AD.The Baths are also called the Baths of Constantine, for they were renovated by Constantine II in the 4th century AD. The large unexcavated area in the east of the Harbour Baths is the Veralunus Court. Towards the north, we encounter a building complex called the Double Churches. The Double Churches or the Virgin Mary Church is important for the Christians. It was the first church dedicated to the Virgin Mary. The most recent excavations indicate that the Church of Virgin Mary was built into the south stoa (of the great Olympieion (Temple to Hadrian Olympios), whose foundations can be still be seen to the north of the church. The Olympieion was a large temple precinct built from about 100 to 130 AD on a filled-in swampy area next to the harbor. The great imperial temple was dedicated to Emperor Hadrian for his beneficiary contributions to the harbour. Similar temples of huge magnitude(60x90 m) were also constructed in Kyzikios, Smyrna and Tarsos during Hadrian's rule.

The Theatre

The Theatre is the most magnificent structure in Ephesos (Figure 10). The Great Theatre is located on the slope of Panayir Hill, opposite the Harbor Street, and easily seen when entering from the south entrance to Ephesos. It was first constructed in the Hellenistic Period, in the third century BC during the reign of Lysimachos, but then during the Roman Period (Claudius, Nero and Trajan), it was enlarged and took its current form. It is the largest theatre in Anatolia and has the capacity of 24,000 seats. The monumental stage building is in typical Roman style and it is three-storied and 18 meters high. The facade facing the audience was ornamented with reliefs, columns with niches, windows and statues. There is another building complex situated at the North of the theater and in the eastern end of the Arcadiane Street. It is known as Theater Gymnasium. The remains of a monumental gate on the Harbour Street may also be seen in the entrance of the Agora and gymnasium.

Figure 9. Ephesos Theater looking from north (Photo by Norman Herr).

The Agora

During Lysimachos' period when Ephesos was moved to its new location, this area was an outer district called Smyrna. Being the most important trade center of Ephesos, Agora was built in the third century B.C in the Hellenistic Period, but the ruins date from the reign of Caracalla (3rd century AD.).

It is in the form of a square, each side 110 meters, and fully surrounded by columns. The Agora has 3 gates, one from the front of the theatre on the northeast, the other one opening to the harbor on the west and the third one from the Celsius Library.

The Serapis Temple built for Egyptian merchants was located near the western gate of the Agora. The colossal columns of the Serapis Temple which was built in the 2nd century are worth seeing. The gate with three passage ways at the right of the Celsus Library was built in 40 A.D by the slaves Mazeus and Mythridates for their emperor, Augustus, who gave them their freedom. The meticulous carvings and masonry of the gate are remarkable. The Marble road starting from the Theatre to the Celsus Library is the portion of the sacred way that leads from Panayir to the Temple of Artemis. The construction of the marble road dates to the 1st century A.D, and it was rebuilt in the 5th century. The western side of the road is enclosed by the agora wall, and on the wall is a higher platform, which was constructed during the reign of Nero. It was built over the wall, for pedestrians. The Nero Stoa with it columns in Doric order is still under renovation.

Celsus Library

This library is one of the most beautiful structures in Ephesos. It was built in 117 A.D between the Nero Stoa, the Mitridates and Mazeus Gate and Hadrian's Gate in the intersection of the Marble Street and the Curetes Street (Figure 11). It was a monumental tomb for Gaius Julius Celsus Polemaeanus, the governor of the province of Asia; from his son Galius Julius Aquila. The grave of Celsus was beneath the ground floor, across the entrance and there was a statue of Athena over it. The scrolls of the manuscripts were kept in cupboards in niches on the walls. The facade of the library has two-stories, with Corinthian style columns on the ground floor and three entrances to the building. There is three windows openings in the upper story. They used an optical trick that the columns at the sides of the facade are shorter than those at the center, giving the illusion of the building being greater in size. The statues in the niches of the columns today are the copies of the originals. The statues symbolize wisdom (Sophia), knowledge (Episteme), intelligence (Ennoia) and valor (Arete). These are the virtues of Celsus.

Figure 10. Celsus Library (Photo Sükrü Tül).

Terrace Houses

Terrace houses are listed in the UNESCO World Cultural Heritage nominations. They were excavated during 1967–1983 excavation campaigns and they provide important evidence for family and daily life during the Roman period. Terrace houses are located on the hill, opposite the Hadrian Temple. They were built according to the Hippodamian plan of the city in which roads transected each other at right angles. There are six residential units on three terraces at the lower end of the slope of the Bülbül Mountain. The oldest building dates back into the 1thC BC and continued in use as residence until the 7th C AD.

Terrace houses are covered with protective roofing which resembles Roman houses. The mosaics on the floor and the frescos have been consolidated and two houses have been opened to the public as a open air museum.

They had interior courtyards (peristyle) in the center, with the ceiling open. They were mostly two-storied, upper stores have collapsed during time. On the ground floor there were living and dining rooms opening to the hall, and upstairs there were bedrooms and guest rooms. The heating system of the terrace houses were the same as that in baths. Clay pipes beneath the floors and behind the walls carried hot air through the houses. The houses also had cold and hot water. The rooms had no window, they were only illuminated with light coming from the open hall, so that most of the rooms were dim. A very interesting find from the Terrace Houses is a 6th century BC statue of an Egyptian priest. This object reflects the interest of the upper class house owner as an antiquarian. The most famous example of these houses, the Socrates room, is now exhibited in Efes Museum and it stands as the most beautiful example of red colouring.

The Curetes Street

It is one of the three main streets of Ephesos leading to the Celsus Library. This street took its name from the priests who were called Curetes. Their names were written in Prytaneion. There were fountains, monuments, statues and shops on the both sides of the street. The shops on the south side were two-storied. Hadrian's Gate is located at the junction of the Curetes Street and the Marble Street. The gate house has three stories. On the first story there are three entrances. The one in the center is wider and spanned by an arch and the other two side entrances are capped by architraves. The second story was formed of four pillars and the third story of six pillars. A gable marks the top of the building. The Octagon was a vaulted burial chamber placed on a rectangular base with the skeleton of a 15 or 16 year old woman in a marble sarcophagus. According to scholars Octagon was a monument to Ptolemy Arsinoe IV, the youngest sister of the famous Cleopatra VII, was murdered in Ephesos in 41 BC. Scholastica Baths were built in the first Century and restored in the fourth century by a rich Christian lady called Scholastica. On the left of the eastern entrance, you can see her statue without head. The original structure was thought to have been three-storied but by the time the upper two stories collapsed. The baths have two entrances, one from the Curetes Street, which is the main entrance, and the other from the side street. The Memmius Monument is situated on the north side of the Domitian Square. It was constructed during the reign of Augustus in the 1st century A.D by Memmius, the grand son of dictator Sulla. One can see the figures of his father and grandfather on the blocks today. The structure has four facades, in the 4th century A.D, a square fountain was later built on the northwest facade. Hercules Gates is located towards the end of the Curetes Street, it took its name from the relief of Hercules on it. It was brought from another place in the fourth century AD to its current place, but the relief on it dates back to the second century AD. Only the two side of the columns remain today and the other parts of it have not been found. The relief of the flying Nike in the Domitian Square is thought to also be a part of this gate. In these reliefs Hercules was depicting with the skin of the Nemean lion in myhtology.

The Temple of Domitian

Located to the south end of the Domitian Street, it is the first structure in Ephesos known to be dedicated to an emperor. It was built on a high and wide terrace set by 50x100 meters in size, on vaulted foundations. The northern size of the terrace seems to be two-stories high, reached by stairs. The stairs are still visible today. The temple, built in pro-style plan, had eight columns on the short side and thirteen columns on the long side, and four additional columns in front of the cella.

At the northern side there was an u-shaped altar, which is now displayed in Izmir museum. The Pollio Fountain was located to the south of the State Agora, across the Odeion. It was built in 97 A.D by the rich Ephesian C.S.Pollio and his family. The water was brought to the fountains of Ephesos from three main sources through aqueducts and distributed from fountains by a branching system of baked clay pipes. It has a high arch facing the temple of Domitian.

It is known to be decorated with a number of statues. One of these statues is the Head of Zeus which is on display in the Ephesos Museum today. Some of these statues were thought to be taken from the Isis Temple, probably after an earthquake, to repair the fountain. The statue group of Odysseus and Polyphemus, that once were on the basin, are now displayed also in Ephesos Museum.

The State Agora

The agora on the southern part of the Basilica is the State Agora, and was built in the Roman Period in the first century B.C. This agora was used not for commerce but for business, it played an important role as a meeting place for the governmental discussions. During the excavations in the northeast corner of the Agora were found a great number of graves from the 7th-6th centuries B.C and a stone-paved road, and a archaic sarcophagus of terra cotta. From this it is understood that in the archaic period this part of the Agora was used as the necropolis of Ephesos. There is a water reservoir at the corner of the Agora, which played an important role in Ephesos. Its water was brought to the city through the Pollio Aqueduct, the remains of the Pollio Aqueduct can be seen 5 kilometers away. The agora is 160x73 meters, with stoas on three sides and a temple in the center, dating from the 1st century A.D

The Basilica of St. John

It is believed that St. John, the Evangelist had spent his last years in the region around Ephesos and is buried in the southern slope of Ayasuluk Hill. Three hundred years after the death of St. John, a small chapel was constructed over the grave in the 4th century. The church of St John was changed into a marvelous basilica during the region of Emperor Justinian in the 6th century AD. The monumental basilica was in the shape of a cross and was covered with six domes (Figure 12). Its construction, being of stone and brick, is an extremely rare find amongst the architecture of its time. Raised by two steps and covered with marble, the tomb of St John was under the central dome, that was once carried by the four columns at the corners. The template located between the hill and the church may be used to compare older and newer versions of the church and basilica.

Figure . Main gate of the St. John Basilica (Photo by Şükrü Tül).

The House of Virgin Mary

Every year, on August 15th a ceremony was organized to commemorate Mary's Assumption by the villagers of Şirince. Towards the end of the 19th century, Christains coming from Izmir rediscovered the church and the shrine. The House of Virgin Mary is located on the top of the "Bülbül" mountain 9 km ahead of Ephesos. It is believed that the place where Mary may have spent her last days. Indeed, she may have come in the area together with Saint John, who spent several years in the area to spread Christianity. Mary preferred this remote place rather than living in crowded place. The house of Virgin Mary is a typical Roman architectural example, entirely made of stones. In the 4th century AD, a church, combining her house and grave, has been built.

THE RAMAZANPAŞA BRIDGE / SAZLIKÖY

The Ramazanpaşa Bridge situated in the East of Sazlıköy has a double importance. First it reflects the former watercourse of the Menderes river, secondly it is a great Ottoman monument built in the provinces. There are documents indicating that Ramazanpaşa who also sponsored the eponymous church which was constructed in the town center of Aydın granted the construction worrks in 1595. The Bridge was renovated by the Bureau of Public Roads in 1996. Six vaults of the bridge were decorated with small windows (Figure 13). The construction of such a bridge in this location highlights the importance of trade routes leading to Menteşe lands.

Figure 12. Deformated Ramazanpaşa Bridge over the Maiandros river (Photo by Ökmen Sümer)

PRIENE / GÜLLÜBAHÇE

Priene is a Helllenistic city which was almost completely excavated. Priene is located on Dilek Peninsula or on the Samsun Mountain. Priene, or the Aegean Pompei, was not extensively inhabited in the Roman period allowing the city to remain in its ancient form. It was formerly on the sea coast, built overlooking the sea on steep slopes and terraces extending from sea level to a height of 380 metres above sea level at the top of the escarpment. Today, after several centuries of changes in the landscape caused by the Maendros, it is an inland site as it is the case with other ancient cities such as Magnesia, Hybanda, Myus and Miletos. The harbour of the city was far from the town center near Atburgazi. According to the legend, the founders of the city were Aigythos, one of the sons of Kodros, the King of Athens and Philotas of Thebes. Old Priene was attacked by and sacked by the Lydians and then by the Persians. Bias, the Judge, one of the most eminent thinkers of ancient times lived in Priene. A silver Priene coin found in Klazomenai is known to have been produced during this period. This coin with a symbol of the Goddess Athena is the only evidence about Priene. At about 350 BC the Persian-empire satrap, Mausolus planned a magnificent new city on the steep slopes of Mycale, where it would be, it was hoped, a permanent deep-water port. Construction had begun when the Macedonians took the region from the Persian Empire and Alexander the Great personally assumed responsibility for the move. Both he and Mausolus intended to make Priene a model city. He offered to pay for construction of the Temple of Athena if it would be dedicated to him, which it was, in 334 BC. The leading citizens were quick to follow suit: most of the public buildings were constructed at private expense and are inscribed with the names of the donors. Despite the expectations of the population Priene lasted only a few more centuries as a deep-water port. In the 2nd century BC Pausanias reports that the Maeander already had silted over the inlet in which Myus stood and that the population had abandoned it for Miletos. Apparently, Miletos was still open then, but Priene could not have been. Very likely, its merchants had preceded the people of Myus to Miletos. By 300 BC the entire Bay of Miletos, except for Lake Bafa, was silted in. Orophernes, the rebellious brother of the Cappadocian king, who had deposited a treasure there and recovered it by Roman intervention, restored the temple of Athena as a thank-offering. Under Roman and Byzantine dominion Priene had a not very prosperous history. In the 13th century BC, it was a primarily a Turkish village. The Turkish population had assigned to the escarpment, Samsun Kale or Samsun Kalesi, "Sampson's Castle", where Sampson was a rich farmer in the region. The ruins, which lie in successive terraces, were the object of missions sent out by the English Society of Dilettanti in 1765 and 1868, and were thoroughly laid open by Carl Humann and Theodor Wiegand for the Berlin Museum. The city, as refounded at a new site in the 4th century, was laid out on a rectangular scheme.

City Walls and the Acropolis

The walls of Priene can be followed without any interpretation. The walls fortified with square shaped towers were made of limestone coming from mount Samsun. The main entrance to the city was located in the east. There is also a second gate situated in the soutwesten slope leading to a spring, this gate is also known as Kaynak Kapı (Spring Gate). Although it is believed that there was a third gate in the west, this gate is now missing. The most intereting point in Priene's location is its positioning in front of a rock hill called Teloneia (Figure 14). The Acropolis is reached through narrow passages in the rocks. Observation towers and and small entrances in the wall are visible in this area.

Figure 13. Menderes plain from acropolis of Priene (Photo Şükrü Tül).

The Temple of Athena

The temple was the oldest, the most significant and the largest edifice of Priene. It was built between 4th and 2th centuries B.C. It was designed by the famous architect Pythius who constructed the Mausoleum of Halicarnassus which is one of the Seven Wonders of the World. It is a classical example of the Anatolian – Ionian architectural style. It was built as a gift from Alexander the Great; he made a donation for the completion of the temple. This is also proven by an inscription on a tablet belonging to the temple, which reads "King Alexander has dedicated this temple to Athena Polias" which is now in the British Museum. It contained a cult statue of goddess Athena 7 m in height. It would appear to have been a copy of statue of Athena in the Parthenon. The proportions of this temple were taken as a classical model or pattern by the Roman architect Vitruvius. According to the plan of the temple, it has 6 columns on the short sides and 11 on the long sides. Each of the pronaos and the opisthodomus has two columns, so the total number of the columns is thirty four. The architectural elements found in the west side of the temple show that they belong to 2nd century BC due to various but especially to economic reasons the building could not be completed up to that period is understood that the temple was completed by the donation made in 158 – 157 B.C. by Prince Orophernes.

The standing Athena, with a helmet on her head is seen with goatskin, spear and shield. In her right hand she holds a Nike. The statue was 6,5 meters high (Figure 15).

Figure . Athena Temple (Photo by Şükrü Tül).

The Theatre

Towards the north of the temple, we come across with Priene's episcopacy church. The Byzantine church stands to the south of the theatre which was built in 6 century A.D. The middle nave of the church is separated from the others by the rows of Doric columns. Here are also the steps leading to the ambo and the seats for the archbishop and the priests. It bears similarities with Islamic architecture. The theater is one of the finest extant theatres of the Greek world. It was built in the 4th century B.C. in the northern part of the city. The building consists of skene, the orchestra (the horseshoe shape in the middle), and the cavea. A proskene was added to the front part of the skene in the beginning of the 2nd century B.C. The very well preserved proskene is 21 meters long, 2.74 meters wide and 2.70 meters high. On the inner and front rows of the columns of the proskene lie tie beams. The stage section consists of the rectangular skene, with a door opening onto the Theatre Street and the proskene situated in front of this. These two stage buildings are 18.41 meters long and 5.82 meters wide. Each floor has three rooms. The orchestra has a floor of pressed earth consisting of five armchairs. The armchairs were placed with differing distances between them.

The Agora

It is impossible to imagine an ancient city without its agora, and at Priene from whichever direction you may come, it is in the agora that you will inevitably find yourself. On entering the agora you will pass a small market on your right where various goods were sold. The agora itself, which was devoted to civil affairs, formed a rectangle measuring 75 x 35 m with the gymnasium on the lower side. Except for the side looking on to the main street, the agora was surrounded by colonnades. In the centre stood a statue dedicated to Hermes, and one can still see a number of round or square pedestals on which marble or bronze statues had been placed. The steps on the south led down to the streets below. On the east there remain traces of the temenos (walled sanctuary) of Olympian Zeus.

DOMATIA / DOĞANBEY

Domatia or Doganbey was the old name of a Greek village set near the ancient city Priene. Greeks left the village during the exchange between Turkey and Greece in 1922. Today the old houses are being restored and are open also to visits. All the houses in the village are unique. There is also a bird watching center where you may observe the birds living in Menderes delta as well as a collection of birds.. Domatia or old Doganbey located in the protected nature-reserve of Millipark is worth seeing.

Figure . Doğanbey National Park Museum, model of Dilek Peninsula (Photo by Ökmen Sümer).

MILETOS

In the areas surrounding Miletos, settlements dated to the Neolithic Age have been excavated. The Neolithic settlements on Killiktepe demonstrate the traces of a seafarer civilization of 7000–9000 years ago. Situated at the mouth of the Meander in the south of the province of Ionia in Western Anatolia, the ancient city of Miletos was the oldest and the most powerful of the twelve Ionian cities in Asia Minor.

The history of Miletos can be traced back to the 2nd millennium B.C. Settlers from Crete arrived here in 1500 B.C., to be followed by the Mycenaeans from mainland Greece, who fortified the city. The origins and earliest history of Miletos are still a subject of controversy. The name "Milawanda" that occurs in Hittite texts may well refer to Miletos. The city was ruled for a time by kings descended from Neileus, but after 800 B.C. administration passed into the hands of the aristocracy. After 687 B.C. it was ruled by dictators known as "tyrants", and it was during this period that the city began to found colonies overseas (Figure 17).

CITY PLAN OF MILETOS

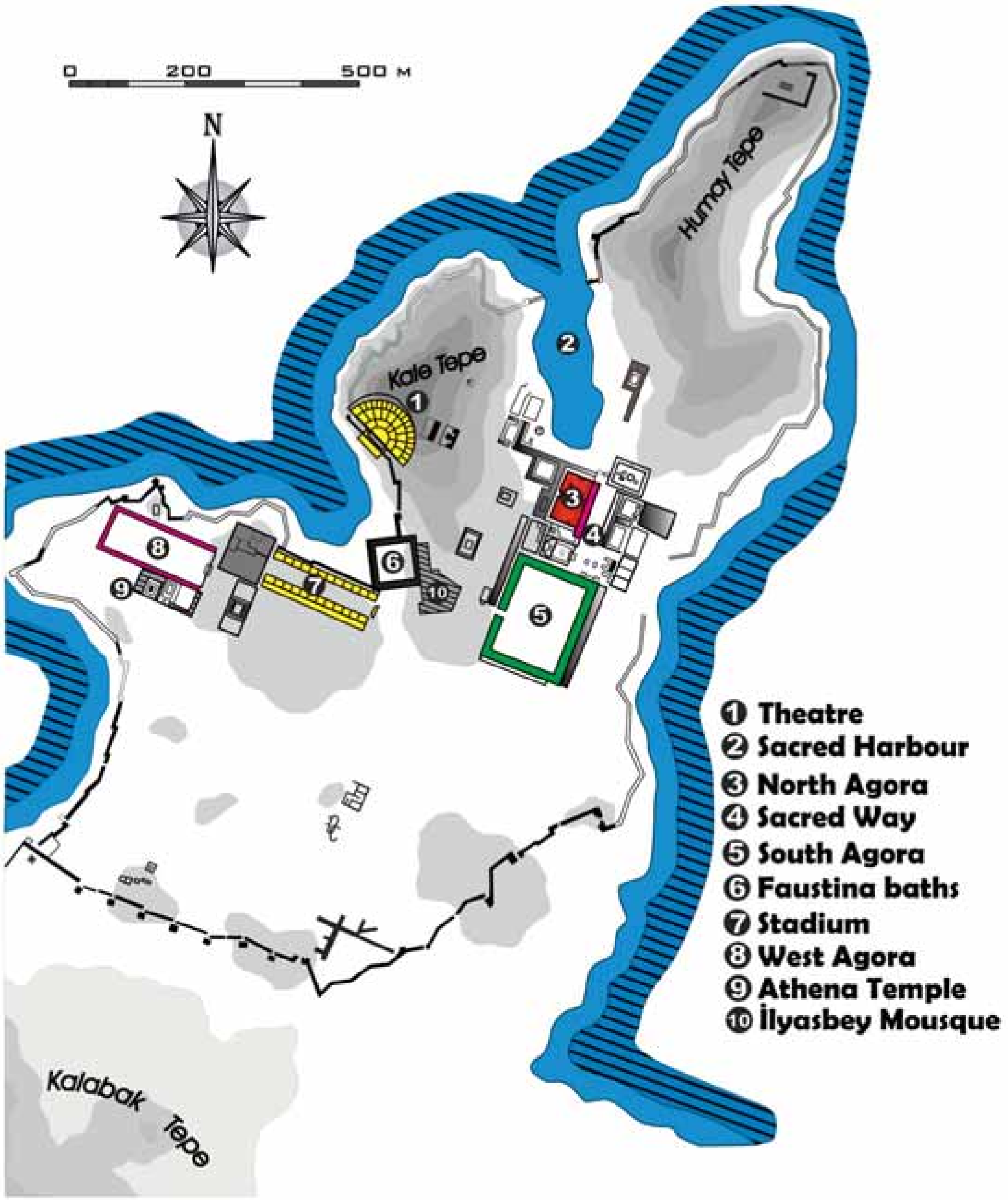

Figure . Miletos city plan (modified by Ökmen Sümer and Şükrü Tül after Gerkan and Weber, 1999).

By the first half of the 6th century, Miletos, thanks to these colonies, possessed a large maritime empire. The distinguished scholars of the city at that time included natural philosophers such as Thales, Anaximenes, Anaximander and Hecataeus. Thales, the first to forecast an eclipse of the sun, produced new theories in geometry and astronomy, Anaximander carved on stone universal laws independent of the gods and Hecataeus excelled in geography. Miletos had a special agreement with Croesus, but after the collapse of Lydia in 547–546 B.C. the city came under Persian hegemony. After the Greek victory over the Persians in the naval battle at Mycale in 479 B.C., Miletos was rebuilt on a grid plan with the help of the famous Milesian architect and town-planner Hippodamos. After 402 B.C. the city came entirely under Persian rule and in the 4th century was ruled by Carian satraps subject to the Persians. In 334 B.C.

Miletos was captured by Alexander the Great. Following his death it was subjected by Antigonus in 313 B.C. and the Seleucides in 301 B.C. The city regained its independence in 188 B.C. In 133 B.C., when the Kingdom of Pergamon was incorporated in the Roman Empire, Miletos became part of the province of Asia Minor. The city declined in size under Byzantine rule, shrinking to the area occupied by the castle known as Palatia to the rear of the theatre. In 1328 it came under Selçuk rule, after which it continued to exist as the small village of Balat.

The Theatre

The Miletos theater will be a best choice to begin visiting Miletos in order to consolidate our knowledge of the city and the topography. Capable of seating 15,000 spectators, it was built in the 4th century B.C. and enlarged in the Hellenistic period, but, as it stands today, it is quite definitely a Roman monument (Figure 18). The wall and observation tower at the top of the upper section of the cavea are Byzantine in origin. Miletos' theatre was built on a hill by sea, overlooking what is known as the Theater Harbor. The theatre had four construction phases in the Hellenistic period and was also renovated under the Romans. The theatre was first built ca. 300 BC. The one or two-story skene was built along the city wall and may have had a proscenium with Doric half-columns like the theatre at Priene. During the second construction phase, from c. 300–250 BC, the skene was lengthened and by this time definitely had two stories. Four doors were built in the lower story of the skene and three in the upper. At this point the proscenium was probably longer than the stage and had sixteen columns. During the third stage, sometime before 150 BC, extensions to either side of the skene (paraskenia) were added. The largest Hellenistic theatre approximately 5300 spectators. The Romans vastly enlarged the theatre after 133 BC, building three stories of seats that reached a height of forty meters and sat 15,000 spectators. In the Roman period all but the central doorway in the lower story of the skene were bricked in, as they were below the stage and no longer needed. The Romans also built a podium (logeion or stage) in front of the proscenium in order to provide a raised performance space. Later, the orchestra was lowered so that it could better accommodate gladiatorial displays and animal hunts and baitings. Regularly spaced exits (vomitoria or aditus) along the length of the praecinctiones allowed audience access to and from the various seating sections of the cavea. The praecinctiones ran parallel to and underneath the rows of seats and supported the upper levels of the cavea; the slope of the hillside supported the lower level. The western entrance has stairs, but stairs were not necessary at the eastern entrance due to the natural slope of the hillside. Some decorative reliefs have survived including a hunting scene with Eros and a column base with relief carvings of a tripod cauldron and griffons. Some of these decorative elements are now exhibited in Izmir Tarih and Sanat Museum. Below the Byzantine castle is a Hellenistic heroon, a monumental tomb to honor a local hero who was deified.

On the west side of the vaulted tomb chamber are five small niches to hold the remains of family members. In the center of the tomb's floor is a rectangular hole for sacrifices. Some obsidians found near Heroon are revealing for the city's early history.

Figure 17. Miletos Theater, looking towards to west, Lade island at left, Mikale Dilek Penninsula at right (Photo by Dick Osseman).

The Harbour Monument\Agora\ Baths of Faustina

The Harbour was erected in commemoration of the naval victory at Actium in 31 B.C. The monument is decorated with reliefs of Triton, a figure half fish, half man. To the north you will see the ruins of the baths, while the remains of a synagogue can be seen between the small hills. The upper elements of the monument are now exhibited in Berlin Museum. Delphinion is a temple, dedicated to Apollo, Delphinius, is one of the most important temples in the city .Excavations carried out in the lower strata present a chronological whole from the years of Persian domination which began in 494 B.C.Right behind the high walls of a Byzantine church, which had been partly restored, one can see the remains of a small 15th century Ottaman bath.A Doric stoa from the period of the Roman Empire extends for some 160 m to end in the proximity of the temple.A fairly broad colonnaded street ran as far as the Agora and from there to the Temple of Apollo at Didyma. The construction of these baths (161–180 A.D.), one of the bost remarkable buildings in Miletos, was made possible by money donated by Faustina, the wife of the Roman Emperor, Marcus Aurelius. Parts of this colossal building of brick and dressed stone blocks are still standing.

One of the most remarkable features is the palaestra, the imposing remains of which lie immediately adjacent to the baths themselves. Beside the pool in one of the cool rooms (frigidaria) is a statue of Meandros, the river god. On the east is the hot room (caldarium) with walls reaching a height of 15 m. There is another frigidarium on the south, together with a dressing-room, or apodyterium. A stoa extends along the other side of the street.

İlyas Bey Mosque

The mosque which is surrounded with a courtyard between the ruins of Miletos, was built in 1403 by Ilyas Bey (1402-1421) of Menteseogullari. The Mosque was abandoned after 1957 eartquake aftermath which Balat village was moved to the south. Renovation works resumed in 2007. Ilyas Bey Mosque is a masterpiece of architecture as a part of a complex, with the ruins of madrasa units on three sides of the mosque, and the tomb of Ilyas Bey to its north, all enclosed within a walled precinct. The mosque has a square plan, whose sides differ only half a meter, with an approximate length of eighteen and a half meters per sides.Inside, the prayer hall is surmounted by a semi-spherical dome fourteen meters in diameter. The dome, which is made of brick and covered with tiles, sits on an octagonal base that rests on the four walls. The most important element of the interior space is the highly ornamented marble mihrab, with an imposing frame about seven and a half meters high and five meters wide. Muqarnas carvings decorate the base and crown of the mihrab niche and border the mihrab frame, which also includes two panels with lantern motifs, carved Quranic inscriptions and geometric designs.

Didymaion / Didyma

Didyma was the largest and most significant sanctuary on the territory of the great classical city Miletos. To approach it, visitors would follow the Sacred Way to Didyma, about 18km long. Along the way, were ritual waystations, and statues of members of the Branchidae family, male and female, as well as animal figures? The temple was first built at the end of the 8th century BC. In the 7th century BC a courtyard was build to host the visitors. Different additions together with double columns surrounding the inner courtyard formed the archaic temple. As Archaic Didymaion was destroyed, burned and plundered in 494 BC (the battle of Lade) the there is not many remains left to the present day. Besides, by the fact that the Hellenistic temple was built over the foundations of the archaic one, findings related to archaic temple are further limited. However, during the excavations, architectural and sculptural fragments found as well as the construction of the plan was possible and various examples of reconstruction were made through ancient authors. Some of the fragments are exhibited in Istanbul Archaeological Museum. Some of these statues of members of Branchiade, dating to the 6th century BC are now in the British Museum, taken by Charles Newton in the 19th century. In the first half of the 6th century BC Didymaion became really important. Ionian cities especially Miletos, reached their most flourishing era. In 560-550 BC the temple was rebuilt with larger proportions. The impact of the temples of Hera at Samos and Artemis at Ephesos are apparent in the Archaic Didymaion. In the pronaos, the double row of columns indicates that it had a roof. In the corners are high reliefs of winged gorgons and behind these are figures of crouching lions. Besides the lions, it is believed that also were certain wild animals' figures. In temple entablature this kind of decoration is quite unusual. These pieces of work were probably made during restoration which took place in the temple can be dated back to the end of the 6th century BC. The first excavations began in 1857 under the direction of Charles Newton. Works were resumed by O. Rayet and A.Thomas. Between 1895-1896, excavations in Didyma were supervised by B Haussoullier and E. Pontremoli. Actual remains of double colonnaded temple, belongs to between Early Hellenistic Era and Hadrianic Time (Figure 19 and Figure 20).

Figure 18. Apollon Temple at Didyma (Photo by Dick Osseman).

Figure 19. Griphone figure from inner decoration of Apollon Temple at Didyma (Photo by Dick Osseman).

MYTHOLOGİCAL EXPRESSİONS AND CULTURAL APPROACHES UNDER THE GEOLOGİCAL AND GEOMORPHOLOGİC ASPECTS*

Şükrü Tül, Ökmen Sümer, E. Yalçın Ersoy (Dokuz Eylül University/ Türkiye)

Humans were impressed by the natural forces since they started to express their ideas, and tried to explain them. They depictured the unknown natural forces as metaphysical. These forces have been described as "God" by the humans as from mythological age, and the events independent of humans were attributed to these "Gods". Human life and cultural wealth in the western Anatolian coastal regions also affected the religious beliefs, and hence resulted in rising of regional "Gods". These regions were established at the delta and transitional environments which forms the sea-land borderline. Two factors affecting the city life are the sea and the rivers that accommodate the formation of deltas. Since the events occurred in such regions are independent of the human life, it is frequently mentioned about Poseidon and the gods of Büyük and Küçük Menderes rivers. These geographical images were used in deific imageries during mythological ages. The sexuality, ability and ages of the gods are strictly depended on length, depositional action, flood sizes, and also disaster hazard of the rivers, as well as ecological varieties. The Büyük Menderes is the longest and biggest river in the region. By the way, Maiandros describe the main god around the region in relation with Büyük Menderes river. (Figure 21).

Meander or Maiandros is a river-god in Greek mythology, patron deity of the Meander river (modern Büyük Menderes River) in Caria, (modern western Turkey). He is one of the sons of Titan gods as Oceanus and Tethys, and is the father of Cyanee, Samia and Kalamos.

The Küçük Menderes is the second biggest river in the region. Kaystros (the god of Küçük Menderes) was younger with respect to Maiandros, and was epicure (Figure 22). Even the Marnas River, a branch of the Derbent, has a god. The length of this river is small and has low depositional action. Marnas has been described by childlike depiction (Figure 23). Geometrical aspects of these rivers, such as meanders and bends, have played an important role in Ionian architecture. Some columns and motifs were similar to river meanders (Figure 24).

This part is taken from Marvin Tameanko

Morphology in Caria (modern western Anatolia) impress human life who lives in this region not only life style but also social life and customs fiction. Cultural, ecclesiastical and politic and economical instruments are under the influence of this geomorphological stuff. For instance, the first example of a Greek map shown on a coin is given bellow, but it must be regarded as speculative and controversial (Figure 25). It is included in this summary of proven map coins, because it is so exceptional that it cannot be ignored. In 1967, A.E.M.

Johnston published a theory that earliest preserved of a Greek map was depicted on a series of rare Ionian coins struck about 334 B.C. Several of these coins were found before 1881 in a hoard of Greek coins in northern India, and more were found in western Asia Minor. Only 35 examples of the silver coins and six of the bronze are known to exist. Johnston claimed, with some justification, that the coin depicts a physical relief map, the first and only one known, of the area around the city of Ephesus in Ionia (modern western Anatolian Grabens).

This section is from Helvacı et al. (2009)

The map appears as an incuse punch mark on the reverses of these rare tetradrachms. The coins were supposedly struck by Memnon of Rhodes when he was commander of the Greek mercenaries in the Persian army of Darius III, 336-330 B.C., who opposed invasion of Alexander the Great. There are also a number of silver Ionian coins of archaic times of various standards of weight in relation with river gods (Figure 26 and 27).

Figure 20. God of the Büyük Menderes (Marnas) river that named is Maiandros, Milet Museum (Photo by Şükrü Tül).

Figure 21. God of the Küçük Menderes river that named is Kaystros, İzmir History and Art Museum (Photo by Şükrü Tül).

Figure 22. God of the Derbent river that named is Marnas, Efes Museum (Photo by Şükrü Tül).

Figure 23 Meandering stream pattern on columns of the Apollon Temple at Didyma (Photo by Ökmen Sümer).

Johnston equated this design to a topographical relief map of the hills, valleys, rivers (especially Küçük and Büyük Menderes rivers), and mountains around the cities of Ephesus and Miletus. On the coins, the prominent mountains lying south of the Küçük Menderes valley, named Mandranbaba Dağı, the Karıncalı Dağı and the Akbaba Dağı are shown dotted area (Figure 25-C).

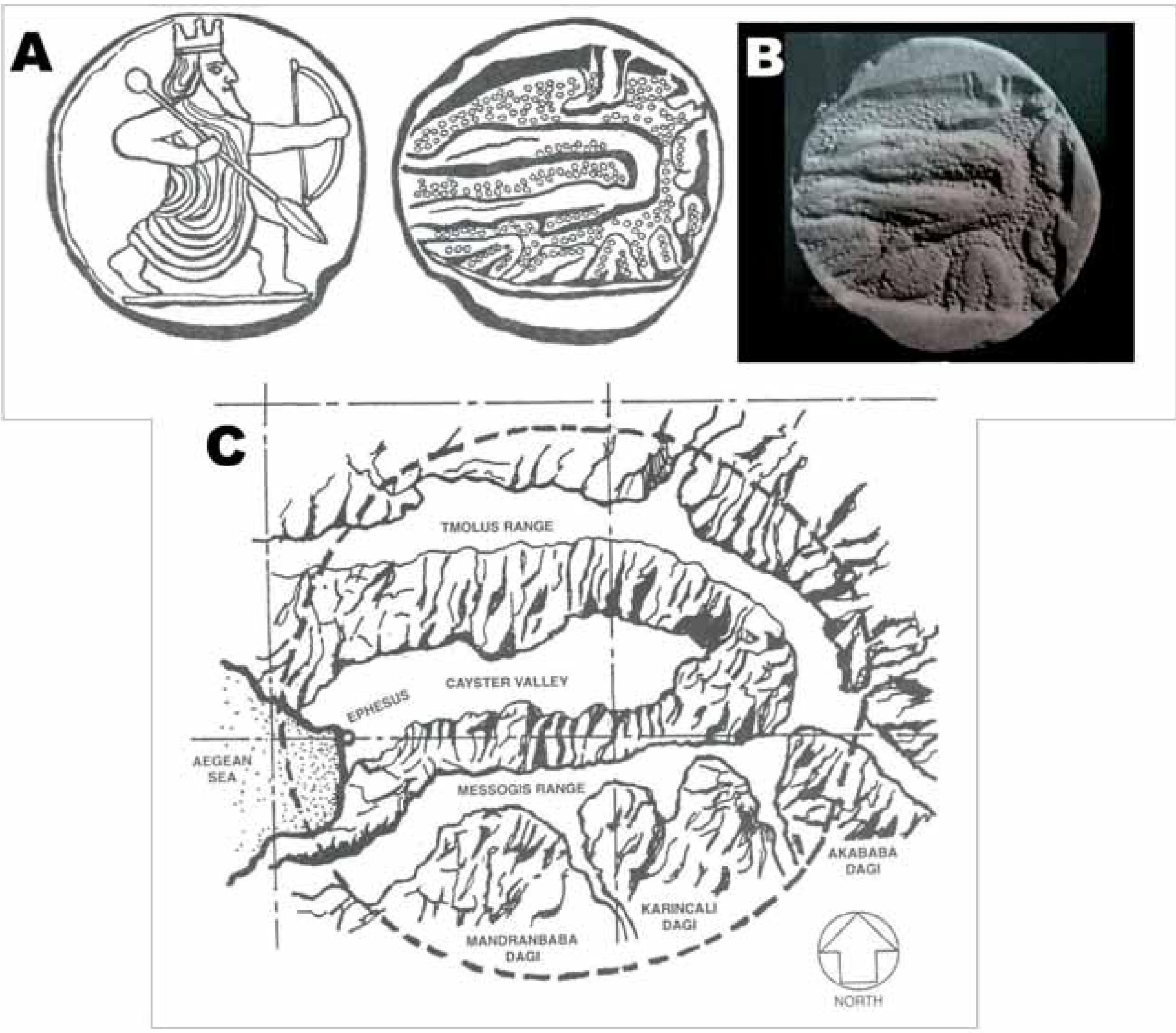

Figure 24. A and B; The Ionian silver tetradrachm, struck at Ephesus in 334 B.C. by Memnon of Rhodes purportedly showing a relief map of the hinterlands of Ephesus. Historia Nummorum, by Barclay V. Head. C; A drawing of a modern map of the area around ancient Ephesus in present day Turkey. The outline of the tetradrachm, shown with dashes, has been superimposed on this modern map so that the similarities of the land features to those angraved in the punch mark can be seen (Johnston, 1967 and Tameanko, 1995).

Figure 25. Ephesos - Domitianus (AD 81–96) Bronze, obverse: portrait of emperor Domitianus, reverse: River-god Marnas reclining, holding reed; Alighieri Collection (Forum Ancient Coins).

Figure 26. Ephesos - Hadrianus (AD 117-138) Bronze, obverse: portrait of emperor Hadrianus, reverse: River-god Kaystros reclining left holding rudder and resting left arm on jug; (Forum Ancient Coins).

SEA LEVEL CHANGES AND HOLOCENE LANDSCAPE EVOLUTION AND DELTA PROPAGADATION OF KÜÇÜK MENDERES*

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Helmut Brückner (Marburg University/Germany) &
John C. Kraft (Delaware University/USA)

One of the characteristics of the Mediterranaean region is that its bordering countries have a continuous settlement history that stretches over many milennia. This especially true for western Anatolia, and in particular for the Ephesus (in Greek times; Ephesos) region which is one of the most famous and frequently visited ancient sites of coastal Turkey (Brückner, 2003; 2005). The ruins at Ephesus have been excavated under Austrian guidance since 1895 out of debris, rubble and alluvium caused by eartquakes, human destruction and the Küçük Menderes river with its tributaries. The present day relief of western Anatolia is mainly a result of different phases of Alpine orogeny. The collision of the African and Eurasian plates caused the westward motion of the Anatolian micro-plate. This triggered a spreading of its western margin and resulted in a horst graben system developing. The grabens in turn became the route way for the rivers of the region (Gediz, Büyük Menderes and Küçük Menderes grabens). The ongoing activity of extensional tectonics, the fault lines in this region is demonstrated by many historical and even modern earthquakes (general geology ye girecek).

Western Anatolia was extended approximately N-S extension during the neotectonic period. Approximately E-W trending Edremit, Bakırçay, Kütahya, Simav, Gediz, Küçük Menderes, Büyük Menderes and Gökova graben bounded by active normal faults are well-known continental rifting areas of the western Anatolia (Şengör et al. 1985; Seyitoğlu & Scott 1991; Emre & Sözbilir 1996; Bozkurt 2000; Yılmaz et al. 2000). The origin and initiation age of crustal extension in the western Anatolia is controversial and proposed different models. The commonly considered model is two episodic stage graben model that involves a Miocene-Early Pliocene first stage (orogenic collapse), and a Plio-Quaternary second phase (westward escape of the Anatolian block) of N-S extension (Koçyiğit et al. 1999; Bozkurt & Sözbilir 2004). This has led to development of the present day E-W trending grabens during Plio-Quaternary time (Yılmaz et al. 2000). Quaternary deposits fill into basins such as Gediz, Büyük and Küçük Menderes grabens.

An important control on the sediment budget of the Küçük Menderes is the geology of the catchment, which is partly build up of easily erodable rocks such as highly weathered mica schist, gneisses and as well as marble that belong to Menderes Massif. Before the construction of barrege and the massive extraction of water for irrigation purpose, the Küçük Menderes was next to Gediz the river with the highest denudation rate in Turkey (Brückner, 2005). The avarage annual area erosion of the drainage basin is 659,84 m^3 sediment per km^2 (Eggeling, 1978). The Küçük Menderes river drains a basin with an annual sediment discharge of 17 m^3/s.

**This section is from Helvacı et al. (2009)*

The suspended sediments discharges of the river below the confluence of all major tributaries is about 0,6 kg/m^3, suggesting an annual sediments discharges of 10kg/s, and average sediment yield of about 0,5 million tonnes per year. The construction of channel in 1934 and the subsequent irrigation network have significantly altered the hydraulic regime of the Küçük Menderes river. The river is braided in their upper reaches, becoming meandering on its flat delta plain (Aksu et.al, 1987). Shorline migration has occured trough progradation fed by a subtantial sediment supply due to a combination of natural and human factors. The delta growth coused the silting up of many marine embayments and thereby spectacular shifts in the paleo-shoreline. In the case of the Küçük Menderes these changes are demostrated by (a) the fact that the former harbour of Ephesus is now 7 km inland, (b) the formar island of Syrie (Korudağ) is now intergrated with the coastal plain, (c) the brackish lakes at the northern flank of the grabens, NNW of Ephesus, were originally part of the marine embeyment (Figure 28).

The Küçük Menderes (ancient Cayster River) delta-floodplain has prograded over 18 km seaward since mid-Holocene time. The surface morphology includes remnants of meandering river patterns, floodplains, and backswamps, and flanking colluvial and alluvial fans of tributary streams. The lower 4 km of the delta are dominated by barrier accretion ridges and ponded deltaic swamps with seasonal evaporative pans (Figure 28). Twentieth-century agricultural engineering includes a canal designed to drain the back swamps and provide water supply for irrigation. Smaller flanking embayments include bypassed lakes (Kraft et al, 2007).

According to the studies on changes in sea level of the Aegean Sea during Holocene, the sea level has reached its current position before 6000 years (Figure 29; Kayan 1988, 1991). This means that rising of 100 m has occurred rapidly in 9000 years between the last 15000 and 6000 years.

Another significant palaeogeographic factors is that the Aegean coasts of Turkey evolved as a result of a) the late Pleistocene – Pliocene marine transgrassion, and b) the subsequent delta growth and coastal regression. After the last glacial sea-level maxiumum 20.000 years ago of around -120m sea level rose and reached its position (or close to it) 6000 – 5000 years B.P. The transgression created marine embeyments which extent far inland to the east around Belevi village at about 18km east in present costal border (Brückner, 2005).

The graben forming the Selçuk plain is as follows. During Holocene, Aegean Sea covered the whole Selçuk plane. The streams such as Küçük Menderes have carried alluvium to this depression. However, the amount of materials came to the plain was less than rate of sea level changing, causing to formation of a bay at Selçuk plain. The data form boreholes indicate that the bay has reached to Belevi channel.

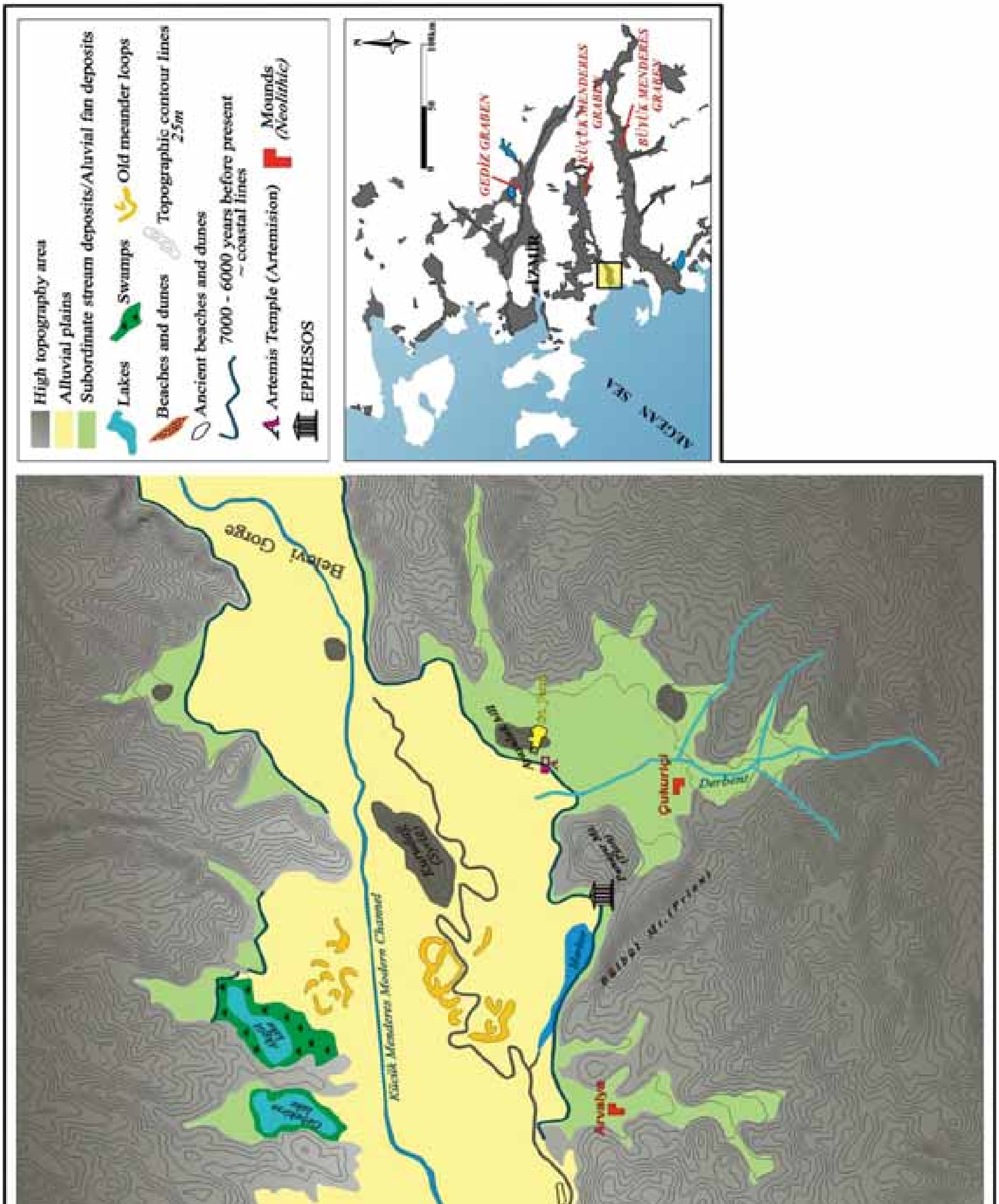

Figure 27. Geo-morphographic map of Selçuk –Ephesus depression (Kayhan, 1994; modified by Ökmen Sümer).

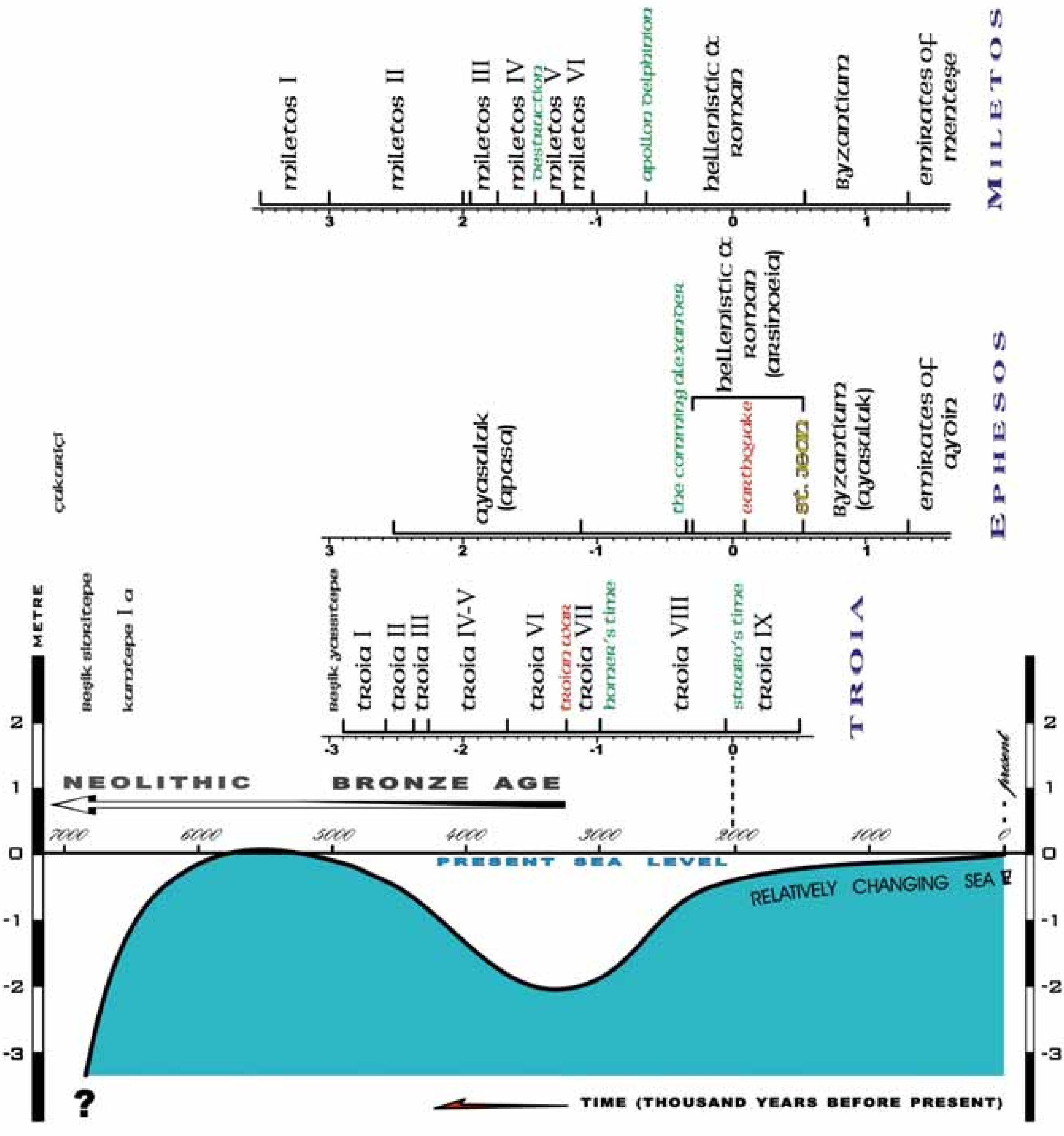

Figure 28. Middle - Late Holocene relative sea level changes in the Troia, Miletos and Ephesos area (Kayhan, 1991; modified by Ökmen Sümer).

The sea level was remaining in current position for a while 6000 years ago. On the other hand, the Küçük Menderes and the other rivers continued to carry alluvial materials to the Selçuk plain. Hence, the coastal range regressed again. The alluvial materials were not anymore accumulated by floods, but the depositions were continued to prograte into the bay. The studies from the other Aegean coastal plains indicate that a temporary descending of 2m occurred in the sea level between 5000-3000 years (Bronze Age). It may be accepted that such a changing in sea level can slightly improve the coastal plains. The sea level has risen again to its recent position (Figure 29).

When compared the sea level change of 2m during the last 5000 years is lees than the previous 100 changing, but its effects on archeology are important. This stage corresponds to pre-Hellenistic ages during the coastal regions settlements. The colonists, that came to the shallow bays, lagoons and backwaters around the Aegean coasts during the beginning of B.C. 1000, and settled on these areas. Hence, archaeological remains of Geometric and Archaic ages remained below the sea level up to day. At the first impression, this event is generally considered as subsidence of the mainland. This interpretation can although be true, more data is needed to be concluded. For example, the first building of the Ephesus Artemisia temple in the Selçuk plain is in such a case, but there is no evidence indicating that there is such a tectonic subsidence during that stage.

Investigations show that sea level on these regions were similar to that of the modern position before 2000 years, and that there is no a clear change in sea level during this time interval. Geomorphologic changes in river outfalls during this stage occurred under the dynamic controls such as waves and currents, and took place via alluvial deposition.

The coastline delineated based on over two dozen cores (Figure 30). Sedimentological analyzes show that the Artemision was built on the deltaic shoreline of torrential alluvium of the tributary Selinus River (Kraft et al., 2001). The foundations of the Croesus Artemision (mid-6th century B.C.) and earlier temples A, B, and C, dating to the 7th and 8th centuries B.C., are shown underlying alluvium of the ancient Selinus River torrential fan and overlying mid-Late Holocene shallow-marine sediments. A mid-Late Bronze age coastline immediately underlies the earliest sacred site and structures. In mid-Hellenistic time, the shoreline was still within 100 or more meters of the Artemision complex.

Archaic–Classical Ephesus lay immediately adjacent, as dictated by Lydian King Croesus, until forcibly removed by early Hellenistic King Lysimachus in the early 3rd century B.C. Plundered by the Goths in 263 A.D., the Artemision was abandoned after 400 A.D. Subsequently, its marble was reused in the large Byzantine church of John, located above on Ayasoluk Hill, and later in the adjacent 12th-century Isa Bey Mosque (Kraft et al., 2007).

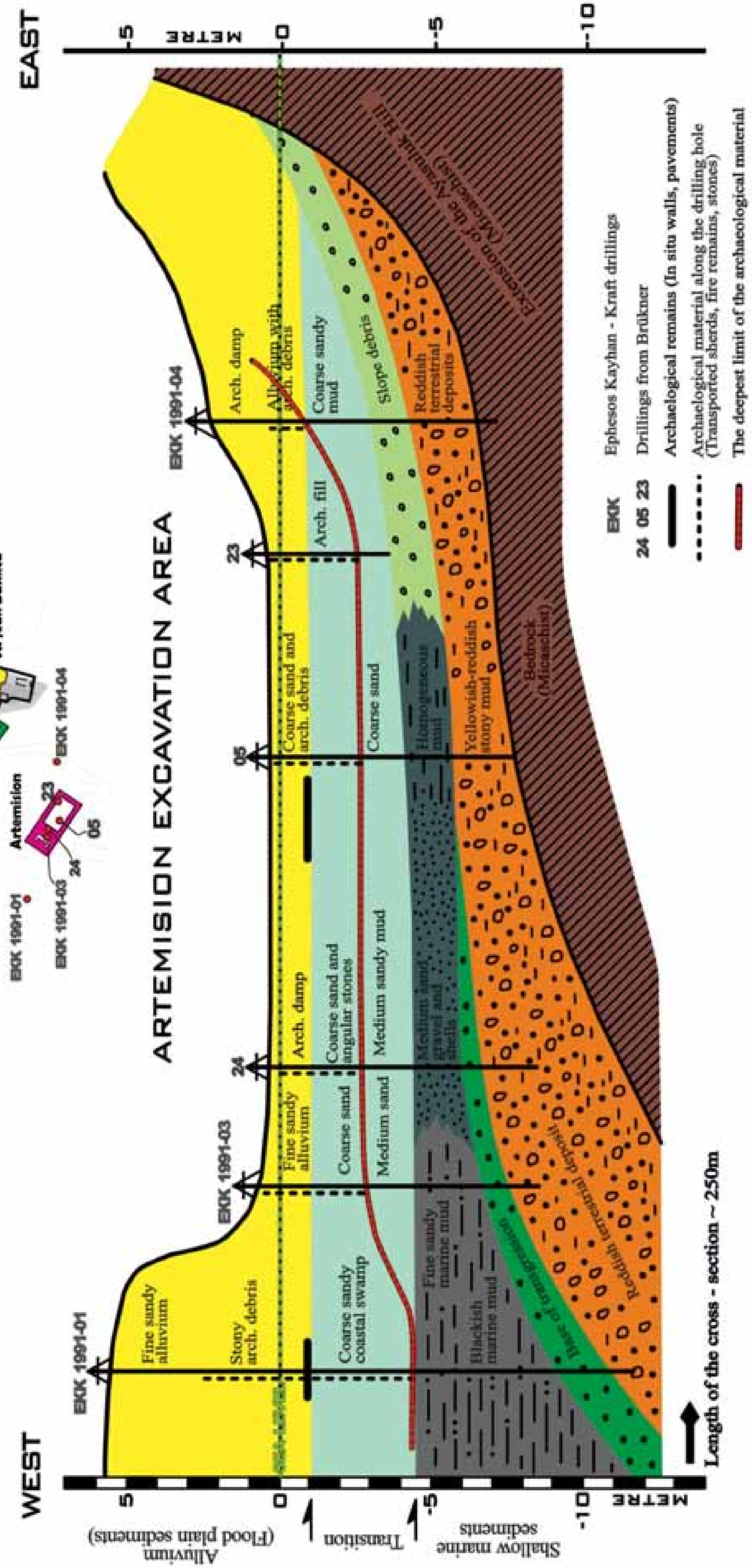

Figure 29. A stratigraphic cross-section through the Artemision excavations area, at the foot of the Selçuk Hill (Ayasoluk Hill) (Kayhan, 1994).

THE SEA, THE RIVERS AND MAN – WHY THE ENVIRONMENT OF EPHESOS AND THE ARTEMISION CHANGED DRAMATICALLY DURING THE PAST MILLENNIA*

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John C. Kraft (Delaware University/USA)
& İlhan Kayan (Ege Üniversitesi, Izmir/Turkey)

The location of the settlement which later became the city of Ephesos was shifted several times. One of the reasons was the dramatic changes of the palaeogeography. The Holocene marine transgression on the one hand and the progradation of the river deltas on the other caused a continuous shift in the shoreline. Human impact on the ecosystems, especially deforestation, contributed strongly to erosion/accumulation processes. One major effect was the silting up of the harbours.

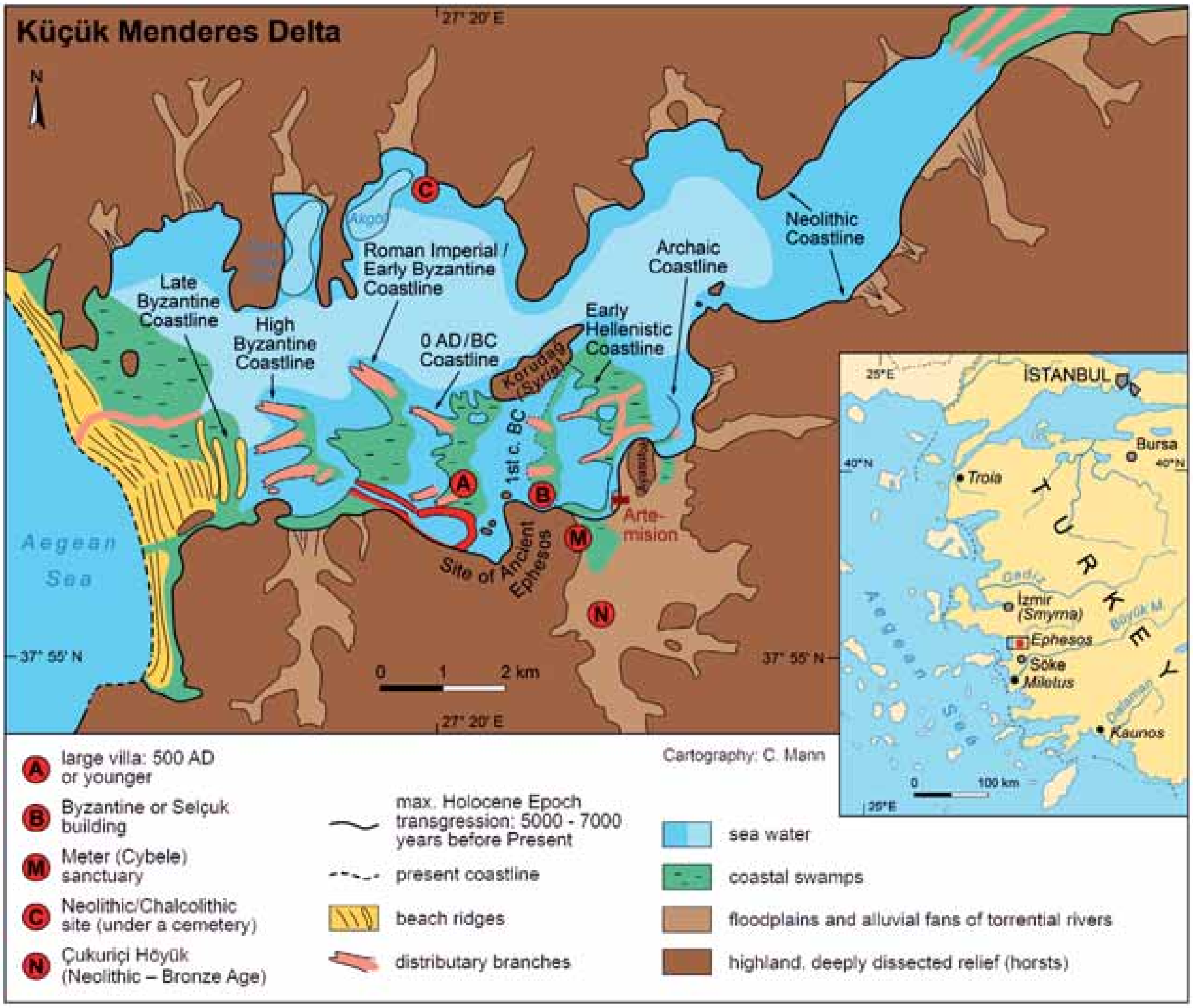


Figure 30. Scenario of the progradation of the Küçük Menderes delta in space and timeThe coastline positions are based on the merge of geological, archaeological and historical data. Note the changes of the morphology of the shoreline: Within the inner part of the marine embayment it was that of an irregular delta with distributary branches, typical of a low energy coast; this pattern changed to higher wave energies during Late Byzantine times after the delta had reached the outer parts of the embayment with a longer fetch and the influence of the longshore current. Positions of the main settlement of the area were Çukuriçi Höyük (Neolithic – Bronze Age), Ayasoluk Hill, above the Meter Sanctuary and the well-known site of ancient Ephesos at the northwestern flank of Panayirdağ. After Brückner 2005, Fig. 1.

This section is from Helvacı et al. (2009)

Global warming after the Last Glacial Maximum lead to a strong rise in sea level from –120 m to its present position, thus creating deep marine indentations along the Aegaean coast of Turkey. They reached their maximum extension around 7,000-6,000 years ago.

The growth of several deltas – the one of the Küçük Menderes (ancient Kaystros or Cayster) being the biggest of the region – finally caused the silting up of the Gulf of Ephesos. This is evidenced by the fact that (i) the present hill Kurudağ was known in Antiquity as the Island of Syrie; (ii) two lakes at the northern flank of the Küçük Menderes graben are remnants of the former gulf; (iii) there are historical accounts about man's strategies to fight siltation.

The scenario of the delta progradation in space and time shown in Figure 31 is based on our geoarchaeological research. Around 200 vibracores were sunken into the ground up to a maximum depth of 25 m. The unearthed sediments were analyzed and the different milieus of deposition determined by the microfauna (ostracods, forams) content. The chronology of events is based on diagnostic ceramic finds and on the 14C-dating of organic material (wood, plants, mollusc shells).

Of special interest is the palaeogeographic situation of the Artemision Figure 32, Figure 33, Figure 34 and Figure 35), the famous Temple of Artemis (Diana), one of the so-called Seven Wonders of the Ancient World. The geological profile (Figure 33) shows that the first building was erected at a former coast on substratum from the Selinus/Marnas rivers, both tributaries to the Küçük Menderes.

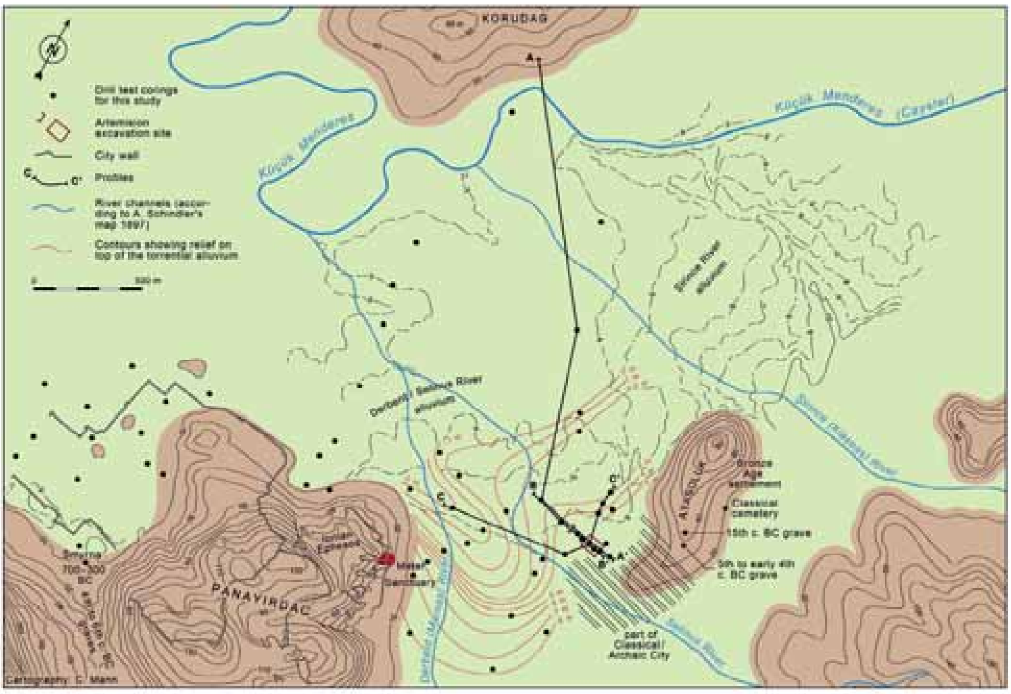


Figure 31. Geomorphology of the Ephesos-Artemison area. The figure shows lines of cross sections and present day contours on the Küçük Menderes, Şirince River and the Derbent/Marnas – Selinus river floodplains (contours in meters). Coarse grained alluvial fans have buried the former coastal and marine sediments and morphologies of the 5th to 1st millennia BC including the Artemision. Red contours show relief on the upper surface of the Derbent (ancient Marnas) and Selinus torrential alluvium (coarse sand, gravel and rock debris, including some structural fill) in the vicinity of the Artemision. Its trend possibly reflects Holocene subsidence in the Derbent graben. Source: Kraft, Kayan & Brückner 2001: Table 5.

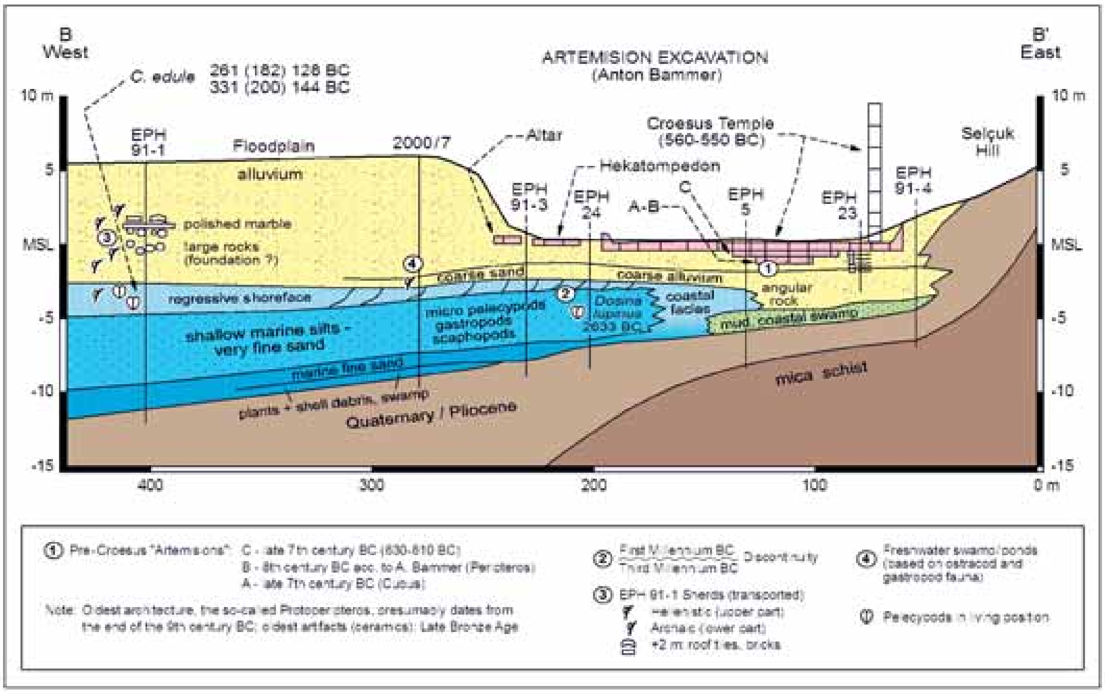


Figure 32. Stratigraphic cross section B – B' through the Artemision complex. The figure shows the Neolithic marine transgression, long term Bronze Age shoreline under the Artemision site and final marine regression from the Artemision site about 200 BC. Radiocarbon 'intercept' dates are shown with 1 sigma standard deviation (68.3 % confidence level). A number of the ^{14}C dates from shallow marine sediments to the north of the Feigengarten excavations of D. Knibbe are shown for time comparison. The floodplain alluvium includes mainly dark silt deposited in floodplain backswamps and shallow ponds. Source: Brückner, Kraft & Kayan 2008: Abb. 6, after Kraft, Kayan & Brückner 2001: Fig. 3.

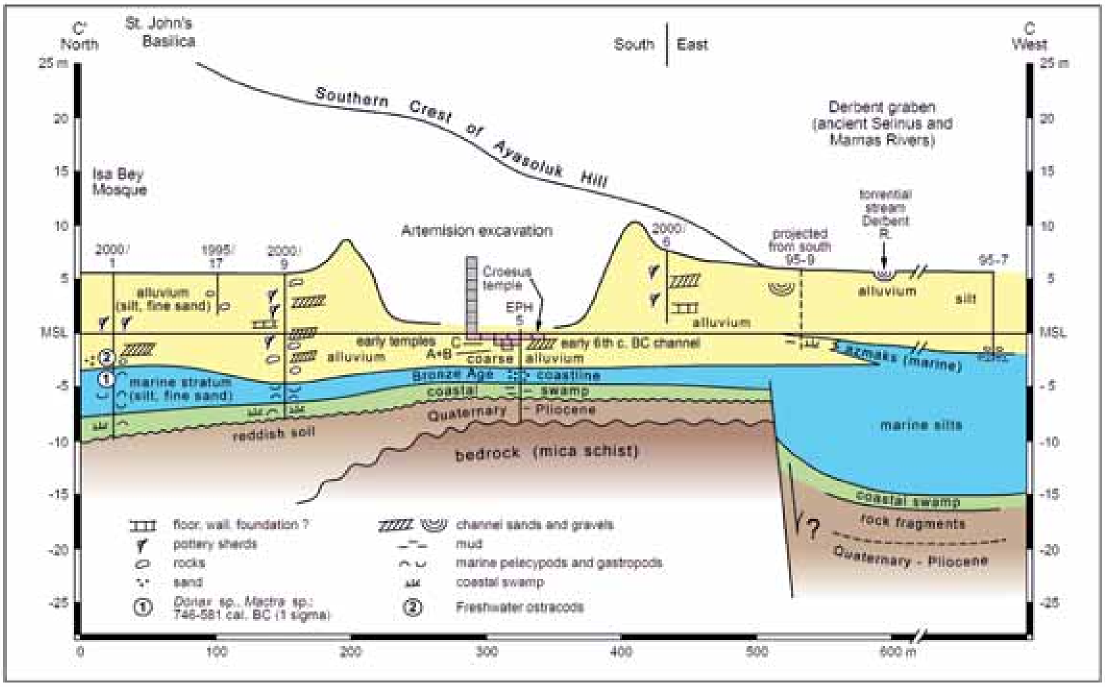


Figure 33. Stratigraphic cross section C – C' through the Artemision complex. The figure shows the site relative to the underlying Bronze Age coastline and earlier coastal swamp. The 'temple sites' are built on Selinus River alluvium overlying Holocene coastal strata (Bronze Age coastal and nearshore marine sediments). Quaternary / Pliocene sediments and Paleozoic bedrock (southwesterly spur of the adjacent Ayasoluk Hill) as well as a N-S graben as posited by Vetters (1971-72, revised 1989) are also shown. Source: Brückner, Kraft & Kayan 2008: Abb. 7, after Kraft, Kayan & Brückner 2001: Fig. 4.

Figure 34. Geoarchaeological research within the Artemision Complex.It is carried out with vibracoring. Both teams are taking out the corers with special lifting devices. They are working in the middle of the Artemision Complex. About 5 m below their feet is the former coast. The pond in the foreground shows the groundwater table and the former pumping system of the excavator Anton Bammer. In the background, behind the stone garden, it is well visible that the ruins were buried under more than 5 m thick river sediments before they were discovered by J. T. Wood in 1869.

Connected with the Artemision was the so-called Sacred Harbour, a safe haven for the sailors. With the prograding deltas of Selinus and Marnas, later also of Klaseas and Cayster (Küçük Menderes), the harbour had to be shifted westwards. Figure 37 shows the presumed positions. The initial one is still debated – the exact position as well as the extension. This is the focus of a new research project.

Corings within the city of Ephesos reveal that many parts of the city were erected on formerly shallow marine and lagoonal strata (blue area in Fig. – Eph 4). Under many of the former buildings and infrastructure (e.g. Olympieion, Halls of Verulanus, Harbour Gymnasium, Arcadiane) marine and coastal sediments can be unearthed. The maximum extension of the shoreline is to be found between Byzantine Palace and Episcopium of the Church of Mary as well as directly at the west gate of the Tetragonos Agora. It is only after sediments from the slopes (colluvium) and fluvial input (alluvium) had filled-up the marine bay that the area could be used and Ephesus could be shifted from Ayasoluk Hill to its new position. It is also evident from the drill cores within the city that, especially in Roman times, a lot of material – including debris from earthquakes – was used by man for the consolidation of the terrain.

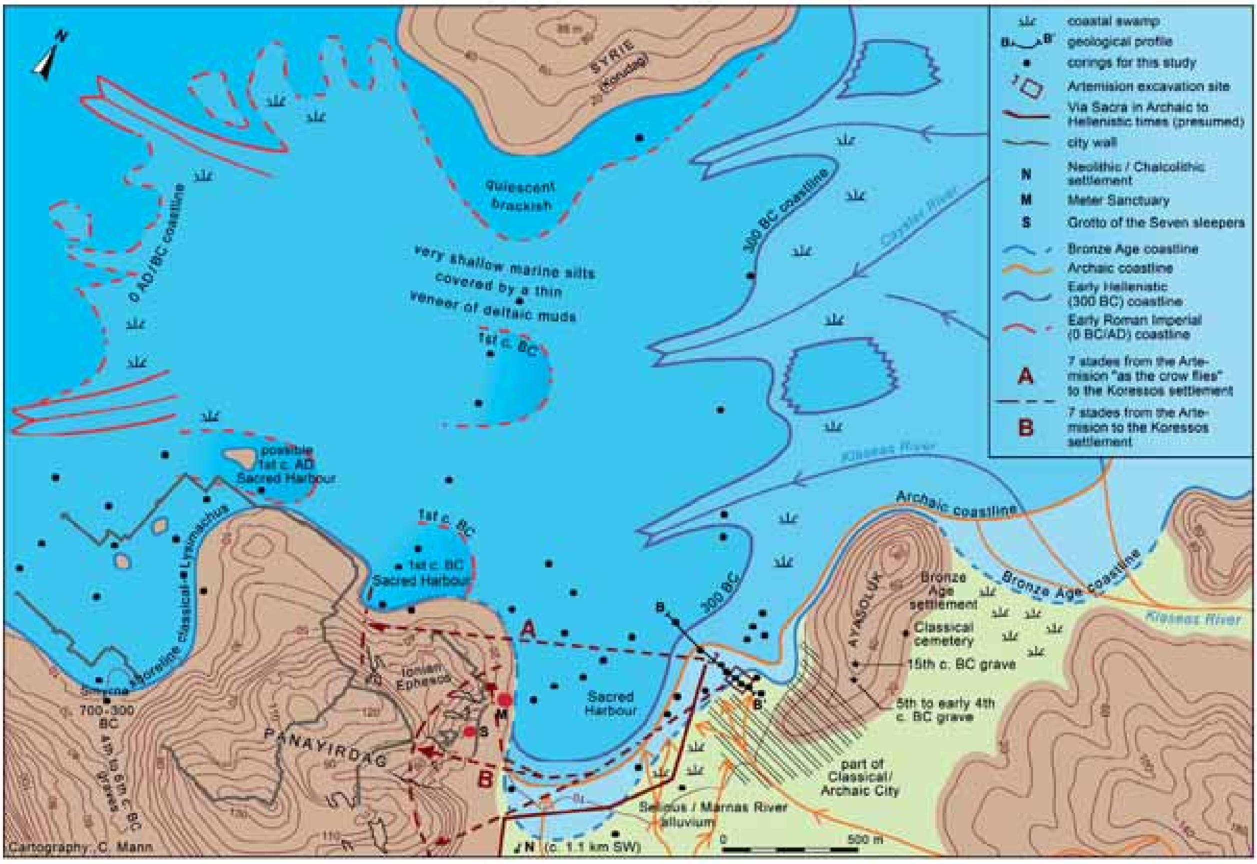
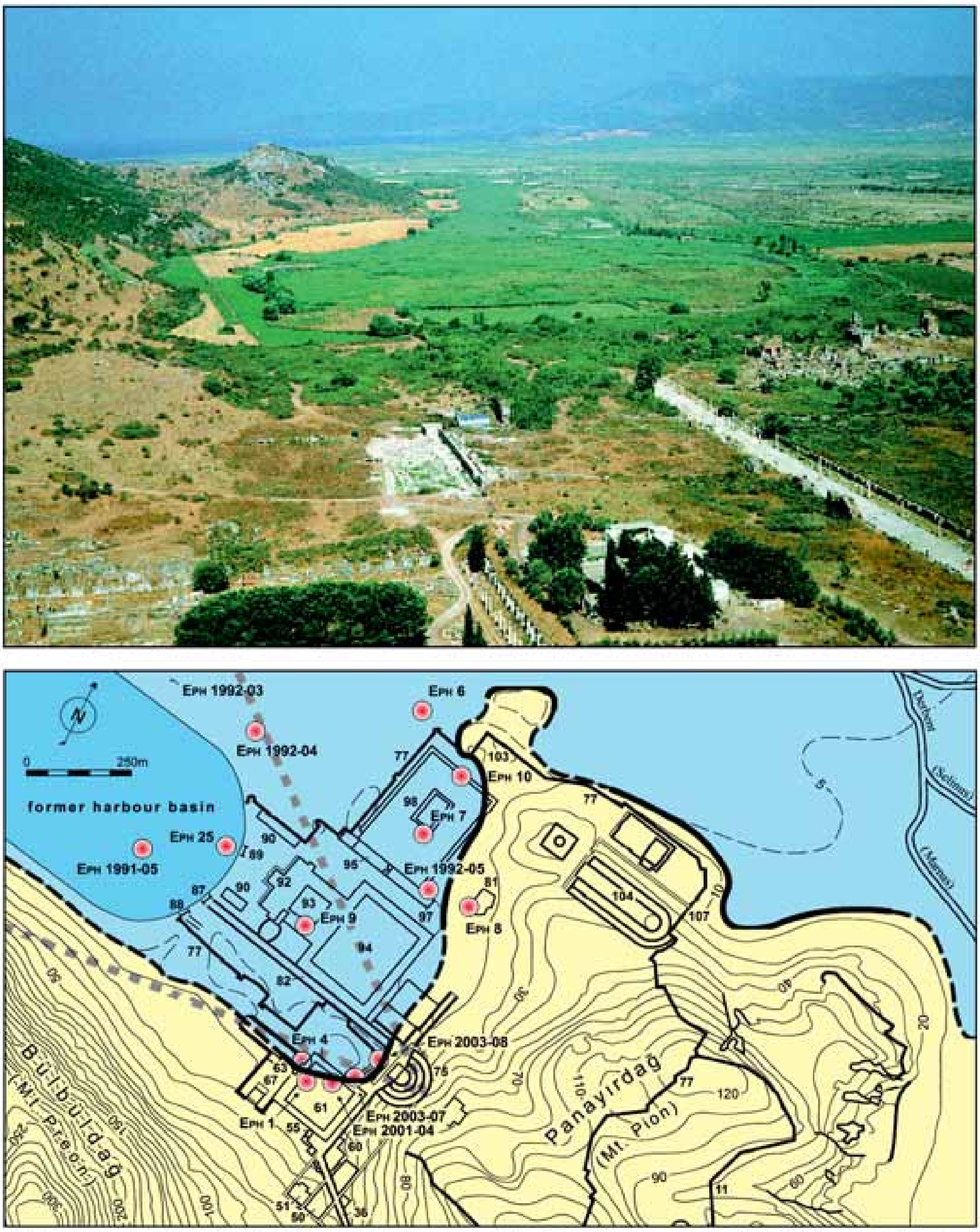


Figure 35. Palaeogeographic reconstructions of the environs of the Artenmision.The figure shows coastlines in the Bronze Age, Archaic/Classical, early Hellenistic, 1st century BC and early Imperial times. The coastal configurations are based on corrected and calibrated 14C dates considering the 2 sigma ranges. Dashed lines A and B illustrate the impact of these palaeogeographic projections on measuring Herodotus' (I.26) statement of 7 stades distance from the Artemision to the Coressus settlement of the Ionian Greeks. Line A indicates 7 stades 'as the crow flies' while lines B indicate 7 stades by walking around the Sacred Harbor. The latter (B) suggests that Coressus may be on the very NE corner of Pion (Panayırdağ) and therefore closely related to the Meter Sanctuary. Source: Brückner, Kraft & Kayan 2008: Abb. 5, after Kraft, Kayan & Brückner 2001: Table 6

In Roman times, the Kaystros delta had passed the city of Ephesos and started to endanger the harbour with siltation. The digging of a canal is an expression of man's fight not to loose their direct access to the sea – in the end a futile endeavour Figure 37. The detailed history of the canal in connection with the only lately discovered necropole is the subject of a new geoarchaeological research project.



11 Hellenistic city wall
36 Curetes Street (Embolos)
50 Terrace House 1
51 Terrace House 2
55 Celsus Library
60 Marble Street
61 Tetragonos Agora (Common Market)
63 West Gate of the Agora
67 Temple precinct (Serapeion)
75 Theatre
77 Byzantine city wall
81 Byzantine Palace Sarhoş Hamam
82 Arcadiane
87 Middle Harbour Gate
88 Southern Harbour Gate
89 Northern Harbour Gate
90 Market buildings at the Harbour
92 Harbour Baths
93 Harbour Gymnasium
94 Xystoi / Halls of Verulanus
95 Church of Mary
97 Episcopium of the Church of Mary
98 Olympieion
103 Crevice Temple
104 Stadium
107 Coressian Gate

Figure 36. The marine history of many parts of the city of Ephesos. Nearly all the area of the photograph (except for the mountains) was once sea. The view is from the theatre westwards over the Arcadiane to the Roman harbour (dark green area). The lower figure shows the land/sea distribution during the time of the maximum marine transgression c. 6000 years ago. After Brückner 2005: Fig. 3.

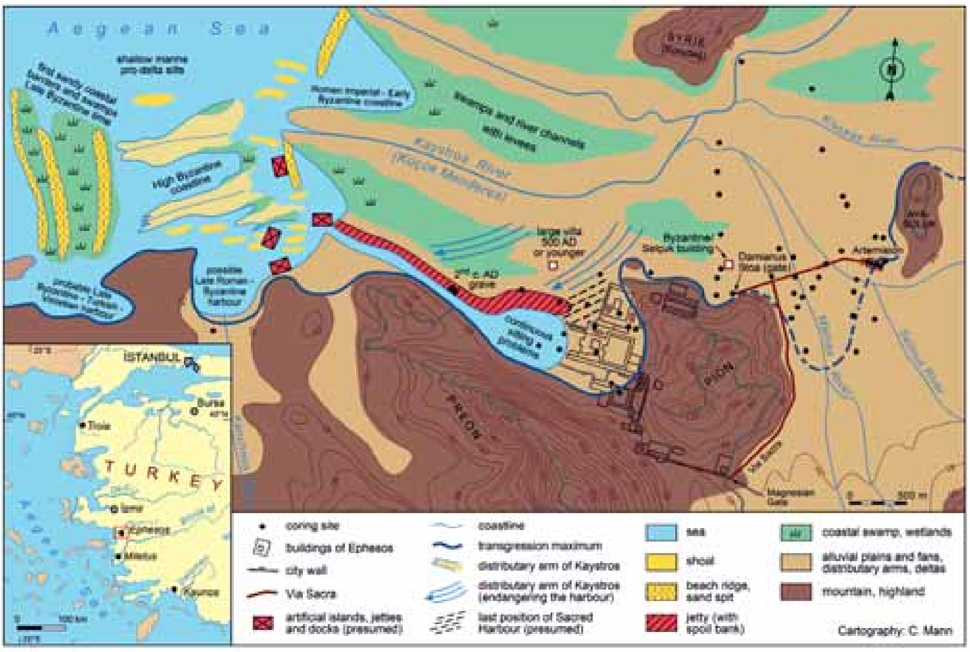


Figure 37. Scenario of the delta growth from the Roman to the Byzantine era.The permanent westward shift in the shoreline forced the people of Ephesos to dig a canal through which ships could enter the city harbour from the sea. In Early Byzantine times, however, the harbour had to be shifted. Note that the morphology of the delta changed in Late Byzantine times when the longshore current started to dominate the coastal morphodynamics. After Brückner, Kraft & Kayan 2008: Abb. 9.

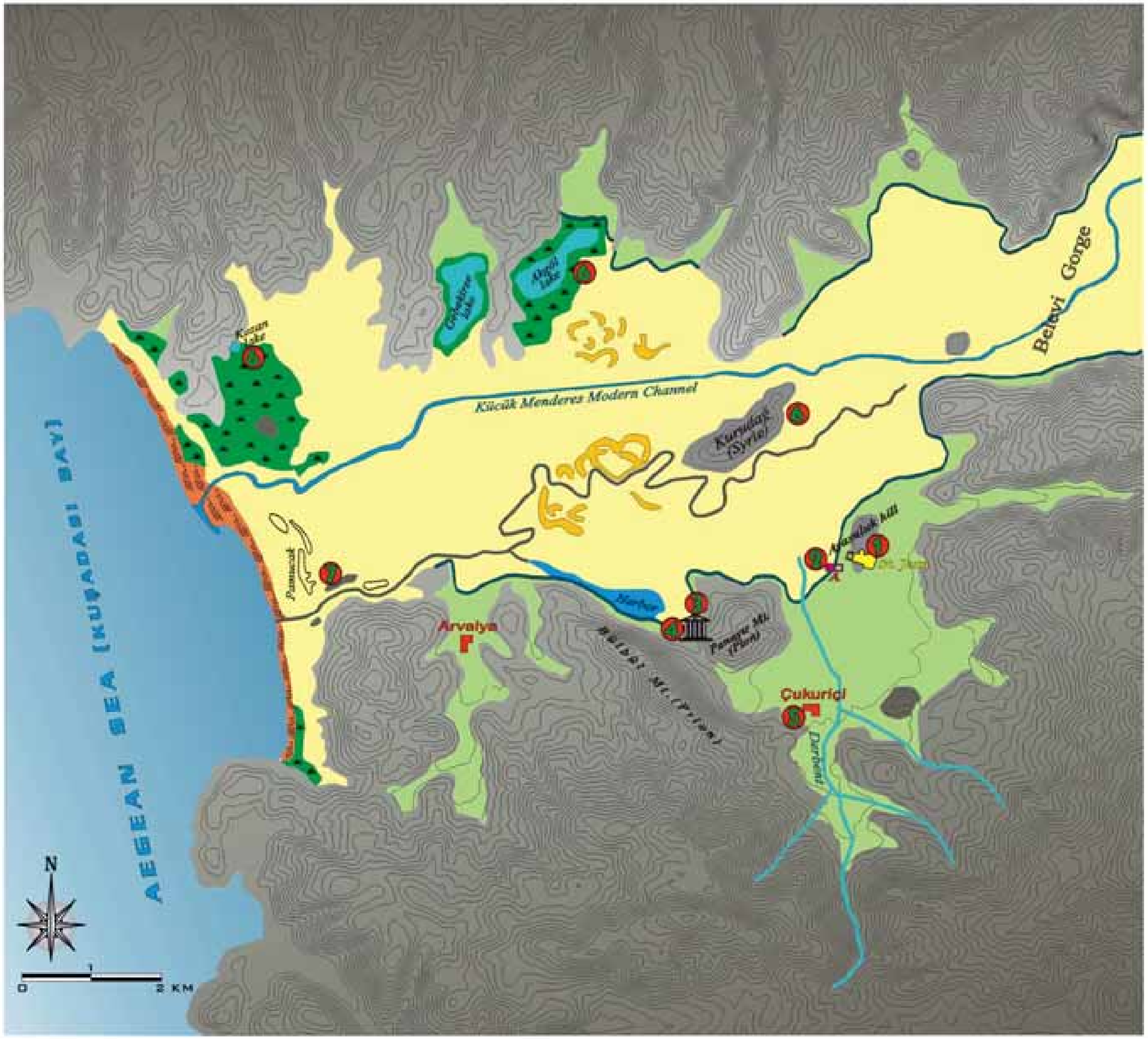
Figure38. Vibracoring in the necropole at the flank of the canal connecting the Roman harbour with the sea. The coring at a grave of the necropole dating from the 3rd century AD (oral comm. by Dr. Steskal) is part of a new project which aims to clarifying the building phases of the canal and its final siltation. The persons are extracting the drill cores. The green reeds in the right part of the photograph mark the area of the canal. The theatre of Ephesos is visible in the background.

Ephesos Timetable

Epoch	Time	Event
Neolithic	7th mill. BC	Earliest finds at **Çukuriçi Höyük**
Prehistoric	Early 3rd mill. BC 3rd/2nd mill. BC	Final destruction and abandonment of the **Çukuriçi** Höyük, formation of an **anchorage ground** at the mouth of the river Cayster
Mycenaean	After 1500 BC	Mentioning of the land of Arzawa, capital **Apaša** (Ephesos?), tombs with Mycenean pottery indicate a late Bronze age settlement of Ayasoluk Hill
Geometric	11th cent. BC 9th cent. BC 8th cent. BC	Significant increase of Greek pottery in the settlement of Ayasoluk, legendary foundation of "Koressos" of Ionian Greeks under their leader Androklos Start of the continuous use of the **Artemision** as a cultic place Formation of a village Smyrna at the place of the later agora
Archaic	6th cent. BC since 546 BC	Foundation of a settlement (city of Ephesos) around the **Temple of Artemis**, donation of King Croesus of Lydia, the "Wonder of the Ancient World" evolves, siltation of the Holy Harbour Rule of the **Persians**
Classical	466 BC 407 BC 356 BC	Kimon frees Ephesos from the Persian rule Admiral Lysandros from Sparta choses Ephesos as headquarter, he develops the harbour (west of Panayırdağ?) Herostratus sets fire to the Artemision, later restauration starts
Hellenistic	289/8 BC 281 BC	**Lysimachos'** foundation of the city Arsinoeia between Panayırdağ and Bülbüldağ, erection of the **Hellenistic city wall** Arsinoeia was renamed to Ephesos after Lysimachos' death
Roman	mid-2nd cent. BC 133 BC mid-1st cent. BC 29 BC 1st cent. AD 23-47 AD 52, 53-55 AD 62 AD 2nd half of 1st c. AD 92/3 AD 130 AD 262/270 AD 359-366 AD around 400 AD	Building of a dam in the harbour as protection measure against the floods of Cayster Constitution of the Roman province of Asia Onset of substantial **expansion of the city** Strabon visits Ephesos **Period of greatest prosperity**, Ephesos becomes **capital of the province of Asia** Several earthquakes cause destructions Apostle Paul in Ephesos Access to harbour is dredged Construction of the Central Harbour Gate Harbour Baths extensively finished Start of the construction of the Olympieion, the Temple of Hadrian **Destruction** of the Artemision and parts of the city by an earthquake series, Plundering by the Goths Series of **severe earthquakes** causing major damages **Enforced rebuiling** of the city, new adaptation of the harbour street as Arkadiane
Byzantine	Since 391 AD 431 AD 467/8 AD 557 AD 7th cent. AD	Christianity as state religion, destruction of pagan buildings, slow shifting towards the harbour region and **reduction of the city area** 3rd Ecumenical Council meets at Ephesos Further earthquakes Another earthquake Plundering of the city by Arabs (?), but continuous inhabitation of Ephesos until the 14th cent. AD
Seldschukian	13th-14th cent. AD	**Rule of the Seldschuks**
Osmanic	Since 1424 AD	Part of the **Osmanic Empire**

Source: Brückner (1997, Tab. 1), compiled from Karwiese (1995) and Ekschmitt (1991), supplemented by S. Ladstätter in 2009. Brückner, H. (1997): Geoarchäologische Forschungen in der Westtürkei - das Beispiel Ephesos. –Passauer Schriften zur Geographie, 15: 39-51; Passau.

KUÇÜK MENDERES TRIP (DAY 1) 26 AUGUST 2009



High topography area
Alluvial plains
Subordinate stream deposits/Aluvial fan deposits
Lakes
Swamps
Old meander loops
Beaches and dunes
Topographic contour lines 25m
Ancient beaches and dunes
7000 - 6000 years before present ~ coastal lines
Artemis Temple (Artemision)
Mounds (Neolithic)
EPHESOS
STOPS

Stop 1: St. Jean Church/ Selçuk castle (Ayasuluk hill). A brief visit for panoramic view of Selçuk plain and Belevi Gorge.

Stop 2: Artemision/ The story of sea-level change in early building phases at Artemision.

Stop 3: Ephesos/ Olympieion and earthquake debris filled grounds of a Hadrianic temple.

Stop 4: Ephesos/ Silted-up ancient harbour of Ephesos, visit of the just recently discovered necropolis flanking the harbor canal, with support by PD Dr. S. Ladstätter.

Lunch Break at Hitit Restaurant

Stop 5: A visit to Çukuriçi Höyük (Neolithic Bronze Age settlement, latest coring results plus tour by Dr. Barbara Horejs)

Stop 6: Selçuk depression/A trip to the ancient Ephesian gulf, Syrie island (today Kurudağ), Akgöl, Gebekirse, and Kazan lakes.

Stop 7: Pamucak/ Roman age human made silt deposits of ancient Ephesos harbour.

THE SEA, THE RİVER AND MAN – WHY THE ENVİRONMENT OF MİLETUS CHANGED DRAMATİCALLY DURİNG THE PAST MİLLENNİA*

Helmut Brückner (Marburg University/Germany), Marc Müllenhoff (geo-present, Korbach / Germany)

& Alexander Herda (Tübingen University/Germany)

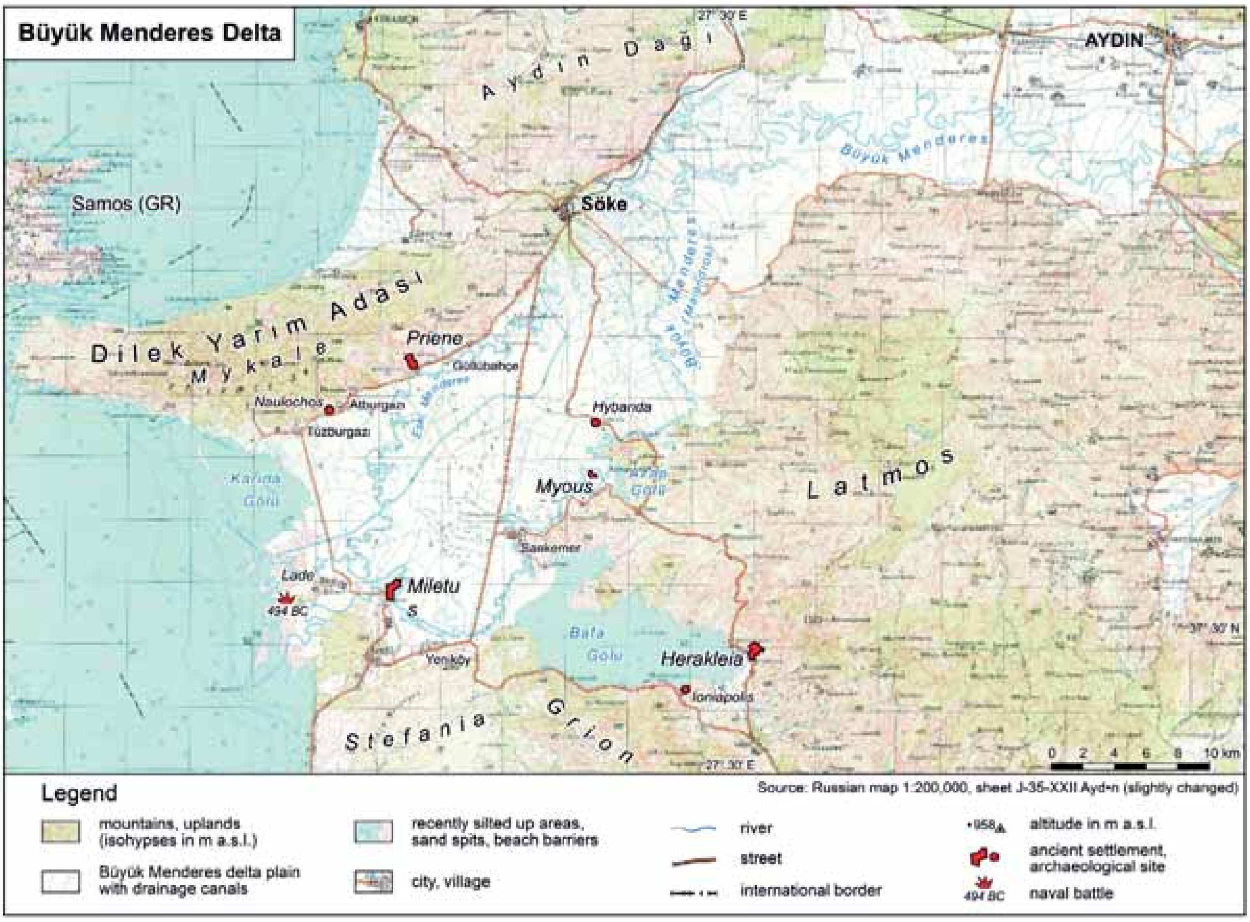


Figure 39. Topographic map of the Büyük Menderes floodplain and delta, with the sites of the ancient cities Myous, Priene and Miletus as well as the former islands Hybanda and Lade. Most of the area of the floodplain and the deltaplain of the Büyük Menderes was once occupied by the sea, the so-called Latmian Gulf, the transgression peak of which was not far from Aydın. The later nearly total siltation of the marine embayment is proven by (a) the still brackish Lake Bafa; (b) the former island Hybanda and Lade, now totally integrated into the plain; the evidence that Myous, Priene and Miletus were once harbour cities. Source: Russian map 1:200,00, sheet J-35-XXII Aydın (slightly changed).

This section is from Helvacı et al. (2009)

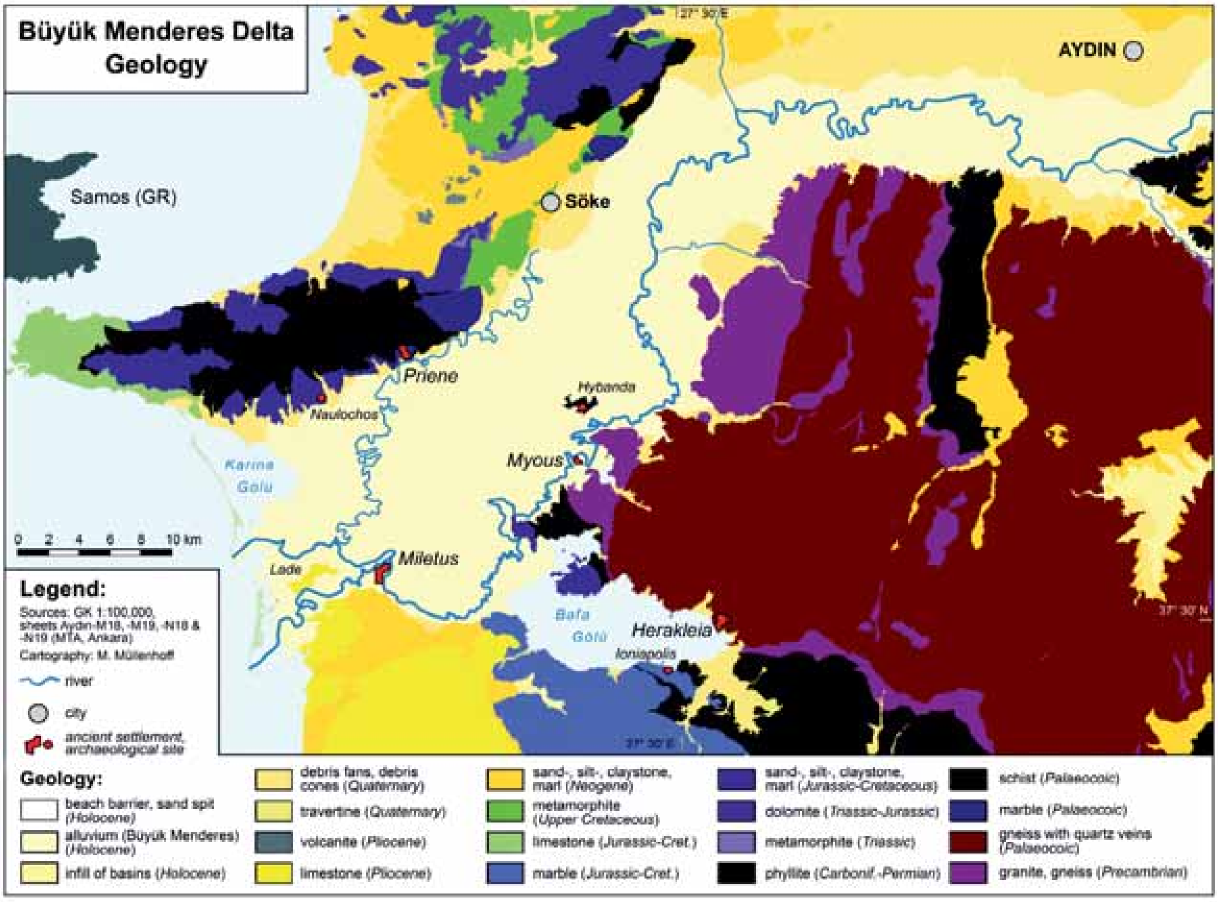


Figure40. Geologic map of the Büyük Menderes floodplain and delta with surrounding mountains. Sources: GK 1:100,000, sheets Aydın-M18, M19, N18 and N19 (MTA, Ankara)

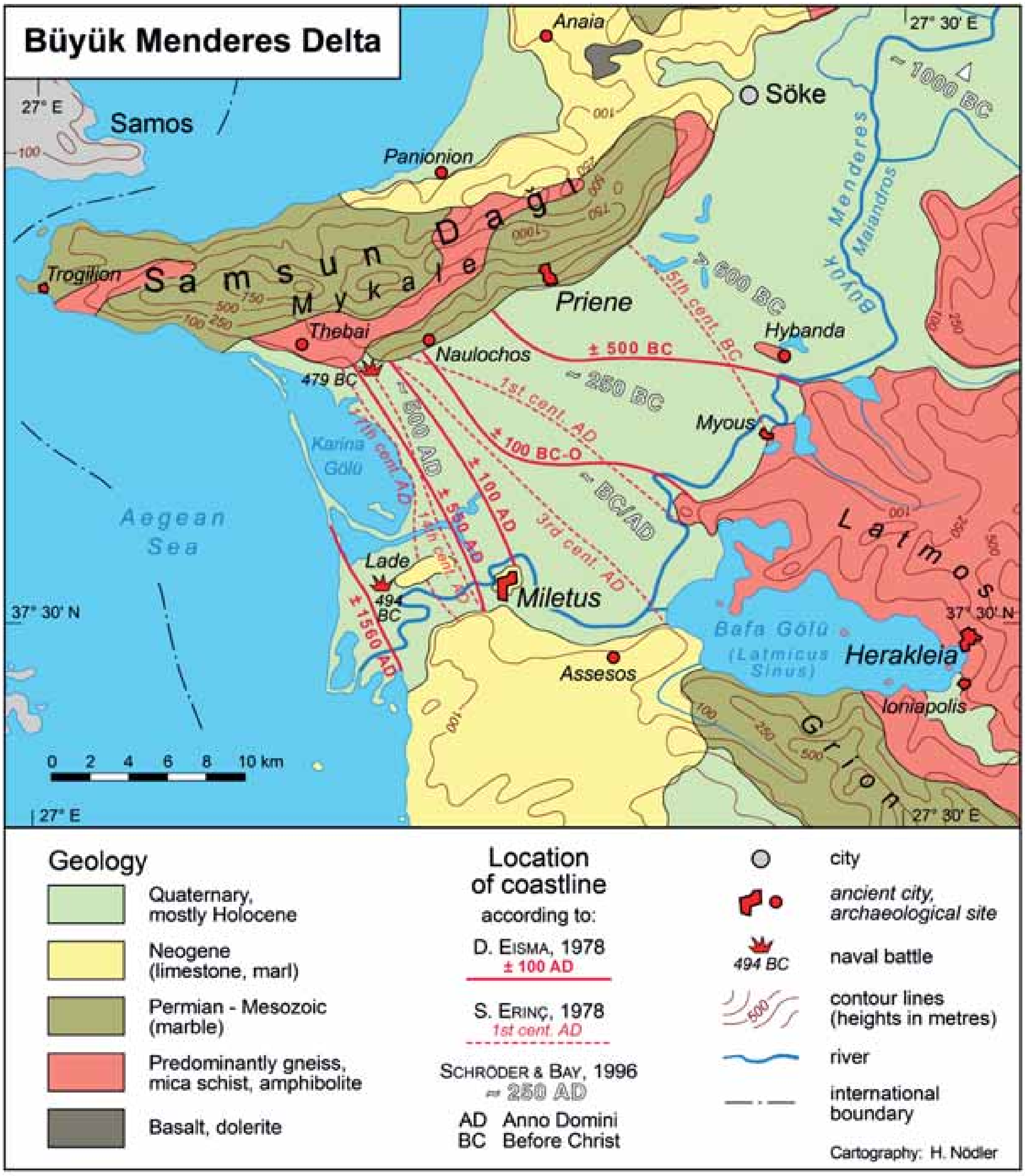


Figure 41. Old scenarios for the progradation of the Büyük Menderes delta in historical times. The area of the alluvial plain and the lakes was once occupied by the so-called Latmian Gulf. The scenarios of Eisma (1978) and Erinç (1978) were based on literary evidence only, while Schröder & Bay (1996) also integrated the interpretation of aerial photographs and satellite images. Source: Brückner 2003, fig. 1.

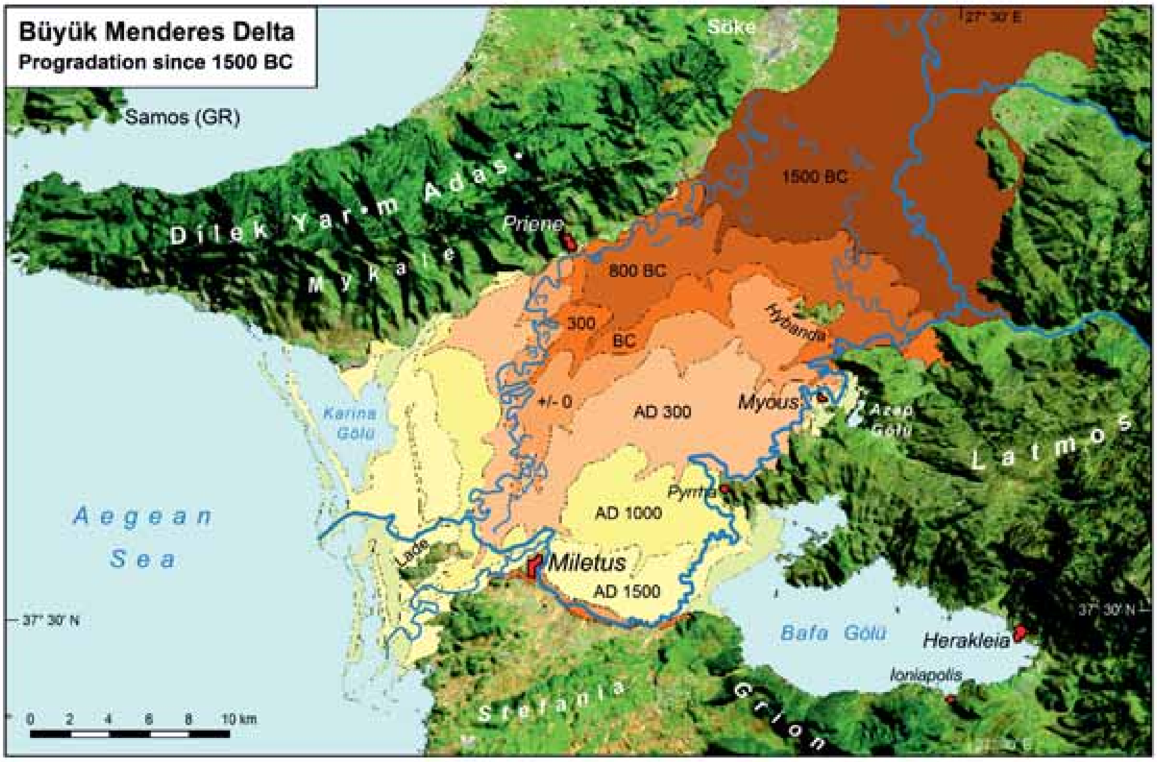


Figure 42. Latest scenario for the progradation of the Büyük Menderes delta since 1500 BC. This scenario is based on the interpretation of nearly 300 vibracorings carried out by H. Brückner and his teams since 1992. Source: Brückner et al. 2004, fig. 1, Müllenhoff 2005, Abb. 56.

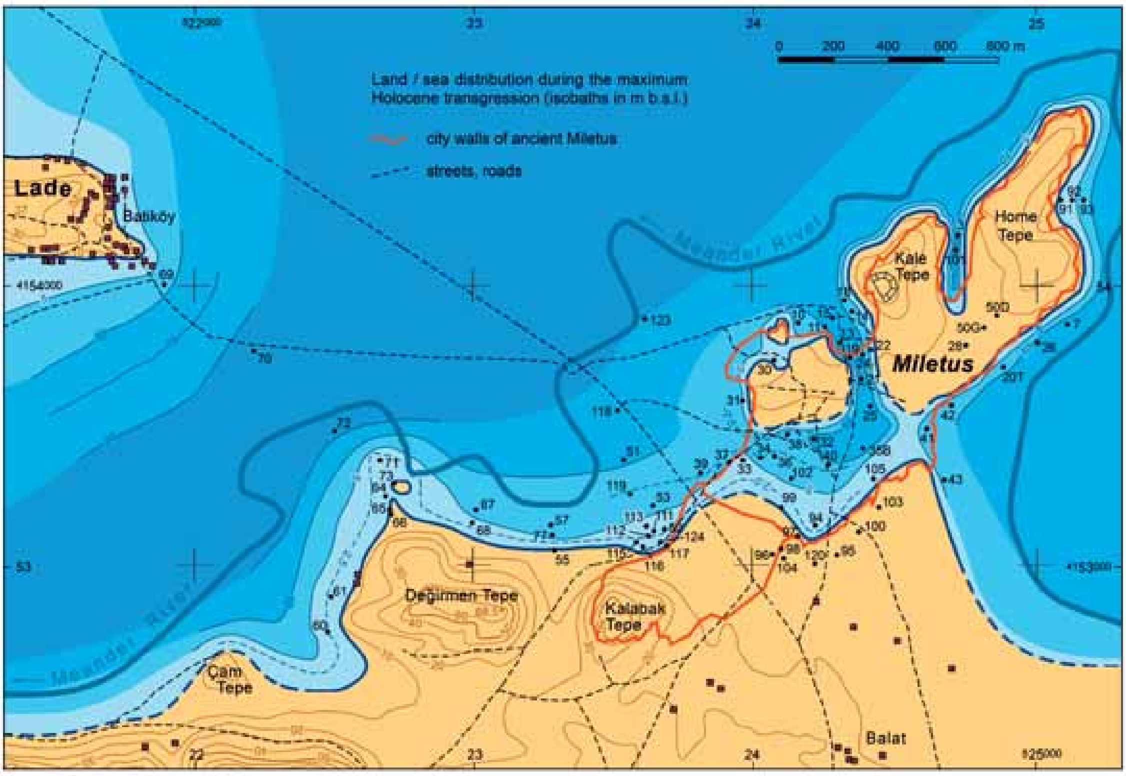


Figure43. The Milesian archipelago 5000 – 6000 yrs BP.During the peak of the Holocene transgression, the area of the later city of Miletus was an archipelago. At the latest in Archaic times, the archipelago had changed to a peninsula. The reasons were siltation due to denudation from the flanking slopes, longshore currents and also human impact (dumping material in the still wet areas). The Milesian peninsula was famous in antiquity, the most prosperous epoch being the Archaic one. Strabo mentions four harbours, two of which are still well recognizable (Lion Harbour, Theatre Harbour), another one is presumed near the Athena Temple and near the South Market on the seaward side to winds and currents. Source: Brückner 2003, fig. 3 (changed).

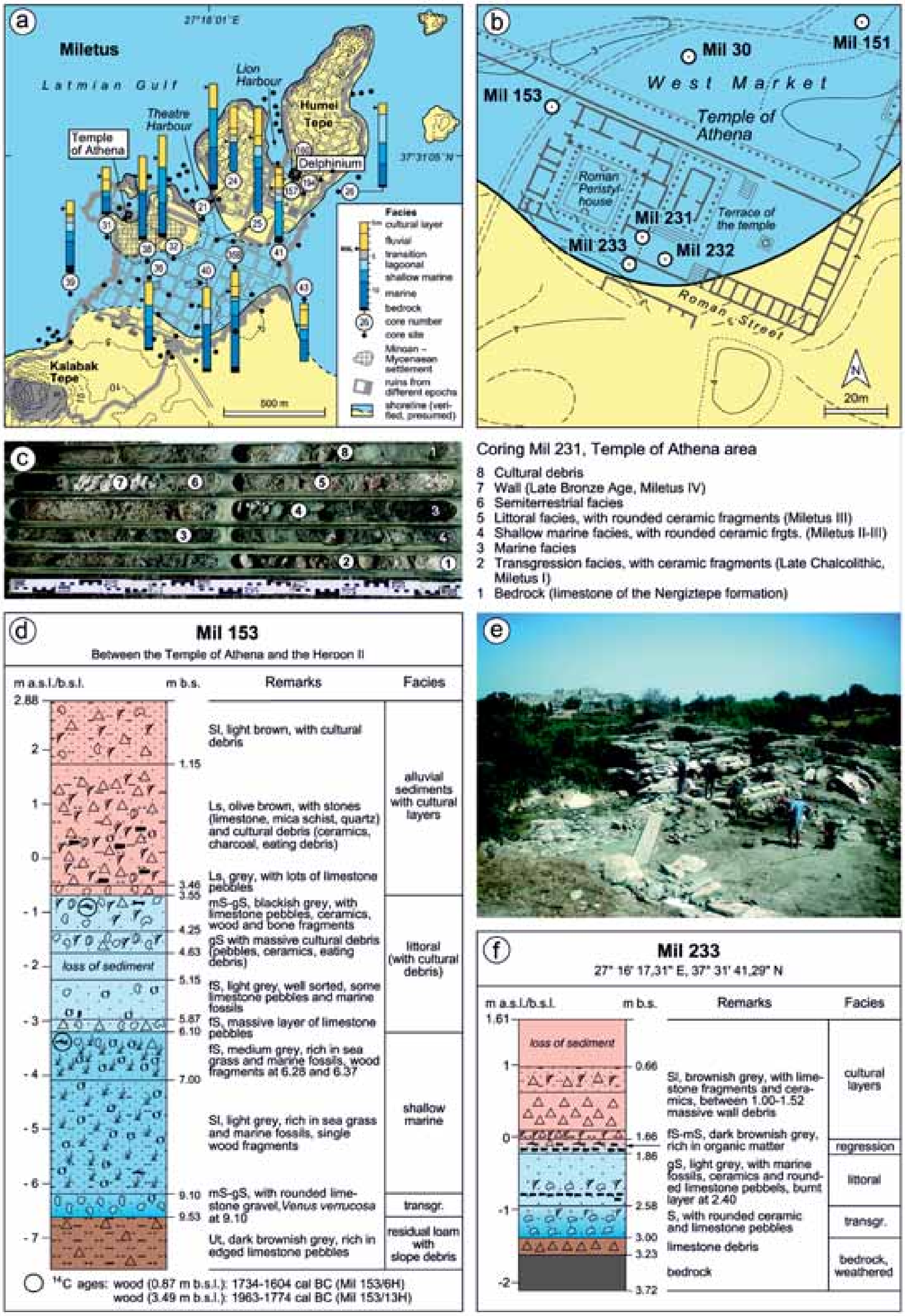


Figure 44. Environmental changes and sea-level fluctuations in the area of the Athena Temple in Miletus. (a) Reconstruction of the Milesian archipelago during the maximum marine transgression around 2500 BC (only some of the more than one hundred corings are shown). (b) Section of Bendt's topographical map (1968) showing the position of the Athena Temple within the city of Miletus, some of the cored sites and the maximum marine transgression. (c) Sediment core Mil 231, with interpretation of the strata (lower right corner of the photograph: end of core at 5 m below surface; top of each core segment is to the left). (d) Details of coring Mil 153, with geology, dating results and facies interpretation. (e) The so-called temple terrace is the ruin of the square building in the middle ground; the two persons standing in front of it are looking on the walls from the building epochs Late Minoan Ia and Ib (Miletus IV, 1700 – 1450 BC); in the foreground the area of corings Mil 231–233. (f) Details of coring Mil 233, with geology, dating results and facies interpretation. Source: Brückner et al. 2006, fig. 3.

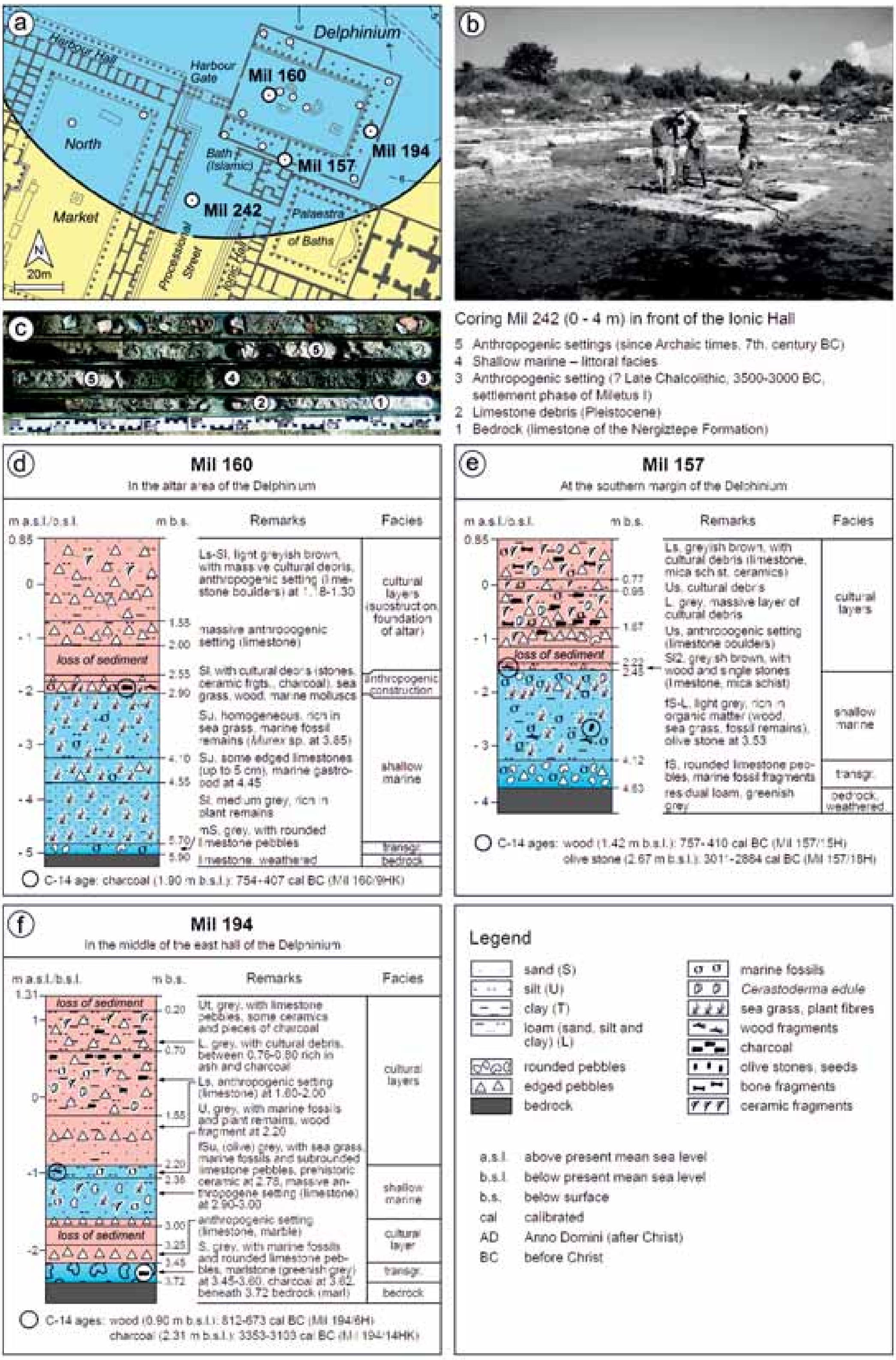


Figure 45. Environmental changes and sea-level fluctuations in the area of the Delphinium in Miletus. (a) Section of Bendt's topographical map (1968) showing the position of the sanctuary within the city of Miletus, the cored sites and the maximum transgression of the sea around 2500 BC. (b) Coring the strata under the altar (coring Mil 160). (c) Photograph of sediment core Mil 242, with interpretation of strata (lower right corner: end of core at 4 m below surface; top of each core sediment is to the left). (d) – (f) Details of corings Mil 157, 160 and 194, with geology, dating results and facies interpretation. Lower right corner: legend (also for Fig. – Mil 6). Source: Brückner et al. 2006, fig. 4.

Figure 46. Virtual Miletus during the Roman Imperial times (1st and 2nd centuries AD). The images are based on the interpretation of more than one hundred corings and on archaeological evidence and historical accounts. Source: M. Müllenhoff, cited by Brückner & Vött 2008, Abb. 8.

Figure 47. View on the Lion harbour, the Delphinium and the Ionian Hall. The view from the Byzantine Castle on the area of the southernmost extension of the Lion Harbour, the Delphinium, the Ionian Hall and the Sacred Road. That the Delphinium is still inundated in September underlines the need for corings to reveal the subsurface strata. Latmos Mts. In the background. Photograph: H. Brückner 09/2005

Figure 48 The pedestal of the Market Gate of Miletus. This famous gate – now re-erected in Berlin's Pergamon Museum – connects the Sacred Road with the South Market. Transect D, cored immediately in front of it, revealed that it was built on formerly shallow marine strata. Photograph: H. Brückner 09/2005.

Figure 49. Coring immediately at the Market Gate of Miletus. The photograph of coring Mil 267 shows the stratigraphy of the strata on which the Market Gate was founded (see also Transect D). Photograph: H. Brückner 09/2005.

Historic and Palaeographic changes in Miletus (Source: Brückner et. al., 2006)

Time	Historic changes	Palaeographic changes
2^{nd} half of 4^{th} mill. (3500-3000BC)	First settlement, ***Late Chalcolithic*** (Miletus I)	Postglacial sea level rise had formed the Milesian archipelago, climax vegetation dominated by deciduous oak forest
Early Bronze Age (3000-2000BC)	**Early Bronze Age Miletus** (Miletus II)	Highest position of local sea level, reduction of settlement area
Middle to Late Bronze Age (2000-1100BC)	***Minoan – Mycenaean Miletus,*** founded by settlers from Crete; from Middle Bronze Age (Miletus III) to late Late Bronze Age (Miletus VI) destruction of Mycenaean fortification in 12^{th} century BC	Intense degradation of vegetation due to increasing anthropogenic impact(among others: introduction of the goat), gradual decline of natural fauna, resulting soil erosion together with a slight marine regression initiated transition of the archipelago to Milesian Peninsula
since 1050 BC	Protogeometric-Geometric Miletus, Colonisation due to excellent natural harbours	Definite connection of the archipelago with the adjacent southern flank of the Meander graben
7^{th} 6^{th} centuries BC	Archaic Miletus, political, economical and cultural prosperity foundation of more than 80 colonies (Black Sea region etc.); Thales, Anaximander, Anaximenes, Hekataios; second half of 6^{th} century BC: enlargement of city centre around the agora and the Delphinium by manmade infill, replanning in a new grid system	Continued degradation of the ecosystem, Palynological analyses prove increase in maquis elements and indicators of human impact, siltation especially north of Kalabak Tepe due to strong erosion and denudation processes
494 BC	Naval battle of Lade, victory of Persians, total defeat, destruction of the city	
after 479 BC	***Classical – Hellenistic Miletus,*** building of new city by enlargement of Late Archaic grid system; industrial processing of wood and wool, metallurgic industry	
64 BC - 4^{th} century AD	***Roman Miletus,*** new economic growth renovation of theatre in $1^{st}/2^{nd}$ centuries AD, dredging of Theatre harbour	Vegetation dominated by maquis and phrygana, endangering of Milesian Peninsula by prograding Maeander Delta, accelerated siltation of Lion and Theatre harbours.
4^{th} century AD – 1327AD	***Byzantine Miletus,*** Episcopal See, erection of castle; gradual decline	Increased siltation by Mederes alluvium, gradual integration of Milesian Peninsula into the floodplain
1327AD – beginning of 20^{th} century AD	Miletus part of Emirate of Menteşe, later of ***Osmanic Empire;*** total decline of the city	Definite siltation of all harbours, loss of access to open sea

Holocene Sea level curves

Helmut Brückner (Marburg University/Germany), Marc Müllenhoff (geo-present, Korbach / Germany) & Alexander Herda (Tübingen University/Germany)

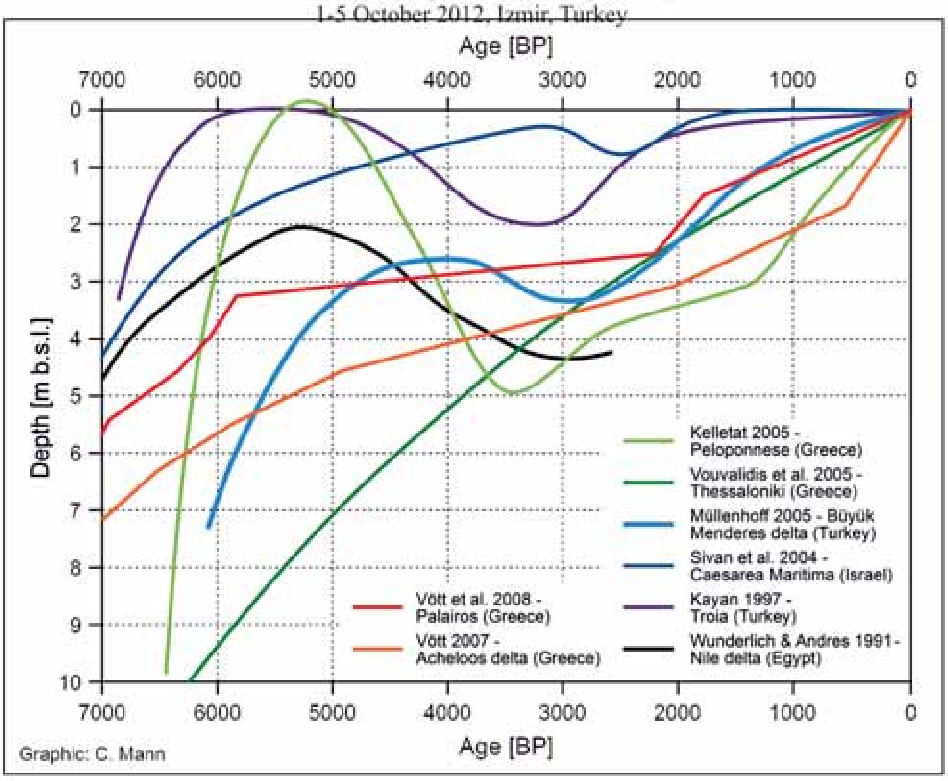


Figure50. Compilation of Holocene sea-level curves from the eastern Mediterranean. Type 1-curves show a relative mid-Holocene sea level highstand between 6000 and 3500 cal BP. In contrast, type 2-curves show a more or less continuous sea level rise during the past 6000 years or so. It is obvious that there is only one major wiggle for the type 1-curves, while the type 2-curves have none at all. Source: Brückner et al. 2009, Fig. 3.

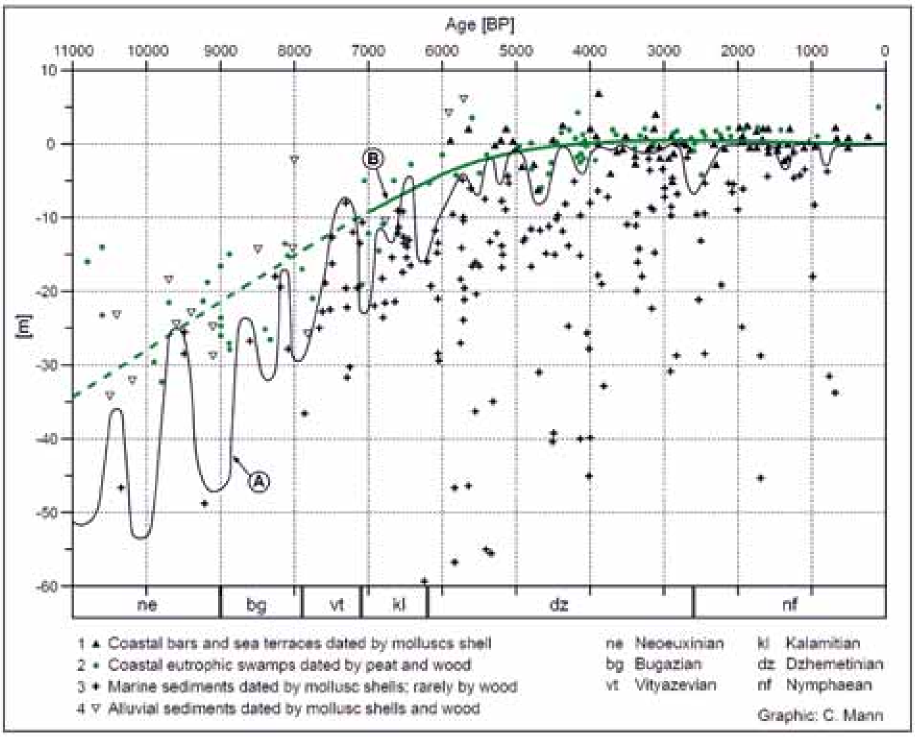


Figure 51. Holocene sea level curve of the Black Sea according to Balabanov (2007) (curve A). Curve A is based on the interpretation of about 400 radiocarbon dates produced on mollusc shells, peat, and wood taken from various environmental settings. Curve B (green) shows the re-interpretation of the data set using exclusively paralic peat as the best sea level indicator. This curve shows that the sea level evolution of the Black Sea generally follows the trend of type 1-curves known from the Mediterranean. Source: Brückner et al. 2009, Fig. 7.

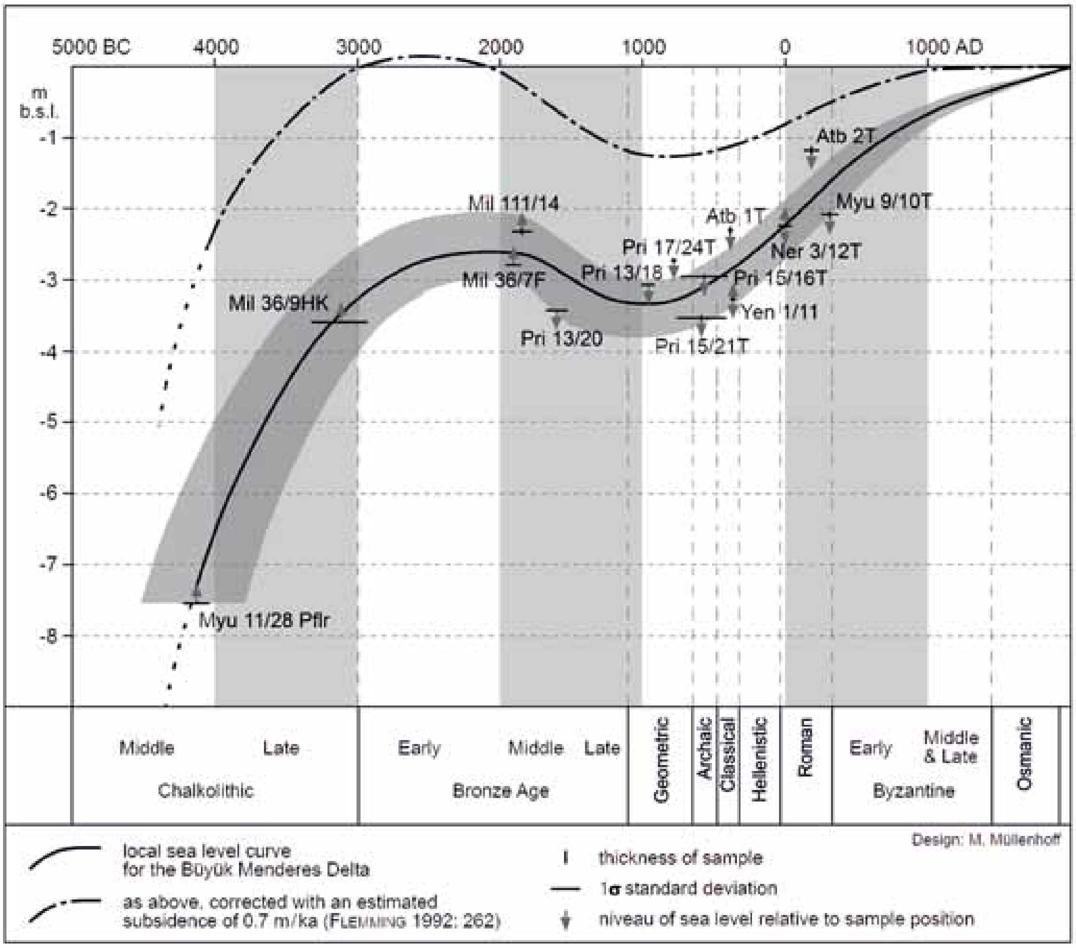


Figure 52. Sea level curve for the Büyük Menderes area for the last six millennia. This curve is based on 14C-dated samples from paralic peat as well as charcoal, plant remains and mollusk shells from littoral facies. Source: Müllenhoff 2005: Abb. 47.

ÇUKURİÇİ HÖYÜK – A PREHISTORIC SITE IN EPHESOS

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Çukuriçi Höyük is the oldest excavated prehistoric site in the vicinity of Ephesos (fig. 1). This artificial mound (so-called *tell* or *höyük*) is composed of settlement remains of different periods (fig. 2), which can be dated from the 7th until the 3rd millennium BC (Neolithic, Chalcolithic and Bronze Ages). First systematic excavations were initiated in 2007 and are continuing as part of the ERC project *From Sedentism to Protourban Societies in Western Anatolia* since 2011. Studies are focusing on the settlement history of Çukuriçi Höyük itself as well as on broader scientific questions in Western Anatolia including environment, ecological resources, climate conditions, changing use of plants and animals and social structures. Besides archaeology, also geophysics, paleogeography, metallurgy, inorganic chemistry, petrography/mineralogy, geology, zoology and genetics, botany, anthracology, organic chemistry, physics and anthropology are involved in the perennial research.

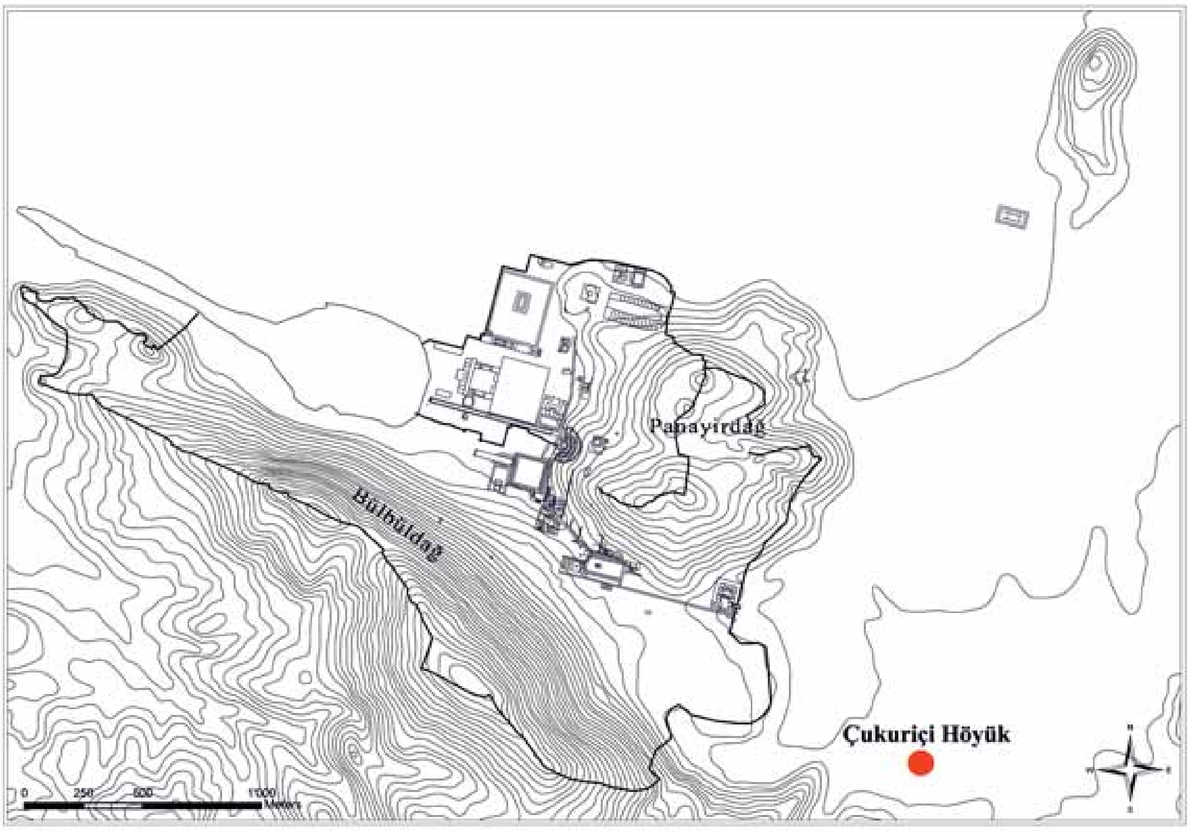

Figure 1. Map of the Çukuriçi Höyük.

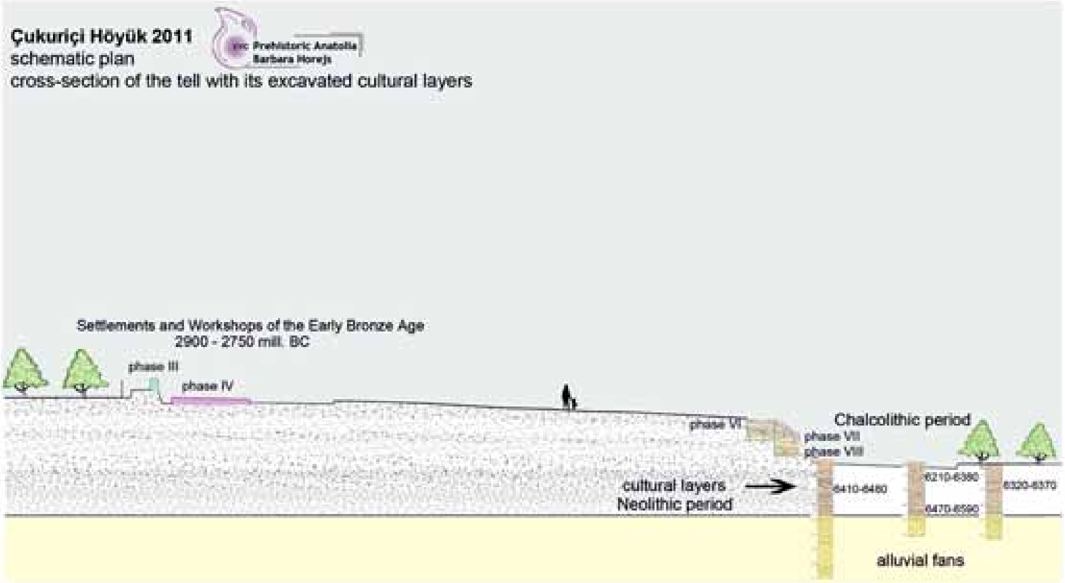

Figure 2. Cross-section showing different periods of settlement in Çukuriçi Höyük.

Early Metallurgy (Bronze Age)

The youngest settlements are dating in Early Bronze Age 1 between 2900–2750 calBC by ^{14}C-dates. Besides ordinary household activities, intensive metallurgical activities were identified by excavating the settlement areas under study and carrying out scientific analyses. Metallurgical workshops with up to now 25 ovens and associated finds indicated that metal processing took place directly in the living quarters (fig. 3). The tools allowed us to identify all the production stages of various metal objects (fig. 4). Especially the smelting debris examinated provided useful clues with regard to the production of arsenical copper at the beginning of the Bronze Age. The copper ores are not clearly identified so far and are one of the main aims of current investigations.

Figure 3. Field view showing metal processing took place directly in the living quarters.

Figure 4. Tools used in metal processing in Çukuriçi Höyük.

Early Farmers (Neolithic period)

Recent excavations in 2011 were conducted at the foot of the Çukuriçi Höyük. Previous geological drills unveiled settlement material down to a depth of 3,80 m below today's surface. Numerous features from Neolithic period (7^{th} millennium BC) were documented in the new excavations, such as different living and activity areas, consisting of houses, huts and pits for storage and cooking. Remains of food production and consumptions are for example preserved from partially burnt plants and mainly domestic animals (pig, cattle, sheeps and goats) as well as fish and seafood. Intensive use of the Aegean sea by the Neolithic inhabitants of this settlement is not only indicated by fish remains, but also by a remarkable high percentage of imported obsidian – a special volcanic stone from the Aegean island of Melos that is used for different tools.