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GEOLOGY AND STRATIGRAPHY OF THE CAINOZQIC SEDIMENTARY ROCKS IN THE KALE-KURBALIK AREA, DENİZLİ, SOUTHWESTERN TURKEY

H.Yavuz HAKYEMEZ*

ABSTRACT.— In this work, the geological and stratigraphical characteristics of the Cainozoic sedimentary rocks exposed at the Kale-Kurbalık (SW Denizli) area have been investigated. In the study area the Palaeozoic and Mesozoic rocks form the basement rocks and are overlain by the Oligocene to the Quaternary aged sedimentary rocks. The Tertiary rocks have been considered in two groups, namely the Akçay group and the Muğla group. The Oligocene to the Burdigalian aged Akçay group is represented by the Karadere, Mortuma, Yenidere, Künar and Kale formations. During this time interval, mostly the terrestrial fine and coarse clastics were deposited, but in the last stage of this time shallow marine carbonates were sedimented on the some parts of the region. There is an angular unconformity between the Mortuma and the Yenidere formations of the Akçay group; others are conformable to each other. The Akçay group is 4100 meter thick. The Upper Astarasian (Middle Miocene) to Pliocene aged Muğla group which overlies the Akçay group uncorformably is formed of the Sekköy, Yatağan and Milet formations. During this time interval, the lacustrine siltstones and carbonates and the terrestrial coarse elastics were deposited. The formations of the Muğla group are conformable and gradational to each other. The Muğla group is 550 meter thick. The Quaternary deposits have been considered in two units, namely "Lower" and "Upper" Quaternary sediments. Only the Mortuma formation of all units of the study area is gently folded, but others have low degree dips. Tectonic activity has played a big important role in the forming of the various sedimentary basins which have been generated since the beginning of the Oligocene up to the present.

INTRODUCTION

This study was carried out on the quadrangles M 21- c4d3 and N 21-a2,b1 of the Kale-Kurbalık area (SW Denizli). This area is of considerable importance to evaluate the Cainozoic geology and stratigraphy of the SW Anatolia (Fig. 1). The fieldwork was undertaken between 1979 and 1981. In this region, the previous researchers confirmed important geological data, i.e. Altınlı (1955), Dizer (1962), Becker-Platen (1970), Lüttig and Steffens (1976), Becker-Platen et al. (1977), Benda and Meulenkamp (1979), Gökçen (1982) and Hakyemez and Örçen (1982) (Fig.2). The first geological research in the area was carried out by Altınlı (1955). Becker - Platen (1970) contributed much to the understanding of the whole region. Lüttig and Steffens (1976) played a significant role in the interpretation of the palaeogeographic evolution of the region. Hakyemez and Örçen (1982) studied the region in detail. The investigators were concerned mainly with the palaeontological or chronostratigraphical aspects of the study area.

STRATIGRAPHY

PALAEOZOIC AND MESOZOIC

Basement rocks

Since the basement rocks are not the subject of this study, only their lithologies, which are important to define the source areas, were shortly described. The main lithologies are quartzite, marble, metamorphic schist, limestone, radiolarite and ophiolite. According to Altınlı (1955) these rocks were formed during the Palaeozoic and Mesozoic time interval.

CAINOZOIC

The Cainozoic aged rock units, which form the subject of this study, overlie the Palaeozoic and Mesozoic basement rocks. The Cainozoic aged rock units are composed of the Akçay and the Muğla groups, and the Quaternary sediments (Fig. 3).

Akçay group

The Akçay group, mainly composed of continental and partly lagoon and marine elastics and car-

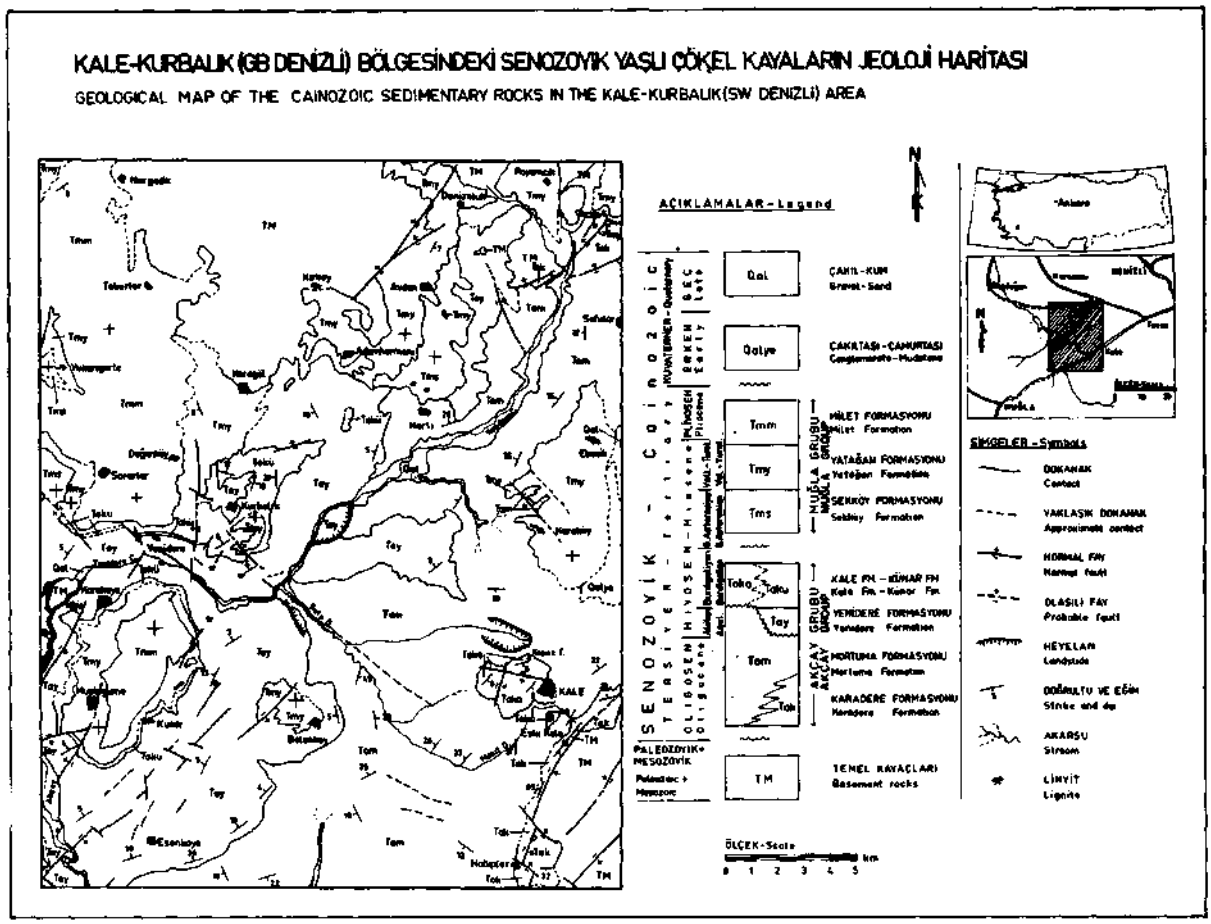

Fig.1— Geological map of the study area.

bonates deposited during the Otigocene to the Burdigalian time interval, consists of the Karadere, Mortuma, Yenidere, Künar and Kale formations. The Akçay group is 4100 m thick. It has a large outcrop in an area between Akçay, Karagöl village, Kırtaş hill and Habipler village, and it crops out in the region between Mugla and Denizli out of the studied area.

Karadere formation.— This formation was named as the Karadere member by Hakyemez and Örçen (1982) formerly. The type section of the formation is located along the Masit creek, 1 km east of the old Kale town. The Karadere formation is dark red and olive green in colour. The conglomerates in the formation were derived from mainly ophiolites and some marbles and limestones. The Karadere formation is formed of five different fades. The first fades is found in the lower part of the formation; the second one appears in the middle and upper parts; the third facies characterizes the middle part; and the last two facies belongs to the upper part:

1. Very poorly sorted conglomerate and mudstone: This facies is formed of matrix-supported, very poorly sorted, thick to very thick of massive bedded conglomerates and mudstones with similar properties. The bases of beds are erosive or straight and sharp, and the gravels are subangular to subrounded. This fades represents the debris flow deposits (Bull, 1972).

2. Cross— and parallel-bedded conglomerate and sandstone: These are grain-supported, poorly to moderately sorted, planar cross-to parallel-bedded conglomerates and trough cross-bedded pebbly sandstones. Gravels are subrounded to subangular, and the gravel im-

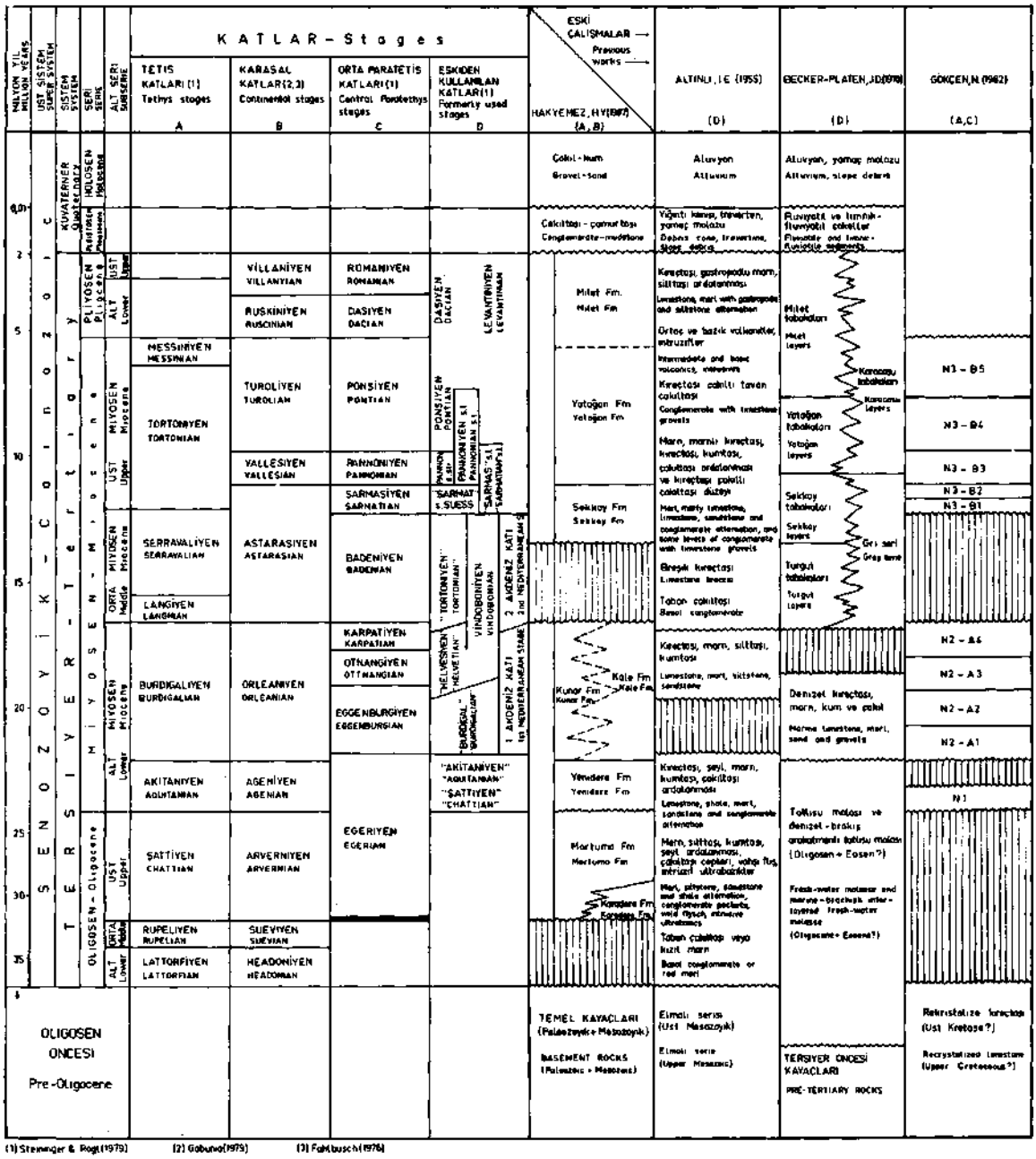

Fig.2– Stratigraphical correlation chart.

brication is common in the parallel beds. The conglomerates grade into sandstones laterally and they alternate vertically. This fades represents the braided channels and bars.

3. Parallel-bedded conglomerate: This facies is made up of grain-supported, moderately to well sorted, parallel and wide lenticular bedded conglomerates. The gravels are subangular to subrounded and the gravel imbrication is absent. This facies has been interpreted as sieve deposits (Hooke, 1967).

4. Parallel-laminated and cross-bedded sandstone : This facies is formed of coarse sandstones with cross-beds or upper flow regime parallel lamina. The cross-bed sets are solitary in general. In any case, the

thin bedded and moderately sorted mudstones overlie the sandstone beds. These are interpreted as sheet flood deposits (Rahn,1967; Bull, 1972).

5. Thin bedded mudstone: The moderately sorted and thin parallel-bedded mudstones form this fades. The facies contains scattered gypsium crystals. They are interpreted as overbank deposits.

The Karadere formation has a fining upwards sequence. This formation covers the basement rocks unconformably; but transitionally grades into the Mortuma formation with which it interfingers laterally. Its thickness is up to 425 m at maximum. There is no fossil in the formation except some destroyed plant fossil traces; so the ages of the formation was defined as Oligocene in relation to that of the Mortuma formation. The depositional environment is considered as a semi-arid and retrograding alluvial fan.

Mortuma formation,— This formation was designated by Hakyemez and Örçen(1982) formerly. The formation has its typical outcrop along the Mortuma creek bcated to the west of the study area. The type section of the formation is seen along the Masit creek. The lowermost part of the formation, which is some 180 m,is composed of mainly yellowish brown and grey coloured, parallel-and cross-bedded conglomerate and sandstone alternation. The properties of this part of the formation is similar to the 2nd facies of the Karadere formation. The rest of the formation, which is about 2200 m thick and yellowish brown, gray and green coloured, is formed of the cyclic units, beginning with conglomerates, continuing upwards with cross to parallel-bedded and laminated sandstones, ending up with thin lignite-bearing siltstones and claystones intercalated with sandstones. Five facies were differentiated in this cyclic alternation :

1. The first facies is formed of 1.5-6.0 m thick cycles. In the lowermost part, on an erosive base, there is a poorly sorted, extra- and ultra- formational lag congiomerate(Laury, 1971) containing a coarse sandstone matrix. This conglomerate is overlain by trough cross-bedded pebbly sandstones with some parallel-laminated levels. Finally, the cycle ends with the cross-laminated silty sandstones and parallel-laminated silty sandstones respectively. This facies represents the meandering-rfver point-bar deposits (Allen, 1964, 1965a, 1965b,1968,1970; Simons et al., 1965).

2. The second facies is formed of 2-4 m thick cross-bedded pebbly sandstones and pebblestones overlying cross-laminated sandstones. This facies grades into the first facies laterally and has been interpreted as intra-channel bars and sand-waves(Harms, 1975; Allen, 1968; Smith, 1970,1971).

3. This facies consists of strongly bioturbated, fine to very fine sandstone and siltstone alternation with plant fossils. The sandstones are characterized by thin layers, cross and parallel-lamination and climbing-ripples whereas the siltstones are very thin layered and parallel-laminated. This facies is interpreted as natural levee and crevasse-splay deposits (Coleman, 1969).

4. This facies is composed of parallel-laminated siltstones and claystones with some parallel-laminated very fine sandstone intercalations. It also contains thin lignite beds, caliche nodules, laminated caliches, thin-walled pelecypods and plant fossils. The bioturbation is strong. This facies was deposited in a flood plain (Allen, 1964,1965a).

5. Strongly bioturbatedsiltstones,claystones and silty very fine sandstones with abundant plant remains form this facies. The facies always overlies a trough cross-bedded sandstone sequence and it grades into first facies laterally. The depositional environment of this facies is assumed to be ox-bow lake(Allen, 19656; Bernard and Major, 1963).

This formation is characterized by a fining trend in terms of grain size vertically as well as laterally in a northeast direction. The Mortuma formation has faulted boundaries with the basement rocks; the lowermost part of the Mortuma formation interfingers with the Karadere formation but the rest of the formation overlies the latter gradationally upwards. In the study area, some thin walled pelecypods and some fragments of plant fossils together with pollens were found only in the lithologies of siltstones and claystones of the formation; but in the lagoonal part of the forma-

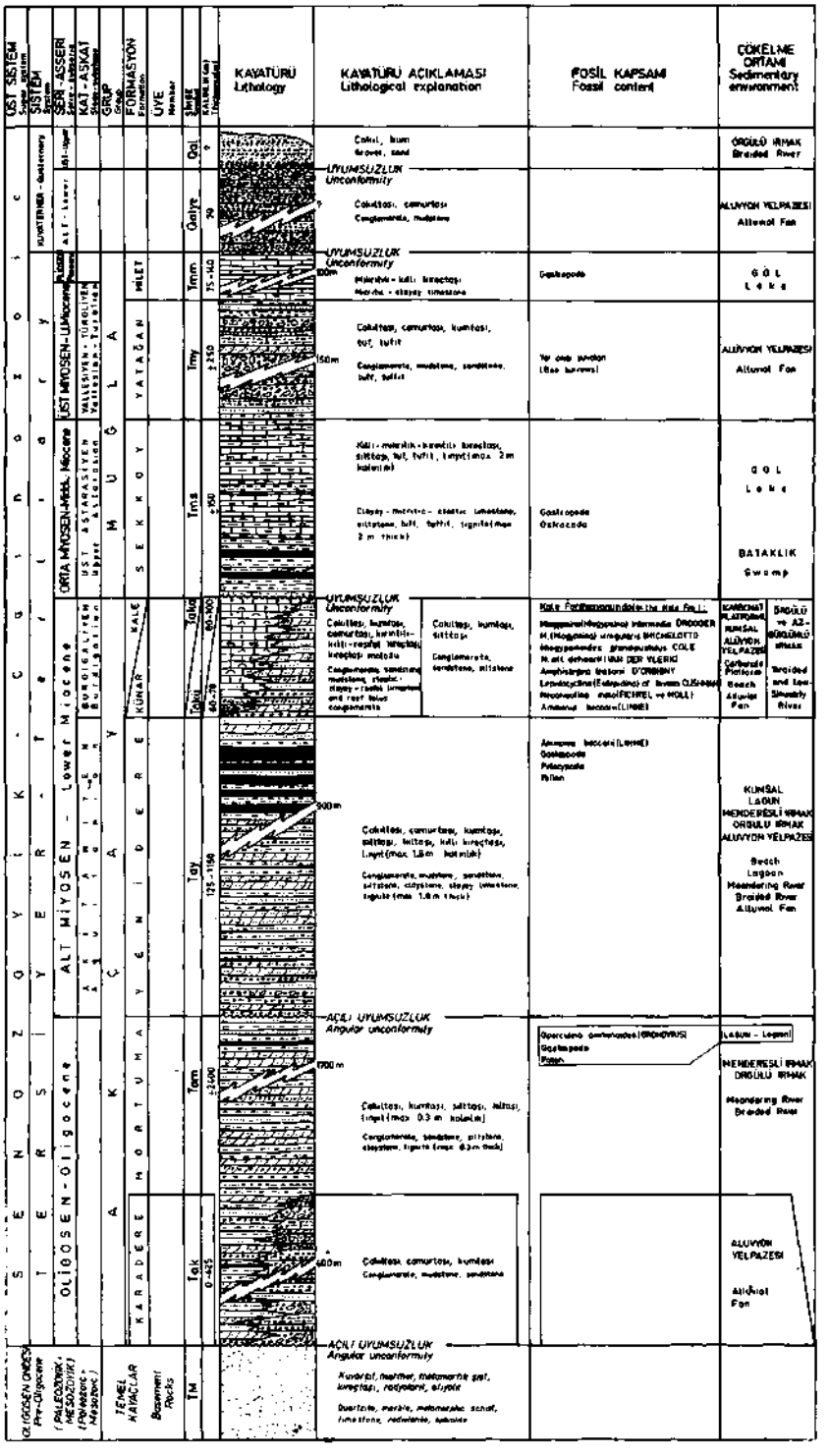

Fig.3– Generalized stratigraphical section of the study area.

tion out of the study area, which lies 4 km south of Çukurköy located to the east of Tavas town, the following fossils were found: Foraminifers such as *Operculina ammonoides* and Miliolidae, gastropods such as *Ampullina (Ampullinopsis)* cf. *bourcarti, Barbatia (Barbatia) albanica, Tympanotonus* sp., *Potamides* sp. together with some ostracods and fish teeth. According to this fossil content, the age of the formation is the Upper Oligocene. The lower 180 m part of the formation was deposited in a braided-river environment, whereas the main part was sedimented in a meandering-river.

Yenidere formation.— Hakyemez and Örçen (1982) differentiated and named this formation formerly. The typical outcrop of the Yenidere formation is found along the Yenidere creek between the Narlı and Yenidere villages. The type section of the formation is exposed along an intermittent stream running from the south of the Kuzlualan hill to the Yenidere creek. The Yenidere formation consists of five levels which have different characteristics:

1. The first level contains three facies. These are (a) very poorly sorted conglomerates and mudstones, (b) cross- and parallel-bedded conglomerates and (c) parallel-laminated and cross-bedded sandstones. The first facies is formed of very poorly sorted, matrix-supported and massive or thick to very thick parallel-bedded conglomerates with subangular gravels, and very poorly sorted and parallel-bedded mudstones with small boulders. These are debris flow deposits. The second facies is composed of poorly sorted, grain-supported, and planar cross-bedded and parallel-bedded conglomerates with subrounded to subangular and occasionally imbricated gravels. The bases of the beds are erosive. These are braided-stream deposits. The last facies consists of parallel-laminated and trough cross-bedded sandstones with some thin mudstone interlayers. These are sheet flood deposits.

2. The second level is similar to the 2nd facies of the first level. But the second level is dominantly formed of cross- and parallel-bedded conglomerate whereas the 1st facies forms the first level mainly. The sediments of the second level are braided-river deposits.

3. The third level contains,five facies: (a) The first facjes is made of 2.5-8.0 m thick cycles which show a rhytmic alternation. In the lowermost part of the cycles, poorly sorted lag deposits with coarse sandstone matrix overlie the underlying cycle with an erosive base. The lag deposits consist of intraclasts in the upper part of this third level whereas they are mainly composed of extraclasts in the lower part. Intraclasts are sandstone, siltstone and claystone gravels, silisified plant fragments and lignite clasts. The trough cross-bedded sandstones with some parallel-laminated medium to coarse sandstones overlie this unit. The uppermost part of the cycle is formed of trough cross-laminated, silty, fine to very fine sandstones, sandstones with climbing-ripple laminae, and parallel-laminated and bioturbated fine to very fine sandstones. This facies represents the meandering-river point bar deposits, (b) The second facies is composed of 1-4 m thick planar cross-bedded pebbly sandstones. It grades into 1st facies laterally. These are intra-channel sand-wave deposits, (c) This facies is rare in the sequence of the formation. It is formed of trough cross-bedded, parallel-laminated and fine to very fine grained silty sandstones with some climbing-ripples, and parallel-laminated siltstones. These are natural levee and crevasse-splay deposits, (d) The fourth facies is made up of thin, clayey limestone interlayered, parallel-laminated siltstones and claystones. It contains some lignite beds ranging from a few mm up to 1.8 m, caliche nodules, plant remains and some freshwater gastropod fossils. The bioturbation is common. The depositional environment is a flood plain, (e) This facies is characterized by strong bioturbation and is composed of silty, fine sandstones and siltstones. It is interpreted as ox-bow lake deposits.

4. This level composed of thin elastics containing lagoon fossils is formed of four facies: (a) The first facies is fine sandstone interlayered, bioturbated siltstones and claystones with gastropods, pelecypods, rare foraminifers *(Ammonia beccarii),* fish teeth and plant fossils. The fossils are lagoon forms and the sandstones are storm sand layers (Hayes, 1967). This facies characterizes the bottom of a lagoon, (b) The wave-rippled

sandstones made up of 30-80 cm thick layers with thin heavy mineral lamina form the second fades and overlie the first facies with an alternating gradation. This facies was deposited in the subaqueous part of a lagoon beach above the wave base, (c) This facies contains the units composed of flaser-bedded siltstone - wave and current ripple cross-bedded fine to medium sandstone alternation, and coarse sandstone-siltstone alternation. The coarse sandstones are characterized by primary current lineation. The facies was deposited in the subaqueous part of a lagoon beach during and after the storm waves flooding into the lagoon, (d) Fine to medium sandstones made up of parallel-beds or cross-beds dipping 10° at maximum form this facies. The facies contains macrofossil shells and shell fragments. The thickness of the set of cross-beds is 1 m at maximum. These are interpreted as the deposits of the upper shoreface of a lagoon (Elliott, 1978).

5. This level is composed of sandstones with marine macrofossils and contains two facies: (a) This facies is formed of planar cross-bedded fine to medium sandstones which contains some marine macrofossils and heavy mineral lamina. The dips of the cross-beds change from 2° up to 8°. These deposits characterize marine upper shoreface. (b) The second faeies is represented by trough cross-bedded and high-angled planar cross-bedded sandstones. The bedding was destroyed by roots in some places. The erosion surfaces between the beds contain iron oxide. These are assumed as sand dune deposits (McKee,1957).

The Yenidere formation overlies the Mortuma formation unconformably and the overlying Künar formation covers the formation conformably. The thickness of the unit is 1150 m at maximum . The Yenidere formation contains the following fossils above the 830th meter: *Ammonia beccarii* and gastropods such as *Melanopsis* cf. *bonelli bonelli, Terebralia* cf. *bidentata bidentata, T.* cf. *subcorrugata, Tympanotonus (Tympanotonus) margaritaceous* cf. var. *tabana, Turritella (Turritella)* cf. *gradata* and *Galeodes lainei* .together with some pelecypods like *Gryphea (Crassbstrea) gryphoides crassissima, Ostrea* cf. *fimbriata* and *Anadara (Anadara)* aff. *turonica* and pollens. According to the gastropods and pelecypods, the age of the formation is the Aquitanian. The described levels in the formation characterize different depositional environments these are from bottom to upwards alluvial fan, braided-river, meandering-river, lagoon and beach.

Künar formation.— This formation was named as the Karakaya member by Hakyemez and Örçen (1982) formerly. The Karakaya member was designated in a later work as the Künar formation by Hakyemez (1987). The type section of the formation is in Yenidere village. The Künar formation is yellowish grey coloured and is mainly formed of three facies:

1. Poorly sorted conglomerate: These deposits are matrix-supported, poorly sorted, parallel-bedded conglomerates. The bases of the beds are sharp or erosive. Gravels were derived from quartzite, marble and radiolarites. Boulders are common in this facies. These are interpreted as debris flow deposits.

2. Cross- and parallel-bedded conglomerate and sandstone: The trough and planar cross-bedded conglomerates and sandstones form this facies. The conglomerates are medium to well sorted and occasionally imbricated. Gravels are derived from quartzite, marble and radiolarites. The conglomerate and sandstone beds are gradational laterally, and they alternate vertically. Sandstones are dominant in the facies. These deposites characterize the braided and low-sinusoity river channels and bars (Collinson, 1978).

3. Cross -laminated sandstone and parallel-laminated siltstone: The trough cross-laminated fine sandstones form the lower part of this facies. The upper part of the facies consists of parallel-laminated siltstones. The facies is a few tens of cm in thickness. It was deposited in the abondoned braided-river channels and/or on the bars before the lower flow stages(Coleman, 1969).

The Künar formation overlies the Yenidere formation conformably and it has been stated that the Künar formation is the continental equivalent of the Kale formation. Although the Sekköy formation uncon-

formably rests on the Künar formation according to chronostratigraphical setting, it is the Yatağan formation that overlies the Künar formation unconformably in the study area as the first unit on the Sekköy formation. The thickness of the Künar formation changes from 50 to 70 meters. The formation contains no fossil. Its age is defined as Burdigalian correlating with the Kale formation. Although the first facies represents debris flows at small alluvial fans; this formation was formed in a fluvial environment, apparently characterized by an anostomosed (braided and low-sinusoity) river type.

Kale formation.— This formation was formerly named by Altınlı (1955) as the "Kale Marine Helvetian". Later, Hakyemez and Örçen (1982) designated the unit as the "Kale formation". The formation has typical outcrops in Kale town and its type section is along NW slope of the Kepez hill. The Kale formation is yellowish white in colour. In the lower part of the formation, sometimes there is a few meter thick conglomerate-sandstone alternation, but in general, the lower part is composed of a thin sandstone-conglomerate alternation overlying the 30-70 cm thick transgressive lag deposits. The rest of the formation is formed of limestones. Various facies are defined in these three levels:

1. The first level composed of conglomerate-sandstone alternation contains two facies: (a) Thin and parallel-bedded conglomerates in granule size, and trough cross-bedded pebbly sandstones in the form of solitary sets form the first facies. It contains medium and parallel-bedded and reddish brown coloured mudstones occasionally. This facies is interpreted as sheet flood deposits, (b) Matrix-supported, medium to poorly sorted, planar cross-bedded and parallel-bedded conglomerates, and trough cross-bedded and parallel-bedded sandstones form the second facies. The bases of beds are erosive and gravels are subrounded. Both lithologies are gradational laterally and alternate vertically. These are braided-stream deposits.

2. Two facies were defined in this level: (a) The first facies is transgressive lag deposits forming a 30-70 cm thick level in the lowermost part of the formation which is composed of macrofossiliferous sandstones including subangular to angular boulders and gravels. (b)The parallel-bedded and trough or low-angled planar cross-bedded , macro and microfbssiliferous fine to medium sandstones, and low-angled planar cross-bedded conglomerates form the second facies. These are beach deposits.

3. Five facies are defined in the limestone sequence: (a) The first facies is formed of thin to medium bedded clayey limestones with ahermatypic corals, abundant ostracods, bentbnic and rare planktonic foraminifers, gastropods and pelecypods. This facies is very limited and was probably deposited in a nearshore part of a carbonate platform close to a river mouth effected by cold currents(Stanley, 1979) where terrestrial silt and clay influx was introduced into the carbonate sedimentation, (b) The parallel- and cross-bedded bioclastic limestones with abundant Miliolidae, Neoalveolina and some Miogypsina form this facies. It also contains gastropods, pelecypods, hermatypic corals, red algae and echinid spicules. These limestones are packstones in general, but the cross-bedded limestones are grainstones. Cement is microsparite. This facies was deposited in a nearshore area partly protected from wave effect and is similar to the 8th facies of Wilson (1975)'s standart facies belts. The cross-bedded limestones imply that the longshore currents were also effective during deposition, (c) The third facies is thin to thick parallel-bedded clastic limestones with abundant Miogypsina, Operculina and Amphistegina. These limestones are packstones and wackestones, and contains red algae, bryozoa, hermatypic corals, gastropods, pelecypods and annelids. The cement is microsparite. This facies was deposited in a relatively deep open platform (7th facies belt of Wilson, 1975). (d) The fifth facies is characterized by thick to very thick parallel-bedded reef limestones mainly composed of hermatypic corals and algae. It also contains some bryozoa, binding foraminifers (Acervulinidae) and echinid spicules. According to Dunham (1962)'s classification, these are boundstones and characterize the patch reefs in a semirestricted platform . (e) This facies is characterized by limestones

which are completely formed of fragments of reefs bounded by a packstone matrix. It contains echinids, corals, algae, pelecypods and less foraminifers, and could be correlated with 4th facies belt of Wilson (1975).

In the study area, the Kale formation overlies the Mortuma formation with an angular unconformity. But in terms of its chronostratigraphical setting, it is considered to be overlying the Yenidere formation; and it has been accepted as the shallow marine equivalent of the Künar formation. According to chronostratigraphical setting, the Sekköy formation unconformably rests on the Kale formation, however there is not any other unit on the Kale formation in the field. The thickness of the Kale formation is about 100 m. The Kale formation contains abundant foraminifers, ostracods, corals, algae, gastropods and pelecypods. Most importantimes of these fossils follow as :

Foraminifers: *Neoalveoline melo, Miogypsina (Miogypsina) irregularis, M.(Miogypsina) intermedia, Miogypsinoides* aff. *dehaarti, M. grandipustulus, Amphistegina* cf. *lessonn, Lepidocyclina (Eulepidina)* cf. *favosa, Ammonia beccarii*.

Gastropods : *Terebralia bidentata bideritata, Galeodes lainei, Tympanotonus (Tympanotonus) margaritaceous, Ficus (Fulgoroficus) conditus.*

Pelecypods: *Ostrea (Ostrea) lamellosa boblayei, Ostrea edulis* var *adriatica*.

Corals: *Paleoplesiastraea desmoulinsi, Defrancia irregularis, Favia melitae, Aquitanastraeaguettardi, Tarbellastraea* cf. *eggerburgensis, Acropora* cf. *exarata, Porites* cf. *collegnian, Acanthocyathus versicostatus, A. verrucosus, A. transilvanicus, Balanophyttia varians, B. concinna*.

According to these fossils and especially occurrence of *M. (Miogypsina) intermedia* species, the age of the formation is defined as Burdigalian.

The unfossiliferous conglomerates and sandstones in the lower part of the succession were deposited on a lower alluvial fan whereas the fossiliferous sandstones and conglomerates were sedimented on a beach transgressively. The limestone facies are the product of a shallow carbonate platform.

Muğla group

The Muğla group, composed of lacustrine and continental sediments deposited during Late Astarasian-Pliocene, consists of the Sekköy, Yatağan and Milet formations. The Muğla group is 550 m thick. It crops out around Tekerler, Sararlar, Muslugüme, Belenköy, Adamharmanı, Avdan, Payamcık and Karaköy villages, and it covers extensive areas in the region between Muğla and Denizli.

Sekköy formation.— This formation was firstly named by Becker-Platen (1970) as "Sekköy layers" and later it was designated by Atalay (1980) as "Sekköy member". Finally, Hakyemez and Örçen (1982) redefined this unit as the "Sekköy formation". The typical outcrop of the formation is located on aslope in the north of Narlı village, the type section is exposed along an intermittent stream in the north of the same village. Three facies are defined in the Sekköy formation. From bottom to upwards these follow as :

1. Lignite-bearing siltstones: This facies forms the lowermost 50 m part of the formation. It is composed of gray coloured, thin to medium parallel-bedded and laminated siltstones containing 1 to 200 cm thick lignite interbeds. Plant remains and gastropod shells form abundance zones in some places, and the bioturbation is high.

2. Clastic limestone: These are white coloured, thin to medium parallel-bedded and occasionally cross-laminated limestones. This facies is 1-2 m thick and overlies the previous facies.

3. Clayey limestone-micritic limestone-calcareous siltstone alternation: This facies forms the uppermost and thickest part of the formation; and it is white coloured, thin to medium parallel-bedded and tuff and tuffit interlayered. It contains abundant organic material.

Although the Sekköy formation rests on the Kale and Künar formations according to chronostratigraph-

ical setting, it unconformably overlies the Yenidere formation which is the first underlying unit of these formations in the study area. On the other hand, it conformably overlies the Middle Astarasian aged meandering river deposits out of the study area, which was named as "Turgut formation" by Hakyemez and Örçen (1982). The Yatağan formation covers the Sekköy formation conformably; its thickness is 150 m at maximum. Some ostracods such as *Candona* cf. *neglecta* and Cytheridae, gastropods such as *Pseudoam nicola sp.,Valvata* sp. and Planorbidae,and pollens were found in the formation. Since these fossils are not characteristic to determine the age of this formation, the age determination has been based on the vertebrate fossil data of Atalay (1980) and radiometric measurements of Becker-Platen et al. (1977) (11.1 + 0.2 my and 13.2 + 0.35 my). The writer agrees with Atalay (1980) that the age of this formation is Upper Astarasian (Latest Middle Miocene). The first facies which forms the lower part of the formation was sedimented in a swamp; the second one characterizes a lacustrine beach; and the last facies was deposited in lacustrine environment. The source of the tuff and tuffit layers was probably located in the Bodrum region (Ercan et al., 1981).

Yatağan formation.— Becker-Platen (1970) designated the formation as Yatağan layers" formerly. Later, Atalay (1980) used the name of the "Yatağan formation" in his work. But Atalay's Yatağan formation also includes the Milet formation (in this paper) and he named the unit the "Bayır member", which is equivalent of the Yatağan formation in this study. Finally, Hakyemez and Örçen (1982) differentiated and designated the unit as the Yatağan formation. The Yatağan formation has its typical outcrop around Adamharmanı village; the type section is along an intermittent stream running to the south about 1.2 km east of the same village. The Yatağan formation is reddish brown in colour. Five facies are defined in the formation:

1. Very poorly sorted conglomerate and mudstone : The matrix-supported, very poorly sorted, massive or thick to very thick parallel-bedded conglomerates and mudstones with similar properties form this facies. The bases of beds are erosive or straight and sharp, and the gravels are angular to subrounded. These are interpreted as debris flow deposits.

2. Cross and parallel bedded conglomerate and sandstone: This facies is formed of grain-supported, poorly to medium sorted, planar cross-bedded and parallel-bedded sandstones. Gravels are subrounded and occasionally imbricated. The bases of beds are generally erosive. Both lithologies are gradational laterally and alternate vertically. This facies represents the braided-stream channels and bars.

3. Parallel-bedded, well sorted conglomerate: These are matrrix-supported,weli sorted and parallel-bedded conglomerates. Gravels are subangular and the gravel imbrication is absent. This facies represents sieve deposits.

4. Parallel laminated and cross-bedded sandstone: Thick parallel-laminated and trough cross-bedded coarse sandstones with some conglomerate sheets in granule size form this facies. In a single level, conglomerate sheets grade from parallel-laminated sandstones to cross-bedded sandstones respectively in the direction of downstream.

5. Thin bedded mudstone: This facies is formed of moderately sorted and thin bedded mudstones with dessication cracks, bee burrows, scattered gypsium crystals, caliche nodules and laminated caliches. It generally alternates with 4th facies, but sometimes is found as interbeds in the pebbly parts of second facies. This facies is interpreted as overbank deposits. In the vertical section, coarse and fine grained sequences alternates frequently. The formation also contains some tuff and tuffit interlayers. It is underlain by the Sekköy formation and overlain by the Milet formation respectively with a conformable and gradational contact. Its thickness is 250 m at maximum. In the moderately sorted and parallel-laminated mudstones, bee burrows and an Hipparion tooth were found. So the age definition has correlatively been based on the vertebrate fossil data of Atalay (1980) and radiometric age determination (9.25 + 0.2 my and 10.2 + 0.15 my) of Becker-Platen et al. (1977); and it is stated that the formation was deposited during the Vallecian to Turolian (Late Miocene) time interval. The depositional environment of the Yatağan formation resembles an arid to semi-arid

alluvial fan complex; the fans are considered to characterize gradational and retrogradational periods during the deposition time. The source of the tuff and tuffit layers was probably located in the Bodrum region and on Kos Island (Ercan et al., 1981).

Milet formation.— This formation was firstly named by Becker-Platen (1970) as "Milet layers". Later, Atalay (1980) renamed it as "Bozarmut member". Finally, Hakyemez and Örçen (1982) designated the same unit as the "Milet formation". The type section of the formation is around Yukarıgörle village. The Milet formation is mainly formed of white coloured micritic limestones and it contains some thin clayey limestone interlayers. At some locations, there is a lignite-bearing, 1 to 2 meters thick siltstone level in the lowermost part of the formation. The Milet formation overlies the Yatağan formation conformably and gradationally. The Early Quaternary sediments overlie the formation. Its thickness is 140 m at maximum. Since it was only some crystallized lacustrine gastropods that were found in the formation, the age of the formation is based on the vertebrate fossil data of Atalay (1980) and stratigraphical relationships. Therefore it is accepted that the formation was sedimented in the Turolian (Very Late Miocene) to the Pliocene time interval. The Milet formation characterizes a lacustrine environment.

QUATERNARY DEPOSITS

Early Quaternary deposits.— These deposits, located on the western part of the study area, are formed of reddish brown coloured and poorly sorted conglomerates and mudstones. The thickness of the Early Quaternary deposits is up to 700 meters. They were deposited in an alluvial fan environment.

Late Quaternary deposits.— These sediments are gravels and sands of the Akçay and the Yenidere creek mainly. They characterize a braided-river environment.

GEOLOGICAL EVOLUTION OF THE BASIN

The sedimentation of the units which are the subject of this study began in the Oligocene. Lüttig and Steffens(1976) has discussed that a SW-NE trending continental basin was formed in the SW Anatolia after the regression had started towards the end of Late Eocene. It was in this basin, that the Karadere and the Mortuma formations were deposited. The sediments of a NE running braided-river system of this basin which later evolved into a meandering-river gradationally passes into lagoonal deposits around Çukurköy and marine units (Dizer, 1962) to the NE of Denizli finally. Alluvial fan sediments deposited at the margins of the river basin are represented by the Karadere formation.

At the end of the Oligocene, a southeastward tilting probably resulting from an uplift of the region at the north or northwest led to formation of gently folding of the Oligocene sediments. The sedimentation during the Aquitanian started with the development of alluvial fans at the northern part of the study area. On this southward inclined continental area, a braided-river and a meandering-river has developed respectively. At the same time, the Tethyan sea started to transgress to the northwards. This event firstly caused to the formation of the lagoonal deposits and consequently to the deposition of the beach sediments over the lagoonal sediments. Shelf sediments crop out to the south of the study area (Poisson, 1977).

Because of the tectonic uplift of the continental area at the end of the Aquitanian, the continental coarse elastics of the Künar formation were deposited on the exposed former beach area from the beginning of the Burdigalian;whereas on the southern part of the study area, a new transgression started and so the marine carbonates of the Kale formation were deposited.

From the end of the Burdigalian up to the Late Astarasian, there was no deposition in the study area. However in the neighbouring districts, the first deposition after the Burdigalian was started by a meandering-river at the beginning of the Middle Astarasian (Hakyemez and Örçen, 1982). The non-depositional stage between the Burdigalian and the Middle Astarasian, which is the equivalent of the Langhian, is the stage of the movement of the Lician nappes (Poisson, 1977). During the Late Astarasian the coal stams formed in the swamps in the centre of the closed basins, and later, the basin changed into a lake environment. As a result of the increasing tectonic movements, the arid type alluvial fans developed along the margins into the Sekköy lake basin which had already dried

up at the end of the Late Astarasian, and the alluvial fan deposition continued during the Late Miocene. The alluvial fans of the Yatağan formation extensively developed all around the SW Anatolia (Becker-Platen, 1970, Hakyemez and Örçen, 1982). The tectonic activity ended at the end of the Late Miocene. .In wetter climatic conditions probably resulting from the Pliocene marine transgression on the south of the study area, the basin changed into a lake again and lacustrine carbonate sedimentation continued till the end of the Pliocene.

The existence of the Early Quaternary aged alluvial fan deposits in the study area shows that the tectonic movements became effective in the Quaternary. The young grabens which were formed by NE—SW trending extensions (Dumont et al., 1979) give further support to this idea.

CONCLUSIONS

In this study, the geology and the stratigraphy of the Cainozoic sedimentary rocks cropped out in four quadrangles were investigated, and the facies characteristics of the formations were defined with the aim of interpreting sedimentary environments.

The geological evolution of the region is also explained primarily based on the environmental development together with the geological and the stratigraphical data.

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