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PALAEO

Palaeogeographical evolution of the Thrace Neogene Basin and the Tethys–Paratethys relations at northwestern Turkey (Thrace)

M. Sakınç [a,b,*], C. Yaltırak [a], F.Y. Oktay [a]

[a] *Department of Geology, Faculty of Mines, Istanbul Technical University, Ayazağa/Istanbul 80626, Turkey*
[b] *Eurasian Institute of Earth Sciences, Istanbul Technical University, Ayazağa/Istanbul 80626, Turkey*

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Abstract

The Thrace Neogene Basin situated in northwestern Turkey was initiated by strike-slip faulting that was active from the Early Miocene until the end of the Pliocene. During the Early Miocene, it began to form under the control of the Thrace–Eskisehir Fault Zone, initiated by continental collision in northwestern Anatolia (Late Oligocene–Early Miocene). During the late Early Miocene, the basin was a site of mainly fluviatile and limnic sedimentation to the west and marine sedimentation via the Paratethyan transgression in the north. With the onset of the Middle Miocene, the Thrace Block started to rotate in a counterclockwise sense and escaped westward with respect to the Strandja–Istanbul block owing to rejuvenation of fossil fault systems within it. In this period, warm marine conditions were also established around the Gulf of Saros through a Mediterranean originated transgression. During the Middle–Late Miocene fluviatile and limnic conditions were created over the western Thrace by the westerly propagation of the Thrace–Eskişehir Fault Zone. One of the principal results of the Early–Middle Miocene tectonics is the tilting of the Strandja–Istanbul Block to the south, severing the Tethys and the Paratethys. During the latest Miocene–Early Pliocene period, the Thrace–Eskisehir Fault Zone was deactivated because of the evolution of the North Anatolian Fault Zone to the south. The resurrected Ganos Fault Zone situated on the dissected fossil suture zone in the Sea of Marmara also joined the North Anatolian Fault Zone, uplifting the Gelibolu Peninsula and, thus, severing the connection that existed between the Sea of Marmara and the Paratethys. The Sea of Marmara eventually became an endemic basin by the activity of the North Anatolian Fault Zone.

Keywords: Thrace Neogene Basin; Paratethys–Tethys connection; North Aegean Sea; North Anatolian Fault Zone; Thrace–Eskisehir Fault Zone

1. Introduction

The Thrace Neogene Basin is situated north of the Aegean graben system and the present basin of the Sea of Marmara (Figs. 1 and 2). This basin is principally formed by the activities of the Thrace (TFZ) and the Ganos fault zones (GFZ) (Perinçek, 1991; Yaltırak, 1996; Tapırdamaz and Yaltırak, 1997). The relations between these fault zones can be classified for establishing the Neogene palaeogeography of the region in the light of the tectonic evolution of the area. The models put forward to account for the origin of the Sea of Marmara (Barka and Kadinsky-Cade, 1988; Wong et al., 1995; Erğun and Özel,

* Corresponding author. E-mail: sakinc@itu.edu.tr

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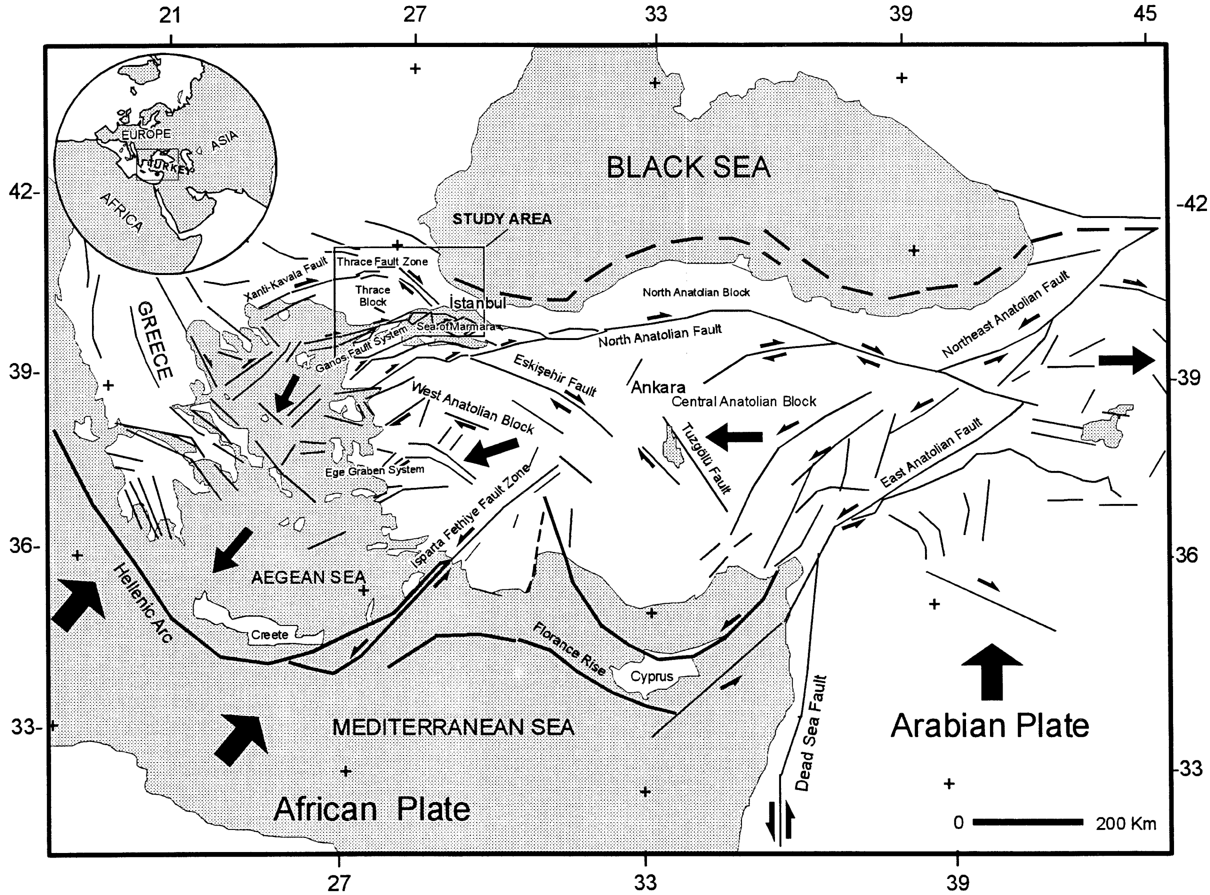


Fig. 1. Tectonic map of the eastern Mediterranean region and its surrounding study area, compiled from Jackson and McKenzie (1984), Okay (1984), Şengör et al. (1985), Perinçek et al. (1987), Şaroğlu et al. (1987), Barka and Kadinsky-Cade (1988), Taymaz (1990), Perinçek (1991), Barka (1992), Wong et al. (1995), Yaltırak (1996), Schindler (1997), Tapırdamaz and Yaltırak (1997) and Yaltırak et al. (1998).

1995) could also be more easily tested by establishing the palaeogeographical evolution of the region. This study is a first attempt to illuminate the tectonic evolution of the Thrace basin by reconstructing its palaeogeography during the Neogene.

Only a limited number of studies exist on the stratigraphy and tectono-sedimentary history of the Neogene sequences of this region, despite the fact that the region has been investigated by many earth scientists since the 19th century (Tchihatcheff, 1863–1867; Calvert and Neumayr, 1880; Andrussov, 1890; English, 1904; Newton, 1904; Hoernes, 1909; Penck, 1917; Arabu, 1917; Gutzwiller, 1923; Chaput, 1931, 1936; Parejas, 1939, 1941). Most of these earlier studies have been focused on the mammal, and the ostracod faunal associations of the Istanbul and Çanakkale Neogene sequences. The Küçükçekmece vertebrate fauna of Istanbul and Bayraktepe fauna of Çanakkale are well known (Sayar and Pamir, 1933; Arıç, 1955; Ozansoy, 1973). This faunal zone has been studied in detail in order to clarify the palaeogeographic relation between the Tethys (Mediterranean) and the Paratethys (Black Sea). A number of authors have mentioned that there was a connection between these two seas over Istanbul (Penck, 1917; Lüttig and Steffens, 1976; Steininger et al., 1985; Sayar, 1987). The Paleogene period of the Thrace basin has been investigated more thoroughly because of hydrocarbon investigations (Doust and Arıkan, 1974; Keskin, 1974; Turgut

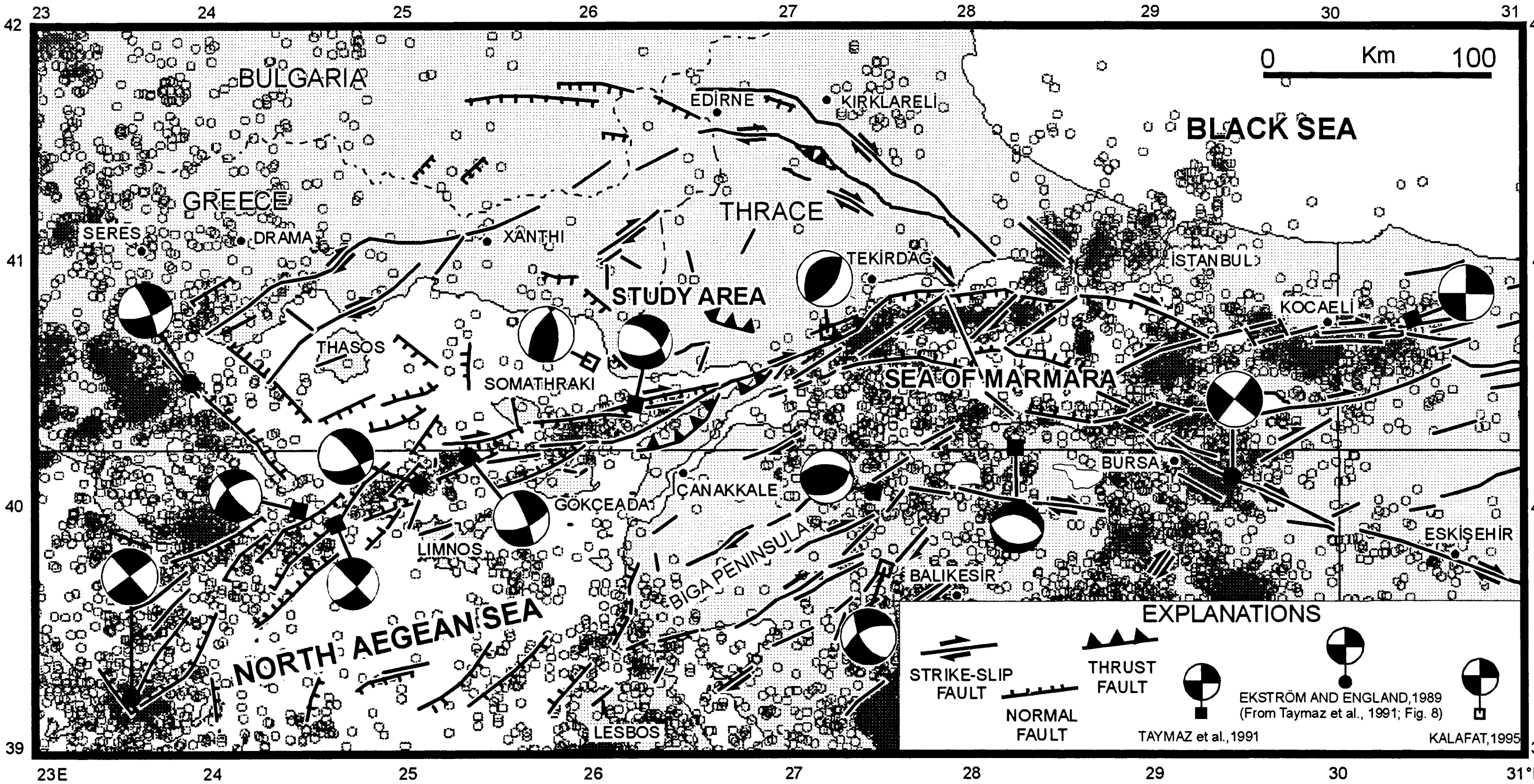
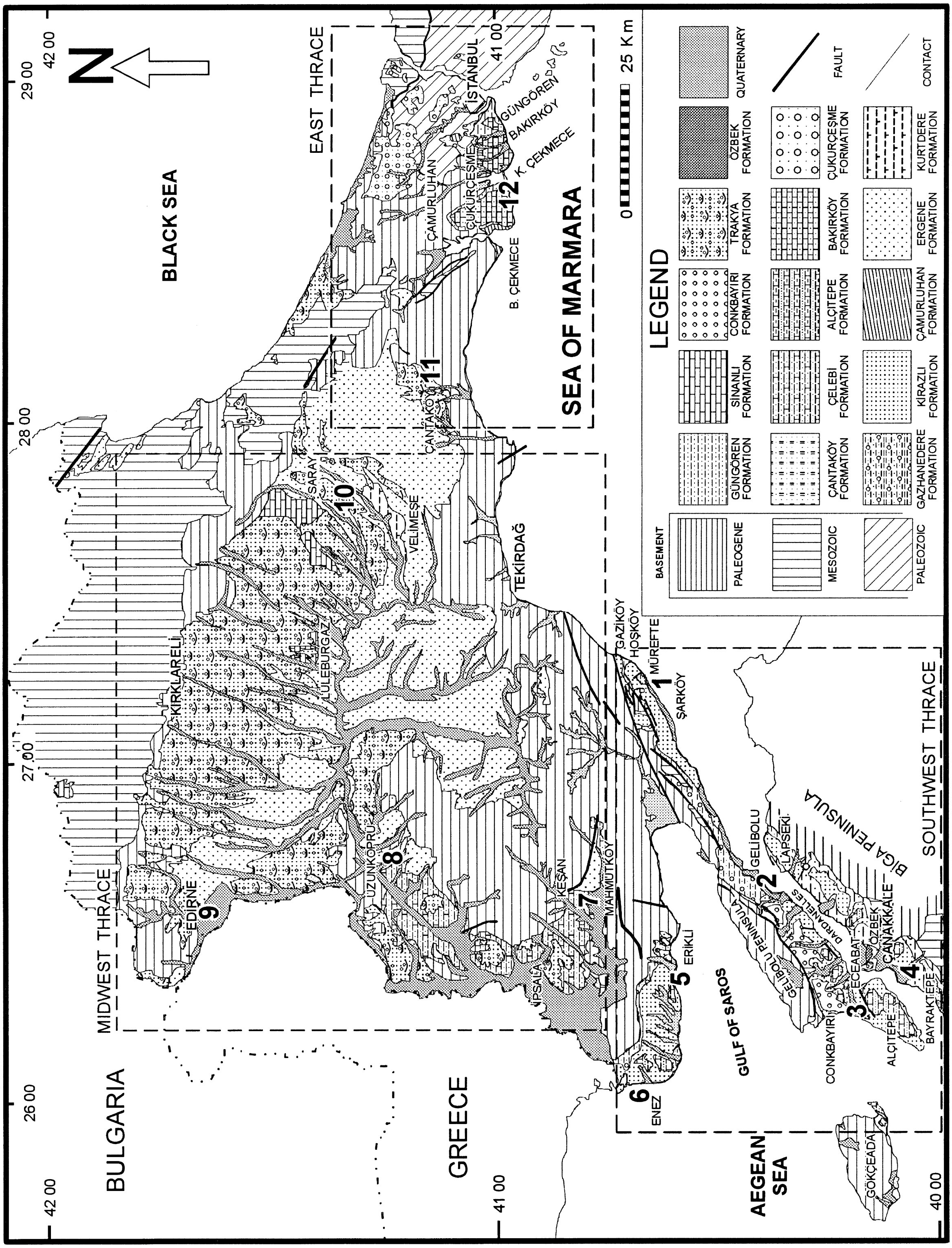


Fig. 2. Seismotectonic map of study area and its surroundings: ISC seismicity map Cornell Univ. GIS Map and information on services http://atlas.gen.cornell.edu. Tectonic lines compiled from Bornovas and Rondogianni-Tsiambau (1983), Barka and Kadinsky-Cade (1988), Gheshitev et al. (1989), Simeakis et al. (1989), Siyako et al. (1989), Perinçek (1991), Wong et al. (1995), Eryilmaz (1996), Yaltırak (1996), Schindler (1997), Tapırdamaz and Yaltırak (1997) and Yaltırak et al. (1998). Fault plane solutions from Taymaz et al. (1991) and Kalafat (1995).


BLACK SEA
SEA OF MARMARA
BULGARIA
GREECE
AEGEAN SEA
GULF OF SAROS
EAST THRACE
MIDWEST THRACE
SOUTHWEST THRACE
BIGA PENINSULA
GELİBOLU PENINSULA
DARDANELLES
0 25 Km
LEGEND
BASEMENT
PALEOGENE
MESOZOIC
PALEOZOIC
GÜNGÖREN FORMATION
SİNANLI FORMATION
CONKBAYIRI FORMATION
TRAKYA FORMATION
ÖZBEK FORMATION
QUATERNARY
ÇANTAKÖY FORMATION
ÇELEBİ FORMATION
ALÇITEPE FORMATION
BAKIRKÖY FORMATION
ÇUKURÇEŞME FORMATION
FAULT
GAZHANEDERE FORMATION
KIRAZLI FORMATION
ÇAMURLUHAN FORMATION
ERGENE FORMATION
KURTDERE FORMATION
CONTACT
İSTANBUL
GÜNGÖREN
BAKIRKÖY
K. ÇEKMECE
B. ÇEKMECE
ÇAMURLUHAN
ÇUKURÇEŞME
ÇANTAKÖY
SARAY
VELİMEŞE
TEKİRDAĞ
KIRKLARELİ
LÜLEBURGAZ
EDİRNE
UZUNKÖPRÜ
KEŞAN
MAHMUTKÖY
İPSALA
ENEZ
ERİKLİ
GAZİKÖY
HOŞKÖY
MÜREFTE
ŞARKÖY
GELİBOLU
LAPSEKİ
ECEABAT
ÇANAKKALE
ÖZBEK
CONKBAYIRI
ALÇITEPE
BAYRAKTEPE
GÖKÇEADA

et al., 1991). Apart from these, studies concerning the seaway connections in the Miocene (Lüttig and Steffens, 1976; Rögl and Steininger, 1983, 1984; Steininger et al., 1985; Sayar, 1987) and those on the passage of mammals from Anatolia to Europe (Görür et al., 1995) constitute the most significant literature about the basin.

2. Stratigraphy

The basement of the basin is formed from Paleozoic sequences to the east, various metamorphics and magmatics to the north and northwest, the Upper Cretaceous–Paleogene ophiolitic melange and the volcano-sedimentary series, the Eocene neritic to littoral carbonates and the Eocene deep marine sequences to the further west. Some Oligo-Miocene continental and brackish-marine sequences are also present in the centre, the north and the northwest of the basin. The Neogene sediments are ubiquitously covering this basement across an angular unconformity in the marginal areas of the basin. The relationship is unconformable in the central parts of the basin (Keskin, 1974; Alişan and Gerhard, 1987; Kasar, 1987; Ediger and Batı, 1988; Turgut et al., 1991).

The Neogene sequences display many different facies associations because of their environments of deposition. These sequences have been lithostratigraphically divided as follows:

2.1. Gazhanedere Formation

This formation has been designated by Saltık (1974) at Gazhanedere (northeastern Mürefte; Fig. 3, Loc. 1). In the type area, the formation is made up of coarse clastics of meandering river origin containing some coal seams and clayey deposits indicating the establishment of temporary swampy limnic conditions (Fig. 4, Locs. 1–5). Around Sarköy (Fig. 3, Loc. 1), it starts with fluviatile cycles of coarse clastics and reddish mudstones. It later develops as green-red coloured clays containing some silty intercalations. To the west, this sequence laterally passes into lacustrine strata composed of clays containing some marl and micritic lenses. Around Gaziköy–Sarköy, the thickness of the formation varies from 150 to 240 m. The thickness of the formation increases towards Gelibolu (Figs. 3 and 4, Locs. 2 and 3) where it is solely formed by reddish coloured and fresh-water bivalve (*Unio* sp.) bearing mudstones passing into brownish-green coloured sandstones–siltstones with some marl intercalations. It is about 300–330 m thick at this locality. Between Çanakkale and Lapseki (Figs. 4 and 5, Loc. 4), the formation is formed by braided river conglomerates vertically passing into reddish-greenish mudstones containing fresh-water ostracodes and bivalves. North of the Ganos Fault (Figs. 3 and 4, Locs. 5 and 6), it starts with reddish mudstones laterally passing into marls and limestones. They are replaced by buff-coloured sands vertically. Some bentonite lenses are also noted in the upper part of the section.

The age of formation is late Orleanian around Şarköy–Mürefte (Table 1, Loc. 1; micro mammals fauna; Ünay and De Bruijn, 1984), Astaracian around Gelibolu (Table 1, Loc. 2; Table 2, Loc. 4; Şentürk et al., 1987) and is pre-early Pannonian around Çanakkale (Table 1, Loc. 2).

2.2. Kurtdere Formation

This formation has been designated by Umut et al. (1983) north of Velimeşe (Figs. 3 and 4, Loc. 10). In the type area the formation starts with grey-green coloured massive sands, clays and siltstones. Towards the top, they pass into clayey sands containing fine pebble lenses. The bedding is not well pronounced and the sedimentation units can only be differentiated by colour. The type section is about 50 m thick. Keskin (1971, 1974) states that the formation unconformably overlies the Danismend Formation of the basement. Vertically, it is conformable

Fig. 3. Geological map of northwestern Turkey (Thrace Peninsula and west of Biga Peninsula), compiled from Parejas (1939), Ternek (1949), Akartuna (1953), Arıç (1955) Kopp et al. (1969), Lebküchner (1974), Umut et al. (1983, 1984), Önal (1984), Sümengen et al. (1987), Şentürk et al. (1987), Yaltırak (1996), Sakınç and Yaltırak (1997), Tapırdamaz and Yaltırak (1997) and Yaltırak et al. (1998).

with the Middle–Upper Miocene Ergene Formation (Umut et al., 1983). For this reason, the age of the formation should be Middle Miocene (Table 3, Loc. 10; Umut et al., 1983).

2.3. Çantaköy Formation

Around Çantaköy (Fig. 3) the sedimentary sequence starting with *Unio*-bearing clayey sands and continuing with white tuffites, has been designated as Çantaköy Formation (Figs. 3 and 4, Loc. 11; Umut et al., 1983). Some lensoidal conglomerate intercalations of volcanic origin are also noted in the formation. The thickness of this sequence is about 120 m in the north. The uppermost part of the formation is made up of evenly laminated clays of limnic origin. The formation lies unconformable on the basement.

Some bivalve and mammal fossils collected from the lower part of the formation indicate Middle Miocene age (Table 3, Loc. 11; Umut et al., 1983).

2.4. Çamurluhan Formation

Around Çamurluhan (Fig. 3, Loc. 12) a sequence of sands containing yellowish coloured marl intercalations has been designated as 'Çamurluhan Formation' (Sayar, 1987) Laminated grey-green coloured clay intercalations are noted towards the top. The type section is about 80 m thick. The formation lies unconformable on the Paleozoic basement. Marine mollusc fossils are sparse within the cross-bedded sand layers. The fauna present in the grey coloured clays is comparable with that of Baden beds of the Vienna Basin (Chaput, 1936).

A similar sequence is observed to lie unconformable on the Oligocene deposits west of Büyükçekmece (Fig. 3). Here, it is composed of a sand-clay alternation with some conglomeratic sandstone intercalations (Fig. 4, Loc. 12). At this locality, the thickness of the formation is about 50 m. To the top, the marls become the dominant lithology. Fish, foraminifera and bivalve fossils indicate a Badenian age for the formation (Table 3, Loc. 12; Rückert-Ülkümen et al., 1993). The two sequence contain the Middle Paratethian faunal assemblages and are unconformably overlain by the Late Miocene aged clastics (Çukurçeşme Formation).

2.5. Kirazli Formation

The sequence of yellowish-buff coloured sands with trough cross-bedding seen on the limnic deposits of Gazhanedere Formation has been designated as Kirazlı Formation by Saltık (1974) (Figs. 3 and 4, Loc. 1). Around Mürefte, the two formations are laterally and vertically transitional. Later, planar cross-bedding becomes the dominating sedimentary structure in the sands. To the top, gypsum lenses are noted. This uppermost part of the sequence is laterally replaced by red sandstones to the northeast. The formation is about 230–300 m thick. The marine fauna found in the uppermost part of the unit indicates a Sarmatian age (Table 1, Loc. 1; İzdar, 1959).

Around Gelibolu, the formation starts with massive sandstones with siltstone intercalations (Figs. 3 and 4, Loc. 2). To the top, high-angle planar cross-bedded sandstones follow the massive sandstones. Some thin conglomeratic intercalations and medium bedded sandstones are also noted. The uppermost part of the unit is formed by siltstone–sandstone alternation. The rodent fauna collected from the basal part of the formation indicates a Vallesian age for the formation (Table 1, Loc. 2; Ünay and De Bruijn, 1984).

Between Gelibolu and Eceabat, the formation starts with trough cross-bedded sands on the variegated deposits of Gazhanedere Formation by vertical passage (Figs. 3 and 4, Loc. 3). It is 400 m thick in this locality. There are also some variegated mudstone intercalations in the basal sands (Fig. 3). Here, fine sandstones follow the basal sands, they are, in turn, followed by medium bedded and carbonate cemented sandstones. Later in the sequence, high angle cross-bedded sandstones are exposed. Clay–silt–sand alternation is seen above these sandstones. Towards the top, *Mactra*-bearing conglomerate intercalations are also present in the sequence. The unit ends with *Mactra*-bearing sandstones. The mammal fossils collected from the formation indicate a Vallesian age for the formation (Table 1, Loc. 3; Kaya, 1989).

Around Çanakkale and south of Lapseki (Fig. 4, Loc. 4), the formation lies conformable on the Gazhanedere Formation. Here the sequence starts with cross-stratified fine sands containing at the base

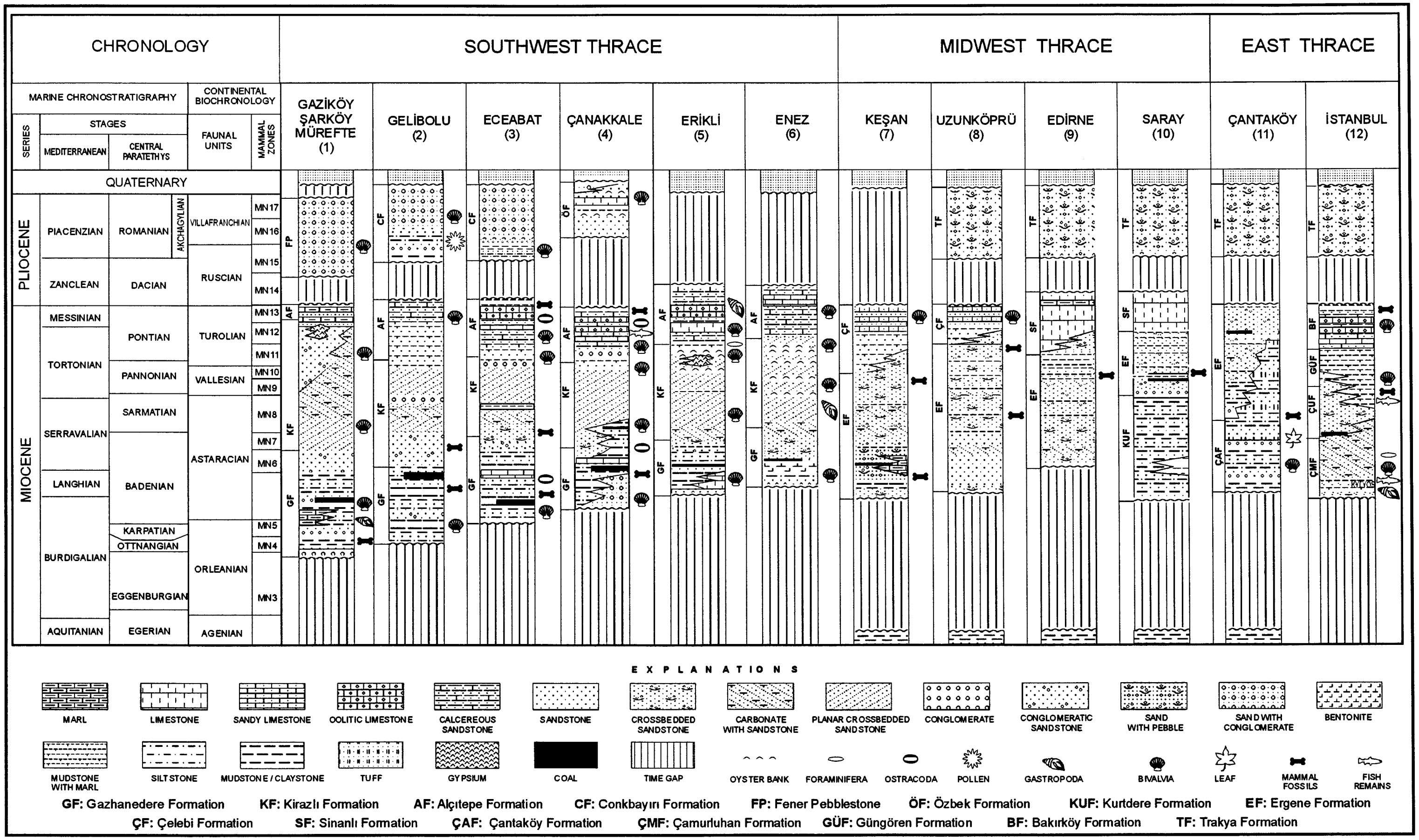
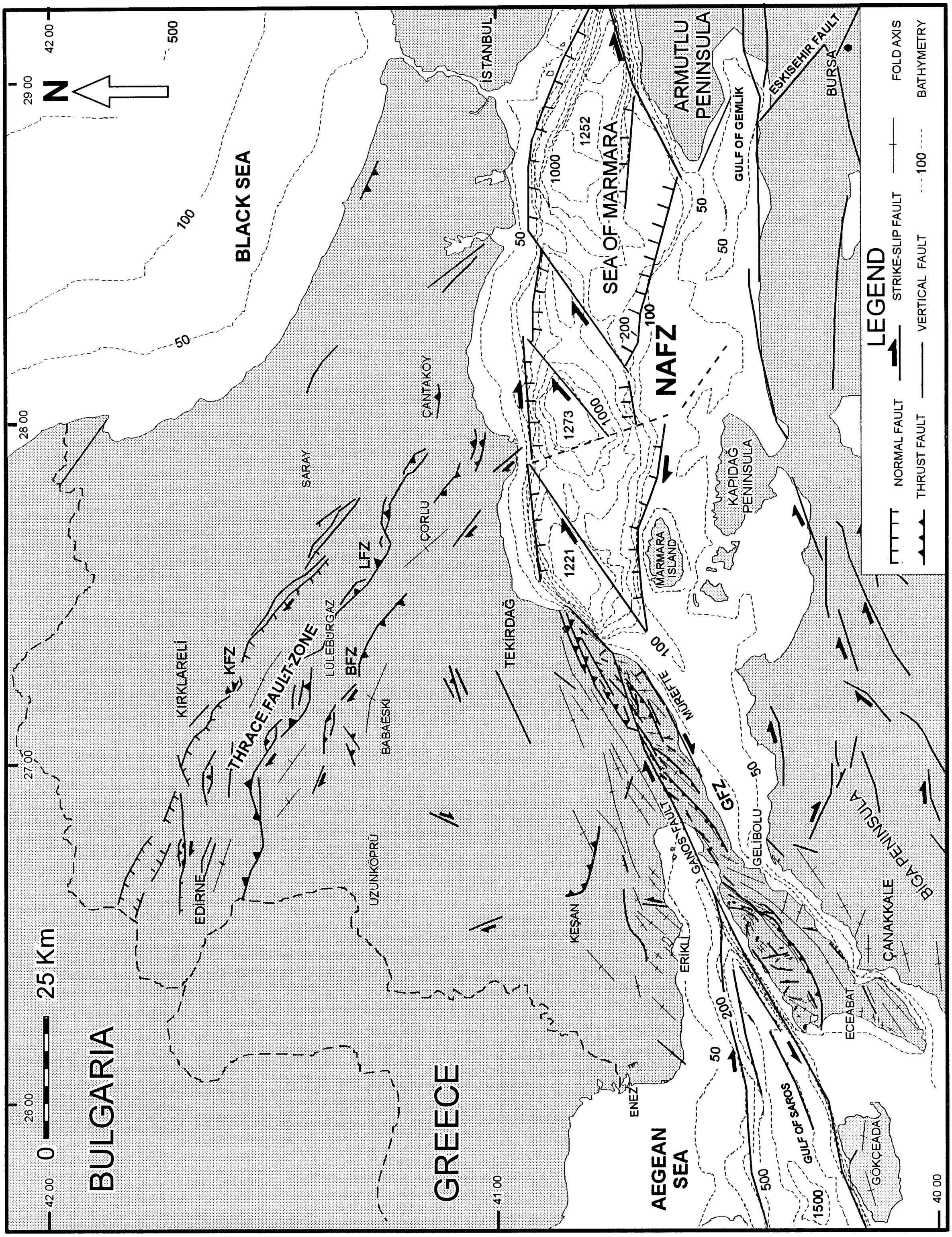


Fig. 4. Correlation chart showing simplified Neogene stratigraphic column sections for selected sites in northwestern Turkey (Thrace Peninsula and west of Biga Peninsula).


BULGARIA
GREECE
BLACK SEA
AEGEAN SEA
SEA OF MARMARA
NAFZ
THRACE FAULT ZONE
KFZ
BFZ
LFZ
GFZ
İSTANBUL
ARMUTLU PENINSULA
GULF OF GEMLİK
ESKISEHIR FAULT
BURSA
KAPIDAĞ PENINSULA
MARMARA ISLAND
TEKİRDAĞ
ÇORLU
SARAY
ÇANTAKÖY
LÜLEBURGAZ
KIRKLARELİ
BABAESKİ
EDİRNE
UZUNKÖPRÜ
KEŞAN
ERİKLİ
ENEZ
GANOS FAULT
MÜREFTE
GELİBOLU
ÇANAKKALE
BİGA PENINSULA
ECEABAT
GÖKÇEADA
GULF OF SAROS
0 25 Km
N
LEGEND
NORMAL FAULT
THRUST FAULT
STRIKE-SLIP FAULT
VERTICAL FAULT
FOLD AXIS
BATHYMETRY

some *Unio*-bearing green mudstone and sandstone lenses. To the top, the lithology turns into *Mactra*-bearing sandstones alternating with fine sands. In this locality, the sequence is about 180 m thick.

The formation exhibits a similar development north of the Gulf of Saros (Figs. 3 and 4, Loc. 5). Here, it starts with cross-bedded sandstones. The upper part of the formation is made up of reddish coloured fine sandstones containing abundant bivalve shells (Table 2, Loc. 5; Örçen, 1975). Some gypsum lenses are also observed in these sandstones.

The formation is represented by dune sands around Enez (Figs. 3 and 4, Loc. 6); it later develops into bivalve-bearing sands. Here, the formation is 80–120 m thick. *Ostrea cuculata*, *O. gingensis* and *Cardium edule* constitute an acme zone in the sands of he middle part of the section (Table 2, Loc. 5).

Mammal fossils indicate an Astaracian–early Vallesian age for the lower part of the formation (Table 1, Locs. 2 and 3; Table 2, Loc. 4; Ünay and De Bruijn, 1984; Şentürk et al., 1987; Kaya, 1989). The marine fauna of the Sarmatian–Serravalian is found in the upper part of the formation (Table 1, Loc. 1; İzdar, 1959; Table 2, Loc. 5; Ternek, 1949).

2.6. Ergene Formation

Various clastics of continental origin unconformably lying on the basement along the Ergene River have been designated by Holmes (1961) as the Ergene Formation. It starts with an alternation of conglomerates, marls and siltstones around Kesan (Figs. 2 and 3, Loc. 7; Umut et al., 1984). Towards the top, they are followed by clayey limestone, fine sandstone, siltstone and marl alternation. The section is about 70 m thick and the rodent fauna derived from the sequence indicates an Astaracian age for the formation (Table 3, Loc. 7; Ünay and De Bruijn, 1984).

The formation is 140 m thick around Mahmutköy (Figs. 2 and 3, Loc. 7). There, it starts with carbonate-cemented sandstones and continues with weakly cemented and cross-bedded sandstones containing lensoidal channel-fill conglomerates. Containing, though rarely, some clay and silt intercalations. Micro mammal fauna found in the sequence indicates Vallesian age for the formation around Mahmutköy (Table 3, Loc. 7; Ünay and De Bruijn, 1984).

The Ergene Formation lies unconformable over the Oligocene sediments (Figs. 2 and 3, Loc. 8) around Uzunköprü. Here, It starts with buff-coloured coarse sandstones. They gradually pass into grey-green coloured clays. In this locality, the thickness of the unit varies from 40 to 120 m. The mammal fauna indicates a Late Miocene age for the formation around Uzunköprü (Table 3, Loc. 8; Umut et al., 1984).

The formation is similarly observed on the Eocene and Oligocene sediments north of Edirne. Here, it is more than 180 m thick being composed of cross-bedded conglomerates containing some brownish-reddish coloured silty and clayey layers to the top. The mammal fauna collected from the unit indicates a Late Miocene age (Table 3, Loc. 9; Umut et al., 1984).

The formation passes laterally and vertically into Çantaköy Formation around Çantaköy (Figs. 2 and 3, Loc. 11). In this locality, the thickness of the sequence is more than 70 m. It primarily consists of gravely sandstones. Some thin coal seams are also observed. The mammal fauna present within the sequence indicates a Late Miocene age (Table 3, Loc. 11; Umut et al., 1984).

2.7. Çukurçeşme Formation

A sequence of weakly cemented conglomerates, pebbly sandstones and sandstones has been designated as Çukurçeşme Formation by Sayar (1976). In the type area (Çukurçeşme; Fig. 2, Loc. 12), it starts with braided-river conglomerates made up of meta-sandstone, gneiss, ophiolite, different volcanic and quartz pebbles. The large-scale planar

Fig. 5. Structural map of northwestern Turkey (Thrace, west of Biga, Sea of Marmara and Gulf of Saros). *NAFZ* = North Anatolian Fault Zone; *KFZ* = Kırklareli Fault Zone; *LFZ* = Lüleburgaz Fault Zone; *BFZ* = Babaeski Fault Zone; *GFZ* = Ganos Fault Zone. Compiled from Şaroğlu et al. (1987), Barka and Kadinsky-Cade (1988), Perinçek (1991), Barka (1992), Wong et al. (1995), Yaltırak (1996), Schindler (1997) and Tapırdamaz and Yaltırak (1997).

Table 1
List of fossils and localities

TABLE-1	NEOGENE												AGE
	MIOCENE										PLIOCENE		
	EARLY		MIDDLE				LATE				EARLY	LATE	
	BURDIGALIAN		LANGHIAN	SERRAVALIAN			TORTONIAN			MESSINIAN	ZANCLEAN	PIACENZIAN	MEDITERRANEAN TETHYS
	OTTNANGIAN KARPATIAN		BADENIAN		SARMATIAN		PANNONIAN		PONTIAN		DACIAN	ROMANIAN	CENTRAL PARATETHYS
	MN3	MN4	MN5	MN6	MN7	MN8	MN9	MN10	MN11-MN12	MN13	MN14-MN15	MN16-MN17	EUROPEAN LAND MAMMAL ZONES (MEIN,1989)
FOSSILS	ORLEANIAN		ASTARACIAN				VALLESIAN		TUROLIAN		RUSCIAN	VILLAFRANCHIAN	EUROPEAN MAMMAL AGE
Turkomys sp.	X	X	X										LOC. 1 Ünay and de Bruijn, 1984
Democricetodon sp.	X	X	X										
Protoalactoga sp.	X	X	X										
Megacritedon sp.	X	X	X	X	X	X	X						
Spermophilinus sp.	X	X	X	X	X	X	X	X					
Schizogalerix sp.				X	X	X	X	X					
Dakkamys sp.				X	X	X	X	X					
Byzantinia sp.				X	X	X	X	X					
Atlantoxerus sp.				X	X	X	X	X					
Unio sp.			X	X	X	X	X	X					Gutzwiller,1923 Izdar, 1959 Kopp et al,1969 Yaltırak,1996
Bhytinia gracalis			X	X	X	X	X	X					
Melanopsis trojanas			X	X	X	X	X	X					
Cardium sp.					X	X	X	X	X				
Planorbis coronu					X	X	X	X	X				
Ostrea crassima					X	X	X	X	X				
Ostrea gingensis					X	X	X	X	X				
Turitella cf. *terebra*					X	X	X	X	X				
Pecten benedictus					X	X	X	X	X				
Mactra podolica							X	X	X	X			
Dreisensia polymorpha											X	X	
Dresiensia tshaudae											X	X	
Neritina fluviatis											X	X	
											X	X	
Diplomyslus marmarensis							X	X	X	X			Gutzwiller,1923
Megacritedon sp.					X	X	X	X					LOC. 2 Unay and de Bruijn, 1984
Byzantinia sp.					X	X	X	X					
Schizogalerix sp.							X	X	X				
Myomimus multicritatus							X	X	X				
Chalicomys cf. *jaegeri*							X	X	X				
Byzantinia cf. *pikermiensis*									X	X	X		
Hystrix cf. *pikermigenia*									X	X	X		
Hipparion sp.									X	X	X		
Chilotherium habereri									X	X	X		
Unio sp.			X	X	X	X	X						This study
Mactra supcaspia							X	X	X	X			
Mactra podolica								X	X	X			
Mactra karabugasica								X	X	X			
Monoporpollenites graminoides											X	X	Onal,1984
Tricalpopolennites densusu											X	X	
Tetradopollenites multiporatus											X	X	
Prinella caspia											X	X	Onal,1984
Clessiniola utandnsis											X	X	
Candona neglata					X	X	X	X					Onal, 1984
Paralimnocythere sp.					X	X	X	X					
Schizogalerix sp.				X	X	X	X						LOC. 3 Unay and de Bruijn,1984 Kaya, 1989
Cricetulodon sp.				X	X	X	X						
Byzantinia sp.				X	X	X	X						
Anchitherium sp.					X	X	X						
Hipparion primigenium							X	X	X				
Chilloterium habereri							X	X	X				
Hipparion mediterraneum									X	X	X		
Sinanodonta brandenburg								X	X	X			Taner ,1979 This study
Exuinocardium nobile								X	X	X			
Thedoxus licherdopoli sriptus								X	X	X			
Melanopsis bergeroni								X	X	X			
Pirenella caspia								X	X	X			
Mactra karabugasica								X	X	X			
Mactra supcaspia								X	X	X			
Dresiensia polymorpha											X	X	
Condana sp.					X	X	X	X					Taner, 1979 Sümengen et al., 1987 Sentürk et al., 1987
Candona neglata					X	X	X	X					
Paralimnocytere sp.					X	X	X	X					
Cyprideis tuberculata								X	X				
Cyprideis turpis								X	X				
Sylandstra posterobursa								X	X				
Cyprinatus salinus								X	X				
Cyprideis torosa									X	X	X		
Miocyprideis sp.									X	X	X		
Loxoconcha rhombodea									X	X	X		

Table 2
List of fossils and localities

TABLE-2													
	NEOGENE												AGE
	MIOCENE										PLIOCENE		
	EARLY		MIDDLE					LATE			EARLY	LATE	
	BURDIGALIAN		LANGHIAN	SERRAVALIAN				TORTONIAN		MESSINIAN	ZANCLEAN	PIACENZIAN	MEDITERRANEAN TETHYS
	OTTNANGIAN KARPATIAN		BADENIAN		SARMATIAN			PANNONIAN		PONTIAN	DACIAN	ROMANIAN	CENTRAL PARATETHYS
	MN3	MN4	MN5	MN6	MN7	MN8	MN9	MN10	MN11-MN12	MN13	MN14-MN15	MN16-MN17	EUROPEAN LAND MAMMAL ZONES (MEIN,1989)
FOSSILS	ORLEANIAN			ASTARACIAN				VALLESIAN		TUROLIAN	RUSCIAN	VILLAFRANCHIAN	EUROPEAN MAMMAL AGE

FOSSILS	RANGE	AGE
Byzantinia ozansoyi	XXXXXXXXXXXXXXXXXXXXXXXX	LOC. 4
Byzantinia dardanellensis	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Trogontherium minitum	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Monosaulax minutus	XXXXXXXXXXXXXXXXXXX	
Byzantinia nikosi	XXXXXXXXXXXXXXXXXXX	
Chalicomys jaegeri	XXXXXXXXXXXXXXXXXXX	
Anchitherium aurelianence	XXXXXXXXXXXXXXXXXXXXXXXXX	Ozansoy,1973 Erdogan, 1978 Sentürk et al.,1987
Listiriodan splendens	XXXXXXXXXXXXXXXXXXXXXXXXX	
Stenofiber jaegeri	XXXXXXXXXXXXXX	
Hyaena eximia	XXXXXXXXXXXXXX	
Hipparion gracile	XXXXXXXXXXXXXX	
Hipparion mediterraneum	XXXXXXXXXXXXX	
Hipparion mathewi	XXXXXXXXXXXXX	
Eucypris grandis	XXXXXXXXXXX	Sentürk et al.,1987
Candona compressa	XXXXXXXXXXX	
Candona kamoensis	XXXXXXXXXXX	
İlyocypris kalkaniensis	XXXXXXXXXXX	
Cyprides turpis	XXXXXXXXXXX	
Loxoconcha romboidea	XXXXXXXXXX	
Cyprideis pannonicus	XXXXXXXXXX	
Cyprideis heterostigma	XXXXXXXXXX	
Cyprideis tuberculata	XXXXXXXXXX	
Paralimnocytere sp.	XXXXXXXXXX	
Unio sp.	XXXXXXXXXXXXXXXXXXXXXXXX	Erguvanlı,1955 Sentürk et al.,1987 This study
Planorbis sp.	XXXXXXXXXXXXXXXXXXXXXXXX	
Pecten prabenedictus	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Ostrea sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Limnocardium sp.	XXXXXXXXXXXXXXXXXXXXX	
Mactra supcaspia	XXXXXXXXXXXXXXXXXXXXX	
Mactra karabugasiga	XXXXXXXXXXXXXXXXXXXXX	
Hydrobia grandis	XXXXXXXXXXXXXXXXXXXXX	
Capaea vindobenensis	XXXXXXXXXXXXXXXXXXXXX	
Melanopsis bergoni	XXXXXXXXXXXXXXXXXXXXX	
	XXXXXXXXXXXXXXXXXXXXX	
Sporus aff aurotus	XXXXXXXXXXXXXXXXXXXX	Erdoğan,1978
Sporus cinctus	XXXXXXXXXXXXXXXXXXXX	
Diplodus sp.	XXXXXXXXXXXXXXXXXXXX	
Arca pectinata	XXXXXXXXXXXXXXXXXXXXXXXX	LOC. 5
Murex craticulatus	XXXXXXXXXXXXXXXXXXXXXXXX	
Anomia ephipium	XXXXXXXXXXXXXXXXXXXXXXXX	
Ostrea cuculata	XXXXXXXXXXXXXXXXXXXXXXXX	
Venus gigas	XXXXXXXXXXXXXXXXXXXXXXXX	
Pecten prabenedictus	XXXXXXXXXXXXXXXXXXXXXXXX	
Chlamys multistrata	XXXXXXXXXXXXXXXXXXXXXXXX	
Bittium reticulatum	XXXXXXXXXXXXXXXXXXXXXXXX	
Mactra bastreoti	XXXXXXXXXXXXXXXXXXXXXXXX	
Andnus konkrensis	XXXXXXXXXXXXXXXXXXXXXXXX	
Cerittium vulgatum	XXXXXXXXXXXXXXXXXXXXXXXX	
Cardium edule	XXXXXXXXXXXXXXXXXXXXXXXX	Ternek,1949 This study
Ostrea gingensis	XXXXXXXXXXXXXXXXXXXXXXXX	
Ostrea digitalina	XXXXXXXXXXXXXXXXXXXXXXXX	
Mactra sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXX	Ternek,1949 This study
Limnocardium sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXX	
Cyrena sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXX	
Ammonia beccari	XXXXXXXXXXXXXXXXXXXXXXXXXXX	Örcen,1975
Nonion sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Tetralophodon grandincisivus	XXXXXXXXXXXXXXX	LOC. 6 Sümengen et al., 1987
Hipparion sp.	XXXXXXXXXXXXXX	
Dicoceros pachyganathus	XXXXXXXXXXXXXX	
Unio sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	Sümengen et al., 1987
Ostrea forskali	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Ostrea lamellosa	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Tapes bastreoti	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Cerostoderma edule	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Divalinga ornata	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Cerithium sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Pecten sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Mactra bastreoti	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Mactra subcaspia	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	

Table 3
List of fossils and localities

TABLE-3	NEOGENE					AGE
	MIOCENE			PLIOCENE		
	EARLY	MIDDLE	LATE	EARLY	LATE	
	BURDIGALIAN	LANGHIAN / SERRAVALIAN	TORTONIAN / MESSINIAN	ZANCLEAN	PIACENZIAN	MEDITERRANEAN-TETHYS
	OTTNANGIAN KARPATIAN	BADENIAN / SARMATIAN	PANNONIAN / PONTIAN	DACIAN	ROMANIAN	CENTRAL PARATETHYS
	MN3 / MN4	MN5 / MN6 / MN7 / MN8	MN9 / MN10 / MN11-MN12 / MN13	MN14-MN15	MN16-MN17	EUROPEAN LAND MAMMAL ZONES (MEIN,1989)
FOSSILS	ORLEANIAN	ASTARACIAN	VALLESIAN / TUROLIAN	RUSCIAN	VILLAFRANCHIAN	EUROPEAN MAMMAL AGE

Fossils	Range	Locality / Reference
Schizogalerix anatolica	XXXXXXXXXXXXXXXXXXXXXXX	LOC. 7 Unay and de Bruijn,1984
Byzantinia bayraktepensis	XXXXXXXXXXXXXXXXXXXXXXX	
Dakkayms sp.	XXXXXXXXXXXXXXXXXXXXXXX	
Trogontherium minitum	XXXXXXXXXXXXXXXXXXXXXXX	
Brachypotherium barchypus	XXXXXXXXXXXXXXXXXXXXXXX	
Schizogalerix sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Byzantinia nikosi	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Hemimactra sp.	XXXXXXXXXXXX	Temek,1949
Melanopsis impressa	XXXXXXXXXXXX	
Melanopsis corrodes	XXXXXXXXXXXX	
Monodacna pseudocatillus	XXXXXXXXXXXX	
Unio lavateri	XXXXXXXXXXXX	
Planorbis sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	LOC. 8 Parejas,1939
Bithinyia sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Byzantinia sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	Umut et al., 1984
Schizogalerix sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Palaeocricetus sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Democritedon sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Palaeoryx aff. *majori*	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Hipparion sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX	LOC. 9 Umut et al., 1984
Mioheyaena montadai	XXXXXXXXXXXXXXXXXXX	
Chilotherium zernowi	XXXXXXXXXXXXXXXXXXX	
Choerolophodon pentelici	XXXXXXXXXXXXXXXXXXX	
Hispanoterium grimmi	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	LOC. 10 Umut et al.,1983
Turkomys sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Schiizogaleriks sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Hipparion sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Hispanoterium grimmi	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	LOC. 11 Umut et al.,1983
Hipparion sp.	XXXXXXXXXXXXXXXXXXXXXX	
Quersus neriitoila	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	Umut et al.,1983
Persea aff. *ındicia*	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Unio sp.	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	Umut et al.,1983
Planorbis cf *thiollierei*	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Hipparion gracile	XXXXXXXXXXXXXXXXXXXXXXXXXX	LOC. 12 Chaput,1939 Arıc, 1955
Gazella gaudry	XXXXXXXXXXXXXXXXXXXXXXXXXX	
Calicotherium cf. *goldfussi*	XXXXXXXXXXXXXXXXXXXXXXXXXX	
Rhinoceras pachygnatus	XXXXXXXXXXXXXXXXXXXXXXXXXX	
Helicotragus rotundicornis	XXXXXXXXXXXXXXXXXXXXXXXXXX	
Testudo marmoreum	XXXXXXXXXXXXXXXXXXXXXXXXXX	
Mastadon pentellici	XXXXXXXXXXXXXXXXXXXXXXXXXX	
Giraffa attica	XXXXXXXXXXXXXXXXXXXXXXXXXX	
Cerithium nodosoplicatum	XXXXXXXXXXXXXXXXX	Sayar and Pamir,1933 Chaput,1939 Arıc,1955 Rückert-Ülkümen et al., 1993
Bittium reticulatum	XXXXXXXXXXXXXXXXX	
Spaniadon nitidus	XXXXXXXXXXXXXXXXX	
Nassa obliqua	XXXXXXXXXXXXXXXXX	
Cerithium vulgatum	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Potamida berbestiensis	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
Mactra podolica	XXXXXXXXXXXXXXXXXXXX	
Mactra bulgarica	XXXXXXXXXXXXXXXXXXXX	
Cypris faba	XXXXXXXXXXXXXXXXXXXX	
Mactra supcaspia	XXXXXXXXXXXXXXXXXXXX	
Mactra caspia	XXXXXXXXXXXXXXXXXXXX	
Mactra bulgarica	XXXXXXXXXXXXXXXXXXXX	
Mactra subturuncata	XXXXXXXXXXXXXXXXXXXX	
Mactra podolica	XXXXXXXXXXXXXXXXXXXX	
Melanopsis trojana	XXXXXXXXXXXXXXXXXXXX	
Thedoxus stefanescu	XXXXXXXXXXXXXXXXXXXX	
Unio carenatus	XXXXXXXXXXXXXXXXXXXX	
Clupea pulchra	XXXXXXXXXXXXXXXXXXXX	Rückert-Ulkümen et al., 1993
Clupeonella bothrophora	XXXXXXXXXXXXXXXXXXXX	
Thymallus laticus	XXXXXXXXXXXXXXXXXXXX	
Thymallus latisulcarus n.sp.	XXXXXXXXXXXXXXXXXXXX	
Palaegadis aequipartitus	XXXXXXXXXXXXXXXXXXXXX	
Prolebias trianguoratundata	XXXXXXXXXXXXXXXXXXXXX	
Atherina charagma.	XXXXXXXXXXXXXXXXXXXXX	
Bolivina viennensis	XXXXXXXXXXXXXXXXXXXX	Rückert-Ulkümen et al., 1993
lobigerina congata	XXXXXXXXXXXXXXXXXXXX	

and trough type cross-bedding is the principle sedimentary structure observed in the conglomerates. Towards the top, the conglomerates are followed by similar cross-bedded sandstones. Some minor intercalations of *Unio*- and *Mactra*-bearing marls and clays with thin coal seams are also present. The thickness of formation varies from 70 to 120 m increasing to the north. The mammal fauna derived from the formation indicates Pannonian age (Table 3, Loc. 12; Chaput, 1936; Arıç, 1955; Sayar, 1976).

2.8. Güngören Formation

The sequence of clays containing number of marl intercalations and some fine sand lenses has been designated as 'Güngören Formation' by Sayar (1976). In the type area (Güngören; Figs. 2 and 3, Loc. 12), the thickness of the unit is about 30 m. However, it varies from 20 to 80 m in other localities. This formation conformably follows the Çukurçeşme Formation and it is in turn, conformably overlain by Bakirköy Formation. Mammal and bivalve fauna indicates a Late Miocene age for the formation (Table 3, Loc. 12). Some fish remains found in the lateral extension of the formation indicate a Sarmatian–Pannonian age (Table 3, Loc. 12; Rückert-Ülkümen et al., 1993).

2.9. Alçıtepe Formation

A sequence of *Mactra*-bearing conglomerates, marl–sandstone intercalation and at the top, cross-bedded oolitic sandstone, sandy limestone and bivalve-bearing sandstone intercalation lies conformably on the Kirazlı Formation around Alçıtepe (Eceabat; Figs. 3 and 4, Loc. 3) and has been designated as 'Alçıtepe Formation' by Önem (1974). Around Alçıtepe, it is 200 m thick and is extensively exposed along the southern part of the Gelibolu Peninsula. The uppermost part of the formation is formed by red-coloured sandstones of continental origin. Around Erikli (north of the Gulf of Saros; Figs. 3 and 4, Loc. 6), some gypsum lenses are noted in the lower most part of the sequence. Here, *Ostrea* banks and some coral reefs are also observed above the conglomerates. Farther north (Enez; Figs. 3 and 4, Loc. 5), the formation starts with loosely cemented red sandstones intercalated with *Mactra*-bearing limestone's and finely laminated claystones. Here, the formation is about 60 m thick. It is unconformably overlain by the younger units.

Around Hosköy, the formation is Late Miocene in age (Table 1, Loc. 1; Gutzwiller, 1923). Around Gelibolu, however, its age is Dacian–Romanian (Table 1, Loc. 3; Taner, 1979). Around Alçıtepe, an ostracod fauna has yielded a Pannonian age for the lower part of the formation and the mammal fossils derived from the uppermost continental clastics indicate a Turolian age (Table 1, Loc. 3; Şentürk et al., 1987; Kaya, 1989). Around Bayraktepe and Bozcaada, the age is Tortonian (Erguvanlı, 1955; Erdoğan, 1978). Around Erikli, the age span is between Tortonian and Pontian (Ternek, 1949; Sümengen et al., 1987; Table 2, Locs. 5 and 6).

2.10. Çelebi Formation

The sequence largely formed by sandy marls and resting conformably on the Ergene Formation has been designated as Çelebi Formation by (Beer and Wright, 1960). This unit has extensive outcrops around the Ipsala–Kesan–Uzunköprü region (Figs. 3 and 4, Locs. 7 and 8). The type section starts with sandy marls which pass into sandy limestones. It is about 100 m thick on the conglomerates of the Ergene Formation. There are also some laminated and clayey limestone intercalations within the sandy limestone facies. The upper part of the formation consists mainly of brackish bivalve fauna-bearing marls.

The age of the formations is Pontian around Mahmutköy (Table 3, Loc. 7; Ternek, 1949). In the type area, however, the mammal fauna derived from the lower part has indicated a Late Miocene age (Table 2, Loc. 8) and the upper layers have yielded a Turolian age (Umut et al., 1984).

2.11. Sinanlı Formation

A sequence starting conformably on the Ergene Formation with limestone–marl and clay intercalation has been designated as Sinanlı Formation (Umut et al., 1983). In the areas near Edirne (Figs. 3 and 4, Loc. 9), the formation begins with marl–limestone–laminated clay intercalation. Some sand layers are also present in the sequence. Towards the top, limestones dominate the formation. The overall thickness of the formation is about 40 m in the type area. Around Lüleburgaz, it is made up of nodular limestone–clay alternation (Figs. 3 and 4, Loc. 10). Sand intercalations are frequent within the clay horizons. In this locality, the formation is about 30 m thick.

The Sinanlı Formation is unconformably overlain by the Thrace formation (Figs. 3 and 4, Locs. 9 and 10). This unit should be Late Miocene in age same as the Ergene Formation with which is vertically and laterally passing.

2.12. Bakırköy Formation

This formation has been designated by Sayar (1976) around Bakırköy and K. Çekmece (Figs. 3 and 4, Loc. 12). In this area, The sequence is formed by *Mactra*-bearing limestones with clay and marl intercalations (Fig. 4, Loc. 12). The formation is about 80 m thick in the type area. It gets thinner to the north. The brackish water bivalve fauna found in the unit indicates Pannonian–Pontian age (Table 3, Loc. 12).

2.13. Fener Conglomerate

This unit is exposed around Hosköy (Fig. 3, Loc. 1) and is composed of thick bedded polygenetic conglomerates bearing fresh-water bivalves (Table 1, Loc. 1) of Pliocene age (Gutzwiller, 1923; Yaltırak, 1995a).

2.14. Conkbayırı Formation

This formation has been designated by Kellog (1973) near Eceabat (Fig. 3, Loc. 3). In the Conkbayırı area, the formation starts with poorly indurated mudstones. Later, it develops into weakly cemented sandstone and conglomerate intercalation (Fig. 4, Locs. 2 and 3). The textural and sedimentary structures observed within the formation indicate an alluvial-fan depositional environment for these sediments. The formation lies unconformably over the Alçıtepe Formation of Turolian age (Sümengen et al., 1987).

The basal horizons have yielded a fresh-water fauna (Taner, 1979; Akchagylian) and the spore–pollen flora (Table 1, Loc. 2) indicating the Late Pliocene age for the formation (Önal, 1984).

2.15. Özbek Formation

It has been designated by Erol and Nuttal (1973) around Özbek (Figs. 3 and 4, Loc. 4). This formation is formed by carbonate cemented conglomerates containing shallow-marine fauna. These conglomerates are gradually replaced by carbonate cemented sandstones towards the top. Some limestone intercalations present in the upper part contain *Ostrea* sp. and Miliolidae indicating shallow-marine conditions. Some Dreissena fossils indicating limnic conditions are also found within the marly horizons of the formation. The early Quaternary age is given for the unit by the previous workers (Erol and Nuttal, 1973; Şentürk et al., 1987).

2.16. Thrace Formation

It has been named by Umut et al. (1983). It is made up of various fluviatile clastics north of the Saray–Kirklareli–Edirne axis (Figs. 3 and 4, Locs. 8–11). The thickness of these clastics varies from 10 to 40 m from one locality to another.

The formation unconformably overlies the Upper Miocene Ergene Formation. Therefore, it must be younger than Late Miocene. No fossil remains have been, so far, found in these deposits. From the stratigraphical point of view, the age span of the formation should be Plio-Quaternary.

3. Structural setting

In the Thrace (Turkey) area, two principal fault zones namely, the Thrace Fault Zone (TFZ; Perinçek, 1987, 1991) and Ganos Fault Zone (GFZ; Yaltırak, 1996; Figs. 5 and 6C) were active during the Neogene Period. The TFZ is situated to the north. This fault zone first started to develop around Kırklareli (Figs. 5 and 6C) and, thus, it was named as the Kırklareli Fault Zone by Perinçek (1987). According to this author, this fault zone migrated to the south in time creating the Lüleburgaz and the Babaeski fault zones accordingly (Figs. 5 and 6C, D).

Perinçek (1991) interprets that the Kırklareli Fault Zone which developed during the middle Late Miocene is the branch of the North Anatolian Fault Zone (NAFZ). Owing to the presence of clear posi-

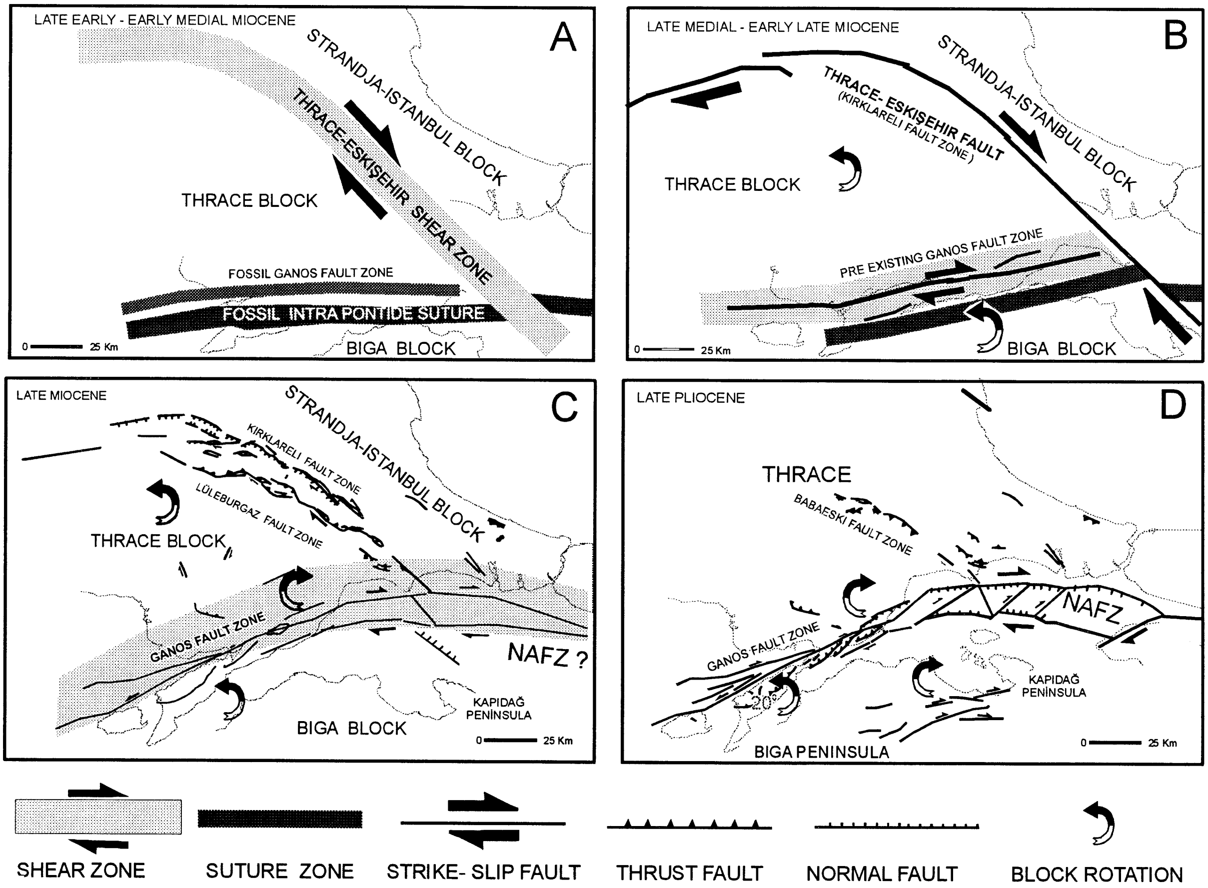


Fig. 6. Palinspastic tectonic model map of northwestern Turkey, compiled from Perinçek (1991), Barka (1992), Wong et al. (1995), Yaltırak (1996), Tapırdamaz and Yaltırak (1997) and Yaltırak et al. (1998).

tive and negative flower structures, he assumed that these faults are right-lateral strike-slip fault zones.

The Ganos Fault Zone (GFZ, Figs. 5 and 6C, D) is, however, an older structure than the TFZ as put forward by Tapırdamaz and Yaltırak (1997). According to these authors, this fault zone has been present since the Eocene, partly in the form of a replacement (Şengör et al., 1985) structure and partly in the form of a resurrected (Şengör et al., 1985) structure.

The third major structure seen in the region is the North Anatolian Fault Zone. As stated by many authors, it developed after the Late Miocene (Ketin, 1948, 1969; Şengör, 1979; Barka and Hancock, 1985; Şengör et al., 1985; Barka and Gülen, 1988; Görür et al., 1997).

In his recent study, Schindler (1997) has shown that the Eskişehir Fault continues up to the Bay of Gemlik. He also stated that it continues into the Sea of Marmara. His maps indicate that the NAFZ cuts the Eskişehir Fault. This situation implies that the Thrace Fault Zone and the Eskişehir Fault may have been segments of a major structure which was later cut and displaced by the NAFZ after the Late Miocene (Yaltırak et al., 1998).

4. Palaeogeographic and tectonic evolution

4.1. Early–Middle Miocene (Aragonian, ‘Orleanian–Astaracian’, Badenian)

In this period, the southern sector of the basin (Around Erikli, Eceabat, Mürefte, Şarköy areas) be-

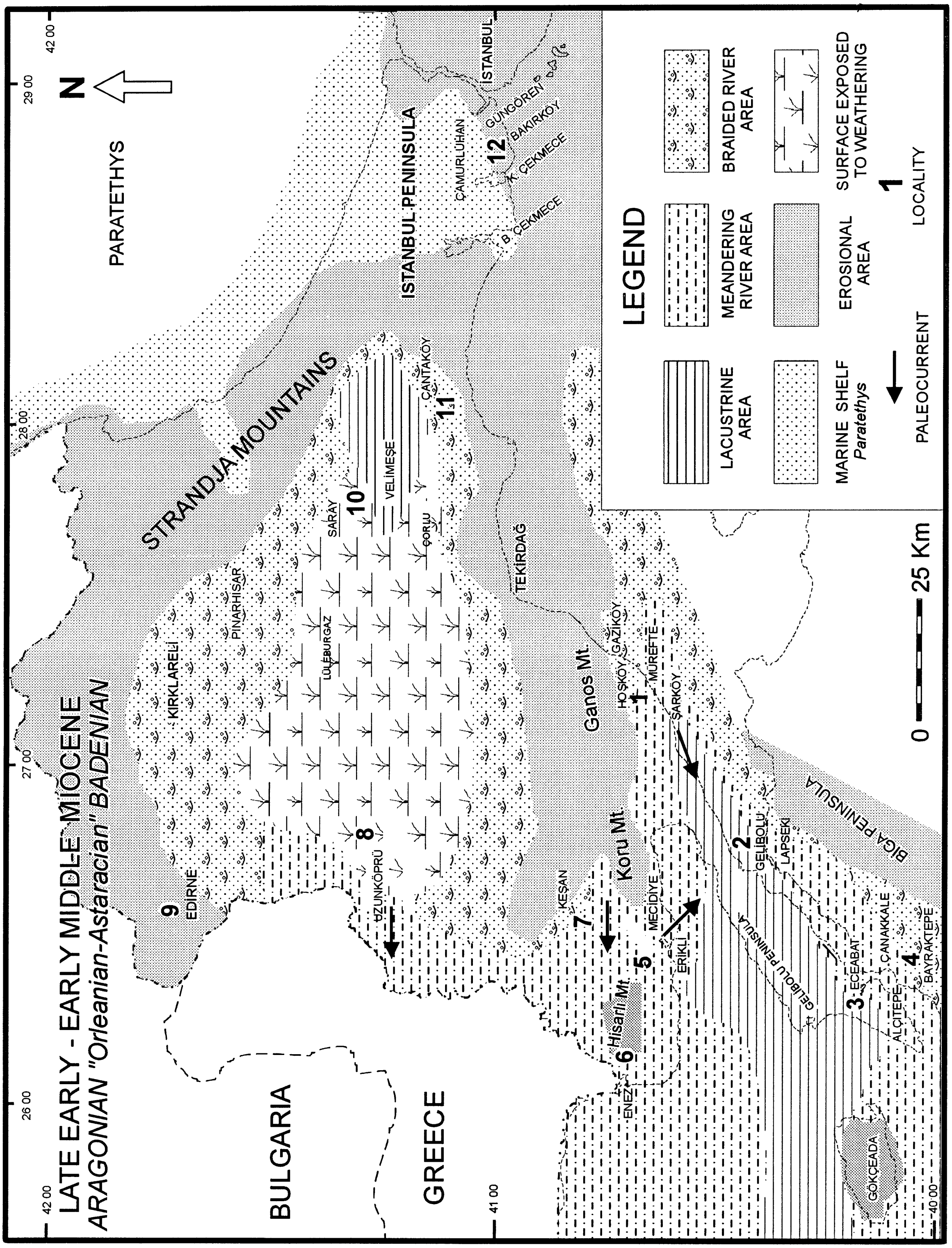


Fig. 7. Palaeogeographic map of the late Early–early Middle Miocene.

came a depositional site in which mainly meandering fluviatile and limnic conditions reigned. Principally, fine-grained clastic sedimentation took place The largest of the lakes is situated in the area between Erikli, Sarköy and Çanakkale strait. Savannah conditions developed on the coastal plains south of Çanakkale and Eceabat. In the areas north of the Uzunköprü– Saray line, the Miocene erosional surface started to be uplifted and thus, to be dissected along the Thrace–Eskisehir shear Zone (Fig. 6A and Fig. 7). The Oligo-Miocene sequence of the basement was also influenced by this intensified erosion and supplied clastic material to the braided-river environment situated south of the same line (Fig. 7). This implies deep dissection of the eroded surface of this area.

East of Dardanelles, alluvial fans and braided rivers developed in front of the uplifted basement rocks of the Biga peninsula (Fig. 7).

In this period, the areas of Strandja Massif, Istanbul Peninsula, Ganos Mountain, Korudağ and Hisarlıdağ were transformed into areas of denudation. However, a tongue of the Paratethys invaded the lowland region of Istanbul Peninsula from the north creating a shallow-marine bay (Çamurluhan Area; Fig. 7). Around Enez–Hisarlıdağ and Uzunköprü, in general, the braided river and limnic conditions existed (Saner, 1985). These are the northern extensions of similar environments seen around Erikli (Fig. 7).

4.2. Late Middle–Early Late Miocene (Serravalian, Vallesian)

In this period, the Thrace–Eskisehir shear zone developed into a strike-slip fault zone (Kırklareli Fault Zone; Fig. 6B) and, because of this, the Strandja Mountains were uplifted. A river system of a braided type started to transport clastic material into the basin situated to the south (Fig. 8). The positive area was still present between Tekirdag and Kesan. The braided river system continued to transport the erosional products into the enlarged basin in the north. A different situation is seen around Istanbul Peninsula. The evolution of TEF system (Fig. 6B) created a considerable uplifting possibly on the Biga Block, thus tilting the Strandja–Istanbul Block to the north. As a result, the waste amount of detrital material created by a rapid and an intensive erosion were carried to the north by the braided and later, by the meandering rivers (Çukurçeşme Formation).

The Paratethys regressed to the north creating large plains that eventually became an area of dune formation.

West of the Uzunköprü–Keşan line, in general, meandering rivers carried the clastic material to the limnic basins present in the further west.

From the tectonics points of view, in this period, The Thrace Block rotated in the counterclockwise direction by the effect of the TEF. The Ganos Fault Zone (Fig. 6B) was activated due to the compression created by the connection of the TEF and the Xanti–Kavala Fault (Figs. 1 and 2; Tapırdamaz and Yaltırak, 1997, figs. 1 and 8).

Around Mürefte (Fig. 8), shores of the lakes were covered by dunes (Kirazlı Formation). The Gazhanedere Formation started to develop unconformably on the Kirazlı Formation around Lapseki because of the compression of the counterclockwise rotated Biga Block (Fig. 6B). Similarly, cross-bedded conglomerates were deposited on the beach dunes along the Gelibolu Peninsula. The trough-like area between the Ganos Mountain and the Biga Peninsula hosted the meandering rivers (Fig. 8).

In this period, the Gulf of Saros also started to open along the reactivated pre-existing Oligo-Miocene alignments. A transgression occurred towards Erikli and Mürefte creating a marine shelf, thus, marine conditions developed in the area of Gulf of Saros. Deltaic sedimentation occurred along with the beach dunes and lakes (Fig. 8).

4.3. Late Miocene (Tortonian–Messinian, Turolian ‘Pannonian–Pontian’)

The Mediterranean transgression was fully established by the start of the Late Miocene creating a warm and shallow-marine conditions in the area to the south of Enez–Erikli line and north of Gelibolu Peninsula (Fig. 9). The GFZ was again reactivated by the commencement of the Late Miocene period, uplifting the Gelibolu Peninsula and, thus, creating a threshold. By this new tectonics, the area between the GFZ and NAFZ was transformed into a shear zone forming the nucleus of the Marmara Basin (Fig. 6C). In time, this basin was developed as a

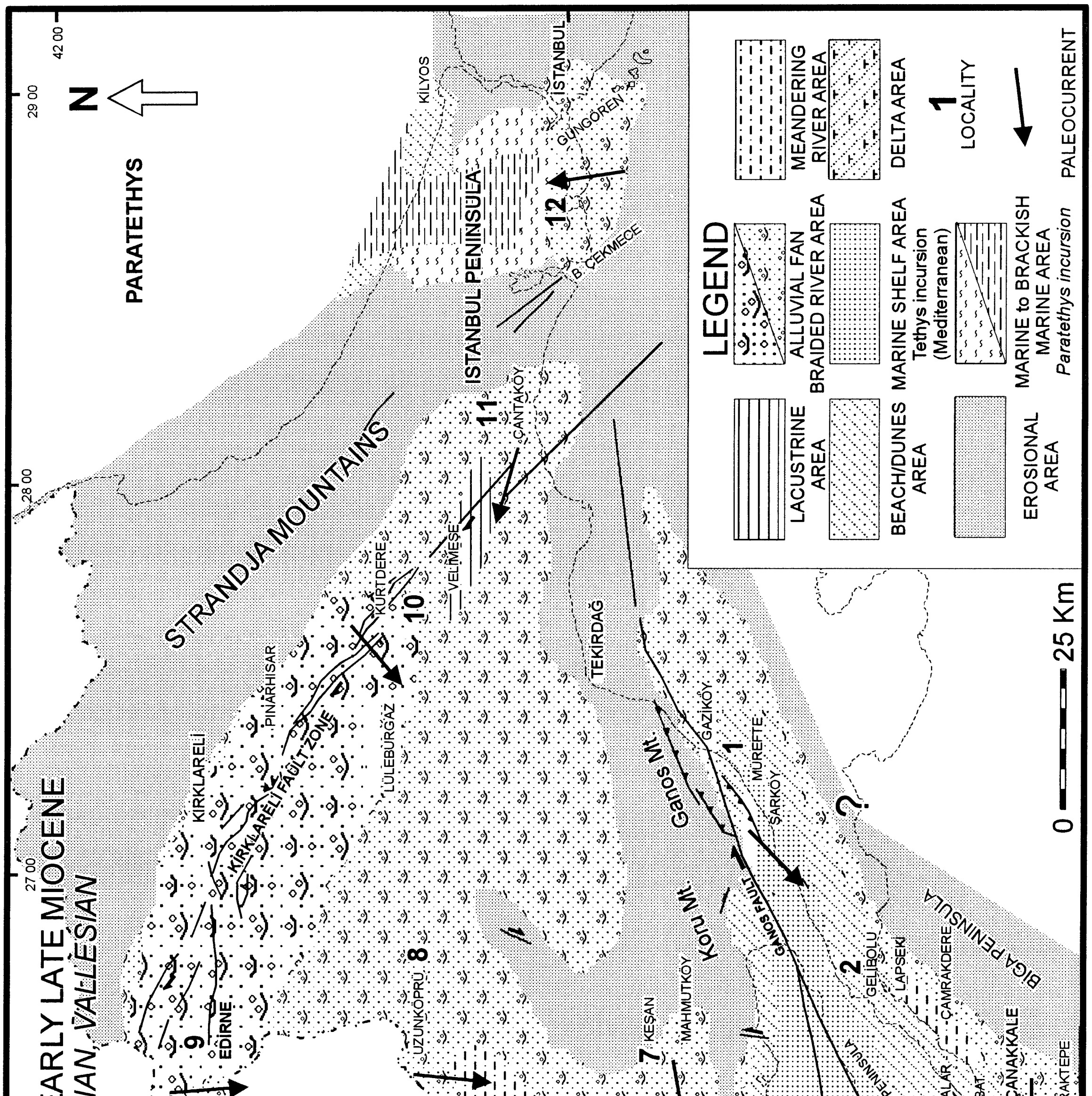


Fig. 8. Palaeogeographic map of the late Middle–early Late Miocene.

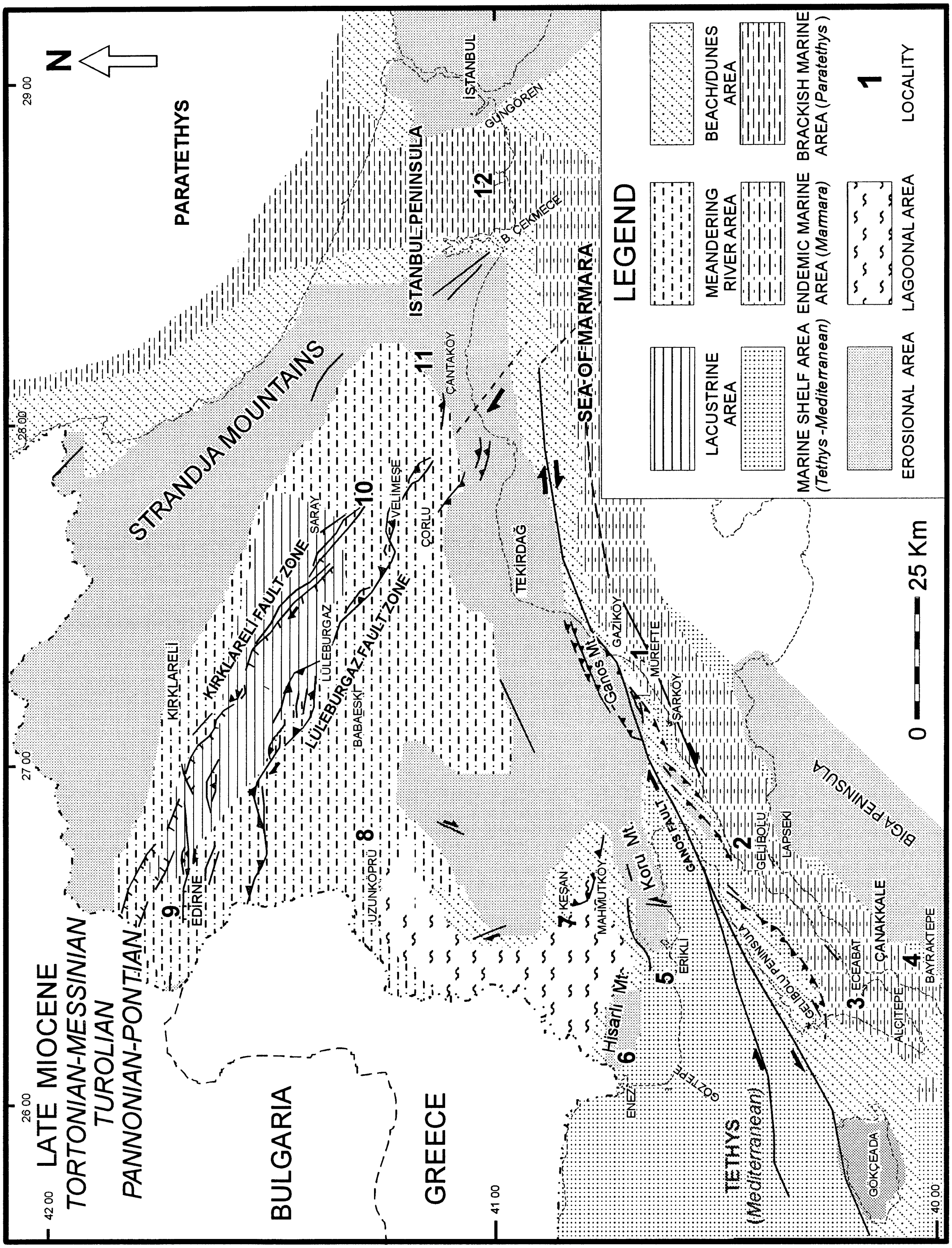


Fig. 9. Palaeogeographic map of the Late Miocene.

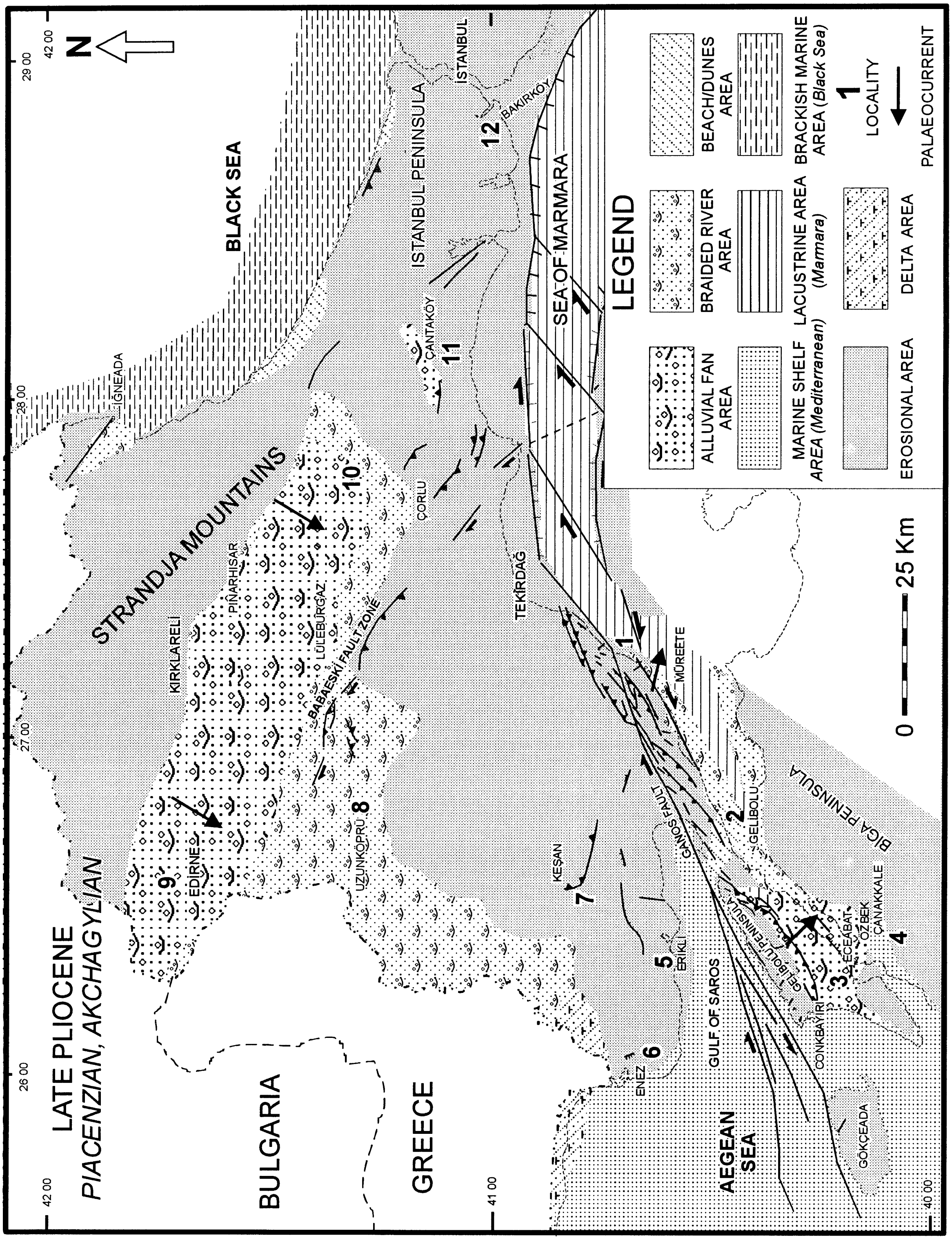


Fig. 10. Palaeogeographic map of the Late Pliocene.

lagoon experiencing marine invasions from time to time. The connection between the primitive Marmara basin and the Paratethys in the north was realized during the Pannonian–Pontian period along the Küçükçekmece–Terkos line by the activation of the NAFZ and tilting of the Strandja–Istanbul Block to the south.

By these tectonic movements, the area between Istanbul and Çanakkale became a shallow and a narrow endemic bay controlled by the Gelibolu threshold (Fig. 6C and Fig. 9). This bay was remained as an endemic bay of the Paratethys after the uplifting of Gelibolu Peninsula during Turolian (Fig. 9). From time to time, Mediterranean transgressions effected this endemic basin creating open-marine conditions (Fig. 9). During the lagoonal phases, near-shore areas became the coastal plains. In this period, the activity of the NAFZ dissected the KFZ causing its migration to the south. This new fault zone is called the Lüleburgaz Fault Zone (LFZ; Fig. 9). The TFZ was inactivated by the counterclockwise rotation of the Thrace Block. This tectonics resulted the joining of the NAFZ and GFZ (Fig. 6C). Therefore, the right-lateral movements developed over the area of the Sea of Marmara joined up with the palaeotectonic alignments and a negative flower structure started to develop.

The Paratethian waters secured the brackish water environments over the area of the Sea of Marmara and North Aegean regions during the Messinian crisis. The transgression of the Paratethys over the fluviatile-limnic basin around Kesan created lagoonal conditions. In time, due to the termination of the connection with the open sea, the area around Uzunköprü became again a fluviatile and, in parts a limnic depositional area (Fig. 8).

The continental faunal association indicates that, during this period, the continental areas (plains) were transformed into the savannah under the subtropical climatical conditions (Tables 1–3).

The mammal fauna of carnivorous and rodents found in Istanbul and Çanakkale implies that the whole continental area of Thrace possibly covered by savannah.

The tilting of the Strandja–Istanbul block to the south continued in this period disconnecting the Marmara Basin and the Paratethys.

4.4. Late Pliocene (Piacenzian–Akchagylian)

The Pliocene period of Thrace was represented by an erosional regime. The activity of GFZ was intensified by the joining to the NAFZ uplifting the area and creating alluvial fans on the Gelibolu Peninsula (Yaltırak, 1995b). The sea regressed nearly to the present position around Gulf of Saros (Fig. 6D and Fig. 10). A gulf was formed by the Late Pliocene (Piacenzian) transgression of the Aegean waters into the mouth of Çanakkale Strait (Fig. 10; Karistineos and Georgiades-Dikeoulia, 1985–1986). The reverse faults seen in the alluvial fans around Saray and Edirne at the southern foothills of Strandja Mountains are the clear evidences of the compression in the region (Fig. 5D and Fig. 9; Tapırdamaz and Yaltırak, 1997).

The bay of the Paratethys (Sea of Marmara) was transformed into a fresh-water lake by the uplifting of the region due to the compressional tectonics. By the bending of NAFZ to the south, the area between the northern and southern border faults has been dissected by the step faulting forming the base of the pull-apart system seen in the Sea of Marmara today.

5. Discussion and conclusion

The Thrace Neogene Basin is an intermontane basin principally developed by the activities of the two strike-slip fault systems namely, the Thrace–Eskişehir and Ganos fault zones following the continental collision and thus, cratonization during the Late Oligocene–Early Miocene period.

It was evolved under the direct control of the TEF during the late Early Miocene as a result of the connection established between the TEF and the Xanti–Kavala Fault (Figs. 1 and 2). The movement was transferred along an arc, which was situated to the eastern margin of the Aegean Sea and was controlled by the escape tectonics.

It is also clarified by this study that the influence of the Paratethys is only observed north of the Istanbul Peninsula during the Early–Middle Miocene period. The comparisons have indicated that no connection was established between the Paratethys and Tethys around Istanbul prior to Pannonian–Pontian. If any connection was realized in this period between the eastern Mediterranean and the eastern Paratethys it must have been east of Anatolia. The only marine influence, experienced during the Badenian, must have been east of the Thrace Neogene Basin. During this period, arrival of the bivalves and fishes into Marmara basin via the middle–central Paratethys indicates that the current systems must have been operating in the counterclockwise direction as it is in the present Black Sea. The eastern Paratethian influence is seen after the Pliocene implying that the central Paratethys ceased in the post-Pliocene period west of the Thrace Neogene Basin (Lüttig and Steffens, 1976). However, west of the Thrace Neogene Basin, the first marine influence is the Mediterranean transgression occurring from the late Serravalian to Messinian.

The comparison of the fossil determinations put forward by the previous workers has indicated that connections existed between the Mediterranean and the Paratethys via Çanakkale during the late Tortonian and ceased during the Messinian crisis. In the east, however, the Istanbul Peninsula had been subjected to the intense compression and tilting due to the evolution of the Marmara Basin, thus, the only connection realized over the Marmara had been severed and, in due course, endemic conditions developed. Because of this, the age of the Paratethian molluscs could be different than the others found in the other basins of the Paratethys.

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References

Akartuna, M., 1953. Çatalca Karacaköy Bölgesinin Jeolojisi. IÜ Fen Fak. Mon. 13, 87 pp.

Alişan, C., Gerhard, J.E., 1987. Palynostratigraphy and source rock properties of three wells drilled in northern Thrace Basin. 7th Biannual Petroleum Congress of Turkey, pp. 461–467.

Andrussov, N., 1890. Die Schichten von Cap Tschauda. Ann. K. K. Nat. Hof. 66.

Arabu, 1917. Remarques stratigraphiques sur les formations Tertiaires du Bassin de la Mer de Marmara. Bull. Soc. Geol. Fr. 4 (17), 390–405.

Arıç, C., 1955. Haliç ve Küçükçekmece Gölü bölgesinin Jeolojisi. Ph.D. Thesis, ITÜ, Mining Fac. Istanbul, 48 pp.

Barka, A.A., 1992. The North Anatolian Fault Zone. Ann. Tecton. 4, 164–195.

Barka, A.A., Hancock, 1985. Tectonic interpretation of enigmatic structures in the North Anatolian Fault Zone. J. Struct. Geol. 5, 217–220.

Barka, A.A., Gülen, L., 1988. New constrains on age and total offset of the North Anatolian Fault Zone: Implications for tectonics of eastern Mediterranean region. Spec. Publ. Middle-East Tech. Univ. Ankara, Turkey, pp. 39–65.

Barka, A.A., Kadinsky-Cade, K., 1988. Strike-slip fault geometry in Turkey and its influence on earthquake activity. Tectonics 7 (3), 663–684.

Beer, H., Wright, J.A., 1960. Stratigraphy of the Ganosdag, Korudag and Kesan Hills District I (Thrace). TPAO Rap. 736.

Bornovas, J., Rondogianni-Tsiambau, T.H., 1983. Geological Map of Greece, 1 : 500,000. Inst. Oil. Min. Ex.

Calvert, F., Neumayr, M., 1880. Die Jungen Ablagerungen am Hellespont. Denkschr. K. K. Akad. Wiss. Math. Nat. Kl. 40, 357–378.

Chaput, E., 1931. Istanbul cıvarında Neojen arazisi bünyesi hakkında müşahadeler. Ist. Darül. F.F.M. 5, 1–32.

Chaput, E., 1936. Voyages d'études géologique et géomorphogénique en Turqie. Mém. Inst. Fr. Archeol. Istanbul II.

Doust, H., Arıkan, Y., 1974. The geology of the Thrace Basin. 2nd Biannual Petroleum Congress of Turkey, Ankara, pp. 119–131.

Ediger, V.S., Batı, Z., 1988. Morphological examination of *Pediatrum* (Chlorophyta) from the Tertiary strata of the Thrace Basin (NW Turkey). Pollen Spores XXX (2), 203–222.

English, Th., 1904. Eocene and later formations surrounding the Dardanelles. Q. J. Geol. Soc., 58 pp.

Erdoğan, K., 1978. On the fossil fishes from the Tortonian of Çanakkale-Bayraktepe. Bult. Geol. Soc. Turkey 21, 141–144.

Erğun, M., Özel, E., 1995. Structural relationship between the Sea of Marmara Basin and the Anatolian Fault Zone. Terra Nova 7, 278–288.

Erguvanlı, K., 1955. Etude geologique de l'île de Bozaada. Bull. Soc. Geol. Fr. 6 (5), 399–401.

Erol, O., Nuttal, C.P., 1973. Çanakkale bazı denizel Kuvaterner depoları. Coğrafya Araş. Derg. 5–6, 27–92.

Eryilmaz, M., 1996. Ege Denizi'nde doğal uzantinin saptanmasinda kullanılan yerbilimleri kriterleri. Ph.D. Thesis, Istanbul Univ., Istanbul, 178 pp. (in Turkish).

Gheshitev, G., Kancev, I., Valkov, V., Marinova, R., Shlyafova, J., Russeva, M., Iliev, K., 1989. Geological Map of Bulgaria, 1 : 100,000. In: Gheshitev, G., Kancev, I. (Eds.), Committee of Geology.

Görür, N., Sakınç, M., Barka, A., Akkök, R., Ersoy, S., 1995. Miocene to Pliocene palaeogeographic evolution of Turkey and its surrounding. J. Human Evol. 28, 309–324.
Görür, N., Çağatay, M.N., Sakınç, M., Sümengen, M., Şentürk, K., Yaltırak, C., Tchapalyga, A., 1997. Origin of the Sea of Marmara as deduced from the Neogene to Quaternary palaeogeographic evolution of its frame. Int. Geol. Rev. 39, 342–352.
Gutzwiller, O., 1923. Beitrage zur Geologie der Umgebung von Merfete (Mürefte) am Marmara Meer. Ph.D. Thesis, Univ. Basel, Basel, 165 pp.
Hoernes, R., 1909. Die Bildung des Bosporus und der Dardanellen. Sitzungsber. K. Akad. Wien 1 (118), 693–758.
Holmes, A.W., 1961. A stratigraphic review of Thraces. TPAO Rap. 368.
İzdar, K.E., 1959. Beitrage zur Geologie der Umgebung von Tepeköy. Ph.D. Thesis, Rhenischen Fredrich Wilhelms-Universitat, Bonn, İzmir, Turkey, 43 pp.
Jackson, J., McKenzie, D., 1984. Active tectonics of the Alpine–Himalayan Belt between western Turkey and Pakistan. Geophys. J. R. Astron. Soc. 77 (1), 185–265.
Kalafat, D., 1995. Anadolu'nun tektonik yapilarinin deprem mekanizmalari açisindan irdelenmesi. Ph.D. Thesis, Istanbul Univ., Istanbul, 217 pp. (in Turkish).
Karistineos, N.K., Georgiades-Dikeoulia, E., 1985–1986. The Marine transgression in the Seres Basin. Ann. Geol. Pays Hellen. XXXIII (I), 221–232.
Kasar, S., 1987. Geology of the Edirne–Kirklareli–Saray (Kuzey Trakya). 7th Biannual Petroleum Congress of Turkey, pp. 281–291.
Kaya, T., 1989. Alçıtepe (Gelibolu Yarımadası) yöresi memeli faunaları Perissodactyla bulguları. TJK Bült. 2, 79–89.
Kellog, H.E., 1973. Geology and petroleum prospect. Gulf of Saros and vicinity southwestern Thrace, Turkey. TPAO Rap. 902.
Keskin, C., 1971. Pınarhisar alanının jeolojisi. TJK Bült. 14 (1), 31–84.
Keskin, C., 1974. Stratigraphy of the North Ergene Basin. 2nd Biannual Petroleum Congress of Turkey, pp. 137–163.
Ketin, İ., 1948. Uber die tektonisch-mechanischen folgerungen aus den grossen anatolischen Erdbeben des letzten Dezenniums. Geol. Rundsch. 36, 77–83.
Ketin, İ., 1969. Kuzey Anadolu Fayı hakkında. Bull. MTA 72, 1–24.
Kopp, K.O., Pavoni, N., Schindler, C., 1969. Geologie Thrakiens IV: Das Ergene Becken. Beih. Geol. Jahrb. 76, 136 pp.
Lebküchner, R.F., 1974. Beitrag zur Kenntnis der Geologie des Oligozäns von Mittel Thrakien (Türkei). Bull. MTA 83, 30 pp.
Lüttig, G., Steffens, P., 1976. Explanatory notes for the Palaeographic atlas of Turkey from the Oligocene to the Pleistocene. Bundesanst. Geowiss. Rohstoffe, Hannover, 64 pp.
Newton, R.B., 1904. Notes on the post-Tertiary and Tertiary Fossils obtained by Col. English from district surrounding the Dardanelles. Q. Geol. Soc. London 60, 227–292.
Okay, A.İ., 1984. Metamorphic belts in Northwest Anatolia. Ketin Simpozyumu, pp. 83–92.
Önal, M., 1984. Gelibolu (Çanakkale) kuzeybatısının jeolojisi. Ph.D. Thesis, Istanbul Üniv., Istanbul, 200 pp.
Önem, Y., 1974. Gelibolu Yarımadası ve Çanakkale dolaylarının jeolojisi. TPAO Rap. 877.
Örçen, S., 1975. Yayla-Erikli (Keşan) dolayının (Edirne ili) jeoloji ve paleontoloji incelemesi. M.S. Thesis Istanbul Üniv. Istanbul, 39 pp.
Ozansoy, F., 1973. Les Ceracteritiqes du Neogene des Dardanelles. Ankara Üniv. DTCF Antropol. 6, 171–180.
Parejas (Ed.), 1939. Trakya linyitleri jeolojik etüdü, Uzunköprü, Kesan, Malkara, Hayrabolu mintikasi. MTA Rap. 981
Parejas (Ed.), 1941. Türkiye'nin Arzani Tektonigi. IÜ Fen Fak. Mon. 1, 106 pp.
Penck, W., 1917. Bau und Oberflechenformen des Dardanellenlandschaft. Z. Ges. Erdk. Berlin.
Perinçek, D., 1987. Trakya Havzası renç fay zonunun sismik özellikleri. Türkiye 7th Petrol Kongresi, pp. 11–21.
Perinçek, D., 1991. Possible strand of the North Anatolian Fault in the Thrace basin, Turkey — an interpretation. TAPG Bull. 75 (2), 241–257.
Perinçek, D., Günay, Y., Kozlu, H., 1987. New observation on strike slip faults in east and southeast Anatolia. 7th Biannual Petroleum Cong. of Turkey, pp. 89–103.
Rögl, F., Steininger, F.F., 1983. Vom Zerfall der Tethys zu Mediterran und Paratethys die Neogene Paläogeographie und palinspastik des zirkum-Mediterranean Raumes. Ann. Naturhist. Mus. Wien 85 (A), 135–163.
Rögl, F., Steininger, F.F., 1984. Neogene Paratethys, Mediterranean and Indo-Pasific sea ways. In: Brenchley, P.J. (Ed.), Fossils and Climate. Wiley, New York, NY, pp. 171–200.
Rückert-Ülkümen, N., Kaya, O., Hottenrott, M., 1993. Neue Beiträge zur Tertiär-Stratigraphie und Otolithenfauna der Umgebung von Istanbul (Küçükçekmece- und Büyükçekmece See) Türkei. Mitt. Bayer. Staatssamml. Paläontol. Hist. Geol. 33, 51–89.
Sakınç, M., Yaltırak, C., 1997. Trakya'nin güney sahillerinin Pleyistosen Paleocoğrafyası ve Evrimi. Bull. MTA 119, 43–62.
Saltık, O., 1974. Şarköy-Mürefte Sahalarının Jeolojisi ve Petrol Olanakları. TPAO Rap. 879.
Saner, S., 1985. Saros Körfezi dolayinin çökelme istifleri ve tektonik yerlesimi, Kuzeydogu Ege Denizi, Türkiye. TJK Bült. 28, 1–10.
Sayar, C., 1976. Haliç Cıvarının Jeolojisi. Istanbul Haliç Sorunları ve Çözüm Yolları Ulusal Semp., pp. 355–374.
Sayar, C., 1987. Istanbul ve çevresi Neojen çökelleri ve Paratetis içindeki konumu. Maden Fakültesi 40 Yıl Bült., pp. 250–266.
Sayar, M., Pamir, H.N., 1933. Une Faune de vértebre fossile Miocéne prés d'Istanbul. C. R. Soc. Géol. Fr. 6, 64–66.
Schindler, C., 1997. Geology of Northwestern Turkey: Results of the MARMARA poly-project. Active Tectonics of Northwestern Anatolia — The Marmara Poly-Project. ETH, Zürich, pp. 329–373.
Simeakis, C., Mercier, J.L., Vergely, P., Kissel, C., 1989. Late Cenozoic rotations along the North Aegean Trough Fault Zone (Greece) structural constraints. In: Kissel, C., Laj, C. (Eds.),

Paleomagnetic Rotations and Continental Deformation. Nato ASI Ser. C 254, 131–143.
Siyako, M., Bürkan, K.A., Okay, A.I., 1989. Tertiary geology and hydrocarbon potential of the Biga and Gelibolu peninsulas. TPAG Bull. 1 (3), 183–200.
Steininger, F.F., Rögl, F., Nevesskaja, L.A., 1985. Sediment distribution maps for selected time interval through the Neogene. Neogene of Mediterranean Tethys and Paratethys; Stratigraphic correlation tables and sediment distribution maps, Wiley, Vienna, pp. 9–102.
Sümengen, M., Terlemez, I., Şentürk, K., Karaköse, C., Erkan, E., Ünay, E., Gürbüz, M., Atalay, Z., Şentürk, K., 1987. Gelibolu Yarımadası ve Güneybatı Trakya Tersiyer Havzasının Stratigrafisi. Sedimentolojisi ve Tektoniği. MTA Rap. 8128.
Şaroğlu, F., Boray, A., Emre, Ö., 1987. Active faults of Turkey. Mineral. Res. Explor. Inst. Turkey Rep. 8643, 399 pp. (unpubl.).
Şengör, A.M.C., 1979. The North Anatolian Transform Fault. its age offset and tectonic significance. J. Geol. Soc. London 136, 269–282.
Şengör, A.M.C., Görür, N., Şaroğlu, F., 1985. Strike-slip faulting and related basin formation in zones of tectonic escape: Turkey as a case study. Soc. Ecol. Paleontol. Mineral. Spec. Publ. 37, 227–264.
Şentürk, K., Karaköse, C., Atalay, Z., Gürbüz, M., Ünay, E., Doruk, N., Batum, I., 1987. Çanakkale Bogazı ve dolayının jeolojisi. MTA Rap. 8130.
Taner, G., 1979. Die Molluskenfauna der Neogenen Formation Der Halbinsel-Gelibolu. VII Int. Congr. on Mediterranean Neogene, Athens. Ann. Geol. Pays Hellen. III, 1189–1194.
Tapırdamaz, C., Yaltırak, C., 1997. Trakyanın Senozoyik volkaniklerinin paleomanyetik özellikleri ve tektonik konumu. Bull. MTA 119, 27–42.
Taymaz, T., 1990. Earthquake source parameters in the eastern Mediterranean Region. Ph.D. Thesis, Cambridge Univ., Cambridge, 244 pp.
Taymaz, T., Jackson, J., McKenzie, D., 1991. Active tectonics of the north and central Aegean Sea. Geophys. J. Int. 106, 433–490.
Tchihatcheff, P., 1863–1867. Asie Mineure, Description physique. Q. Part. Geol. I–III.
Ternek, Z., 1949. Geological study of the region of Keşan-Korudağ. Ph.D. Thesis, Istanbul Univ., Istanbul, 78 pp.
Turgut, S., Türkaslan, M., Perinçek, D., 1991. Evolution of the Thrace sedimentary basin and its hydrocarbon prospectivity. In: Spencer, A.M. (Ed.), Generation, Accumulation, and Production of Europe's Hydrocarbons, Oxford University Press, pp. 415–437.
Umut, M., Kurt, Z., İmik, M., 1983. Tekirdag ili-Silivri (Istanbul)-Pınarhisar (Kırklareli) alanının jeolojisi. MTA Rap. 7349.
Umut, M., Imik, M., Kurt, Z., Özcan, I., Ates, M., Karabıyıkoglu, M., Saraç, G., 1984. Edirne ili-Kırklareli ili-Lüleburgaz (Kırklereli ili) Uzunköprü (Edirne ili) civarinin jeolojisi. MTA Rap. 7604.
Ünay, E., De Bruijn, H., 1984. One some Neogene rodent assemblages from both sides of the Dardanelles, Turkey. Newsl. Stratigr. 13, 119–132.
Wong, H.K., Lüdman, T., Ulug, A., Görür, N., 1995. The Sea of Marmara: a plate boundary sea in an escape tectonic regime. Tectonophysics 244, 231–250.
Yaltırak, C., 1995a. Gaziköy-Mürefte arasının sedimantolojisi ve tektoniği. TPJD Bült. 6 (1), 93–112.
Yaltırak, C., 1995b. Gelibolu Yarımadası'nda Pliyo-Kuvaterner sedimantasyonunu denetleyen tektonik Mekanizma. Nezihi Canitez Sempozyumu, 12–14 Nisan, Istanbul, Jeofizik, 10, pp. 103–106.
Yaltırak, C., 1996. Ganos Fay Sisteminin tektonik tarihi. TPJD Bült. 8 (1), 137–156.
Yaltırak, C., Alpar, B., Yüce, H., 1998. Tectonic elements controlling the evolution of the Gulf of Saros (northeastern Aegean Sea, Turkey). Tectonophysics 300, 227–248.