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Neotectonics of Turkey – a synthesis

Erdirn Bozkurt*

Tectonic Research Unit, Department of Geological Engineering, Middle East Technical University, 06531
Ankara, Turkey

Abstract – Turkey forms one of the most actively deforming regions in the world and has a long history of devastating earthquakes. The better understanding of its neotectonic features and active tectonics would provide insight, not only for the country but also for the entire Eastern Mediterranean region. Active tectonics of Turkey is the manifestation of collisional intracontinental convergence- and tectonic escape-related deformation since the Early Pliocene (~5 Ma). Three major structures govern the neotectonics of Turkey; they are dextral North Anatolian Fault Zone (NAFZ), sinistral East Anatolian Fault Zone (EAFZ) and the Aegean–Cyprean Arc. Also, sinistral Dead Sea Fault Zone has an important role. The Anatolian wedge between the NAFZ and EAFZ moves westward away from the eastern Anatolia, the collision zone between the Arabian and the Eurasian plates. Ongoing deformation along, and mutual interaction among them has resulted in four distinct neotectonic provinces, namely the East Anatolian contractional, the North Anatolian, the Central Anatolian ‘Ova’ and the West Anatolian extensional provinces. Each province is characterized by its unique structural elements, and forms an excellent laboratory to study active strike-slip, normal and reverse faulting and the associated basin formation. © 2001 Éditions scientifiques et médicales Elsevier SAS

1. Introduction

Turkey is one of the most seismically active regions in the world. As a result, it has a long history of large earthquakes that have killed many thousands of people and caused economic devastation, including the Kocaeli ($M = 7.4$) and Düzce ($M = 7.2$) events of 17 August and 12 November 1999, near İstanbul. It is located within the ‘Mediterranean Earthquake Belt’, whose complex deformation results from the continental collision between the African and Eurasian plates (figure 1). Turkey is thus an excellent natural laboratory to study post-collisional intracontinental convergence- and tectonic escape-related deformation, and the consequent structures that include fold and thrust belts, suture zones, active strike-slip faulting, and active normal faulting and the associated basin formation.

* Correspondence and reprints.

E-mail address: erdirn@metu.edu.tr (E. Bozkurt).

The neotectonics of Turkey is governed by three major elements: (1) the Aegean–Cyprean Arc, a convergent plate boundary where the African Plate to the south is subducting beneath the Anatolian Plate to the north; (2) the dextral North Anatolian Fault Zone; and (3) the sinistral East Anatolian Fault Zone (figure 1). The latter two are intracontinental strike-slip faults along which the Anatolian Plate, a wedge of amalgamated fragments of crust, moves westward away from the collision zone between the Arabian and the Eurasian plates [1, 2] at a rate of $\sim 20 \text{ mm year}^{-1}$ [3–8]. This activity is the result of interactions between northward-moving African and Arabian plates and the relatively stable Eurasian Plate. The two strike-slip faults meet and form a continental triple junction to the east of Karlıova in north-eastern Turkey (figure 1).

The westward extrusion of the Anatolian wedge is accompanied by anticlockwise rotation as well as translation [4, 9–14]. This is attributed to a response of the continental lithosphere moving laterally away from zones of compression (tectonic escape), to minimize topographic relief and to avoid subduction of buoyant continental material. It is still debated whether the westward motion is driven by push forces caused by topography in eastern Turkey, or by pull forces caused by subduction south of the Aegean (see section on western Turkey).

This paper summarizes the available literature on the active tectonics of Turkey with a special reference and emphasis to the papers presented in the special issue. The data presented in the contributing papers will be useful in elucidating the active tectonics of Turkey.

2. Tectonic framework

Following the complete demise of the Palaeotethyan Ocean, continental rifting in the present-day eastern Mediterranean commenced by the Late Triassic and resulted in the formation of Mesozoic Neotethyan Ocean [1]. This rifting ceased during the Middle Jurassic with the development of a passive margin to the south of Cyprus [15], while com-

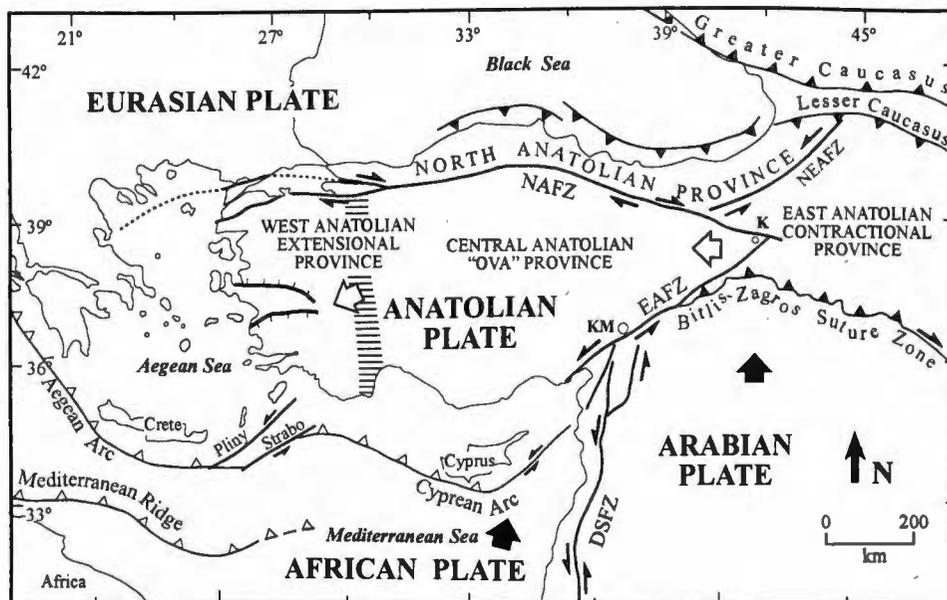


Figure 1. Simplified tectonic map of Turkey showing major neotectonic structures and neotectonic provinces (from Şengör et al. [2]; Barka [3]). K – Karlıova, KM – Kahramanmaraş, DSFZ – Dead Sea Fault Zone, EAFZ – East Anatolian Fault Zone, NAFZ – North Anatolian Fault Zone, NEAFZ – Northeast Anatolian Fault Zone. Heavy lines with half arrows are strike-slip faults with arrows showing relative movement sense. Heavy lines with filled triangles shows major fold and thrust belt: small triangles indicate direction of vergence. Heavy lines with open triangles indicate an active subduction zone, its polarity indicated by the tip of small triangles. The heavy lines with hachures show normal faults: hachures indicate down-thrown side. Bold filled arrows indicate relative movement direction of African and Arabian plates; open arrows, relative motion of Anatolian Plate. Short arrows show the sense of plate motion, half arrows the relative motion senses on strike-slip faults. The hatched area shows the transition zone between the western Anatolian extensional province and the central Anatolian 'ova' province from Şengör et al. [2].

plex processes of terrain accretion and new continental crustal build-up started to the north [1, 16]. Convergence between the African and Eurasian plates, which began in the Late Cretaceous (~90 Ma) (e.g. [1, 17]), resulted in the progressive closure of these ocean basins and amalgamation of the surrounding continental fragments. The consequent subduction-accretion complexes and emplacement of ophiolites produced the crust presently exposed in Turkey and Cyprus (e.g. [1, 18]).

During the Early Miocene, the northward subduction of the African Plate has begun south of Cyprus [19]. The northern branch of the Neotethyan Ocean was closed by the final collision and suturing of the Eurasian Plate in the north and Anatolian-Iranian platform in the south during Late Palaeocene-late Burdigalian along the İzmir-Ankara and Lesser Caucasus sutures [1, 20, 21]. On the other hand, the northward subduction of the southern branch of the Neotethys (known as the Bitlis Ocean), running from southeastern Turkey to Cyprus, continued its evolution through late Middle Miocene [1, 22–24] and then was closed entirely during the continent-continent collision across the Arabian Plate in the south and the Eurasian Plate in the north along the Bitlis-Zagros Suture zone [1, 22].

The collision of the Arabian promontory with Eurasia, the terminal closure and the suturing of the Neotethyan Bitlis Ocean lasted diachronously in the time interval between late Middle Miocene in the east and Late Pliocene-Quaternary in the west [1, 24]. The late Middle Miocene terminal suturing of Arabia with Anatolia along the Bitlis-Zagros Suture Zone and the N-S directed compression made it impossible for the northward motion of Arabian Plate with respect to African Plate until the Early Pliocene time [23, 25–27]. As a result, in the time interval between late Middle Miocene and Early Pliocene, the eastern part of Anatolia has experienced a long-lasting intracontinental convergence [28] that resulted in crustal thickening and uplift, up to 2 km [29], of the intervening Anatolian-Iranian plateau (including the uplift of Cyprus) as analogues to the Tibetan Plateau [30]. The uplift of Cyprus has been attributed to the effects of collision and underthrusting of the Eratosthenes Seamount [e.g. 31–35 and references therein]. This time also corresponds to the generation of many compressional structures, such as east-west trending thrust-to-reverse faults and associated ramp basins, and similarly trending folds, together with many regional unconformities [36–38]. The agreement between the timing of escape tectonics in Anatolia and the commencement of

seafloor spreading in the southern Red Sea and in the eastern Gulf of Aden indicate that the active tectonics of Turkey and the neighbouring regions are the result of Red Sea opening and northward differential relative motions of the African and Arabian plates [23].

Following the demise of intracontinental collision across the Bitlis–Zagros Suture Zone, the earlier compressional–contractional tectonic regime in eastern Anatolia was replaced by a new compressional–extensional tectonic regime (tectonic escape/extrusion tectonics) by the early Early Pliocene. This has resulted in the generation of intracontinental transform fault, namely the North Anatolian Fault Zone. The EAFZ is younger than the NAFZ and did probably form in the Late Pliocene (e.g. [39]). Consequently, the intervening Anatolian wedge began to move westward on the oceanic lithosphere of the African Plate. However, the intracontinental convergence in the Great Caucasus and the Transcaucasus still continues as evidenced by the high seismicity of thrusting in origin (e.g. 7 December 1988, Spitak earthquake in Armenia, and 29 April 1991, Rachat–Dzhava earthquake in Georgia: [40–43]). The seismicity of the Caucasus is much weaker than for Turkey and only supports a very low convergence rate [e.g. 44, 45]. The generation of NAFZ and EAFZ together with the westward movement of Anatolian Plate allowed the Arabian Plate to move northward faster than the African Plate [6, 13, 46, 47].

Present-day kinematic studies show that the Arabian Plate is moving in a N–NW direction at a rate of 25 mm year⁻¹ [6, 13, 46–48] while the African Plate is also moving to the north but at a rate of only 10 mm year⁻¹ [13, 47]. The left lateral motion along the Dead Sea Fault Zone accommodates the differential motion between the African and Arabian plates. However, the rates from GPS contradict the plausible values for the rates on geological time scales. For example, the DSFZ has a slip rate no higher than ~7 mm year⁻¹ [4]. These rate discrepancies appear to be caused because the GPS solutions have used a global plate motion model, which overestimates the relative motion between Arabia and Eurasia [45].

Within the plate boundary network of eastern Mediterranean–Arabian region, the Dead Sea Fault Zone links seafloor spreading in the Red Sea with the northern boundary of the Arabian Plate, influencing the tectonics of the Cyprean arc, possibly since Neogene times. This outlines the importance of the DSFZ for the active tectonics of Turkey.

The formation of the North Anatolian and East Anatolian fault zones, and the consequent westward escape of the Anatolian Plate along its boundary structures has resulted in the generation of four distinct neotectonic provinces in Turkey: (1) East Anatolian Contractional Province, (2) North Anatolian Province, (3) Central Anatolian ‘Ova’ Province and (4) West Anatolian Extensional Province [2].

In the following sections, the characteristics of each province and the major tectonic features that govern the neotectonic characteristics of Turkey and the surrounding regions will be summarized.

3. Major Structures

3.1. North Anatolian Fault Zone (NAFZ)

The North Anatolian Fault Zone is one of the best-known strike-slip faults in the world because of its remarkable seismic activity, extremely well developed surface expression and importance for the tectonics of eastern Mediterranean region [2, 49–55]. The fault zone is a close analogue to the San Andreas Fault System in California [50, 56]. To the east, the NAFZ forms a typical triple-junction and joins with the sinistral East Anatolian Fault Zone (EAFZ) at Karliova (*figure 1*).

The NAFZ is an approximately 1500 km-long, broad arc-shaped, dextral strike-slip fault system that extends from eastern Turkey in the east to Greece in the west (*figure 1*). It is predominantly a single zone of a few hundred metres to 40 km wide. Along much of its length, this fault zone consists of a few shorter subparallel fault strands that sometimes display an anastomosing pattern. This transform fault zone forms the part of the boundary between the Eurasian Plate to the north and Anatolian Plate to the south (*figure 1*), being subparallel to the Black Sea coast. This fault zone is also characterized by several second order faults that splay from it into the Anatolian Plate.

The NAFZ starts around Karliova in the east and it runs NW to Vezirköprü where it makes a left bend and continues westward. Around Kargı, it makes another left bend and then runs in a SW direction. The NAFZ does not terminate at the Karliova triple junction but, continues towards SE [57]. The triple junction has migrated westward and so strike-slip faulting occurred east of Karliova before the triple junction migrated to its present position [e.g. 39]. This section has ruptured during two successive earthquakes in 19 and 20 August 1966 ($M = 6.8$ and $M = 6.2$, respectively: [58–60]).

Just east of the Sea of Marmara around Dokurcun, the NAFZ splays into two major strands (*figure 1*): (1) The northern strand that traverses in part the Sea of Marmara and constitutes the most active section of the NAFZ. This includes the segment that slipped in the 17 August 1999 earthquake. (2) The southern strand bounds the southern margin of Sea of Marmara to the east, then bends southward and runs in SW direction into the Aegean Sea.

Several depressions are aligned along the NAFZ and its major splays. Most of these basins form as: (1) pull-apart basins, where there is an over-step along the fault trace (e.g. Niksar basin: [61–66]; Taşova–Erbaa basin: [66]; Erzincan basin: [61, 67]; Adapazarı basin: [68]); (2) fault-wedge basins (e.g. Suşehri: [69]; Gölova basin: [70]; Vezirköprü basin:

[71]); (3) complex pull-apart basins, bounded by an active strike-slip along one margin and a thrust fault along the other (e.g. Geyve basin: [72]); (4) composite pull-aparts, formed by coalescence of smaller pull-apart basins (e.g. Merzifon-Suluova basin: [73]; Erzincan basin: [74–76]); and (5) negative flower structure, bounded by strike-slip faults which show considerable amount of extension (e.g. Kazova basin along the Almus Fault Zone: [77]). These basins are important features since they contain valuable information on the age and evolution of the North Anatolian Fault Zone. The stratigraphy and structure of these basins have been the subject of many scientific studies [e.g. 62, 65, 66, 69–74, 78–87].

The age and cause of dextral motion along NAFZ is controversial and there are basically three different views: (1) The right-lateral motion commenced by the Middle Miocene and it is the result of the westward motion of Anatolia away from the collision zone in eastern Turkey when Arabian and Eurasian plates collided [9, 54, 88]. (2) Others claimed that the NAFZ did not initiate until the latest Miocene or Early Pliocene [66, 69–77, 83, 84, 89–96]. (3) There are also claims that the NAFZ was initiated in the eastern Anatolia during the Late Miocene and propagated westwards reaching the Sea of Marmara region during the Pliocene [3, 54, 98–106]. (4) More recently, it is speculated that the initiation of the NAFZ is ~16 Ma or older in the east but less than 3 Ma in the west [107].

There was no evidence that the NAFZ became active in the late Middle Miocene – it is just a prediction from a Şengör's model [54, 88]. It is also untenable that the NAFZ is as young as 3 Ma because it has too much slip to have developed since then given its known slip rate. However, there is now a lot of evidence that NAFZ formed in the earliest Pliocene (~5 Ma) as suggested, for the first time, by Barka and Kadinsky-Cade [93].

Geological works along NAFZ estimate a total offset ranging from 85 ± 5 km to 20–25 km [2, 3, 20, 54, 62, 66, 69, 70, 72, 80, 83, 91, 92, 95, 96, 103–106, 108, 109]. The analysis of geological data suggests that the rate of motion on the NAFZ is about 5–10 mm year⁻¹ [3], or 17 ± 2 mm year⁻¹ [4], while the plate motions and seismological data suggest rates of 30–40 mm year⁻¹ [110]. This discrepancy arises from the exaggerated slip rate by treating the intense seismicity on the NAFZ during 1939–1967 as typical of all time. On the other hand, recent GPS data indicate present-day rates of about 15–25 mm year⁻¹ [6, 13, 111, 112]. The extrapolation of recent rates to Early Pliocene yields a total displacement of 75–125 km, which is in close agreement with the estimate of 85 ± 5 km [4, 20, 66, 109].

During the past 60 years, NAFZ has produced earthquakes along different sections in a system manner that is atypical of long faults. Beginning with 1939 Erzincan earthquake ($M = 7.9$ to 8.0), which produced about 350 km of ground rupture, the NAFZ ruptured by nine moderate to large earthquakes ($M > 6.7$), and formed more than 1000 km surface rupture along the fault. Most of the earthquakes occurred

sequentially in a westward progression. These include 26 December 1939 Erzincan ($M = 7.9$ to 8.0), 20 December 1942 Erbaa-Niksar ($M = 7.1$), 26 November 1943 Tosya ($M = 7.6$), 1 February 1944 Bolu–Gerde ($M = 7.3$), 26 May 1957 Abant ($M = 7.0$), 22 July 1967 Mudurnu valley ($M = 7.1$), 13 March 1992 Erzincan ($M = 6.8$), 17 August 1999 Kocaeli ($M = 7.4$), and 12 November 1999 Düzce earthquakes [9, 49, 51, 53, 66, 69, 70, 72, 89, 95, 113–147].

The analysis and distribution of historical earthquakes reveal that among the two westernmost branches of the NAFZ, it is the northern strand that is the most active one and has accommodated more large earthquakes. In addition, Stein and others [148] showed that preceding shocks triggered earthquakes along the NAFZ. Following the 17 August 1999 Kocaeli earthquake, stress was transferred to the nearby fault segments. To the east, the Düzce Fault ruptured during an earthquake in 12 November 1999 [138, 140–145, 149]. To the west, the stress was possibly accumulated on the branches of the North Anatolian Fault Zone in the Marmara region, and there are claims that these faults are close to failure [150, 151]. Apart from the stress transformed during the Kocaeli earthquake, the Sea of Marmara to the south of İstanbul is a region where the strain has been aseismically accumulating since the last earthquake in 1719 [152, 153]. The close proximity of these faults to İstanbul, a major city with more than 10 million inhabitants, makes it even more important.

The characteristics of the NAFZ in the Marmara region became the topic of intense research since the two earthquakes in 1999 [101, 102, 154, 155]. Different models have been proposed for the origin of Sea of Marmara to account for the deformation and dynamics of the strands of the NAFZ and to reveal the origin and evolution of Sea of Marmara (e.g. [3, 4, 54, 93, 97, 98, 100–106, 144, 156–164]). However, there is still no consensus on the nature and length of faults in the Sea of Marmara.

The section of the NAFZ on land is well known and mapped because of the extremely well developed surface expression and geological features. Because of the lack of detailed deep seismic and the bathymetry of the Sea of Marmara, our knowledge about the geometry of the NAFZ in the Sea of Marmara is limited. But, recent seismic reflection studies in the region bring new light on the geology and structure of the Sea of Marmara [101, 102, 154]. The marine seismic reflection profiles reveal the detailed structure and active faulting across the Sea of Marmara [66, 101, 102, 154, 159, 160]. The Sea of Marmara comprises several deep marine asymmetric strike-slip basins (e.g., the Çınarcık, Central Marmara, Tekirdağ basins), separated by NE-trending submarine ridges that rise several hundreds of metres above the seafloor. The basins consist of Plio-Quaternary sediments reaching over 3 km and constitute part of the Sea of Marmara. There are two distinct, steep, continuous bathymetric features (submarine escarpments) that bound the Sea of Marmara, both in the north and in the south, and mark the

location of major active faults [102]. These structures are named as the North and South Boundary Faults [102] after Wong et al. [160]. The Northern Boundary Fault enters the Sea of Marmara through the axis of İzmit Bay (the İzmit Fault) in the east and emerges in Thrace in the west, forming the Ganos Fault [96, 103–106, 164]. The fault then bounds the northern margin of Gallipoli Peninsula (Dardanelles) and extends into the Aegean Sea. The extension of the fault zone to the west in the Aegean Sea bounds the Northern Aegean Trough [3, 110, 165–167]. The section within the Sea of Marmara crosscuts the Central Marmara Basin (the Central Marmara Fault of Okay et al. [102]) and bounds the southern margin of Thrace Basin before it emerges on land. The Southern Boundary Fault runs in an E–W direction and bounds the southern margin of İzmit Bay (known as Gölcük and Yalova segments). The NAFZ in the Sea of Marmara possesses a more complex structure than is summarized here, and readers are referred to a paper by Okay and others [102] for the most recent detailed information.

The Marmara region also forms a transition zone between the area of pure strike-slip deformation, where the Anatolian Plate is displaced westward in the north and the western Anatolian extensional province with diffuse N–S extension [2]. The local GPS network around the Sea of Marmara indicates that the Anatolian Plate is moving westward at a rate of about 20 mm year⁻¹ [5, 6, 47, 168–170].

3.2. East Anatolian Fault Zone (EAFZ)

The East Anatolian Fault Zone is a 550 km-long, approximately northeast-trending, sinistral strike-slip fault zone (*figure 1*) that comprises a series of faults arranged parallel, subparallel or obliquely to the general trend [2, 4, 22, 23, 90, 110, 171–181]. It was first described by Allen [121]. The fault zone is a transform fault forming parts of boundaries between the Anatolian and the Eurasian plates and, between the Arabian and African plates. It is considered as a conjugate structure to the NAFZ.

The EAFZ extends from Karlıova in the northeast to Kahramanmaraş area in the southwest, where it meets and forms triple junctions with the NAFZ and the DSFZ, respectively (*figure 1*) [2, 9, 39, 90, 172, 176, 178–185].

The EAFZ consists of some pure strike-slip faults oriented parallel to the plate motion, which behave as transform faults, and other segments where the faulting is oblique to the plate motion. These ‘stepovers’ also contain strike-slip faults but the geometry requires distributed shortening in their surroundings. On the other hand, Muehlberger and Gordon [176] suggested that the EAFZ is not moving as a single entity but instead is moving in several discrete segments, each with a different amount of slip, and that it comprises, from the deformational standpoint, two segments: (1) those are involved in N–S compression and act as restraining bends; and (2) almost linear strike-slip faults with differing styles.

The left-lateral slip along the fault zone contributes to the westward extrusion of Anatolia. The structure of the fault zone is complicated with several pull-apart basins (e.g. Gölbaşı basin [39], Hazar Gölü [23, 172, 174, 175]), conjugate fractures, folding and considerable thrust component [22, 90, 110, 171, 176, 178, 186–188].

The age of the East Anatolian Fault Zone is highly debated and proposed ages fall into four categories: (1) It is placed in the Late Miocene–Early Pliocene [2, 22, 23, 90, 178, 188]; (2) It is Late Pliocene [179–181]; (3) The EAFZ began to form 1.8 Ma [189]; and (4) the fault zone became active around 3 Ma when Malatya-Ovacık fault zone was abandoned [190]. The argument by Yürür and Chorowicz [189] is based on the assumption that the volcanism south of Kahramanmaraş is Quaternary and started at 1.8 Ma, and that it is the same as the volcanism in the Karasu Valley. They argued that this volcanism is extension-related, and so requires the present geometry of strike-slip faulting. As a result, they argued the faulting formed at 1.8 Ma. But, it is disputed by Arger and others [191] who have dated the same volcanism to be Miocene (19–15 Ma) and suggested that there has no demonstrable relationship to either extension or strike-slip faulting.

The total offset along the fault zone is still debated. The offset of Euphrates river channel and the pre-Pliocene rock units suggest a total left-lateral displacement of 3.5–13 km and 15–27 km, respectively [23, 90, 171, 174, 175, 179–181, 182]. However, it has to be considered whether the modern river gorge is younger than the 3 Ma age of the faulting. On the other hand, based on the similar reasoning a 35–40 km total offset was also proposed [39]. The rate of slip along the EAFZ is estimated, based on geological data, as 6–10 mm year⁻¹, whereas recent GPS data reveals slip rates of 11 ± 2 mm year⁻¹ [6], which is essentially the same as the rate of 13 ± 1 mm year⁻¹ that Westaway [4] suggested. Taymaz and others [110] estimated slip rates of 25–35 mm year⁻¹ for the fault zone.

Unlike the NAFZ, very little of the EAFZ has ruptured in any earthquake that has been studied in detail. Most of the EAFZ has been traced using satellite imagery and geomorphological observations indicative of strike-slip faulting [52, 183, 192] where earthquakes are associated with sinistral fault segments [90, 193]. The fault zone has ruptured during many destructive earthquakes, such as 22 May 1971 Bingöl ($M = 6.8$) and 1986 Sürgü ($M = 6.0$) earthquakes during the 20th Century [90, 110, 177, 182, 194, 195].

The EAFZ and the DSFZ meet at a triple junction between the Arabian, African and Anatolian plates near Kahramanmaraş (*figure 1*) [2, 4, 39, 52, 90, 172, 176, 178–181, 183–185, 196]. Although the nature, age and total offset of the DSFZ are relatively well established [197–201] (see below), the nature and geometry of the fault zone as it approaches to the triple junction is still debated. It is also claimed that these fault zones have no connection and that EAFZ continues in southwest direction from Karlıova through Osmaniye,

Yumurtalık, and Gulf of İskenderun, to Cyprus [4, 23, 39, 110, 191, 202–204]. On the other hand, others claim that faulting runs through these places but it is not part of the EAFZ – it is the boundary between the Anatolian and African plates, which meets the EAFZ farther east at the triple junction. The continuation of the EAFZ to the SW of Kahramanmaraş triple junction is represented by similarly trending left-lateral strike slip faults. They constitute Karataş–Osmaniye and Yumurtalık fault zones that bound the northwestern margin of the Gulf of İskenderun. This section of the fault has also ruptured during many earthquakes, including 1945 and 1952 Adana–Misis ($M = 5.7$ and $M = 5.3$), 1979 Adana–Kozan ($M = 5.1$), 1986 Gaziantep ($M = 5.0$), 1989 İskenderun ($M = 4.9$), 1991 Kadirli–Adana ($M = 5.2$), 1994 Adana–Ceyhan ($M = 5.0$), 1994 Adana–İskenderun ($M = 4.$), 27 June 1998 Adana–Ceyhan ($M = 6.2$); 17 January 2001 Osmaniye ($M = 4.9$) earthquakes [e.g. 202, 203, 205].

3.3. Dead Sea Fault Zone (DSFZ)

Dead Sea Transform Fault Zone is a 1000 km-long, approximately N–S trending, sinistral intraplate strike-slip fault zone. Its internal structure is dominated by left-stepping *en échelon* strike-slip faults separated by pull-apart basins or rhomb grabens (e.g. Gharb basin, Hula basin, Dead Sea rift and Gulf of Elat) filled with Neogene–Quaternary sediments [197–201, 206–225 and references therein]. The pull-apart basins alternate with structural saddles where compressional structures are often present [222]. The Dead Sea Fault Zone is also accompanied with regional uplift (up to 1 km in places; [222]) and, intense and widespread igneous activity from the Gulf of Aqaba to the Amik basin (Hatay) [e.g. 226, 227]. It extends from the Red Sea in the south to the East Anatolian Fault Zone to the north. From the tectonic point of view, the DSFZ joins the divergent plate boundary along the Red Sea with the zone of plate convergence along the Alpine-Himalayan belt in southern Turkey [23].

In terms of plate tectonics, the DSFZ is considered to be plate boundary of transform type, separating the African Plate to the west and Arabian Plate to the east [1, 22, 184, 190, 209, 228, 229]. The Arabian Plate is moving northward faster than the African Plate [6, 13, 46–48]. This differential movement between the plates is taken up by DSFZ.

The age of the DSFZ has been the subject of debate for many years and proposals fall into four major categories: (1) the movement along the fault zone commenced by the Middle Miocene [211]. (2) The fault zone was activated during the Late Miocene, following the opening of Gulf of Suez when the motion of Arabia relative to Africa began [230, 231]. (3) The fault motion began, based on the age of the dikes affected by the segments of the fault zone, later than at 20 Ma [207, 232]. (4) The DSFZ originated during the break-away of Arabia from Africa at around 18 Ma (Early Miocene: [23, 222]. The assumptions (1), (3) and (4) are all essen-

tially the same because people are just assigning different numerical ages to equivalent interpretations, when the actual age is not tightly constrained. Whereas the assumption (2) seems not plausible because given slip rate of the DSFZ, it has slipped way too far for it to possibly be this young.

The earlier workers suggested that the offset along the DSFZ is about 110 km for the southern section between Lebanon and the Gulf of Aqaba [198, 199, 206, 233, 234] and 70–80 km for the northern section between Syria and southeastern Turkey [233]. However, recently it is claimed that the fault zone acquired only 10–20 km of total slip [235]. On the other hand, some argued that the movement along the DSFZ has taken place in two separate stages [206, 236]: (1) a 60–65 km offset during 25–14 Ma and (2) 40–45 km offset during the last 4.5 Ma. The continuing movement along the fault zone is proven by the displacement of Upper Quaternary sediments [237, 238] and seismic activity [200, 201, 239].

3.4. Aegean Arc

Convergence between the African and Anatolian plates in the Eastern Mediterranean takes place by subduction along the Aegean and Cyprean arcs [e.g. 192, 240–244]: the African Plate is descending beneath the Anatolian Plate in a N–NE direction. The geometry and the nature of these arcs, particularly that of the Cyprean Arc, is the matter of ongoing debate.

The Aegean arc system plays an important role in the geodynamical evolution of the Aegean region. The nature and structure of trench is variable across the Aegean Arc. The western extension of arc is marked by Ionian trench along which the convergence between the Aegean lithosphere and the Ionian basin is taken up. On the other hand, the eastern part of the Aegean arc acts rather as transform fault [245]. Several trenches (e.g., the Pliny, SE Cretan, and the Strabo trenches) have been distinguished along the eastern parts of the Aegean Arc [246].

It is suggested that the initiation of subduction along the Aegean Arc has taken places approximately 13 Ma ago [247]. However, others claimed that the age of Aegean subduction zone is at least 26 Ma [242]. In some other studies, younger ages (around 5 Ma or somewhere between 5–10 Ma) have been assigned for the Mediterranean subduction [192, 248]. The migration of the trench system to south–southwest (subduction roll-back processes) resulted in extensional regime in the overriding Aegean plate (back-arc region) that subsequently led the formation of the present-day Aegean Sea [249]. It is now a conventionally argued that the effects of roll-back processes of the Aegean subduction zone control the Late Neogene to Recent geodynamic evolution of the southern Aegean region [242, 243, 247, 249–257]. Meulenkamp and others [242] argued that roll-back processes started in about 12–11 Ma (latest Serravallian to earliest Tortonian time), whereas Le Pichon and others [170] suggested that

the collision between the African promontory and the central part of the Aegean arc commenced by the Pliocene. The retreating nature and high dip angle of the slab being subducted is also supported by the seismic tomographic studies [242, 258, 259].

3.5. Cyprean Arc

The Cyprean Arc is considered the presently active plate boundary, which accommodates the convergence between the African plate to the south and the Anatolian Plate to the north in the eastern Mediterranean [9, 30, 52, 260–262] (*figure 1*). West of Cyprus, northeastward subduction of the eastern Mediterranean oceanic crust has been proposed on the basis of earthquake data and the assumption of the continuation of the plate boundary from the Aegean arcs [10, 13, 32, 88, 261–266]. South of Cyprus, the northward subduction is influenced by collision of Eratosthenes Seamount [24, 34, 228, 267, 268]. In contrast, there is no subduction to the east of Cyprus [24, 52, 193, 219, 269–274], where strike-slip deformation dominates.

Although western section of the Cyprean Arc is established, the eastern prolongation of the Cyprean Arc toward the Syrian coast, where deformation and mode of convergence at the plate boundary are influenced by the differential motion among the African, Arabian and Anatolian plates, [4, 6, 13] is the most controversial and least known part of the arc. There is no arc-trench system in this area. The subduction stops at the eastern limit of oceanic lithosphere, which is south of Cyprus. The views fall into four major categories: (1) there is no well-defined boundary in this area [275]; (2) the plate boundary occurs as two separate segments north and south of Cyprus [e.g. 247, 276, 277]; (3) the main area of active convergence, based on seismicity, extends from Cyprus to the İskenderun Bay toward the Kahramanmaraş triple junction where the East Anatolian Fault Zone and the Dead Sea Fault Zone meets [9, 10, 39, 52, 54, 215, 228]; (4) the deformation in the easternmost Cyprean Arc is partitioned along strike-slip fault systems forming sets of positive flower structures, distributed over a wide zone, rather than forming a sharp plate boundary between African and Anatolian plates [262]. There the Anatolian–African boundary is marked by the Kyrenia–Misis–Andırın fold-thrust fault zone, a positive flower structure dominated by sinistral strike-slip motion with a considerable amount of thrust component [271], and the sinistral East Anatolian Fault Zone. It is also suggested that to the east of Cyprus on land, the northward motion of the Arabian Plate relative to African Plate was prohibited by the late Middle Miocene terminal suturing of Arabia with Anatolia until late Early Pliocene [23]. The key distinction between models is that dray the Anatolian–Africa plate boundary running ENE from SE Cyprus and coming ashore somewhere around Antakya and interpretations that have it running NE from NE Cyprus and coming ashore near Karataş.

Several papers have been published on the seismicity of the Cyprean area [278–284 and references therein] and they all documented that strong ($M = 6.0$ or larger) earthquakes occurred during the instrumental period. The research on the geometry, nature and structure of the Aegean and Cyprean arcs is still continuing and several papers have recently been published [e.g. 285–289].

3.6. Bitlis Suture

During the Middle Miocene to early Late Miocene (Langhian-Serravalian), Arabian and Eurasian plates collided along the Bitlis–Zagros Suture zone [1]. This has resulted in the uplift of mountains along the suture, and the quite shallow marine environments were converted to molasse basins. The Bitlis Suture is a complex continent-continent and continent-ocean collisional boundary that lies north of fold-and-thrust belt of the Arabian platform and extends from southeastern Turkey to the Zagros mountains in Iran [1, 26, 27, 88, 174, 175, 290–294]. Southern Anatolian orogenic belt, an assemblage of different tectonic units made up of Upper Cretaceous–Middle Eocene volcano-sedimentary association marks the suture zone. There, three tectonic zones separated by major thrusts have been identified: (1) Arabian Platform, (2) Zone of imbrication and (3) Nappe region [26, 27]. While Jura-type border folds represent the former, the latter two form the main orogenic zone.

The Arabian Platform consists of a Lower Palaeozoic–Miocene autochthonous sedimentary succession. The ophiolitic nappes were emplaced on the platform during Late Cretaceous–Eocene time [27 and references therein]. The imbricated sequence is made up of numerous thrust slices, each of which retains a continuous sequence that is usually related to its stratigraphy prior to thrusting. They suggest an oceanic realm (Southern Neotethys or Bitlis Ocean) that existed during Late Cretaceous–Middle Eocene [26, 27 and references therein]. The uppermost tectonic units of the Southeast Anatolian orogen is represented by an ophiolitic lower unit (Berit metaophiolite and Yüksekova ophiolite) and an upper unit of metamorphics (Bitlis, Pötürge, Malatya and Keban massifs). During Middle Miocene, the uppermost tectonic unit was ruptured that resulted in the formation of a back-arc basin (Maden basin) behind a volanic arc to the south of nappes [27].

Convergence between Arabia and Eurasia produced south-erly transported nappes and their emplacement occurred in three major periods during the Late Cretaceous, late Early Eocene (obduction of ophiolites over Arabian Platform), and Early–Middle Miocene (emplacement of the ophiolites and the tectonically overlying metamorphics over the Arabian Platform).

As a summary, the Bitlis suture closed in the Eocene. This closure was then followed by prolonged convergence that involved distributed shortening all over the place, then the strike-slip fault zones (NAFZ and MOFZ) came into being

at ~5 Ma, then the geometry changed at ~3 Ma when the EAFZ developed.

4. Neotectonic provinces

4.1. East Anatolian Contractual Province

The area to the east of Karlıova triple junction is characterized by a N–S compressional tectonic regime (*figure 1*). Conjugate strike-slip faults of dextral and sinistral character paralleling to North and East Anatolian fault zones are the dominant structural elements of the region. Some of these structures include Ağrı Fault, Bulanık Fault, Çaldıran Fault, Erciş Fault, Horasan Fault, Iğdır Fault, Malazgirt Fault, Süphan Fault, Balıkgözü Fault Zone, Başkale Fault, Çobandede Fault Zone, Dumlu Fault Zone, Hasan Timur Fault Zone, Kavakbaşı Fault, Kağızman Fault Zone, Doğubayazıt Fault Zone, Karayazı Fault, Tutak Fault Zone, Yüksekova–Şemdinli Fault Zone and the Northeast Anatolian Fault Zone (*figure 2*) [2, 22, 80, 90, 91, 93, 171, 174, 175, 179–181, 187, 295–310 and references therein]. Many pull-apart basins have developed along these structures (e.g., Erzurum and Ağrı basins [e.g. 78, 311, 312]). Although the conjugate strike-slip fault system dominate the active tectonics of eastern Anatolia, the E–W trending basins of compressional origin form the most spectacular structures of the region as they indicate the N–S convergence and shortening of the Anatolian plateau [313]. Muş, Lake Van and Pasinler basins form the best examples of ramp basins in the region [e.g. 298, 299, 314].

The faults are seismically active and form the source for many earthquakes. Some of the major earthquakes in the 20th Century are 13 September 1924 Pasinler ($M = 6.8$), 1975 Lice ($M = 6.6$), 24 November 1976 Çaldıran ($M = 7.3$), 30 October 1983 Horasan–Narman ($M = 6.8$), 5 May 1986 ($M = 5.8$) and 6 June 1986 Doğanşehir ($M = 5.6$) earthquakes [52, 110, 183, 195, 295, 296, 300, 301, 315–322].

The Northeastern Anatolian Fault Zone (NEAFZ) is one of the most important structures of Eastern Anatolia. It is an approximately 350 km-long fault zone running from near Erzurum to Caucasus Mountains, including the Borjomi–Kazbeg fault [47], and consists of several segments. Westaway [4] termed it as Erzurum–Tibilis fault zone. It displays a typical left-lateral motion with a subordinate thrust component [80, 306, 310]. GPS measurements suggest slip rates of 8 ± 5 mm year⁻¹ [1], whereas geologic estimates average as 18–25 mm year⁻¹ [306]. Westaway [4] estimated rates of 0.9 mm year⁻¹ from seismic moments and of less than 6 mm year⁻¹ from kinematic considerations.

N–S trending fissures, which have functioned as magma conduits and form parallel with the orientation of N–S shortening, are the other structural elements of the Eastern Anatolia. These fissures have localized the widespread Plio-Quaternary volcanic activity of this region, which includes

extinct volcanoes such as Nemrut, Süphan, Ağrı, and Kösedag [2, 22, 29, 189, 191, 204, 323–329].

The present-day configuration of these structures are in close agreement with regional stress field resulting from the approximately N–S convergence between the Arabian and Eurasian plates. The overall shortening in roughly N–S direction is estimated as 10 ± 2 mm year⁻¹ [6]. This GPS estimate was reworked by Mitchell and Westaway [45], who discussed how to reconcile it with geological evidence.

4.2. North Anatolian Province

The North Anatolian Province represents the area to the north of NAFZ (*figure 1*) and is characterized by a number of strike-slip faults and faults with strong E–W thrust component (*figure 1*). These structures are interpreted as the indication of a possible incipient formation of a new strand to the NAFZ enabling the western Pontides to be pushed onto the oceanic lithosphere of the Black Sea [2]. The slip rates (e.g. Bartın fault) in the region are less than 5 mm year⁻¹ [47]. To the east, the Northeast Anatolian Fault forms a boundary between Eastern Anatolia and Northern Anatolia.

Seismicity of the southern margin of the Black Sea bordering Pontides is limited. The northern margin of the Black Sea has been identified as the site of active thrusting, and the 3 September 1968 Bartın earthquake ($M = 6.8$) has demonstrated that the thrust faults can produce destructive earthquakes [2, 183, 330, 331].

4.3. Central Anatolian ‘Ova’ Province

The Central Anatolian Wedge (*figure 1*) is a region where discrete pieces of continental lithosphere deformed internally and produced a large bulk strain that thus has resulted in the generation of new structures or reactivation of old structures. The region is under approximately N–S and NNE–SSW shortening, related to the collisional processes between Anatolian and African plates along the Cyprean arc, while it is rotating anticlockwise [2, 6, 11, 47, 54, 65, 77, 332–339]. In this frame, the eastern parts of the Anatolian Plate are deformed by a number of second-order faults. The area is also characterized by extensional basins called ‘ovas’ [2], bounded by oblique-slip faults. These structures are mostly dextral and sinistral strike-slip faults such as Akpınar Fault, Delice Fault, Kangal Fault, Niğde Fault, Salanda Fault, Almus Fault Zone, Laçın Fault Zone, Merzifon Fault Zone, Malatya–Ovacık Fault Zone, Tuzgözü Fault Zone, Yıldızeli Fault Zone, Central Anatolian Fault Zone, Taşova–Çorum Fault Zone, Yağmurlu–Ezinepazarı Fault Zone, and Yakapınar–Göksun Fault Zone.

Many of these faults zones – the Almus, Yağmurlu–Ezinepazarı, Taşova–Çorum, Göksun–Yazyurdu, Malatya–Ovacık, and Central Anatolian Fault Zone (*figure 3*) [69, 70, 77, 94, 190, 334, 340–351] – splay from the NAFZ, run in SW direction across the Anatolian Plate for hundreds of kilo-

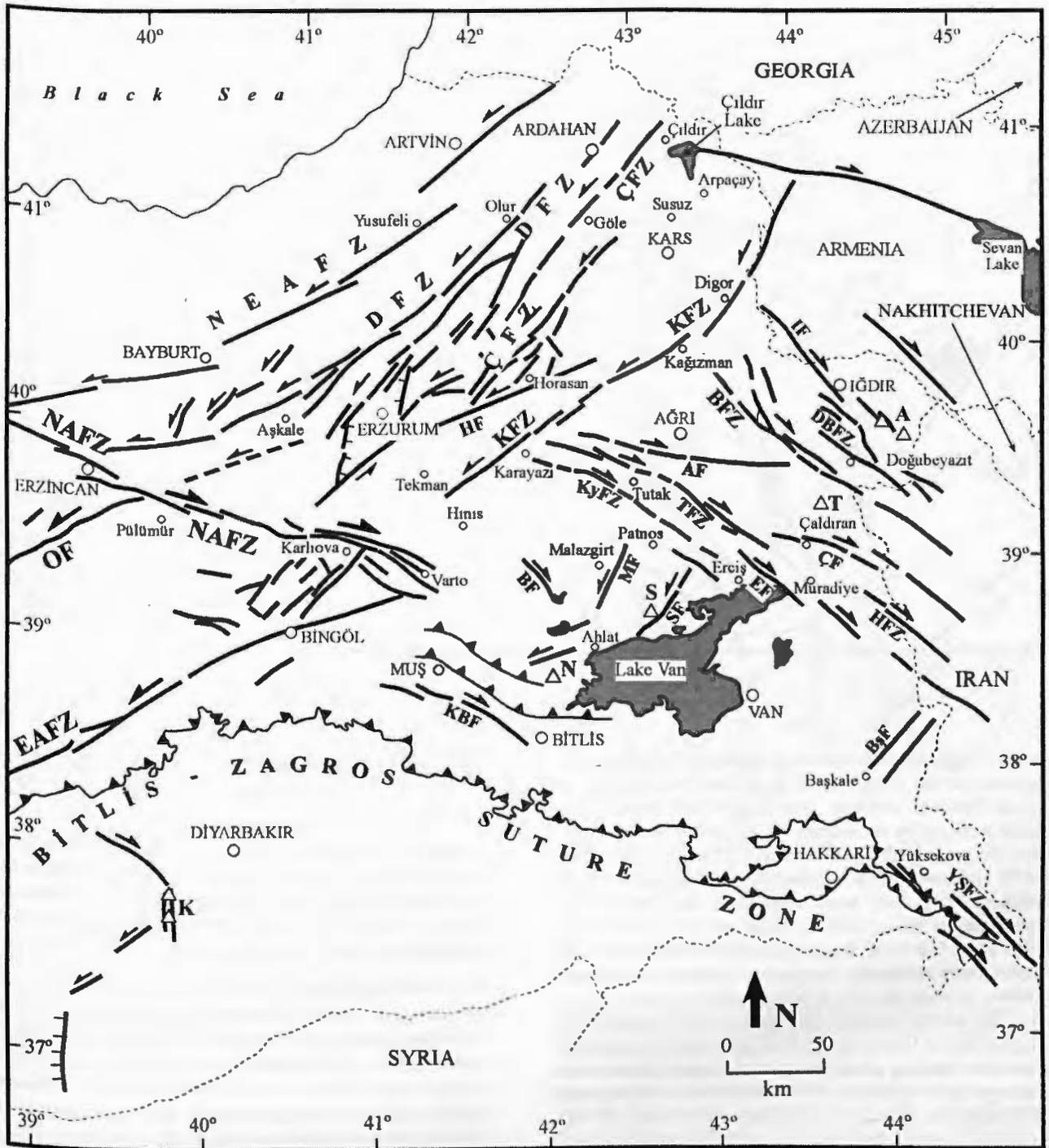


Figure 2. Simplified map showing major structural elements of Eastern Anatolia (modified from Şaroğlu et al. [181], Koçyiğit et al. this issue). Heavy lines with half arrows are strike-slip faults with arrows showing relative movement sense. Heavy lines with filled triangles shows major fold and thrust belt (Bitlis-Zagros Suture Zone) and the Muş Thrust Faults: small triangles indicate direction of vergence. A - Ağrı Dağı, K - Karacadağ, N - Nemrut Dağı, S - Süphan Dağı, T - Tendürek Dağı, AF - Ağrı Fault, BF - Bulank Fault, ÇF - Çaldıran Fault, EF - Erciş Fault, HF - Horasan Fault, IF - Iğdır Fault, MF - Malazgirt Fault, OF - Ovacık Fault, SF - Süphan Fault, BFZ - Balıkgözü Fault Zone, BŞF - Başkale Fault, ÇFZ - Çobandede Fault Zone, DFZ - Dumlulu Fault Zone, HFZ - Hasan Timur Fault Zone, KBF - Kavakbaşı Fault, KFZ - Kağızman Fault Zone, DBFZ - Doğubayazıt Fault Zone, EAFZ - East Anatolian Fault Zone, KyFZ - Karayazı Fault, NAFZ - North Anatolian Fault Zone, TFZ - Tutak Fault Zone, YŞFZ - Yüksekova-Şemdinli Fault Zone, NEAFZ - Northeast Anatolian Fault Zone

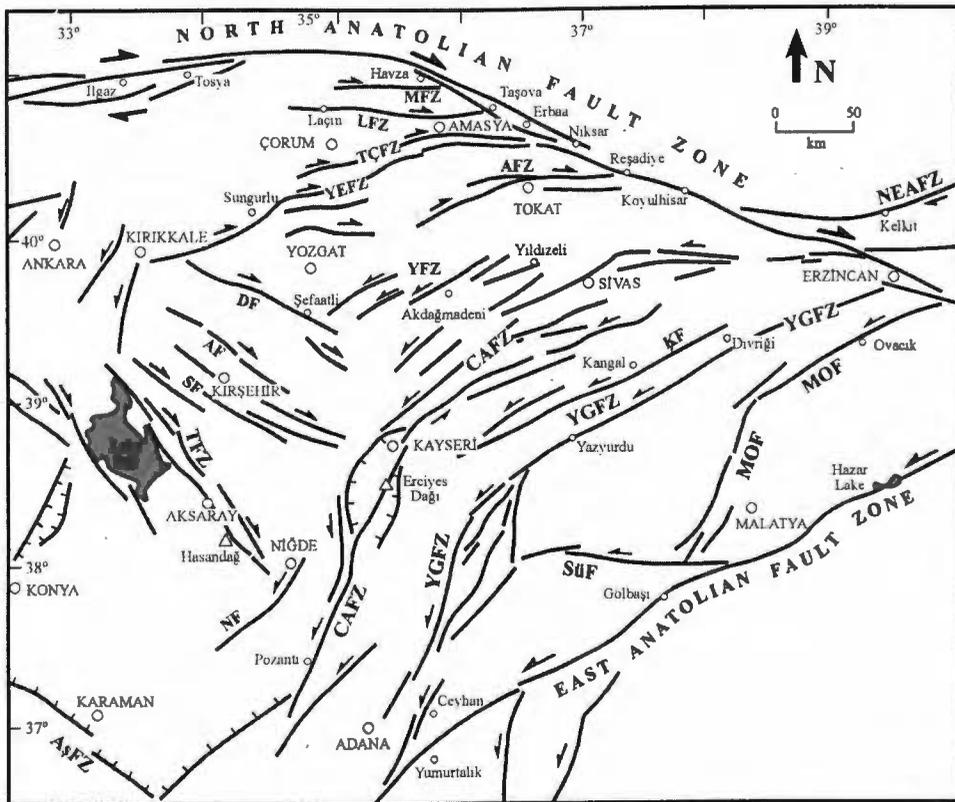


Figure 3. Simplified map showing major structural elements of east Central Anatolia (modified from Koçyiğit and Erol, this issue, Bozkurt and Koçyiğit [77], Şaroğlu et. al [181], Dirik and Gönçüoğlu [346], Bingöl [450]). Heavy lines with half arrows are strike-slip faults with arrows showing relative movement sense. The heavy lines with hachures show normal faults: hachures indicate down-thrown side. AF – Akpınar Fault, DF – Delice Fault, KF – Kargal Fault, NF – Niğde Fault, SF – Salanda Fault, LFZ – Laçın Fault Zone, MFZ – Merzifon Fault Zone, MOFZ – Malatya-Ovacık Fault Zone, TFZ – Tuzgölü Fault Zone, YFZ – Yıldızeli Fault Zone, AŞFZ – Akşehir Fault Zone, CAFZ – Central Anatolian Fault Zone, TÇFZ – Taşova-Çorum Fault Zone, YEFZ – Yağmurlu-Ezinepazarı Fault Zone, YGFZ – Yakapınar-Göksun Fault Zone, NEAFZ – Northeast Anatolian Fault Zone.

metres [77], and display distinct geometries. The present configuration of the NAFZ master strand and its splays form a typical ‘fishbone structure’ (see Şengör and Barka [333]), which is created by the rotation of ‘en échelon’ wedges away from the main NAFZ [77, 350, 351]. They branch off the NAFZ and trend in approximately E–W direction for some distance. Then, they bend southwards and trend in an approximately NE to NNE-direction running into the Anatolian Plate. The E–W trending sections of the splay faults display fairly strike-slip character with some reverse components, whereas the NE- to NNE-trending sections mainly have the normal oblique-slip character (see Bozkurt and Koçyiğit [77]). The thrust nature of the faults is attributed to a decrease in offset along the principle escape faults and to a shortening in the length of its purely strike slip segments [332] while the normal fault character is the result of anticlockwise rotation along the NE- to NNE-trending sections of the splays [77]. Considerable amount of anticlockwise rotation has been documented along the Almus Fault Zone [65]. More, anticlockwise rotations since Late Eocene reached 33° in Central Anatolia [334]. Similarly, anticlockwise rotations in Central Anatolia during the Neogene time were reported in many other recent works [335–339]. It is also suggested that within the wedge-shaped terrane confined between the EAFZ and the NAFZ, the degree of anti-

clockwise rotation during tectonic escape within the last 2–3 Ma has diminished from approximately 25° in the east to approximately 10° towards the southwest [335].

Among the above-mentioned strike-slip faults, the Malatya–Ovacık, Central Anatolian, Tuzgölü and Eskişehir fault zones form the major neotectonic structures in Central Anatolia (figure 3). The brief summary of the characteristics of these fault zones will be given below.

The Malatya–Ovacık Fault Zone (MOFZ) is a 240 km-long, sinistral strike-slip fault zone that splays from the NAFZ near Erzincan. It runs in WSW direction (the Ovacık segment) for ~120 km, then bends into SW direction (the Malatya segment) and runs into the Anatolian Plate (figure 3). This structure is suggested to be active and formed the boundary between the Anatolian and Arabian plates during ~5–3 Ma. It took up 29 km of relative motion between these plates. The MOFZ intersected the NAFZ across the Erzincan basin, which was the site of triple junction (Erzincan triple junction) among the Arabian, Anatolia and Eurasian plates. The MOFZ was abandoned at ~3 Ma when the modern East Anatolian Fault Zone and the eastern segments of the North Anatolian Fault Zone beyond Erzincan developed. The readers are referred to Chorowicz and others [344],

Westaway and Arger [190], Arger et al. [191] and, Westaway and Arger (this volume) for detailed information.

The Central Anatolian Fault Zone (CAFZ) is a 730 km-long sinistral mega shear zone, formed by the reactivation and propagation of an older palaeotectonic structure, namely the 'Ecemiş Corridor' or 'Ecemiş Fault' [352–355] in the Plio-Quaternary times as a result of continued intracontinental convergence between the Arabian and Eurasian plates [347]. The fault zone runs from Erzincan in the northeast to the Eastern Mediterranean Sea (figure 3). It is seismically less active and comprises numerous segments. Total displacements during the palaeotectonic and neotectonic periods are 75 km and 24 km, respectively. It is speculated that although the present-day slip along the CAFZ is only 3 mm year⁻¹, this system form the eastern boundary of the Anatolian Plate instead of the East Anatolian Fault Zone in the future [347]. The Central Anatolian Fault Zone displays typical characteristics of strike-slip faulting and is characterized by the development of variably sized pull-apart basins (e.g., Erciyes, Tuzla gölü, Sultansazlığı pull-part basins) along a sinistral double bend that permitted the emplacement of the Erciyes stratovolcanic complex. The fault zone is also locus of major volcanic activity in the Kayseri region and palaeomagnetic study of young lava flows (1–2 Ma) and palaeomagnetic study of young lava flows (1–2 Ma) reveal anticlockwise rotations by about 10° during the last 1 Ma [335]. However, Westaway [356] claims that as no new quantitative conclusions are reached concerning rates of slip or total amounts of slip, it remains unproven whether there really is a ~700 km-long active left-lateral fault zone with a slip rate of several millimetres per year in this locality, as was claimed by Koçyiğit and Beyhan [347]. On the other hand Koçyiğit and Beyhan [348] provided further evidence for the favour of active fault system.

The Tuzgözü Fault Zone (TFZ) [2, 171], a 200-km-long, northwest-trending dextral strike-slip fault zone, is one of the most prominent structures of Central Anatolia (figure 3). The fault zone bounds the northeastern margin of the Tuzgözü basin. The initiation of movement along the TFZ is Late Cretaceous [349, 357, and references therein], but there are also claims that the fault zone became active during the Miocene [358]. The fault zone is a strike-slip fault with a considerable normal component. The N–S and NE–SW trending distribution of volcanic cones is attributed to the dextral and normal faulting along the Tuzgözü Fault Zone [2, 342, 343, 359–361].

The WNW–ESE trending Eskişehir Fault Zone is a dextral structure with considerable amount of normal component (figures 3 and 4). It extends from Uludağ (Bursa) to Afyon. Our knowledge of the fault zone is limited. This fault has ruptured during the 1956 Eskişehir earthquake (M = 6.5) [183, 362].

The historical and instrumental earthquake records show that the eastern parts of Central Anatolia is seismically less active, when compared with other parts of Anatolia [51, 60, 135, 153, 194, 363, 364]. The region has experienced a num-

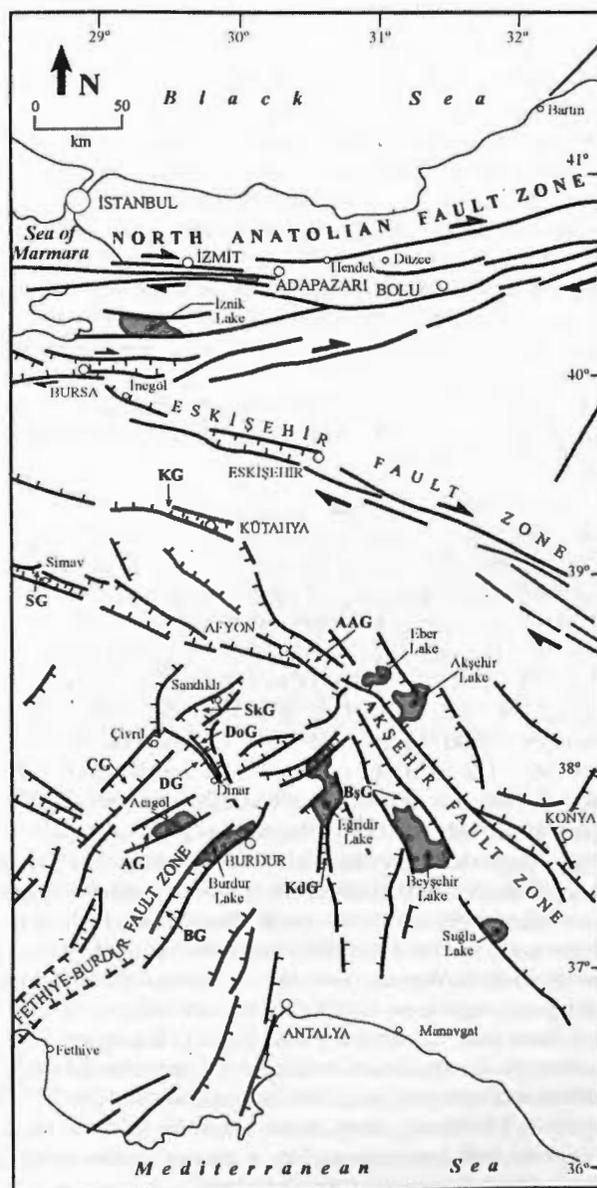


Figure 4. Simplified map showing major structural elements of Isparta Angle and the adjacent areas (modified from Şaroğlu et al. [181], Koçyiğit [369], Koçyiğit et al. [448], Bingöl [450]). Heavy lines with half arrows are strike-slip faults with arrows showing relative movement sense. Heavy lines with hachures show normal faults: hachures indicate down-thrown side. AG – Acıgöl Graben, BG – Burdur Graben, ÇG – Çivril Graben, DG – Dinar Graben, KG – Kütahya Graben, SG – Simav Graben, AAG – Akşehir-Afyon Graben, BŞG – Beyşehir Graben, DoG – Dombayova Graben, KdG – Kovada Graben, SkG – Sandıklı Graben.

ber of historical and instrumental earthquakes, such as the 1717 and 1835 Ecemiş, May 1914 Gemerek (M = 5.6), 1938 Kırşehir (M = 6.8), 21 February 1940 Erciyes (M = 5.3), and

14 August 1996 Mecitözü–Çorum ($M = 5.6$) earthquakes, which occurred along this structure [49, 125, 365–367].

In contrast to its eastern parts, the western parts of the Central Anatolia is dominated by a series of NE–SW- and NW–SE-trending cross-graben and horst structures bounded by active, oblique-slip normal faults with strike-slip components (figure 4) [368–376, and references therein]. This region, which lies at the apex of Isparta Angle [e.g. 268, 377–381, and references therein], form a transitional zone between the rapidly extending western Anatolia and the eastern part of Central Anatolia where strike-slip dominated tectonic regime is prevailing. Isparta Angle is interpreted as the result of interference between SE-vergent Lycian Nappes and SW-vergent Akşehir–Beyşehir Nappes emplaced during polyphase development from Late Cretaceous to latest Miocene [379, 382].

Some of the best examples to these structures include the NW–SE trending Dinar, Beyşehir, and Akşehir–Afyon grabens and NE–SW trending Burdur, Acıgöl, Sandıklı, Çivril and Dombayova grabens and their bounding faults (figure 4). Many earthquakes have originated from these structures, such as 3 October 1914 Burdur (M_0 7.1), 7 August 1925 Dinar ($M = 5.8$), 19 July 1933 Çivril ($M = 5.8$), 12 May 1971 Burdur ($M = 6.2$), 1 October 1995 Dinar ($M = 6.1$), and 15 December 2000 Akşehir ($M = 5.8$) earthquakes [60, 194, 383–392]. The existence of two sets of normal faults indicates that the region is extending biaxially, with both NE–SW and NW–SE components of extension [4]. Barka and others [393] suggested that the NE–SW trending left-lateral Fethiye–Burdur Fault Zone (FBFZ), which is interpreted as the northeastern continuation of the Pliny–Strabo Fault Zone on the land, and the Eskişehir Fault form the major boundary between the Western Anatolian extensional province and the Isparta Angle area. GPS measurements indicate slip rates of 1.5 cm year^{-1} along the FBFZ [6, 47]. The recent GPS studies, the distribution of historical and instrumental earthquakes, and morphological features indicate that the FBFZ is active. However, others claimed that the FBFZ is not a transform fault boundary and the dominant motion is dip-slip (normal) normal, not sinistral [369].

4.4. Western Anatolia

Western Anatolia forms one of the most seismically active and rapidly extending regions in the world [6, 12, 60, 110, 135, 394–399, and references therein]. It is currently experiencing an approximately N–S continental extension at a rate of $30\text{--}40 \text{ mm year}^{-1}$ [13, 170]. It is a part of the ‘Aegean Extensional Province’, a region of distributed extension that covers parts of Greece, Macedonia, Bulgaria and Albania (figure 1).

Approximately E–W trending grabens (e.g. Edremit, Bakırçay, Kütahya, Simav, Gediz, Küçük Menderes, Büyük Menderes, and Gökova grabens) and their basin-bounding active normal faults are the most prominent neotectonic fea-

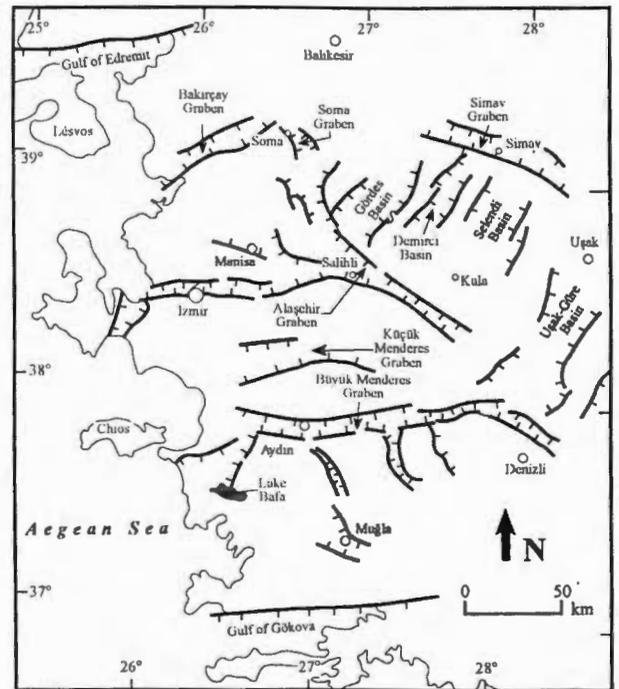


Figure 5. Simplified map showing major structural elements of Western Anatolia (simplified and modified from Bingöl [450], Bozkurt [427], Yılmaz et al. [429] Seyitoğlu [435]). Heavy lines with hachures show normal fault: hachures indicate down-thrown side.

tures of Western Turkey (figures 4 and 5) [e.g. 2, 400–430, and references therein]. Other, less prominent, structural elements of Western Turkey are the NNE-trending basins and their intervening horsts (e.g. Gördes, Demirci, Selendi, and Uşak-Güre basins; figure 5) [e.g. 403, 429, 431–436, and references therein].

The activity of basin bounding faults is shown by numerous historical earthquakes, such as the 22 February 1653 and 20 September 1899 Menderes, 18 November 1919 Soma ($M = 6.9$), 31 March 1928 Torbalı ($M = 6.3$), 23 April 1933 Gökova ($M = 6.5$), 22 September 1939 Dikili-Bergama ($M = 6.5$), 6 October 1942 Edremit Körfezi–Ayvacık ($M = 6.8$), 16 July 1956 Söke–Balat ($M = 7.1$), 2 March 1965 Salihli ($M = 5.8$), 13 June 1965 Honaz ($M = 5.3$), 23 March 1969 Demirci ($M = 5.9$), 28 March 1969 Akşehir ($M = 6.5$), 28 March 1970 Gediz ($M = 7.2$), and 11 October 1986 Çubukdağ ($M = 5.5$) earthquakes [e.g. 60, 125, 194, 316, 395, 397, 399, 408, 437, and references therein].

The cause and origin of crustal extension in the Aegean has long been debated, and proposals fall into four different models: (1) ‘Tectonic escape’ model: the westward extrusion of the Anatolian block along its boundary structures since the late Serravalian (12 Ma) [2, 10, 54, 403, 421]. (2) ‘Back-arc spreading’ model: back-arc extension caused by the south–southwestward migration of the Aegean Trench

system [192, 242, 247]. However, there is no consensus on the inception date for the subduction roll-back process and proposals range between 60 Ma and 5 Ma [192, 242, 247, 249, 438]. (3) 'Orogenic collapse' model: the extension is induced by the spreading and thinning of over-thickened crust following the latest Palaeocene collision across Neotethys during the latest Oligocene–Early Miocene [411, 412]. (4) 'Episodic': a two-stage graben model that involves a Miocene–Early Pliocene first stage (orogenic collapse), and a Plio-Quaternary second phase (westward escape of the Anatolian block) of N–S extension [425].

The age of the grabens is also controversial and proposals fall into three major categories: (1) The grabens began to form during the Tortonian [1, 2, 403]. (2) The basins started to form during the Early Miocene and continued their evolution since then [411, 412]. (3) The grabens are Plio-Quaternary structures [425, 427–429].

5. The contributing articles

This special issue of *Geodinamica Acta* (Paris) publishes selected scientific contributions that were originally presented at the 'Third International Turkish Geology Symposium'. This symposium was held at the Middle East Technical University (METU) in Ankara from 31 August to 4 September 1998. This meeting at METU provided an opportunity for Earth scientists to present up-to-date results and ideas from a wide range of current research activity in this region. About 200 presentations, both oral and by poster, covered a wide range of geological topics. The manuscripts in this volume include a selection of papers presented during the 'Neotectonic' theme of the symposium.

The twelve articles in this volume deal with a wide range of aspects of the neotectonics of Turkey, in particular that of Western and Central Anatolia. They are divided into three main groups. The first five articles discuss the graben formation in Western Anatolia and the timing of the start of this extension (Yılmaz and Karacık, Genç et al., Gürer et al., and Akgün and Sözbilir), together with the documentation of a historical earthquake along the Fethiye–Burdur fault zone (Akyüz et al.). The next four articles discuss the structure, kinematics and volcanism along the Central Anatolian Fault Zone (Koçyiğit and Erol, Dirik, and Parlak et al.) and the Malatya–Ovacık Fault Zone (Westaway and Arger) in East-Central Anatolia. The final three articles discuss the age of basin formation and dextral motion along the North Anatolian Fault Zone (Ünay et al.), the neotectonic characteristics of the Eastern Anatolia (Koçyiğit et al.) and finally the basin formation, volcanism and structural analysis of the Karasu valley, located in the area where East Anatolian and Dead Sea fault zones interact (Rojay et al.).

5.1. Western Anatolia

The first three articles aim to shed light on the continuing debate about the age of neotectonic extension in Western Turkey. The article by Yılmaz and Karacık examines the structural and stratigraphical characteristics of Neogene sedimentary and magmatic rocks on the northern side of the Gulf of Edremit. Extension in this locality involved two successive stages, separated by a phase of erosion when a sub-horizontal erosional land surface was produced: thus supporting the episodic two-stage graben model proposed by Koçyiğit et al. [425]. The earlier phase of N–S extension occurred in the Late Miocene to Early Pliocene when a conjugate pair of NE- and NNW-trending normal faults with subordinate strike-slip components developed. These structures are responsible for the development of Etili and Gülpınar grabens and intervening Kazdağ and Ezine horsts. Following this erosion, the N–S extension reactivated with the opening of the E–W trending Edremit graben. This time corresponds to the uplift of Kazdağ horst to its present day E–W position and the consequent opening of the Bayramiç half graben. Yılmaz and Karacık suggest that the opening of the present-day E–W-trending Edremit graben post-dates the Late Miocene–Early Pliocene structures in this region, and so is possibly Pleistocene–Quaternary (less than 5 Ma) in age.

Genç, Altunkaynak, Karacık, Yazman and Yılmaz describe the evolution of the N–S trending Neogene Çubukdağ graben, which is later cut and delimited by E–W trending structures. The graben opened during the Late Miocene as oblique slip faults (Orhanlı and Gökaya fault zones) with minor sinistral slip became active, possibly under a N–S extensional regime. Acidic explosive volcanism occurred along these structures as fissure eruptions. The N–S oblique-slip faulting and associated basin formation persisted until Pliocene. East-west trending major grabens then began to form and their basin-bounding normal faults cut and fragmented the Upper Miocene–Pliocene successions. The N–S extension was also interrupted by an erosional period. Since the initiation of E–W faulting and basin formation, the Çubukdağ graben has continued to develop, as a cross-graben between the Gediz graben in the north and the Kuşadası graben in the south.

Gürer, Bozcu, Kamil and Yılmaz discuss the evolution of the extensional Söke basin, located between Kuşadası and the Dilek Peninsula at the western end of the Büyük Menderes graben. They describe the stratigraphy and structure of this basin and conclude that basins of various ages and different orientations developed in the Söke area during the interval between the Early Miocene and Quaternary. The first stage of graben formation began with Early Miocene NE- to ENE-trending oblique-slip faulting. Hanging-walls of these faults were the sites of Early–Middle Miocene sedimentation. This basin fill was later folded during a phase of N–S compression. Following this event, an E–W trending nor-

mal fault (Yamaçköy Fault) and an associated graben formed under approximately N–S extension. This fault localizes the igneous activity until the Pliocene when the N–S extension ceased. The region was then subjected to erosion, which was followed by the reactivation of the N–S extension during the Pliocene (?)–Pleistocene time when the Büyük Menderes graben began to form.

Akgün and Sözbilir document the palynostratigraphy of the two Oligo-Miocene mollase basins, Kale–Tavas and Denizli basins, in western Turkey. The article describes in detailed the results of geological mapping and measured sections from the coal-bearing sequences of the basin fills. The molasse basins contain alluvial fan-braided river sediments that begin with a basal conglomerate unconformably above the ophiolitic rocks of the Lycian Nappes. The age of the mollase sediments is Chattian to Aquitanian–Burdigalian (Late Oligocene–Early Miocene), much younger than as previously believed (Early Oligocene: [439–443]. Metamorphic clasts derived from the Menderes Massif occur high up in the stratigraphic succession (late Early Miocene) of the Tavas basin [444]. This suggests that the southern Menderes Massif was not exposed at the Earth's surface during the Early Oligocene, and that this massif was buried beneath the Lycian Nappes at least until the Late Oligocene [445].

The geological and archaeological evidence for a post-Roman earthquake (possibly in A.D. 417) surface faulting at Cybria, an ancient city in nearly 1 km NW of the modern town of Gölhisar (Southwest Anatolia), are reported by Akyüz and Altunel. Geological observations include the cross-cutting relationships between a series of NNE–SSE trending, left-stepping fault segments and Pliocene sediments. Archaeological observations are from the damaged relics at Cibrya, including surface rupture-associated offset of seating rows in the stadium and shaking-induced damage, such as broken corners of blocks, collapsed walls, broken columns, and tilted and toppled blocks. The detailed observations from this ancient city are consistent with left-lateral slip along the fault zone. It is finally concluded that the intensity of the earthquake was at least IX, suggesting a magnitude of about 7.0.

5.2. Central Anatolia

The first article in this section, by Westaway and Arger, investigates the characteristics of, and left-lateral slip along, the Malatya-Ovacık Fault Zone (MOFZ). It is suggested that this fault zone formed the boundary between the Anatolian and Arabian plates during ~5–3 Ma. The MOFZ splays southwestward from the North Anatolian Fault Zone across the Erzincan basin, where it formed the triple junction between the Anatolian, Eurasian and Arabian plates. During this time interval, a total of 29 km left-lateral displacement occurred along this fault zone. The internal structure of the MOFZ was complex. Its central part is interpreted as the internal fault of a transpressional stepover, where slip has

resulted in thickening of the brittle upper crust and uplift of the adjoining mountain ranges to altitudes of ~3300 m. Because of the geometry and local kinematics of the Erzincan triple junction, the slip along the MOFZ was unable to continue and the fault zone became inactive at ~3 Ma, when NAFZ propagated eastward and the East Anatolian Fault Zone began to develop. The authors also reconsider the evolution of the Erzincan basin and suggest that the basin is not a simple pull-apart, but has instead formed in response to complex deformation, involving components of NAFZ- and MOFZ-parallel extension caused by the geometry of the Erzincan triple junction and the north-south shortening caused by Arabia–Eurasia convergence.

The next three articles concern basin formation, volcanism and structural characteristics in localities that Koçyiğit and Beyhan [346] regarded as within the Central Anatolian Fault Zone (CAFZ). Koçyiğit and Akyol investigate the Erciyes pull-apart basin, a 35 km-wide, 120 km-long and about 1.2 km-deep, lazy S-shaped, still active transtensional asymmetric depression, that – according to Koçyiğit and Beyhan [347] – formed in a releasing double bend on the CAFZ in the Middle Pliocene. To the northeast of Kayseri, the NE-trending segments of the CAFZ (Kızılırmak–Erkilet and Dökmetaş faults) bend southwards and run in approximately N–S direction, thus resulting in a releasing double bend. The bending along these segments therefore results in local transtensional deformation and the basin bounding faults have acquired an oblique character with considerable amount of normal component. The total amount of throw along these structures reaches up to 1225 m. The basin comprises two separate depressions, the Sultansazlığı and Kayseri–Sarımsaklı depressions, separated by Erciyes stratovolcano. The volcano began to develop as a basaltic fissure eruptions during the Late Pliocene (probably younger than 2.8 Ma). This was followed by the growth of a central cone, made up of alternating andesitic lavas and pyroclastics. During the Late Quaternary, the central vent was clogged, and the volcanic activity continued until prehistoric times as flank eruptions through numerous volcanic cones, lava domes, lava streams and ash flows, which form spectacular landforms in the area.

Dirik gives a detailed description of the structure and evolution of the northwestward arched segment of Koçyiğit and Beyhan's [347] CAFZ. The interpreted sinistral motion along the fault zone became reactivated in the Middle Pliocene. The central part of the fault zone is dominated by depressions, which are interpreted as the result of left stepping and/or releasing bending between the different fault segments during the Late Pliocene–Quaternary time. The author also regards the Sultansazlığı and Tuzla Gölü depressions as the best examples of pull-apart basins in his study area.

Finally, Parlak, Delaloye, Demirkol and Ünlügenc describe the geochemical characteristics of Pliocene–Pleistocene alkali basalts, which have erupted to the southwest of Sivas. The authors conclude that these basalts were

most likely derived from an asthenosphere source as a result of decompression melting resulting from crustal thinning caused by localised extension accompanying slip on the Kızılırmak segment of the CAFZ.

5.3. Other articles

The third group of articles concerns the North Anatolian Fault Zone, eastern Anatolia, and the transitional zone between the Dead Sea and East Anatolian fault zones. First, Ünay, Emre, Erkal and Keçer document the rodent fauna from fluvial and alluvial fan sediments, deposited within the Adapazarı basin. This is a typical pull-apart basin that formed between right-stepping segments (the Dokurcun and İzmit–Adapazarı segments) of the right-lateral North Anatolian Fault Zone to the east of Sea of Marmara. The fauna from the lowermost sediments suggest that the basin began to form and that the dextral motion along this strand of the NAFZ commenced during the latest Pliocene. This work reports the first ever mammal ages from any pull-apart basin along the NAFZ.

Koçyiğit, Yılmaz, Adamia and Kuloshvili describes the major structural elements of eastern Anatolia and the Lesser Caucasus. They propose that the neotectonics of the region are characterised by a strike-slip-dominated compressional–extensional regime, which began in the Pliocene. In contrast, previous authors (e.g. [1, 22, 29, 446, 447]) have suggested that eastern Anatolia has been undergoing compressional deformation, with dominant E–W trending thrust to reverse faults and folds and NE- to NW-trending subordinate strike-slip faults, since the Early Miocene. The major structures form NW- to NE-trending conjugate sets of dextral and sinistral strike-slip faults, N–S to NNW-trending normal faults, fissures, and associated Plio-Quaternary volcanoes. This paper gives detailed descriptions of these major structures and discusses their tectonic significance.

The final paper, by Rojay, Heimann and Toprak describes the structure of the Karasu valley in the extreme south of Turkey and documents new K–Ar dates for this region's basaltic volcanism. The Karasu Valley is interpreted as an asymmetrical depression, which developed between segments of the sinistral Dead Sea Fault Zone (DSFZ) and the Karasu Fault Zone (KFZ). The KFZ is interpreted a sinistral fault zone with substantial oblique normal slip, which links the DSFZ and the East Anatolian Fault Zone (EAFZ). The quaternary basin fill of the Karasu Valley is intercalated with alkali basalts. Thirteen new K–Ar ages were obtained from these basalts, which range from 1.57 ± 0.08 Ma to 0.05 ± 0.03 Ma. The slip rate on the KFZ, estimated from distances by which these dated basalt flow units are offset, is about 4.1 mm year^{-1} .

6. Concluding remarks

Several topics regarding the nature of neotectonic deformation in Turkey have emerged from the papers in this volume. The age and origin of E–W and north-trending basins in Western Anatolia, the volcanism and faulting along the Malatya-Ovacık and Central Anatolian fault zones, pull-apart basin formation along the NAFZ, the neotectonics of Northeastern Anatolia, and the relationship between the EAFZ and DSFZ in southern Turkey, form major topics. The main conclusions of these papers can be summarized as follows:

- E–W trending grabens began to develop in western Turkey around 5 Ma–4 Ma or possibly even later. This is in close agreement with the recent claims that the neotectonic extension and E–W graben formation in western Anatolia commenced during the Pliocene [425–429, 448]. It contradicts the previous contention that the N–S and E–W trending grabens are synchronous and have formed under ongoing N–S extension since the Late Oligocene or Early Miocene [411–413, 435].
- The models proposed for other normal fault zones in western Turkey are consistent with the episodic two-stage model envisaged for the Gediz Graben [425] and the Büyük Menderes Graben [427], but the proposed interval of erosion between the two phases of N–S extension is controversial. The present articles infer a brief period of rapid erosion probably during the Pliocene. However, Koçyiğit et al. [425] claimed instead that the two phases of extension in their study region were separated by a period of N–S compression during the Late Miocene–Early Pliocene.
- Lower–Middle Miocene sediments in western Anatolian basins (e.g., Çubukdağ graben south of İzmir, Gulf of Edremit, Söke–Kuşadası graben) were folded during a period of N–S compression, prior to the initiation of N–S neotectonic extension in the region.
- The documentation of Lower–Middle Miocene sediments in the Söke area by Gürer and others confirm the previous contentions that similar-aged sediments were deposited within the present-day extent of the Büyük Menderes graben, as reported from the Dalama (Aydın) and Şevketin Dağı (Nazilli) areas [411, 412, 427–429, 439–443]. However, such occurrences of sediment are fortuitous: they have nothing to do with the Büyük Menderes graben and were apparently deposited well before the development of this graben [427, 428].
- Although the article by Akgün and Sözbilir does not report directly on the characteristics of neotectonic structures in Western Anatolia, their conclusions have an important bearing on the age of extensional tectonics in the region. The Upper Oligocene–Lower Miocene sediments have been interpreted as the earliest sediments of the E–W trending Gediz and Büyük Menderes grabens [411–413, 435, and references therein]. Based on this assumption, it has also been suggested that the N–S extension in Western Anatolia com-

menced by the latest Oligocene–Early Miocene time. However, the age of mollase sediments in the Kale–Tavas and Denizli basins and the Middle Miocene ages from the basal sequence of Büyük Menderes graben [449] suggest that the beginning of the neotectonic extensional period in Western Anatolia should at least be Middle Miocene or younger, supporting the other recent claims [425, 427–429].

– The geological and archaeological evidence from the ancient city Cybria (Akyüz and Altunel) is interpreted as indicating that a segment of the Fethiye–Burdur Fault Zone has ruptured during historical earthquakes.

– A kinematic model is proposed to explain that the present-day major fault geometry developed circa 3 Ma (Westaway and Arger). The relative motion between Anatolian and Arabian plates was taken up by the Malatya–Ovacık Fault Zone (MOFZ) during about 5–3 Ma. The East Anatolian Fault Zone became active around 3 Ma when the MOFZ ceased to be active.

– Part of the Central Anatolian Fault Zone (CAFZ) slipped many tens of kilometres in the Eocene (e.g. [1, 347, 353, 354, 356]). Structures along other parts of it are interpreted here as evidence of transtensional deformation and/or pull-apart basin formation, and it is suggested that this young phase of slip began in the Pliocene. Pliocene to Quaternary alkali basaltic volcanism has also occurred adjacent to part of this interpreted fault zone.

– The dextral motion along the fault strands forming the present geometry of the North Anatolian Fault Zone began in the latest Pliocene, based on the mammal age from the basin fill of Adapazarı basin. Barka et al. [66] have previously proposed that the switch from the MOFZ and NAFZ to the EAFZ and NAFZ forming an active conjugate fault pair led to changes in the geometry of the NAFZ, which resulted in some fault strands that were active before this change becoming superseded following this change. However, Barka et al. [66] thought that this change occurred at ~1 Ma, but without clear age control evidence. The present results, which place the timing of this change in the Late Pliocene (i.e., at or just after ~3 Ma), are consistent with the preferred ~3 Ma timing of the ending of activity on the MOFZ from Westaway and Arger ([189] and this issue) and suggests that the timing of this major change in fault geometry is now quite well constrained.

– The neotectonics of eastern Anatolia is characterized by a strike-slip dominated compressional–extensional regime that commenced in the Pliocene.

– The Karasu Valley forms a linkage between the DSFZ and the EAFZ and is the site for very young basaltic volcanism (1.57 ± 0.08 Ma to 0.05 ± 0.03 Ma).

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References

- [1] Şengör A.M.C., Yılmaz Y., Tethyan evolution of Turkey: a plate tectonic approach, *Tectonophysics* 75 (1981) 181–241.
- [2] Şengör A.M.C., Görür N., Şaroğlu F., Strike-slip faulting and related basin formation in zones of tectonic escape: Turkey as a case study, in: Biddle K.T., Christie-Blick N. (Eds.), *Strike-slip Faulting and Basin Formation*, Soc. Econ. Paleontol. Mineral. Sp. Pub., 37, 1985, pp. 227–264.
- [3] Barka A.A., The North Anatolian Fault zone, *Annales Tecton.* 6 (1992) 164–195.
- [4] Westaway R., Present-day kinematics of the Middle East and Eastern Mediterranean, *J. Geophys. Res.* 99 (1994) 12071–12090.
- [5] Straub C., Kahle H.G., Active crustal deformation in the Marmara Sea region, NW Anatolia, inferred from GPS measurements, *Geophys. Res. Lett.* 22 (1995) 2533–2536.
- [6] Reilinger R.E., McClusky S.C., Oral M.B., King W., Toksöz M.N., Global Positioning System measurements of present-day crustal movements in the Arabian–Africa–Eurasia plate collision zone, *J. Geophys. Res.* 102 (1997) 9983–9999.
- [7] Kahle H.G., Straub C., Reilinger R., McClusky S., King R., Hurst K., Veis G., Kastens K., Cross P., The strain rate field in the eastern Mediterranean region, estimated by repeated GPS measurements, *Tectonophysics* 294 (1998) 237–252.
- [8] Pfister M., Rybach L., Şimşek Ş., Geothermal reconnaissance of the Marmara Sea region (NW Turkey): surface heat flow density in an area of active continental extension, *Tectonophysics* 291 (1998) 77–89.
- [9] McKenzie D.P., Plate tectonics of the Mediterranean region, *Nature* 220 (1970) 239–343.
- [10] Dewey J.F., Şengör A.M.C., Aegean and surrounding regions: complex multiple and continuum tectonics in a convergent zone, *Geol. Soc. Am. Bull.* 90 (1979) 84–92.
- [11] Rotstein Y., Counterclockwise rotation of Anatolian block, *Tectonophysics* 108 (1984) 71–91.
- [12] Jackson J.A., McKenzie D.P., Rates of active deformation in the Aegean Sea and surrounding regions, *Basin Res.* 1 (1988) 121–128.
- [13] Oral M.B., Reilinger R.E., Toksöz M.N., Kong R.W., Barka A.A., Kınık İ., Lenk O., Global positioning system offers evidence of plate motions in eastern Mediterranean, *EOS Transac.* 76 (9) (1995).
- [14] Seber D., Vallve M., Sandol E., Steer D., Barazangi M., Middle, East tectonics: applications of Geographic Information Systems (GIS), *GSA Today* 7 (1997) 1–6.
- [15] Garfunkel Z., Constraints on the origin and history of the Eastern Mediterranean basin, *Tectonophysics* 298 (1998) 5–35.
- [16] Şengör A.M.C., Natal'in B.A., Turcic-type orogeny and its role in the making of the continental crust, *Ann. Rev. Earth Sci.* 24 (1996) 263–337.
- [17] Dewey J.F., Helman M.L., Turco E., Hutton D.H.W., Knott S.D., Kinematics of the western Mediterranean, in: Coward M.P., Dietrich D., Park R.G. (Eds.), *Alpine Tectonics*, Geological Society Special Publication no. 45, Geological Society, London, 1989, pp. 265–283.
- [18] Malpas J., Xenophontos C., Williams D., The Ayia Varvara Formation of SW Cyprus: a product of complex collisional tectonics, *Tectonophysics* 212 (1992) 193–211.
- [19] Eaton S., Robertson A.H.F., The Miocene Pakhour Formation, southern Cyprus, and its relation to the Neogene tectonic evolution of the eastern Mediterranean, *Sediment. Geol.* 86 (1993) 273–292.

- [20] Seymen İ., Tectonic characteristics of the North Anatolian Fault Zone in Kelkit Valley, Ph.D. Thesis, İstanbul Technical University, İstanbul, 1975 (in Turkish with English abstract).
- [21] Adamia S.A., Chkhotua T., Kakelia M., Lordkipanidze M., Shavishvili I., Tectonics of the Caucasus and adjoining regions: implications for the evolution of Tethys ocean, *J. Struct. Geol.* 3 (1981) 437–447.
- [22] Dewey J.F., Hempton M.R., Kidd W.S.F., Şaroğlu F., Şengör A.M.C., Shortening of continental lithosphere: the neotectonics of eastern Anatolia – a young collision zone, in: Coward M.O., Ries A.C. (Eds.), *Collisional Tectonics*, Geological Society Special Publication no. 19, Geological Society, London, 1986, pp. 3–36.
- [23] Hempton M.R., Constraints on Arabian plate motion and extensional history of the Red Sea, *Tectonics* 6 (1987) 687–705.
- [24] Robertson A.H.F., Grasso M., Overview of the late Triassic–Recent tectonic and palaeo-environmental development of the Mediterranean region, *Terra Nova* 7 (1995) 114–127.
- [25] Robertson A.H.F., Clift P.D., Degnan P., Jones G., Palaeogeographic and paleotectonic evolution of eastern Mediterranean region, *Palaeogeogr., Palaeoclimat., Palaeoecol.* 87 (1991) 289–344.
- [26] Yılmaz Y., New evidence and model on the evolution of the southeast Anatolian orogen, *Geol. Soc. Am. Bull.* 105 (1993) 251–271.
- [27] Yılmaz Y., Yiğitbaş E., Genç C.Ş., Ophiolitic and metamorphic assemblages of southeast Anatolia and their significance in the geological evolution of the orogenic belt, *Tectonics* 12 (1993) 1280–1297.
- [28] McKenzie D.P., Speculations on the consequence and causes of plate motions, *Geophys. J. Royal Astron. Soc.* 18 (1969) 1–32.
- [29] Şengör A.M.C., Kidd W.S.F., Post-collisional tectonics of the Turkish-Iranian plateau and a comparison with Tibet, *Tectonophysics* 55 (1979) 361–376.
- [30] Dewey J.F., Pitman W.C., Ryan W.B.F., Bonnin J., Plate tectonics and evolution of the Alpine system, *Geol. Soc. Am. Bull.* 84 (1973) 3137–3180.
- [31] Ben-Avraham Z., Nur A., Collisional processes in the eastern Mediterranean, *Geol. Rund.* 75 (1986) 209–217.
- [32] Woodside J.M., Tectonic elements and crust of the eastern Mediterranean Sea, *J. Geophys. Res.* 99 (1977) 12071–12090.
- [33] Woodside J.M., Disruption of the African plate margin in the eastern Mediterranean, in: Salem, et al. (Eds.), *Geol. Libia*, 1991, pp. 2319–2329.
- [34] Robertson A.H.F., et al., Evidence of collisional processes associated with ophiolite obduction in the eastern Mediterranean: results from Ocean Drilling Program Leg 160, *GSA Today* 11 (1995) 213–221.
- [35] Robertson A.H.F., Tectonic significance of the Eratosthenes Seamount: a continental fragment in the process of collision with a subduction zone in the eastern Mediterranean (Ocean Drilling Programme Leg 160), *Tectonophysics* 298 (1998) 63–82.
- [36] Kelling G., Gökçen S.L., Floyd P.A., Gökçen N.D., Neogene tectonics and plate convergence in the eastern Mediterranean: new data from southern Turkey, *Geology* 14 (1987) 425–429.
- [37] Karig D.E., Kozlu H., Late Palaeogene evolution of the triple junction region near Maraş, south-central Turkey, *J. Geol. Soc., London* 147 (1990) 1023–1034.
- [38] Gürsoy H., Temiz H., Poisson A.M., Recent faulting in the Sivas area (Sivas Basin), Central Anatolia-Türkiye, Cumhuriyet Univ., *J. Engineer. Fac., Serie A – Earth Sci.* 9 (1992) 1–11.
- [39] Westaway R., Arger J., The Gölbaşı basin, southeastern Turkey: A complex discontinuity in a major strike-slip fault zone, *J. Geol. Soc., London* 153 (1996) 729–743.
- [40] Cisternas A., Philip H., Bousquet J.C., Cara M., Deschamps A., Dorbath L., Dorbath C., Haessler H., Jimenez E., Nercessian A.M., Rivera L., Romanowicz B., Gvishiani A., Shebalin N.V., Aptekman I., Arefiev S.M., Borisov B.A., Gorshkov A., Graizer V., Lander A., Pletnev K., Rogozhin A.I., Tatevissian R., The Spitak (Armenia) earthquake of 7 December: field observations, seismology and tectonics, *Nature* 339 (1989) 675–679.
- [41] Haessler H., Deschamps A., Dumumier H., Fuenzalida H., Cisternas A., The rupture process of the Armenian earthquake from broad-band teleseismic body wave records, *Geophys. J. Inter.* 109 (1992) 151–161.
- [42] Rebai S., Philip H., Dorbath L., Borisoff B., Haessler H., Cisternas A., Active tectonics in the Lesser Caucasus: coexistence of compressive and extensional structures, *Tectonics* 12 (1993) 1089–1114.
- [43] Fuenzalida H., Dorbath L., Cisternas A., Rivera L., Eyidoğan H., Barka A.A., Haessler H., Philip H., Lybéris N., Mechanism of the Erzincan earthquake and its aftershocks, tectonics of the Erzincan basin and decoupling on the North Anatolian Fault, *Geophys. J. Inter.* 129 (1997) 1–28.
- [44] Westaway R., Continental extension on sets of parallel faults: observational evidence and theoretical models, in: Roberts A.M., Yielding G., Freeman B. (Eds.), *The geometry of normal faults*, Geological Society Special Publication no. 56, Geological Society, London, 1991, pp. 143–169.
- [45] Mitchell J., Westaway R., Chronology of Neogene and Quaternary uplift and magmatism in the Caucasus: constraints from K–Ar dating of volcanism in Armenia, *Tectonophysics* 304 (1999) 157–186.
- [46] DeMets C., Gordon R.G., Argus D.F., Stein S., Current plate motions, *Geophys. J. Inter.* 102 (1990) 425–478.
- [47] Barka A.A., Reilinger R., Active tectonics of the Mediterranean region: deduced from GPS, neotectonic and seismicity data, *Annali di Geophys.* XI (1997) 587–610.
- [48] DeMets C., Gordon R.G., Argus D.F., Stein S., Effects of recent revisions to the geomagnetic reversal time scale on estimates of current plate motions, *Geophys. Res. Lett.* 21 (1994) 2191–2194.
- [49] Ketin İ., Relations between general tectonic features and the main earthquake regions of Turkey, *Min. Res. Explor. Inst. Bull.* 71 (1968) 63–67.
- [50] Ketin İ., About the North Anatolian Fault, *Min. Res. Explor. Inst. Bull.* 72 (1969) 1–25 [in Turkish with English abstract].
- [51] Ambraseys N.N., Some characteristic features of the North Anatolian Fault Zone, *Tectonophysics* 9 (1970) 143–165.
- [52] McKenzie D.P., Active tectonics of the Mediterranean region, *Geophys. J. Royal Astron. Soc.* 30 (1972) 109–185.
- [53] Dewey J.F., Seismicity of Northern Anatolia, *Bull. Seismol. Soc. Am.* 66 (1976) 843–868.
- [54] Şengör A.M.C., The North Anatolian Transform Fault: its age, offset and tectonic significance, *J. Geol. Soc., London* 136 (1979) 269–282.
- [55] Kıratzi A.A., A study of the active crustal deformation of the North and East Anatolian fault zones, *Tectonophysics* 225 (1993) 191–203.
- [56] USGS, Implications for Earthquake risk reduction in the United States from the Kocaeli, Turkey, Earthquake of August 17, 1999, U.S. Geological Survey Circular 193 (2000).
- [57] Tchalenk J.S., A reconnaissance of the seismicity and tectonics of the northern border of Arabian Plate (Lake Van region), *Rev. géog. Phys. géol. Dynm.* 19 (1977) 189–208.
- [58] Ambraseys N.N., Zatopek A., The Varto Ustukran earthquake of 19 August 1966, *Bull. Seismol. Soc. Am.* 58 (1968) 47–102.

- [59] Wallace R., Earthquake of August 19, 1966, Varto area, Eastern Turkey, *Bull. Seismol. Soc. Am.* 58 (1968) 11–56.
- [60] Ambraseys N.N., Engineering seismology, *Earthq. Engineer. Struct. Dynam.* 17 (1988) 1–105.
- [61] Aydın A., Nur A., Evolution of pull-apart basins and their scale independence, *Tectonics* 1 (1982) 91–105.
- [62] Barka A.A., Hancock P.L., Neotectonic deformation patterns in the convex-northwards arc of the North Anatolian Fault Zone, in: Dixon J.E., Robertson A.H.F. (Eds.), *The geological evolution of the Eastern Mediterranean*, Geological Society Special Publication no. 17, Geological Society, London, 1984, pp. 763–774.
- [63] Tatar O., Determination of extension directions in naturally deformed limestones within strike-slip fault zones using microfractures: Nixsar basin (Turkey) as a case study, *Turkish J. Earth Sci.* 5 (1996) 45–53.
- [64] Tatar O., Neotectonic structures indicating extensional and contractional strain within Pliocene deposits near the NW margin of the Nixsar pull-apart basin, Turkey, *Turkish J. Earth Sci.* 5 (1996) 81–90.
- [65] Tatar O., Piper J.D.A., Park R.G., Gürsoy H., Palaeomagnetic study of block rotations in the Nixsar overlap region of the North Anatolian Fault Zone, central Turkey, *Tectonophysics* 244 (1995) 251–266.
- [66] Barka A.A., Akyüz S.H., Cohen H.A., Watchorn F., Tectonic evolution of the Nixsar and Tasova-Erbaa pull-apart basins, North Anatolian Fault Zone: their significance for the motion of the Anatolian block, *Tectonophysics* 322 (2000) 243–264.
- [67] Hempton M.R., Dunne L.A., Sedimentation in pull-apart basins: active examples in eastern Turkey, *J. Geol.* 92 (1984) 513–530.
- [68] Neugebauer J., Structures and kinematics of the North Anatolian fault zone, Adapazarı-Bolu region, *Tectonophysics* 243 (1995) 119–134.
- [69] Koçyiğit A., Süşehri basin: an active fault-wedge basin on the North Anatolian Fault Zone, Turkey, *Tectonophysics* 167 (1989) 13–29.
- [70] Koçyiğit A., Tectonic setting of the Gölova basin, total offset of the North Anatolian Fault Zone, Eastern Pontide, Turkey, *Annales Tecton.* 4 (1990) 155–170.
- [71] Dirik K., Geological history of the northward arched segment of the North Anatolian Transform fault Zone, *Geol. J.* 28 (1993) 251–266.
- [72] Koçyiğit A., Tectonic setting of the Geyve basin: age and total displacement of the Geyve fault zone, *METU Pure Appl. Sci.* 21 (1988a) 81–104.
- [73] Rojay F.B., Tectonostratigraphy and Neotectonic Characteristics of the Southern Margin of Merzifon-Suluova Basin (Central Pontides, Amasya), Ph.D. Thesis, Middle East Technical University, Ankara, 1993.
- [74] Barka A.A., Gülen L., Complex evolution of the Erzincan basin (eastern Turkey), *J. Struct. Geol.* 11 (1989) 275–283.
- [75] Koçyiğit A., Neotectonic structures and related landforms expressing the contractional and extensional strains along the North Anatolian Fault at the northwestern margin of the Erzincan Basin, NE Turkey, *Bull. Tech. Univ. İstanbul* 44 (1991) 455–473.
- [76] Koçyiğit A., Rojay F.B., Erzincan basin and 1992/3/13–15 earthquakes: an active composite pull-apart basin on the North Anatolian Fault Zone, *Türkiye. International Workshop: Work in Progress on the Geology of Türkiye*, Keele, England, April 9–10, Abstracts (1992) p. 39.
- [77] Bozkurt E., Koçyiğit A., The Kazova basin: an active negative flower structure on the Almus Fault Zone, a splay fault system of the North Anatolian Fault Zone, Turkey, *Tectonophysics* 265 (1996) 239–254.
- [78] Irlitz W., Lithostratigraphie und tektonische Entwicklung des Neogens in Nordostanatolien, *Bei. Geol. Jahrb.* 37 (1972) 51–78.
- [79] Tatar Y., Tectonic structures along the North Anatolian fault zone, northeast of Refahiye (Erzincan), *Tectonophysics* 29 (1975) 401–410.
- [80] Tatar Y., Tectonic study of the Erzincan-Refahiye section of the North Anatolian Fault Zone, Hacettepe Univ. Earth Sci. 4 (1978) 201–236 (in Turkish with English abstract).
- [81] Barka A.A., Geology and tectonic evolution of some basins along the North Anatolian Fault Zone, *Ketin Symposium Proc.* (1984) pp. 209–227 (in Turkish with English abstract).
- [82] Hempton M.R., The North Anatolian fault and complexities of continental escape, *J. Struct. Geol.* 4 (1982) 502–504.
- [83] Toprak V., Neotectonic Characteristics of the North Anatolian Fault Zone between Koyulhisar and Süşehri (NE Turkey), *METU J. Pure Appl. Sci.* 21 (1988) 155–168.
- [84] Barka A.A., Gülen L., New constraints on the age and total offset of the North Anatolian Fault Zone: implications for tectonics of the Eastern Mediterranean region, *METU J. Pure Appl. Sci.* 21 (1989) 39–63.
- [85] Aktimur T., Ateş S., Yurdakul E., Tekirli E., Keçer M., Geology Nixsar-Erbaa and Destek region, *Min. Res. Expl. Inst. Turkey Bull.* 114 (1992) 1–36 (in Turkish with English abstract).
- [86] Andrieux J., Över S., Poisson A., Bellier O., The North Anatolian Fault Zone: distributed Neogene deformation in its northward convex part, *Tectonophysics* 243 (1995) 135–154.
- [87] Bellier O., Över S., Poisson A., Andrieux J., Recent temporal change in stress state and modern stress field along the North Anatolian Fault Zone (Turkey), *Geophys. J. Inter.* 131 (1997) 61–86.
- [88] Şengör A.M.C., Mid-Mesozoic closure of Permo-Triassic Tethys and its implications, *Nature* 279 (1979) 590–593.
- [89] Tokay M., Geological observations on the North Anatolian fault zone between Gerede and Ilgaz, in: *Proceedings of Symposium on North Anatolian Fault Zone and Earthquake Belt*, Min. Res. Expl. Inst. Publ., Ankara, 1973, pp. 12–29 (in Turkish with English Abstract).
- [90] Arpat E., Şaroğlu F., The East Anatolian Fault System: thoughts on its development, *Min. Res. Expl. Inst. Turkey Bull.* 78 (1972) 33–39.
- [91] Şaroğlu F., Geological and Structural Evolution of East Anatolia during Neotectonic Period, Ph.D. Thesis, İstanbul University, İstanbul, 1985 (unpublished; in Turkish with English abstract).
- [92] Şaroğlu F., The age and offset on the North Anatolian Fault, *METU J. Pure Appl. Sci.* 21 (1988) 65–79.
- [93] Barka A.A., Kadinsky-Cade C., Strike-slip fault geometry in Turkey and its influence on earthquake activity, *Tectonics* 7 (1988) 663–684.
- [94] Bozkurt E., Koçyiğit A., Almus Fault Zone: its age, total offset and relation to the North Anatolian Fault Zone, *Turkish J. Earth Sci.* 4 (1995) 93–104.
- [95] Koçyiğit A., Basic geologic characteristics and total offset of the North Anatolian Fault Zone in Süşehri area, NE Turkey, *METU Pure Appl. Sci.* 22 (1988) 43–68.
- [96] Yaltrak C., Tectonic history of the Ganos fault System, *Turkish Assoc. Petrol. Geol. Bull.* 8 (1996) 137–156 (in Turkish with English abstract).
- [97] Crampin S., Evans R., Neotectonics of the Marmara Sea region of Turkey, *J. Geol. Soc., London* 143 (1986) 343–346.

- [98] Suzanne P., Lyb ris N., Chorowicz J., Nurlu M., Y r r T., Kasapođlu E., La g ometrie de la faille nord anatolienne   d'images Landsat-MSS, Bull. Geol. Soc. France 8 (1990) 589–599.
- [99] Barka A.A., Neotectonics of the Marmara region, in: Schindler C., Pfister M. (Eds.), Active Tectonics of Northwestern Anatolia – The MARMARA Poly Project; A multidisciplinary approach by Space Geodesy, Geology, Hydrogeology, Geothermics and Seismology. Vdf. Hochschulverl an der ETH, Zurich, 1997, pp. 55–87.
- [100] G r r N., Cađatay M.N., Sakın  M., S mengen M., Őent rk K., Yaltrak C., Tchapalyga A., Origin of Sea of Marmara as deduced from Neogene to Quaternary paleogeographic evolution of its frame, Inter. Geol. Rev. 39 (1997) 342–352.
- [101] Okay A.İ., Demirbađ E., Kurt H., Okay N., KuŐu İ., An active, deep marine strike-slip basin along the North Anatolian Fault in Turkey, Tectonics 18 (1999) 129–148.
- [102] Okay A.İ., Kaslılar- zcan A., İmren C., Boztepe-G ney A., Demirbađ E., KuŐu İ., Active faults and evolving strike-slip basins in the Marmara Sea, northwest Turkey: a multichannel seismic reflection study, Tectonophysics 321 (2000) 189–218.
- [103] T yst z O., Barka A.A., YiđitbaŐ E., Geology of the Saros Graben: its implications on the evolution of the North Anatolian Fault in the Ganos-Saros region, NW Turkey, Tectonophysics 293 (1998) 105–126.
- [104] Yaltrak C., Sakın  M., Oktay F.Y., Discussion to the paper by Armijo, R., Meyer, B., Hubert, A. and Barka, A.A. Westward propagation of the North Anatolian Fault into the northern Aegean: timing and kinematics, Geology 27 (1999) 267–270.
- [105] Yaltrak C., Alpar B., Sakın  M., Y ce H., Origin of the strait of  anakkale (Dardanelles): regional tectonics and the Mediterranean–Marmara incursion, Marine Geol. 16 (2000) 139–156.
- [106] Yaltrak C., Sakın  M., Oktay F.Y., Kinematics and evolution of the northern segment of the North Anatolian Fault Zone (Gabos Fault) in the area between Marmara and Gulf of Saros, in: Tatar O., Kavak K.S.,  zden S. (Eds.), Tektonik AraŐtırma Grubu 3. Toplantısı, ATAG-3 Proceedings, 2000, pp. 77–89 (in Turkish with English abstract).
- [107] Gautier P., Brun J.P., Moriceau R., Sokoutis D., Martinod J., Jolivet L., Timing, kinematics and cause of Aegean extension: a scenario based on a comparison with simple analogue experiments, Tectonophysics 315 (1999) 31–72.
- [108] Barka A.A., Seismo–tectonic aspects of the North Anatolian Fault Zone, PhD Thesis, University of Bristol, Bristol, 1981.
- [109] Armijo R., Meyer B., Barka A.A., Hubert A., Propagation of the North Anatolian fault into the Northern Aegean: timing and kinematics, Geology 27 (1999) 267–270.
- [110] Taymaz T., Jackson J., McKenzie D.P., Active tectonics of the North and Central Aegean Sea, Geophys. J. Inter. 106 (1991) 433–490.
- [111] Ayhan M.E., Demir C., Kahveci M., Kaplan M., 1990–1993 Yılları GPS  l mleri ile Gerede-Adapazarı b lgesindeki alanın belirlenmesi, in: T rk Haritacılıđının 100. yılı Bilimsel Kongresi, Ankara, 1995, pp. 55–66 (in Turkish with English abstract).
- [112] McClusky S., Balassanian S., Barka A., Demir C., Gergiev I., Hamburger M., Kahle H., Kastens K., Kekelidse G., King R., Kotzev V., Lenk O., Mahmoud S., Mishin A., Naderia M., Ouzounis A., Paradisissis D., Peter Y., Prilepin M., Reilinger R., Sanlı I., Seeger H., Tealeb A., Toks z N., Veis G., GPS constraints on crustal movements and deformations for plate dynamics, J. Geophys. Res. 105 (2000) 5695–5720.
- [113] Pamir H.N., Ketin İ., Das Anatolische Erdbeben Ende 1939, Geol. Rund. 32 (1941) 278–287.
- [114] Par jas E., Akyol İ.H., Altunlu E., Le tremblement de terre d'Erzincan du 17 Decembre 1939, Istanbul University, Fen Fak ltesi Mecmuası NVI (1942) 177–222.
- [115] Blumenthal M., Zur Geologie der Landsrecken der Erdbeben von endein Nord-Anatolien und dortselbst ausgefurte macroseismische Beobachtungen, Min. Res. Expl. Inst. Turkey Bull. 8 (1943) 33–58.
- [116] Blumenthal M., Ladik earthquake zone, Min. Res. Expl. Inst. Turkey Bull. 10 (1945) 153–174 (in Turkish with English abstract).
- [117] Pamir H.N., Akyol İ.H.,  orum and Erbaa earthquakes, T rk Cođrafya B lteni 1 (1943) 2–12 [in Turkish with English abstract].
- [118] TaŐman C.E., Gerede-Bolu earthquake, Min. Res. Expl. Inst. Turkey Bull. 9 (1944) 31–134 (in Turkish).
- [119]  cal N., 26 May 1956 Abant earthquake. Kandilli Observatory, Istanbul, Seismology Publ. 4 (1959) (in Turkish).
- [120] Ambraseys A.A., Zatopek A., TaŐdemirođlu M., Aytun A., The Mudurnu Valley, West Anatolia Earthquake of 22 July 1967, UNESCO Publ. 22 (1968) 1–135.
- [121] Allen C.R., Active Faulting in Northern Turkey, Division of Geological Science, California Institute of Technology Contribution No. 1577, 1969.
- [122] Ambraseys N.N., Zatopek A., The Mudurnu valley, West Anatolia, Turkey, earthquake of 22 July 1967, Bull. Seismol. Soc. Am. 59 (1969) 521–589.
- [123] Taban A., Geology and Earthquake Activity of the Cities of Turkey, T rkiye Cumhuriyeti, İmar İŐkan Bakanlıđı, Afet İŐleri Genel M d rl đ , Ankara, 1980.
- [124] Riad S., Meyers R., Earthquake catalog for the Middle East countries 1900–1983 World Data Center A. Report, SE-40, 1985.
- [125] Eyidođan H., Utku Z., G cl  U., Deđirmenci E., T rkiye B y k Depremleri Makro-sismik Rehberi. Istanbul Teknik  niversitesi, Maden Fak ltesi Yayını, 1991 (in Turkish).
- [126] Ikedai Y., Suzuki Y., Herece E., Őarođlu F., IŐkara A.M., Honkuru Y., Geological evidence for the last two faulting events on the North Anatolian Fault Zone in the Mudurnu Valley, Western Turkey, Tectonophysics 193 (1991) 335–345.
- [127] Barka A.A., Eyidođan H., The March 13, 1992 Erzincan earthquake, Terra Nova 5 (1993) 190–194.
- [128] King G.C.P., Stein R.S., Lin J., Static stress changes and the triggering of failure stress change caused by the Erzincan earthquake ($M_s = 6.8$), Geophys. Res. Lett. 23 (1994) 1561–1564.
- [129] Tatar O., Temiz H., Tutkun S.Z., Park R.G., Stimpson I.G., Surface deformation and tectonic setting of the 113 March 1992 Erzincan earthquake, Eastern Turkey, Geol. J. 28 (1993) 327–333.
- [130] Barka A.A., Slip distribution along the North Anatolian Fault associated with the large earthquakes of the period 1939 to 1967, Bull. Seismol. Soc. Am. 86 (1996) 1238–1254.
- [131] Barka A.A., The 17 August 1999 İzmit earthquake, Science 285 (1999) 1858–1859.
- [132] Pinar A., Honkura Y., Kikuchi M., A rupture model for the Mudurnu Valley, Turkey earthquake and its implication for seismotectonics in the western part of the North Anatolian fault zone, Geophys. Res. Lett. 23 (1996) 29–32.
- [133] Nalbant S.S., Barka A.A., Alptekin  ., Failure stress change caused by the Erzincan earthquake ($M_s = 6.8$), Geophys. Res. Lett. 23 (1996) 1561–1564.
- [134] Fuenzelida H., Rivera L., Haessler H., Legrand D., Philip H., Dorbath L., Cisternas A., Seismic source study of the Racha–Dzhava (Georgia) earthquake from aftershocks and broad-band teleseismic body wave records: an example of active nappe tectonics, Geophys. Inter. J. 129 (1977).

- [135] Ambraseys N.N., Jackson J.A., Faulting associated with historical and recent earthquakes in the Eastern Mediterranean region, *Geophys. J. Inter.* 133 (1998) 390–406.
- [136] Koçyiğit A., Bozkurt E., Cihan M., Özacar A., Teksöz, B., Neotectonic frame of Turkey: a special emphasis on the Gölcük-Arifiye earthquake of August 17, 1999 (NE Marmara, Turkey). International Conference on Earthquake Hazard and Risk in the Mediterranean region, Near East University, Northern Cyprus, 18–22 October 1999, p. 21.
- [137] Koçyiğit A., Bozkurt E., Cihan M., Özacar A., Teksöz M., 17 Ağust Gölcük-Arifiye earthquake rupture and its tectonic significance. ATAG-3; Aktif Tektonik Araştırma Grubu Üçüncü Toplantısı Bildiri Özetleri, 1999, p. 6 (in Turkish).
- [138] Koçyiğit A., Bozkurt E., Cihan M., Özacar A., Teksöz B., 12 November 1999 Dağdibi (Düzce-Bolu) Earthquake: Preliminary Geologic Report. Middle East Technical University, Faculty of Engineering, Department of Geological Engineering, Tectonic Research Unit, 1999 (in Turkish).
- [139] Koçyiğit A., Bozkurt E., Cihan M., Özacar A., Teksöz B., Neotectonic Frame of Turkey: A special emphasis on the Gölcük-Arifiye earthquake (NE, Marmara, Turkey): International conference on earthquake hazard and risk in the Mediterranean region, October 18–22, 1999, Neareast University, North Cyprus, Proceeding, 2000, pp.1–11.
- [140] Taymaz T., Marmara Bölgesi'nin aktif tektoniği: Gölcük ve Düzce depremleri, Ulusal Standart Deprem İstasyonları Ağı, Erken Uyarı Sistemi ve Deprem Bilgi Bankası. TÜBİTAK Bilim ve Teknik 385 (1999) 44–47 (in Turkish).
- [141] Taymaz T., Marmara bölgesinin sismotektoniği: 1999 Gölcük-Sapanca-Düzce depremlerinin kaynak mekanizması çözümleri. In: BADSEM 2000– Batı Anadolu'nun Depremselliği Sempozyumu, Proceedings, 24–27 Mayıs 2000, İzmir, 2000, pp.209–219 (in Turkish with English abstract).
- [142] Toksöz M.N., Reilinger R.E., Doll C.G., Barka A.A., Yalçın N., İzmit (Turkey) earthquake of 17 August 1999: first report, *Seismol. Res. Lett.* 70 (1999) 669–679.
- [143] Akyüz H.S., Barka A.A., Altunel E., Hartleb R., Sunal G., Field observations and slip distribution of the November 12, 1999 Düzce earthquake ($M = 7.1$), Bolu-Turkey, in: Barka A.A., Kozacı O., Akyüz S.H., Altunel E. (Eds.), 1999 İzmit and Düzce Earthquakes: Preliminary Results, İstanbul Technical University Publ., İstanbul, 2000, pp. 63–70.
- [144] Armijo R., Meyer B., Barka A.A., Chabaliere J.B., Hubert-Ferrari A., Çakır Z., The fault breaks of the 1999 earthquakes in Turkey and the tectonic evolution of the Sea of Marmara: a summary, in: Barka A.A., Kozacı O., Akyüz S.H., Altunel E. (Eds.), 1999 İzmit and Düzce earthquakes: preliminary Results, İstanbul Technical University Publ., İstanbul, 2000, pp. 55–62.
- [145] Emre Ö., Taymaz T., Duman T.Y., Doğan A., Gölcük ve Düzce depremlerinin yüzey kırıkları ve sismolojik özellikleri, TÜBİTAK Bilim ve Teknik 386 (2000) (1999) 38–42 (in Turkish).
- [146] Kavak K.S., Özden S., Tutkun S.Z., Tatar O., Doğan B., 17 Ağustos 1999 Kocaeli depreminin yüzey kırığı ve neotektonik önemi, in: Tatar O., Kavak K.S., Özden S. (Eds.), Tektonik Araştırma Grubu 3. Toplantısı, ATAG-3 Proceedings, 2000, pp. 6–11.
- [147] Wright T., Fielding E., Parsons B., England P., Haynes M., Source parameters of the 17 August 1999 İzmit earthquake from SAR interferometry, in: Barka A.A., Kozacı O., Akyüz S.H., Altunel E. (Eds.), 1999 İzmit and Düzce Earthquakes: Preliminary Results, İstanbul Technical University Publ., İstanbul, 2000, pp. 289–293.
- [148] Stein R.S., Barka A.A., Dieterich J.H., Progressive failure on the North Anatolian fault since earthquake stress triggering, *Geophys. J. Inter.* 128 (1997) (1939) 594–604.
- [149] Komut T., Düzce depremi yüzey kırığının değerlendirilmesi, in: BADSEM– Batı Anadolu'nun Depremselliği Sempozyumu, Proceedings, 24–27 Mayıs 2000, İzmir, 2000, pp.189–197 (in Turkish with English abstract).
- [150] Gürbüz C., Aktar M., Eyidoğan H., Cisternas A., Haessler H., Barka A., Ergin M., Türkelli N., Polat O., Üçer S.B., Kuleli S., Barış S., Kaypak B., Bekler T., Zor E., Biçmen F., Yörük A., The seismotectonics of the Marmara region, *Tectonophysics* 316 (2000) 1–17.
- [151] Parson T., Toda S., Stein R., Barka A.A., Dieterich J., Heightened odds of large earthquakes near İstanbul: An interaction-based probability calculation, *Science* 28 (2000) 661–665.
- [152] Ambraseys N.N., Finkel C.F., The Saros-Marmara earthquake of 9 August, *Earthq. Engineer. Struct. Dyn.* 15 (1987) 189–211.
- [153] Ambraseys N.N., Finkel C.F., The Seismicity of Turkey and adjacent areas: a historical review, 1500–1800, İstanbul, Muhittin Salih Eren, 1995.
- [154] Le Pichon X., Taymaz T., Şengör A.M.C., The Marmara Fault and the future İstanbul earthquake, in: Karaca M., Ural D.N. (Eds.), Proceedings of the International Conference on the Kocaeli Earthquake, 17 August 1999, İstanbul University Press House, İstanbul, 1999, pp. 41–54.
- [155] Şengör A.M.C., Demirbağ E., Tüysüz O., Kurt H., Görür N., Kuşçu İ., A preliminary note on the structure of the Gulf of İzmit: implications for the westerly prolongation of the North Anatolian Fault, in: Karaca M., Ural D.N. (Eds.), Proceedings of the International Conference on the Kocaeli Earthquake, 17 August 1999, İstanbul University Press House, İstanbul, 1999, pp. 25–37.
- [156] Barka A.A., Toksöz M.N., Gülen L., Kadinsky-Cade K., Segmentation, seismicity and earthquake potential of the eastern section of the North Anatolian Fault Zone, Hacettepe Univ. Earth Sci. 14 (1987) 337–352 (in Turkish with English abstract).
- [157] Akgün M., Ergün M., İzmit Körfezinin yapısı ve Kuzey Anadolu Fayı (KAF) ile ilişkisinin irdelenmesi, *Jeofizik* 9 (1995) 71–78 (in Turkish with English abstract).
- [158] Ergün M., Özel E., Structural relationship between the Sea of Marmara basin and the North Anatolian fault, *Terra Nova* 7 (1995) 278–288.
- [159] Smith A.D., Taymaz T., Oktay F., Yüce H., Alpar B., Başaran H., Jackson J.A., Kara S., Şimşek M., High resolution seismic profiling in the Sea of Marmara (northwest Turkey): Late Quaternary sedimentation and sea-level changes, *Geol. Soc. Am. Bull.* 107 (1995) 923–936.
- [160] Wong H.K., Ludmann T., Uluğ T.A., Görür N., The Sea of Marmara: a plate boundary sea in an escape tectonic regime, *Tectonophysics* 244 (1995) 231–250.
- [161] Özhan G., Bayrak D., A seismic study of the Plio-Quaternary sediments in the İzmit Bay, *Geol. Soc. Turkey Bull.* 41 (1998) 151–154 (in Turkish with English abstract).
- [162] Emre Ö., Erkal T., Tchepalyga A., Kazancı N., Keçer M., Ünay E., Neogene–Quaternary evolution of the eastern Marmara region, northwest Turkey, *Min. Res. Expl. Inst. Bull.* 120 (1998) 119–145.
- [163] Hubert A., Barka A.A., Jacques E., Nalbant S., Meyer B., Armijo R., Tapponier P., King J., Seismic hazard in the Marmara Sea region following the 17 August 1999 İzmit earthquake, in: Barka A.A., Kozacı O., Akyüz S.H., Altunel E. (Eds.), 1999 İzmit and Düzce earthquakes: preliminary results, İstanbul Technical University Publ., İstanbul, 2000, pp. 311–316.
- [164] Yalıturak C., Alpar B., Yüce H., Tectonic elements controlling the evolution of the Gulf of Saros (northeastern Aegean Sea, Turkey), *Tectonophysics* 300 (1998) 227–248.

- [165] Lybérís N., Tectonic setting of the North Aegean Trough, in: Dixon J.E., Robertson A.H.F. (Eds.), The geological evolution of the Eastern Mediterranean, Geological Society Special Publication vol. 17, Geological Society, London, 1984, pp. 709–725.
- [166] Roussos N., Triantafyllos L., Structure of the central North Aegean Through: an active strike-slip deformation zone, *Basin Res.* 3 (1991) 39–48.
- [167] Saatçılar R., Ergintav S., Demirbağ E., İnan S., Character of active faulting in the North Aegean Sea, *Marine Geol.* 160 (1999) 339–353.
- [168] Straub C., Kahle H.G., Global positioning System (GPS) estimates of crustal deformation in the Marmara Sea region, Northwestern Anatolia, *Earth Planet. Sci. Lett.* 121 (1994) 495–502.
- [169] Straub C., Kahle H.G., Schinder C., GPS and geologic estimates of the tectonic activity in the Marmara region, NW Anatolia, *J. Geophys. Res.* 102 (1997) 27587–27601.
- [170] Le Pichon X., Chamot-Rooke C., Lallemand S., Noomen R., Veis G., Geodetic determination of the kinematics of Central Greece with respect to Europe: implications for Eastern Mediterranean tectonics, *J. Geophys. Res.* 100 (1995) 12675–12690.
- [171] Arpat E., Şaroğlu F., Türkiye'deki bazı önemli genç tektonik olaylar, *Bull. Geol. Soc. Turkey* 18 (1975) 91–101 [in Turkish with English abstract].
- [172] Hempton M.R., Dewey J.F., Şaroğlu F., The East Anatolian transform fault: along strike variations in geometry and behaviour, *EOS Transac.* 62 (1981) 393.
- [173] Hempton M.R., Dunne L.A., Dewey J.F., Sedimentation in active strike-slip basins, southern Turkey, *J. Geol.* 91 (1983) 401–412.
- [174] Hempton M.R., Result of the detailed mapping near lake Hazar (eastern Taurus Mountains), in: Tekeli O., Gönçüoğlu M.C. (Eds.), *Geology of the Taurus Belt*. Min. Res. Expl. Inst. Turkey Publ., 1984, pp. 223–238.
- [175] Hempton M.R., Structure and deformation history of Bitlis suture near lake Hazar, southeastern Turkey, *Bull. Geol. Soc. Am.* 96 (1985) 233–243.
- [176] Muehlberger R.W., Gordon M.B., Observations on the complexity of the East Anatolian Fault, Turkey, *J. Struct. Geol.* 9 (1987) 899–903.
- [177] Taymaz T., Eyidoğan H., Jackson J., Source parameters of large earthquakes in the East Anatolian Fault Zone (Turkey), *Geophys. J. Inter.* 106 (1992) 537–550.
- [178] Lybérís N., Yürür T., Chorowicz J., Kasapoğlu E., Gündoğdu N., The East Anatolian fault: an oblique collisional belt, *Tectonophysics* 204 (1992) 1–15.
- [179] Şaroğlu F., Emre Ö., Boray A., Türkiye'nin Diri Fayları ve Depremsellikleri. Min. Res. Expl. Inst. Turkey Report No. 8174, 1987 (in Turkish).
- [180] Şaroğlu F., Emre Ö., Kuşçu İ., The East Anatolian fault zone of Turkey, *Annal. Tecton.* 6 (1992) 99–125.
- [181] Şaroğlu F., Emre Ö., Kuşçu İ., Active Fault Map of Turkey. General Directorate of Mineral and Research Exploration of Turkey Publication, 1992.
- [182] Seymen İ., Aydın A., Bingöl deprem fayı ve bunun Kuzey Anadolu fayı ile ilişkisi, *Min. Res. Expl. Inst. Turkey Bull.* 79 (1972) 1–8 (in Turkish with English abstract).
- [183] Jackson J., McKenzie D., Active tectonics of the Alpine-Himalayan Belt between Western Turkey and Pakistan, *Geophys. J. Royal Astr. Soc.* 7 (1984) (1984) 185–264.
- [184] Gülen L., Barka A., Toksöz M.N., Continental collision and related complex deformation: Maraş triple junction and surrounding structures, SE Turkey, Hacettepe Univ. Earth Sci. 14 (1987) 319–336 (in Turkish with English abstract).
- [185] Chorowicz J., Luxey P., Lybérís N., Carhalho J., Parrot J.F., Yürür T., Gündoğdu N., The Maraş triple junction (Southern Turkey) based on digital elevation model and satellite imagery interpretation, *J. Geophys. Res.* 99 (1994) 20225–20242.
- [186] Perinçek D., Geological investigation of the Çelikhhan-Sincik-Koçali area (Adıyaman Province), İstanbul University, Fac. Sci. Bull. Serie B 44 (1979) 127–147.
- [187] Perinçek D., Günay Y., Kozlu H., Doğu ve Güneydoğu Anadolu bölgesindeki yanal atımlı faylar ile ilgili yeni gözlemler, *Proceedings of 7th Biannual Petroleum Congress of Turkey*, 1987, pp. 89–103 (in Turkish with English abstract).
- [188] Perinçek D., Çemen İ., The structural relationship between the East Anatolian and Dead Sea fault zones in Southeastern Turkey, *Tectonophysics* 172 (1990) 331–340.
- [189] Yürür M.T., Chorowicz J., Recent volcanism, tectonics and plate kinematics near the junction of the African, Arabian, and Anatolian plates, *J. Volcan. Geother. Res.* 85 (1998) 1–15.
- [190] Westaway R., Arger J., Kinematics of the Malatya–Ovacık Fault Zone, Third International Turkish Geology Symposium, METU-Ankara, Abstracts, 1998, p. 197.
- [191] Arger J., Mitchell J., Westaway R., Neogene and Quaternary volcanism of south-eastern Turkey, in: Bozkurt E., Winchester J.A., Piper J.D.A. (Eds.), *Tectonics and magmatism in Turkey and the Surrounding Area*, Geological Society Special Publication no. 173, Geological Society, London, 2000, pp. 459–487.
- [192] McKenzie D.P., Active tectonics of the Alpine-Himalayan belt: the Aegean Sea and surrounding regions, *Geophys. J. Royal Astron. Soc.* 55 (1978) 217–254.
- [193] McKenzie D.P., The East Anatolian Fault: a major structure in eastern Turkey, *Earth Planet. Sci. Lett.* 29 (1976) 189–193.
- [194] Ambraseys N.N., Finkel C.F., Seismicity of the Northeast Mediterranean region during early 20th century, *Annal. Geophys.* 5B (1987) 701–726.
- [195] Ambraseys N.N., Temporary seismic quiescence, SE Turkey, *Geophys. J.* 96 (1989) 411–431.
- [196] Muehlberger R.W., The splintering of the Dead Sea Fault Zone in Turkey, Hacettepe Univ. Earth Sci. 8 (1981) 123–130.
- [197] Quennell A.M., The structural and geomorphic evolution of the Dead Sea rift, *Quart. J. Geol. Soc., London* 114 (1958) 1–24.
- [198] Quennell A.M., Tectonics of the Dead Sea rift, 20th International Geological Congress, Mexico 1959 (1956) 385–405.
- [199] Freund R., Garfunkel Z., Zak I., Goldberg M., Weissbrod T., Berin B., The shear along the Dead Sea rift, *Phil. Trans. Roy. Soc., London, Serie A* 267 (1970) 107–130.
- [200] Mart Y., Rabinowitz P.D., The northern Red Sea and the Dead Sea Rift, *Tectonophysics* 124 (1986) 85–113.
- [201] Joffe S., Garfunkel Z., Plate kinematics of the circum Red Sea – a re-evaluation, *Tectonophysics* 141 (1987) 5–22.
- [202] Koçyiğit A., Yılmaz R., Aktaş K., Erkmén C., Nurlu M., Baykal M., Kılıç T., Seismotectonic characteristics of the 27 June 1998 Yakapınar–Ceyhan (Adana) earthquake, Turkey, Third International Turkish Geology Symposium, METU-Ankara, Abstracts, 1998 p. 321.
- [203] Gürsoy H., İnan S., Tatar O., Ünlügenç U., Demirkol C. Surface deformation, liquefaction-induced features and tectonic setting of 27 June 1998 Adana-Ceyhan earthquake, Third International Turkish Geology Symposium, METU-Ankara, Abstracts, 1998, p. 323.
- [204] Yurtmen S., Rowbotham G., İşler F., Floyd P.A., Petrogenesis of basalts from southern Turkey: the Plio-Quaternary

- volcanism to the north of İskenderun, in: Bozkurt E., Winchester J.A., Piper J.D.A. (Eds.), *Tectonics and magmatism in Turkey and the surrounding area*, Geological Society Special Publication vol. 173, Geological Society, London, 2000, pp. 489–512.
- [205] Pınar A., Barış Ş., Kalafat D., Işıkar A.M., A rupture model for the June 27 1998 Adana–Ceyhan earthquake ($M_s = 6.2$), Third International Turkish Geology Symposium, METU-Ankara, Abstracts, 1998, p. 322.
- [206] Freund R., Zak I., Garfunkel Z., On the age and rate of sinistral movement along the Dead Sea rift, *Nature* 220 (1968) 253–255.
- [207] Eyal M., Eyal Y., Bartov Y., Steinitz G., The tectonic development of the western margin of the Gulf of Elat (Aqaba) rift, *Tectonophysics* 80 (1981) 135–146.
- [208] Garfunkel Z., Dead Sea Rift – Introduction, *Tectonophysics* 141 (1981) 1–4.
- [209] Garfunkel Z., Internal structure of the Dead Sea leaky transform (rift) in relation to plate kinematics, *Tectonophysics* 80 (1981) 81–108.
- [210] Ben-Avraham Z., Almagor G., Garfunkel Z., Sediments and structure of the Gulf of Elat, *Sediment. Geol.* 23 (1979) 239–267.
- [211] Garfunkel Z., Zak I., Freund R., Active faulting in the Dead Sea rift, *Tectonophysics* 80 (1981) 1–26.
- [212] Ben-Avraham Z., Structural framework of the Gulf of Elat (Aqaba), northern Red Sea, *J. Geophys. Res.* 90 (1985) 703–726.
- [213] Baldrige W.S., Eyal Y., Bartov Y., Steinitz G., Eyal M., Miocene magmatism of Sinai related to the opening of the Red Sea, *Tectonophysics* 197 (1991) 181–201.
- [214] Doser D.I., Yarwood D.R., Strike-slip faulting in continental rifts: examples from Sabukia, East Africa and other regions, *Tectonophysics* 197 (1991) 213–224.
- [215] Girdler R.W., The Dead Sea transform fault system, *Tectonophysics* 180 (1990) 1–13.
- [216] Girdler R.W., The Afro–Arabian rift system – an overview, *Tectonophysics* 197 (1991) 139–153.
- [217] Greene L.C., Richards D.R., Johnson R.A., Crustal structure and tectonic evolution of the Anza Rift, northern Kenya, *Tectonophysics* 197 (1991) 203–211.
- [218] Mart Y., The Dead Sea Rift: from continental rift to incipient ocean, *Tectonophysics* 197 (1991) 155–179.
- [219] Mart Y., Ptolemais basin: the tectonic origin of a Senonian marine basin underneath the southeastern Mediterranean Sea, *Tectonophysics* 234 (1994) 5–17.
- [220] Heimann A., Ron H., Geometrical changes of plate boundaries along part of the northern Dead Sea transform: geochronology and palaeomagnetic evidence, *Tectonics* 12 (1993) 477–491.
- [221] Khair K., Khawlie M., Haddad F., Barazangi M., Seber D., Chaimov T., Bouger gravity and crustal structure of the Dead Sea transform fault and adjacent mountain belts in Lebanon, *Geology* 21 (1993) 739–742.
- [222] Garfunkel Z., Ben-Avraham Z., The structure of the Dead Sea basin, *Tectonophysics* 255 (1996) 155–176.
- [223] Hall J.K., Digital topography and bathymetry of the area of the Dead Sea depression, *Tectonophysics* 266 (1996) 177–185.
- [224] Sneh A., The Dead Sea Rift: lateral displacement and downfaulting phases, *Tectonophysics* 263 (1996) 277–292.
- [225] Wdowinski S., Zilberman E., Kinematic modelling of large-scale structural asymmetry across the Dead Sea Rift, *Tectonophysics* 266 (1996) 187–201.
- [226] Çapan U.Z., Vidal P., Cantagrel J.M., K–Ar, Nd, Sr and Pb isotopic study of the Quaternary volcanism in Karasu Rift (Hatay), N-end of Dead sea rift zone in SE Turkey, Hacettepe Univ. Earth Sci. 14 (1987) 165–178.
- [227] Parlak O., Kop A., Ünlügenç U., Demirkol C., Geochemistry and geochronology of basaltic rocks in the Karasu graben near Kırkhan (Hatay), Southern Turkey, *Turkish J. Earth Sci.* 7 (1998) 53–61.
- [228] Rotstein Y., Kafka L.A., Seismotectonics of the southern boundary of Anatolia, eastern Mediterranean region: subduction, collision and arc jumping, *J. Geophys. Res.* 87 (1982) 7694–7706.
- [229] Aksu A.E., Calon T.J., Piper D.W.J., Turğut S., İzdar E., Architecture of late orogenic Quaternary basins in northeastern Mediterranean Sea, *Tectonophysics* 210 (1992) 191–213.
- [230] Lybérís N., Tectonic evolution of the Gulf of Suez and the Gulf of Aqaba, *Tectonophysics* 153 (1988) 209–220.
- [231] Steckler M.S., Berthelot F., Lybérís N., Le Pichon X., Subsidence in the Gulf of Suez: implications for rifting and plate kinematics, *Tectonophysics* 153 (1988) 249–270.
- [232] Steinz G., Bartov Y., The Miocene–Pliocene history of the Dead Sea segment of the Rift in the light of K–Ar ages of basalts, *Israel J. Earth Sci.* 40 (1991) 199–208.
- [233] Dubertet L., Liban, Syrie et Bordure des pays voisins. Extrait des notes et mémoires sur le Moyen-Orient, tome VIII, Museum National d’Histoire Naturelle, Paris, 1966, pp. 251–358.
- [234] Bandel K., Khouri H., Lithostratigraphy of the Triassic of Jordan, *Facies* 4 (1981) 1–23.
- [235] Chaimov T.A., Barazangi M., Crustal shortening in the Palmyride Fold Belt, Syria, and implications for movement along Dead Sea fault system, *Tectonics* 9 (1990) 1369–1386.
- [236] Girdler R.W., Styles P., Seafloor spreading in the Western Gulf of Aden, *Nature* 271 (1978) 615–617.
- [237] Zack I., Freund R., Recent strike-slip movements along the Dead Sea rift, *Israel J. Earth Sci.* 15 (1966) 33–37.
- [238] Zack I., Freund R., Asymmetry and basin migration in the Dead Sea rift, *Tectonophysics* 80 (1981) 27–38.
- [239] Fleury J., Chorowicz J., Somma J., Discussion on transcurent fault activity on the Dead Sea Transform in Lebanon and its implications for plate tectonics and seismic hazard, *J. Geol. Soc., London* 156 (1999) 1243–1248.
- [240] Papazachos B.C., Comninakis P.E., Geophysical and tectonic features of the Aegean arc, *J. Geophys. Res.* 76 (1971) 8517–8533.
- [241] Fytikas M., Innocenti F., Manetti P., Mazzuoli R., Peccerillo A., Villari L., Tertiary to Quaternary evolution of the volcanism in the Aegean region, in: Dixon J.E., Robertson A.H.F. (Eds.), *The Geological Evolution of the Eastern Mediterranean*, Geological Society Special Publication vol. 17, Geological Society, London, 1984, pp. 687–700.
- [242] Meulenkamp J.E., Wortel W.J.R., Van Wamel W.A., Spakman W., Hoogerduyn Strating E., On the Hellenic subduction zone and geodynamic evolution of Crete in the late middle Miocene, *Tectonophysics* 146 (1988) 203–215.
- [243] Spakman W.A.V., Wortel M.J.R., Vlaar N.J., The Aegean subduction zone: a tomographic image and its geodynamic implications, *Geophys. Res. Lett.* 15 (1988) 60–63.
- [244] Mart Y., Woodside J., Preface: Tectonics of the Eastern Mediterranean, *Tectonophysics* 234 (1994) 1–3.
- [245] Le Pichon X., Angelier J., Aubouin J., Lybérís N., Monti S., Renard V., Got H., Hsü K., Marty Y., Mascle J., Mathews D., Mitropoulos D., Tsoflias P., Chronis G., From subduction to transform motion: a seabeam survey of the Aegean trench system, *Earth Planet. Sci. Lett.* 44 (1979) 441–450.

- [246] Jongsma D., Bathymetry and shallow structure of the Pliny and Strabo trenches, south of the Aegean Arc, *Geol. Soc. Am. Bull.* 88 (1977) 797–805.
- [247] Le Pichon X., Angelier J., The Aegean arc and trench system: a key to the neotectonic evolution of the eastern Mediterranean area, *Tectonophysics* 60 (1979) 1–42.
- [248] Mercier J.L., Extensional–compressional tectonics associated with the Aegean arc: comparison with the Andean Cordillera south of Peru–north Bolivia, *Philos. Trans. R. Soc. London Ser. A* 300 (1981) 337–355.
- [249] Le Pichon X., Angelier J., The Aegean Sea, *Philop. Trans. R. Soc. London Ser. A* 300 (1981) 357–372.
- [250] Le Pichon X., Land-locked oceanic basins and continental collision: the Eastern Mediterranean as a case example, in: Hsü K. (Ed.), *Mountain Building Processes*, Academic Press, London, 1982, pp. 201–211.
- [251] Kasapoğlu E.K., Toksöz M.N., Tectonic consequences of the collision of the Arabian and Eurasian plates: finite element models, *Tectonophysics* 100 (1983) 71–95.
- [252] Kasapoğlu E.K., Seismotectonic characteristics of Eastern Mediterranean: A finite elements analysis, *Hacettepe Univ. Earth Sci.* 14 (1987) 309–317.
- [253] Toksöz M.N., Kasapoğlu E., Collision of the Arabian and Eurasian plates: finite element models, *EOS Abstracts* (1988) T51A-2.
- [254] Meulenkamp J.E., Van Der Zwaan G.J., Van Wamel W.A., On Late Miocene to recent vertical motions in the Cretan segment of the Aegean arc, *Tectonophysics* 234 (1994) 53–72.
- [255] Taymaz T., Jackson J., Westaway R., Earthquake mechanisms in the Aegean trench near Crete, *Geophys. J. Inter.* 102 (1990) 695–731.
- [256] Royden L., Evolution of retreating subduction boundaries formed during continental collision, *Tectonics* 12 (1993) 303–325.
- [257] Taymaz T., S-P-wave travel-time residuals from earthquakes and lateral inhomogeneity in the upper mantle beneath the Aegean and the Aegean Trench near Crete, *Geophys. J. Inter.* 127 (1996) 545–558.
- [258] De Jonge M.R., Wortel M.J.R., Spakman W., Regional scale tectonic evolution and the seismic velocity structure of the lithosphere and upper mantle: The Mediterranean region, *J. Geophys. Res.* 99 (1994) 12091–12108.
- [259] Wortel M.J.R., Spakman W.A.V., Structure and dynamics of subducted lithosphere in the Mediterranean region, *Proc. K. Ned. Akad. Wet.* 95 (1992) 325–347.
- [260] Smith A.G., Alpine deformation and the oceanic areas of the Tethys, Mediterranean and Atlantic, *Geol. Soc. Am. Bull.* 82 (1971) 2039–2070.
- [261] Nur A., Ben-Avraham Z., The eastern Mediterranean and the Levant: tectonics of continental collision, *Tectonophysics* 46 (1978) 297–311.
- [262] Vidal N., Alvarez-Marrón J., Klaeschen D., The structure of the Africa-Anatolia plate boundary in the eastern Mediterranean, *Tectonics* 19 (2000) 723–739.
- [263] Kempler D., Ben-Avraham Z., The tectonic evolution of the Cyprean Arc, *Annal. Tecton.* 1 (1987) 58–71.
- [264] Ben-Avraham Z., Kempler D., Ginzburg A., Plate convergence in the Cyprean Arc, *Tectonophysics* 146 (1988) 231–240.
- [265] Woodside J.M., Regional vertical tectonics in the eastern Mediterranean, *Geophys. J. Royal Astronom. Soc.* 47 (1976) 493–514.
- [266] Ambraseys N.N., Adams R.D., Seismicity of the Cyprus region, *Terra Nova* 5 (1993) 88–94.
- [267] Robertson A.H.F., Kidd R.B., Ivanov M.K., Limonov A.F., Woodside J.M., Galindo-Zaldivar J., Nieto L., The scientific party of the 1993 TTR-3 Cruise, Probing continental collision in the Mediterranean Sea, *EOS Transactions AGU* 75 (1994) 233.
- [268] Glover C., Robertson A.H.F., Neotectonic intersection of the Aegean and Cyprus tectonic arcs: extensional and strike-slip faulting in the Isparta Angle, SW Turkey, *Tectonophysics* 298 (1998) 103–132.
- [269] Morelli C., Eastern Mediterranean: geophysical results and implications, *Tectonophysics* 46 (1978) 333–346.
- [270] Harsch W., Kupfer T., Rast B., Sagesser R., Seismotectonic considerations on the nature of the Turkish–African plate boundary, *Geol. Rund.* 70 (1981) 368–384.
- [271] Kempler D., Garfunkel Z., The northeast Mediterranean triple junction from a plate kinematic point of view, *Bull. İstanbul Technical University* 44 (1991) 425–454.
- [272] Kempler D., Garfunkel Z., Structure and kinematics in the northeastern Mediterranean: a study of an irregular plate boundary, *Tectonophysics* 234 (1994) 19–32.
- [273] Swarbrick R.E., Sinistral strike-slip and transpressional tectonics in an ancient oceanic setting: the Mamonia Complex, southeast Cyprus, *J. Geol. Soc., London* 150 (1993) 381–392.
- [274] Payne A.S., Robertson A.H.F., Neogene supra-subduction zone extension in the Polis graben system, West Cyprus, *J. Geol. Soc., London* 152 (1995) 613–628.
- [275] Ben-Avraham Z., The Structure and tectonic setting of the Levant continental margin, eastern Mediterranean, *Tectonophysics* 46 (1978) 313–331.
- [276] Lort J.M., The tectonics of the eastern Mediterranean: a geophysical review, *Rev. Geophys. Space Physics* 9 (1971) 189–216.
- [277] Biju-Duval B., Letouzey J., Montadert L., Structure and evolution of the Mediterranean basins, Initial Report of Deep Sea Drilling Project 42 (1978) 951–984.
- [278] Ambraseys N.N., The seismic history of Cyprus. *Rev. Union Int. Secours, Geneva* 3 (1965) 25–48.
- [279] Ambraseys N.N., Reappraisal of the Seismicity in Cyprus (1894–1991). Imperial College, ESEE Research Report 92-9 (1992) 47–67.
- [280] Papazachos B.C., Distribution of seismic foci in the Mediterranean and surrounding area and its tectonic implications, *Geophys. J.R. Astron. Soc.* 33 (1973) 421–432.
- [281] Papazachos B.C., Large seismic faults in the Aegean Arc, *Annal. Geofisika* 39 (1996) 891–903.
- [282] Pantazes T.H., Archaeoseismicity of Cyprus, *Asfalistika Chronika* 21 (1993) 245–313.
- [283] Salamon A., Hofstetter A., Garfunkel Z., Ron H., Seismicity in the eastern Mediterranean region: perspective from the Sinai subplate, *Tectonophysics* 263 (1996) 293–305.
- [284] Papazachos B.C., Papaioannou C.A., Lithospheric boundaries and plate motions in the Cyprus area, *Tectonophysics* 308 (1999) 193–204.
- [285] Spakman W.S., Van Der Lee, Van Der Hilst, Travel-time tomography of the European–Mediterranean mantle down to 1400 km, *Phys. Earth Planet. Inter.* 79 (1993) 3–73.
- [286] Alessandrini B., Beranzoli L., Drakatos G., Falcone C., Karantonis G., Mele F.M., Stavrakakis G., Back arcs basins and P-wave crustal velocity in the Ionian and Aegean regions, *Geophys. Res. Lett.* 24 (1997) 527–530.
- [287] Pinar A., Kalafat D., Source processes and seismotectonic implications of the 1995 and 1996 Cyprus, eastern Mediterranean Region, earthquakes, *Tectonophysics* 301 (1999) 217–230.

- [288] Vacher P., Spakman W., Wortel M.J.R., Numerical tests on the seismic visibility of metastable minerals in subduction zones, *Earth Planet. Sci. Lett.* 170 (1999) 335–349.
- [289] Duermeijer C.E., Nyst M., Meijer P.T., Langereis C.G., Spakman W., Neogene evolution of the Aegean arc: paleomagnetic and geodetic evidence for a rapid and young rotation phase, *Earth Planet Sci. Lett.* 176 (2000) 509–525.
- [290] Şengör A.M.C., White G., Dewey J.F., Tectonic evolution of the Bitlis Suture, southeastern Turkey: implications for the tectonics of the Eastern Mediterranean, *Rapp. Comm. Int. Mer. Médit.* 25/26 (1979) 95–97.
- [291] Şengör A.M.C., Mesozoic-Cenozoic tectonic evolution of Anatolia and surrounding regions, *Bull. Bur. Rech. Géol. Min. France* 115 (1980) 1–137.
- [292] Aktaş G., Robertson A.H.F., The Maden complex, SE Turkey: evolution of a Neotethyan active margin, in: Dixon J.H., Robertson A.H.F. (Eds.), *The geological evolution of the Eastern Mediterranean*, Geological Society Special Publication no. 17, Geological Society, London, 1985, pp. 375–402.
- [293] Yiğitbaş E., Yılmaz Y., Post-Late Cretaceous strike-slip tectonics and its implications for the Southeast Anatolian Orogen, Turkey, *Inter. Geol. Rev.* 38 (1996) 818–831.
- [294] Yiğitbaş E., Yılmaz Y., New evidence and solution to the Maden Complex controversy of the Southeast Anatolian orogenic belt (Turkey), *Geol. Rund.* 85 (1996) 250–263.
- [295] Arpat E., 1975 Lice earthquake, *Yer Yuvarı ve İnsan 2* (1977) 18–28 (in Turkish with English abstract).
- [296] Arpat E., 1976 Çaldıran earthquake, *Yer Yuvarı ve İnsan 2* (1977) 29–42 (in Turkish with English abstract).
- [297] Arpat E., Şaroğlu F., İz H.B., 1976 Çaldıran depremi, *Yeryuvarı ve İnsan 2* (1977) 29–41 (in Turkish with English abstract).
- [298] Şaroğlu F., Güner Y., The active Tutak fault, its characteristics and relations to the Çaldıran fault, *Yeryuvarı ve İnsan 4* (1979) 11–14 (in Turkish with English abstract).
- [299] Şaroğlu F., Güner Y., Factors affecting the geomorphological development of eastern Turkey – relations between geomorphology, tectonics and volcanism, *Geol. Soc. Turkey Bull.* 24 (1981) 39–50 (in Turkish with English abstract).
- [300] Barka A.A., Şaroğlu F., Güner Y., Horasan–Narman depremi ve bu depremin Doğu Anadolu neotektoniğindeki yeri, *Yeryuvarı ve İnsan 8* (1983) 16–20 (in Turkish with English abstract).
- [301] Toksöz M.N., Guenette M., Gülen L., Keough G., Pulli J.J., Sav H., Olguner A., Source mechanism of Narman–Horasan earthquake, *Yeryuvarı ve İnsan 8* (1983) 47–52 (in Turkish with English abstract).
- [302] Gönçüoğlu C.M., Turhan N., Geology of the Bitlis Metamorphic belt, in: Tekeli O., Gönçüoğlu C.M. (Eds.), *Geology of the Taurus Belt*, Mineral Research and Exploration Institute of Turkey Publication, Ankara, 1984, pp. 237–244.
- [303] Koçyiğit A., Karayazı Fault, *Bull. Geol. Soc. Turkey* 28 (1985) 67–72 (in Turkish with English abstract).
- [304] Koçyiğit A., Muratbağı–Balabantaş (Horasan) arasında Çobandede Fay Kuşağı'nın jeotektonik özellikleri ve Horasan–Narman depremi yüzey kırıkları, *Cumhuriyet Univ., J. Engineer. Fac., Serie A – Earth Sci.* 2 (1985) 17–33 (in Turkish with English abstract).
- [305] Koçyiğit A., Superimposed basins and their relations to the recent strike-slip fault zone: a case study of Refahiye superimposed basin adjacent to the North Anatolian Transform Fault, northeastern Turkey, *Inter. Geol. Rev.* 38 (1996) 701–713.
- [306] Philip H., Cisternas A., Gvishiani A., Gorshkov A., The Caucasus: an actual example of the initial stages of continental collision, *Tectonophysics* 161 (1989) 1–21.
- [307] Bozkuş C., Çayırılı–Tercan Tersiyer havzası doğusunun (Tercan–Aşkale arası) stratigrafisi, *Bull. Geol. Soc. Turkey* 34 (1992) 97–102 (in Turkish with English abstract).
- [308] Ambraseys N.N., Melville C.P., Historical evidence of faulting in eastern Anatolia and northern Syria, *Terra Nova* 6 (1994) 1–10.
- [309] Trifonov V.G., Karakhanian A.S., Kozhurin A.I., Major active faults of the collision area between the Arabian and the Eurasian plates, in: Bolt B.A., Amirbekian R. (Eds.), *Continental collision zone earthquakes and seismic hazard reduction, PUBLISHER? LOCATION? 1994*, pp. 56–76.
- [310] Chorowicz J., Dhont D., Gündoğdu N., Neotectonics in the eastern Anatolian fault region (Turkey) advocates crustal extension: mapping from SAR ERS imagery and Digital Elevation Model, *J. Struct. Geol.* 21 (1999) 511–532.
- [311] Rögl F., Steininger F.F., Vom Zerfall der Tethys zu Mediterran und Paratethys, *Annalen des Naturhistorischen Museums Wien* 85/A (1983) 135–163.
- [312] Atalay İ., Geology and Geomorphology of the Erzurum Plain and its surroundings, Atatürk University Publications, Erzurum, 1978 (in Turkish with English abstract).
- [313] Wong H.K., Degens E.T., Finckh P., Structures in modern lake Van sediments as revealed by 3.5 KHz high resolution profiling, in: Degens E.T., Kurtman F. (Eds.), *The Geology of Lake Van*, Min. Res. Expl. Inst. Publ., 169, 1978, pp. 11–19.
- [314] Atalay İ., Geomorphology and soil geography of the Muş Plain and its surroundings, Ege University Publications, İzmir, 1983 (in Turkish with English abstract).
- [315] Cantez N., Üçer B., A catalogue of focal mechanism diagrams for Turkey and adjoining areas, Publication no. 25, İstanbul Technical University, İstanbul, 1967.
- [316] Ergin K., Güçlü U., Uz Z., Türkiye ve Civarının Deprem Kataloğu (1965–1970), Publication no. 28, İstanbul Technical University, İstanbul, 1967 (in Turkish).
- [317] Eyidoğan H., The source parameters of the Lice, Turkey earthquake, *Individual studies by participants at the IISE, Tokyo* 16 (1980) 107–130.
- [318] Eyidoğan H., The Narman, eastern Turkey earthquake of 30 October 1983; active conjugate faulting and the migration of the seismicity, in: *Proceedings of the Workshop on Historical Seismicity and Seismotectonics of the Mediterranean Region*, 10–12 October 1990, İstanbul, 1985, pp. 224–234.
- [319] Eyidoğan H., The Narman, Eastern Turkey earthquake of 30 October 1983: Active conjugate faulting and the migration of the seismicity, *Proceedings of Workshop on Historical Seismicity and Seismotectonics of the Mediterranean Region*, Turkish Atomic Authority, Ankara, Turkey, 1990, pp. 224–233.
- [320] Özgül N., Seymen İ., Arpat E., 30 Ekim 1983 Narman–Horasan depreminin makrosismik ve tektonik özellikleri, *Yeryuvarı ve İnsan 8* (1983) 21–25 (in Turkish with English abstract).
- [321] Toksöz M.N., Arpat E., Şaroğlu F., East Anatolian earthquake of 24 November 1976, *Nature* 270 (1977) 423–425.
- [322] Eyidoğan H., Nalbant S.S., Barka A.A., King G.C.P., Static stress changes induced by the 1924 Pasinler ($M = 6.8$) and 1983 Horasan–Narman ($M = 6.8$) earthquakes, *Northeastern Turkey, Terra Nova* 11 (1999) 38–44.
- [323] Yılmaz Y., Comparisons of the young volcanic associations of the west and the east Anatolia under the compressional regime: a review, *J. Volcan. Geother. Res.* 44 (1990) 69–87.
- [324] Yılmaz Y., Güner Y., Şaroğlu F., Geology of the Quaternary volcanic centres of the east Anatolia, *J. Volcan. Geother. Res.* 85 (1998) 173–210.

- [325] Ercan T., Fujitani T., Madsuda J.I., Notsu K., Tokel S., Uı T., Doğu ve Güneydoğu Anadolu Neojen–Kuvaterner volkaniklerine ilişkin yeni kimyasal, radyometrik ve izotopik verilerin yorumu, *Min. Res. Expl. Inst. Turkey Bull.* 110 (1990) 143–164 (in Turkish with English abstract).
- [326] Pearce J.A., Bender J.F., De Long S.E., Kidd W.S.F., Low P.J., Güner Y., Şaroğlu F., Yılmaz Y., Moorbath S., Mitchell J.G., Genesis of collision volcanism in Eastern Anatolia, Turkey, *J. Volcan. Geother. Res.* 44 (1990) 189–229.
- [327] Adıyaman O., Chorowicz J., Köse O., Relationships between volcanic patterns and neotectonics in Eastern Anatolia from analysis of satellite images and DEM, *J. Volcan. Geother. Res.* 85 (1998) 17–32.
- [328] Keskin M., Pearce J.A., Mitchell J.G., Volcano-stratigraphy and geochemistry of collision-related volcanism on the Erzurum–Kars Plateau, northeastern Turkey, *J. Volcan. Geother. Res.* 85 (1998) 355–404.
- [329] Yalçın H., Gündoğdu M.N., Gourgaud A., Vidal P., Uçurum A., Geochemical characteristics of Yamadağı volcanics in central east Anatolia: an example from collision zone volcanism, *J. Volcan. Geother. Res.* 85 (1998) 303–326.
- [330] Alptekin O., Nabelek J.L., Toksöz M.N., Source mechanism of the Bartın earthquake of September 3, in Northwestern Turkey: evidence for active thrust faulting at the southern Black Sea margin, *Tectonophysics* 122 (1986) 73–88.
- [331] Tan O., Source parameters of 1968 September 3 Bartın (NW-Turkey) earthquake, BSc Thesis, İstanbul Technical University, İstanbul, 1996 (unpublished; in Turkish with English abstract).
- [332] Şengör A.M.C., Türkiye'nin Neotektoniğinin Esasları, *Geol. Soc. Turkey Conference Series 2*, 1980 (in Turkish with English abstract).
- [333] Şengör A.M.C., Barka A.A., Evolution of escape-related strike-slip systems: implications for distribution of collisional orogens, 29th International Geological Congress, Kyoto, Japan, Abstracts 1, (1992) p. 232.
- [334] Tatar O., Piper J.D.A., Gürsoy H., Temiz H., Regional significance of neotectonic counterclockwise rotation in Central Turkey, *Inter. Geol. Rev.* 38 (1996) 692–700.
- [335] Tatar O., Piper J.D.A., Gürsoy H., Palaeomagnetic study of the Erciyes sector of the Ecemiş Fault Zone: neotectonic deformation in the eastern part of the Anatolian Block, in: Bozkurt E., Winchester J.A., Piper J.D.A. (Eds.), *Tectonics and magmatism in Turkey and the surrounding area*, Geological Society Special Publication no. 173, Geological Society, London, 2000, pp. 423–440.
- [336] Gürsoy H., Piper J.D.A., Tatar O., Temiz H., A palaeomagnetic study of the Sivas Basin, Central Turkey: crustal deformation during lateral extrusion of the Anatolian block, *Tectonophysics* 271 (1997) 89–105.
- [337] Gürsoy H., Piper J.D.A., Tatar O., Mesci L., Palaeomagnetic study of the Karaman and Karapınar volcanic complex, Central Turkey: neotectonic rotation in the south-central sector of the Anatolian block, *Tectonophysics* 299 (1998) 191–211.
- [338] Gürsoy H., Piper J.D.A., Tatar O., Palaeomagnetic study of the Galatean Volcanic Province, north-central Turkey: Neogene deformation on the northern border of the Anatolian block, *Geol. J.* 34 (1999) 7–23.
- [339] Platzman E.S., Tapırdamaz C., Sanver M., Neogene anticlockwise rotation of central Anatolia (Turkey): preliminary palaeomagnetic and geochronological results, *Tectonophysics* 299 (1998) 175–189.
- [340] Toprak V., Central Kızılırmak Fault Zone: northern margin of Central Anatolian volcanics, *Turkish J. Earth Sci.* 3 (1994) 29–38.
- [341] Toprak V., Göncüoğlu M.C., Keçiboyduran–Melendiz Fault and its regional significance (Central Anatolia), *Hacettepe Univ. Earth Sci.* 16 (1993) 55–65.
- [342] Toprak V., Göncüoğlu M.C., Tectonic control on the development of Neogene–Quaternary Central Anatolian Volcanic province, Turkey, *Geol. J.* 28 (1993b) 357–369.
- [343] Torak V., Vent distribution and its relation to regional tectonics, Cappadocian Volcanics, Turkey, *J. Volcan. Geothermal Res.* 85 (1998) 55–67.
- [344] Chorowicz J., Luzey P., Yürür T., Rudant J.P., Gündoğdu N., Lybérıs N., Slip motion estimation along the Ovacık fault near Erzincan (Turkey) using ERS1 radar image, *Remote Sensing Environ.* 52 (1995) 66–70.
- [345] Toprak V., Kaymakçı N., Determination of stress orientation using slip lineation data in Pliocene ignimbrites around Derinkuyu Fault (Nevşehir), *Turkish J. Earth Sci.* 4 (1995) 39–47.
- [346] Dirik K., Göncüoğlu M.C., Neotectonic characteristics of Central Anatolia, *Inter. Geol. Rev.* 38 (1996) 807–817.
- [347] Koçyiğit A., Beyhan A., A new intracontinental transcurrent structure: the Central Anatolian Fault Zone, Turkey, *Tectonophysics* 284 (1998) 317–336.
- [348] Koçyiğit A., Beyhan A., Reply to Rob Westaway's comment on 'A new intracontinental transcurrent structure: the Central Anatolian Fault Zone, Turkey', *Tectonophysics* 314 (1999) 481–496.
- [349] Çemen İ., Göncüoğlu M.C., Dirik K., Structural evolution of the Tuzgözü basin in Central Anatolia, Turkey, *J. Geol.* 107 (1999) 693–706.
- [350] Kaymakçı N., Tectonostratigraphic evolution of the Çankırı Basin (Central Anatolia, Turkey), *Geologica Ultraiectina, Mededlingen van de Faculteit Aardwetenschappen, Universiteit Utrecht No.* 190, 2000.
- [351] Kaymakçı N., White S.H., Van Dijk M., Palaeostress inversions in a multiphase deformed area: kinematic and structural evolution of the Çankırı basin (central Turkey), Part 1 – northern area, in: Bozkurt E., Winchester J.A., Piper J.D.A. (Eds.), *Tectonics and magmatism in Turkey and the surrounding area*, Geological Society Special Publication no. 173, Geological Society, London, 2000, pp. 295–323.
- [352] Yetiş C., Geology of the Çamardı (Niğde) region and the characteristics of the Ecemiş Fault Zone between Madenbogaz and Kamışlı, İstanbul University, Faculty of Science Bulletin, Serie B 43 (1978) 41–61.
- [353] Yetiş C., Ecemiş Fay Kuşağının jeotektonik evrimi, *Yerbilimleri* 11 (1984) 1–12 (in Turkish with English abstract).
- [354] Yetiş C., New observations on the age of the Ecemiş Fault, in: Tekeli O., Göncüoğlu M.C. (Eds.), *Geology of the Taurus Belt, Mineral Research and Exploration Institute Special Publication*, 1984, pp. 386–394.
- [355] Yetiş C., Demirkol C., Geotectonic evolution of the Ecemiş fault zone, *Hacettepe Univ., Earth Sci.* 11 (1984) 1–12.
- [356] Westaway R., Comment on 'a new intracontinental transcurrent structure: the Central Anatolian Fault Zone, Turkey' by A. Koçyiğit and A. Beyhan, *Tectonophysics* 314 (1999) 469–479.
- [357] Görtür N., Oktay F.Y., Seymen İ., Şengör A.M.C., Palaeotectonic evolution of Tuzgözü basin complex, Central Turkey, in: Dixon J.E., Robertson A.H.F. (Eds.), *The geological evolution of the Eastern Mediterranean*, Geological Society Special Publication no. 17, Geological Society, London, 1984, pp. 81–96.
- [358] Dellaloğlu A., Aksu R., Kulu-Şerefiikoçhisar-Aksaray Dolayının Jeolojisi ve Petrol Olanakları, *Turkish Petroleum Corporation report no.* 2020, 1984 (in Turkish, unpublished).

- [359] Emre Ö., Hasandağ-Keçiborludağı Yöresi Volkanizmasının Jeomorfolojisi. Ph.D. Thesis, İstanbul University, İstanbul, 1991 (unpublished, in Turkish with English abstract).
- [360] Dhont D., Chorowicz J., Yürür T., Froger J.L., Köse O., Gündoğdu N., Emplacement of volcanic vents and geodynamics of Central Anatolia, Turkey, *J. Volcan. Geother. Res.* 85 (1998) 33–55.
- [361] Pasquare G., Poli S., Venzolli L., Zanchi A., Continental arc volcanism and tectonic setting in Central Anatolia, *Tectonophysics* 146 (1988) 217–230.
- [362] Öcal N., 1956 Eskişehir Depremi Makro ve Mikrosismik Gözlemleri. Seismology Institute Publication, İstanbul Technical University, İstanbul, 1959 (in Turkish).
- [363] Ambraseys N.N., Studies in historical seismicity and tectonics, *Geodynamics of Today*, The Royal Society of London Publication, London, 1975, pp. 7–16.
- [364] Ambraseys N.N., Finkel C.F., Long-term seismicity of İstanbul and of the Sea of Marmara region, *Terra Nova* 3 (1991) 527–539.
- [365] Paréjas E., Pamir H.N., 19/4/1938 Orta Anadolu Yer Depremi. İstanbul University, Faculty of Science Publication IV, 1939.
- [366] Öztin F., Bayülke N., Historical earthquakes of İstanbul, Kayseri and Elazığ, Proceedings of Workshop on Historical Seismicity and Seismotectonics of the Mediterranean Region, Turkish Atomic Energy Authority, Ankara, 1990, pp. 234–253.
- [367] Kalafat D., Pınar A., August 14, 1996 ($M_s = 5.6$) Mecitözü–Çorum and January 22, 1997 ($M_s = 5.5$) Antakya (Turkey) earthquakes: implication for inner deformation pattern. Third International Turkish Geology Symposium, METU-Ankara, Abstracts, 1998, p. 320.
- [368] Koçyiğit A., Güneybatı Türkiye ve yakın dolayında levhaiçi yeni tektonik gelişim, *Bull. Geol. Soc. Turkey* 27 (1984) 1–16 (in Turkish with English abstract).
- [369] Koçyiğit, Güneybatı Türkiye'nin depremselliği, in: BADSEM 2000–Batı Anadolu'nun Depremselliği Sempozyumu, Proceedings, 24–27 Mayıs 2000, İzmir, 2000, pp. 30–39 (in Turkish with English abstract).
- [370] Price S., Scott B., Fault block rotations at the edge of a zone of continental extension: southwest Turkey, *J. Struct. Geol.* 16 (1994) 381–392.
- [371] Temiz H., Poisson A., Andrieux J., Barka A.A., Kinematics of the Plio-Quaternary Burdur–Dinar cross-fault system in SW Anatolia (Turkey), *Annal. Tectonic.* XI (1997) 102–113.
- [372] Altunel E., Barka A.A., Akyüz S.H., Palaeoseismicity of the Dinar fault, SW Turkey, *Terra Nova* 11 (1999) 297–302.
- [373] Cihan M., Koçyiğit A., Sandıklı (Afyon) grabeninin neotektonik özellikleri, in: BADSEM 2000 – Batı Anadolu'nun Depremselliği Sempozyumu, Proceedings, 24–27 Mayıs, 2000 İzmir, 2000, pp. 166–174 (in Turkish with English abstract).
- [374] Koçyiğit A., Özacar A.A., Cihan M., Batı Anadolu horst-graben sisteminin doğu uzantısı ve Isparta Açısı ile ilişkisi nedir?: “Fethiye–Burdur Zonu” olarak bilinen yapının tektonik niteliği, *Tektonik Araştırma Grubu 4. Toplantısı, ATAG-5*, 16–17 Nov 2000, pp. 4–5.
- [375] Özacar A.A., Koçyiğit A., Dombayova grabeninin neotektonik özellikleri, In: BADSEM 2000 – Batı Anadolu'nun Depremselliği Sempozyumu, Proceedings, 24–27 Mayıs 2000, İzmir, 2000, pp. 175–183 (in Turkish with English abstract).
- [376] Yağmurlu F., Burdur fayının sismotektonik özellikleri, In: BADSEM 2000 – Batı Anadolu'nun Depremselliği Sempozyumu, Proceedings, 24–27 Mayıs 2000, İzmir, 2000, pp.143–151 (in Turkish with English abstract).
- [377] Brunn J.H., Dumont J.F., De Graciansky P.C., Gutnic M., Juteau T., Marcaux J., Poisson A., Outline geology of the Western Taurides, in: Campwell A.S. (Ed.), *Geology and history of Turkey*. Petroleum Exploration Society of Libya, Tripoli, 1971, pp. 225–257.
- [378] Özgül N., Toroslarn bazı temel jeoloji özellikleri, *Geol. Soc. Turkey Bull.* 19 (1976) 65–78 (in Turkish with English abstract).
- [379] Kissel C., Averbuch O., Frizon de Lamotte D., Monod O., Allerton S., First paleomagnetic evidence for a post-Eocene clockwise rotation of Western Taurides thrust belt east of the Isparta re-entrant (Southwestern Turkey), *Earth Planet. Sci. Lett.* 117 (1993) 1–14.
- [380] Frizon de Lamotte D., Poisson A., Aubourg C., Temiz H., Post-Tortonian westward and southward thrusting in the core of the Isparta re-entrant (Taurus, Turkey): geodynamic implications, *Bull. Soc. Géol. France* 166 (1995) 59–67.
- [381] Flecker R., Ellam R.M., Müller C., Poisson A., Robertson A.H.F., Turner J., Application of Sr isotope stratigraphy and sedimentary analysis of the origin and evolution of Neogene basins in the Isparta Angle, Southern Turkey, *Tectonophysics* 298 (1998) 83–101.
- [382] Gutnic M., Monod O., Poisson A., Dumont J.F., *Géologie des Taurides occidentales (Turquie)*, *Mém. Soc. Géol. France*, Paris, N.S., 137, 1979.
- [383] Demirtaş R., Karakısam S., Demir M., 1 Ekim 1995 Dinar depremi, *Deprem Araştırma Bülteni* 72 (1995) 5–38 (in Turkish).
- [384] Erinç S., Bener M., Sungur K., Göçmen K., 12 Mayıs 1971 Burdur Depremi, İstanbul Üniversitesi Coğrafya Enstitüsü Yayınları 66 (1971) (in Turkish).
- [385] Taymaz T., Price S.P., The 12.05.1971 Burdur earthquake sequence: a synthesis of seismological and geological observations, *Geophys. J. Inter.* 108 (1992) 589–603.
- [386] Eyidoğan H., Barka A.A., The October 1, 1995 Dinar earthquake, SW Turkey, *Terra Nova* 8 (1996) 479–485.
- [387] Kalafat D., 1 Ekim Dinar depremi ve saha gözlemleri, *Deprem Araştırma Bülteni* 74 (1996) 95–113 (in Turkish).
- [388] Kara M., Pınar A., İnce S., Güngör, Ögütücü Z., 1995 Dinar depremi ve artçı sarsıntıları 3 boyutlu dağılımı, *Deprem Araştırma Bülteni* 74 (1996) 46–68 (in Turkish).
- [389] Pınar A., Source inversion of the October 1, 1995, Dinar earthquake ($M_s = 6.1$): a rupture model with implications for seismotectonics in SW Turkey, *Tectonophysics* 292 (1998) 255–266.
- [390] Wright T.J., Parsons B.E., Jackson J.A., Haynes M., Fielding E.J., England P.C., Clarke P.J., Source parameters of the 1 October Dinar (Turkey) earthquake from SAR interferometry and seismic bodywave modelling, *Earth Planet. Sci. Lett.* 171 (1999) 23–37.
- [391] Altunel E., Barka A.A., Akyüz S.H., Dinar Fayının 1 Ekim 1995 depremi öncesi aktivitesi, in: Tatar O., Kavak K.S., Özden S. (Eds.), *Tektonik Araştırma Grubu 3. Toplantısı, ATAG-3 Proceedings*, 2000, pp. 59–86 (in Turkish with English abstract).
- [392] Koral H., Surface rupture and rupture mechanism of the October 1, 1995 ($M_w = 6.2$) Dinar earthquake, SW Turkey, *Tectonophysics* 327 (2000) 15–24.
- [393] Barka A.A., Reilinger R., Şaroğlu F., Şengör A.M.C., The Isparta angle: its importance in neotectonics of the eastern Mediterranean region, *IESCA-1995 Proceedings* 1 (1997) 3–17.
- [394] Eyidoğan H., Jackson J.A., A seismological study of normal faulting in the Demirci, Alaşehir and Gediz earthquake of-1970 in western Turkey: implications for the nature and geometry of deformation in the continental crust, *Geophys. J. Royal Astronom. Soc.* 81 (1985) 569–607.

- [395] Eyidoğan H., Rates of crustal deformation in western Turkey as deduced from major earthquakes, *Tectonophysics* 148 (1988) 83–92.
- [396] Jackson J.A., King G., Vita-Finzi C., The neotectonics of the Aegean: an alternative view, *Earth Planet. Sci. Lett.* 61 (1992) 303–318.
- [397] Taymaz T., The source parameters of the Çubukdağ (W. Turkey) earthquake of October 11, *Geophys. J. Inter.* 113 (1993) 260–267.
- [398] Altunel E., Evidence for damaging historical earthquakes at Priene, Western Turkey, *Turkish J Earth Sci.* 7 (1998) 25–35.
- [399] Altunel E., Geological and geomorphological observations in relation to the 20 September 1899 Menderes earthquake, Western Turkey, *J. Geol. Soc., London* 156 (1999) 241–246.
- [400] Dumont J.F., Uysal Ş., Şimşek Ş., Karamandere İ.H., Letouzey F., Güneybatı Anadolu'daki grabenlerin oluşumu, *Min. Res. Expl. Inst. Turkey Bull.* 92 (1979) 7–17.
- [401] Kaya O., Miocene reference sections for the coastal parts of west Anatolia, *Newslett. Stratig.* 10 (1981) 164–191.
- [402] Hancock P.L., Barka A.A., Kinematic indicators on active normal faults in western Turkey, *J. Struct. Geol.* 9 (1987) 419–427.
- [403] Şengör A.M.C., Cross-faults and differential stretching of hanging walls in regions of low-angle normal faulting: examples from western Turkey, in: Coward M.P., Dewey J.F., Hancock P.L. (Eds.), *Continental Extensional Tectonics*, Geological Society Special Publication no. 28, Geological Society, London, 1987, pp. 575–589.
- [404] Yağmurlu F., Salihli güneyinde üste doğru kabalaşan Neojen yaşlı altıvyon yelpaze çökeltileri ve Gediz grabeninin tektono-sedimenter gelişimi, *Geol Soc. Turkey Bull.* 30 (1987) 33–40 (in Turkish with English abstract).
- [405] İztan H., Yazman M., Geology and hydrocarbon potential of the Alaşehir (Manisa) area, western Turkey (1990) 327–338.
- [406] Westaway R., Block rotation in western Turkey. 1. Observational evidence, *J. Geophys. Res.* 95 (1990) 19857–19884.
- [407] Westaway R., Block rotation in western Turkey. 2. Theoretical models, *J. Geophys. Res.* 95 (1990) 19885–19901.
- [408] Westaway R., Neogene evolution of the Denizli region of western Turkey, *J. Struct. Geol.* 15 (1993) 37–53.
- [409] Jones M., Westaway R., Microseismicity and structures of the Germencik area, west Turkey, *Geophys. J. Inter.* 106 (1991) 293–300.
- [410] Paton S., Active normal faulting, drainage patterns and sedimentation in southwestern Turkey, *J. Geol. Soc., London* 149 (1992) 1031–1044.
- [411] Seyitoğlu G., Scott B., Late C., Cenozoic crustal extension and basin formation in west Turkey, *Geol. Mag.* 128 (1991) 155–166.
- [412] Seyitoğlu G., Scott B., The age of the Büyük Menderes Graben (western Turkey) and its tectonic implications, *Geol. Mag.* 129 (1992) 239–242.
- [413] Seyitoğlu G., Scott B., The cause of N–S extensional tectonics on western Turkey: tectonic escape vs back-arc spreading vs orogenic collapse, *J. Geodyn.* 22 (1996) 145–153.
- [414] Seyitoğlu G., Scott B.C., Rundle C.C., Timing of Cenozoic extensional tectonics in west Turkey, *J. Geol. Soc., London* 149 (1992) 533–538.
- [415] Westaway R., Evidence for dynamic coupling of surface processes with isostatic compensation in the lower crust during active extension of western Turkey, *J. Geophys. Res.* 99 (1994) 20203–20223.
- [416] Westaway R., Dependence of active normal fault dips on lower-crustal flow regimes, *J. Geol. Soc., London* 155 (1998) 233–253.
- [417] Cohen H.A., Dart C.J., Akyüz H.S., Barka A.A., Syn-rift sedimentation and structural development of Gediz and Büyük Menderes graben, western Turkey, *J. Geol. Soc., London* 152 (1995) 629–638.
- [418] Dart C.J., Cohen H.A., Akyüz S.H., Barka A.A., Basinward migration of rift-border faults: implications for facies distributions and preservation potential, *Geology* 23 (1995) 69–72.
- [419] Emre T., Gediz grabeninin jeolojisi ve tektoniği, *Turkish J. Earth Sci.* 5 (1996) 171–185 (in Turkish with English abstract).
- [420] Emre T., Sözbilir H., Field evidence for metamorphic core complex, detachment faulting and accommodation faults in the Gediz and Büyük Menderes grabens, western Anatolia, in: Pişkin Ö., Ergün M., Savaşçın M. Y., Tarcan G. (Eds.), *IESCA Proceedings*, 1, 1995, pp. 73–93.
- [421] Görür N., Şengör A.M.C., Sakıncı M., Tüysüz O., Akkök R., Yiğitbaş E., Oktay F.Y., Barka A.A., Sarıca N., Ecevitoglu B., Demirbağ E., Ersoy Ş., Algan O., Güneysu C., Akyol A., Rift formation in the Gökova region, southwest Anatolia: implications for the opening of the Aegean Sea, *Geol. Mag.* 132 (1995) 637–650.
- [422] Ediger V., Batu Z., Yazman M., Paleopalynology of possible hydrocarbon source rocks of the Alaşehir–Turgutlu area in the Gediz graben (western Anatolia), *Bull. Turkish Assoc. Petrol. Geol.* 8 (1996) 94–112.
- [423] Temiz H., Gürsoy H., Tatar O., Kinematics of the Late Pliocene–Quaternary normal faulting in the southeastern end of the Gediz graben, Western Anatolia, Turkey, *Inter. Geol. Rev.* 40 (1998) 638–646.
- [424] Yılmaz Y., Geology of Western Anatolia. In: Schindler, C and Pfister, M. (Eds.) *Active tectonics of Northwestern Anatolia – The MARMARA Poly Project; A multidisciplinary approach by Space Geodesy, Geology, Hydrogeology, Geothermics and Seismology*. Vdf. Hochschulverl., an der ETH Zurich, 1997, pp. 31–53.
- [425] Koçyiğit A., Yusufoglu H., Bozkurt E., Evidence from the Gediz graben for episodic two-stage extension in western Turkey, *J. Geol. Soc., London* 156 (1999) 605–616.
- [426] Kurt H., Demirbağ E., Kuşçu İ., Investigation of the submarine active tectonism in the Gulf of Gökova, southwest Anatolia-southeast Aegean Sea, by multi-channel seismic reflection data, *Tectonophysics* 305 (1999) 47–496.
- [427] Bozkurt E., Timing of extension on the Büyük Menderes Graben, western Turkey, and its tectonic implications, in: Bozkurt E., Winchester J.A., Piper J.D.A. (Eds.), *Tectonics and magmatism in Turkey and the surrounding area*, Geological Society Special Publication no. 173, Geological Society, London, 2000, pp. 385–403.
- [428] Sarıca N., The Plio-Pleistocene age of Büyük Menderes and Gediz grabens and their tectonic significance on N–S extensional tectonics in West Anatolia: mammalian evidence from the continental deposits, *Geol. J.* 35 (2000) 1–24.
- [429] Yılmaz Y., Genç S.C., Gürer O.F., Bozcu M., Yılmaz K., Karacık Z., Altunkaynak Ş., Elmas A., When did the western Anatolian grabens begin to develop? in: Bozkurt E., Winchester J.A., Piper J.D.A. (Eds.), *Tectonics and magmatism in Turkey and the surrounding area*, Geological Society Special Publication 173, Geological Society, London, 2000, pp. 353–384.
- [430] Duvarcı E., Geoelectric structure of inland area of the Gökova rift, southwest Anatolia and its tectonic implications, *J. Geodyn.* 31 (2001) 33–48.
- [431] Nebert K., Tavşanlı'nın batı ve kuzeyindeki linyit ihtiva eden Neojen sahasının mukayeseli stratigrafisi ve tektoniği, *Min.*

- Res. Expl. Inst. Turkey Bull. 54 (1960) 7–35 (in Turkish with English abstract).
- [432] Nebert K., Linyit içeren Soma Neojen bölgesi, Batı Anadolu, Min. Res. Expl. Inst. Turkey Bull. 90 (1978) 20–69 (in Turkish with English abstract).
- [433] Ercan T., Satır M., Kreuzer H., Türkecan A., Günay E., Çevikbaş A., Ateş M., Can B., Batı Anadolu Senozoyik volkanitlerine ait yeni kimyasal, izotopik ve radyometrik verilerin yorumu, Geol. Soc. Turkey Bull. 28 (1985) 121–136 (in Turkish with English abstract).
- [434] İnci U., Torbalı (İzmir) kuzeyindeki Miyosen tortul istifinin fasiyes ve çökelme ortamları, Min. Res. Expl. Inst. Turkey Bull. 112 (1991) 13–26 (in Turkish with English abstract).
- [435] Seyitoğlu G., Late Cenozoic tectono-sedimentary development of the Selendi and Uşak-Güre basins: a contribution to the discussion on the development of E-W and north trending basins in western Turkey, Geol. Mag. 134 (1997) 163–175.
- [436] Bozkuş C., Kavacık (Dursunbey-Balıkesir) Neojen grabeninin stratigrafisi ve tektoniği, Turkish J. Earth Sci. 5 (1996) 161–170 (in Turkish with English abstract).
- [437] Nalbant S.S., Hubert A., King G.C.P., Stress coupling between the earthquakes in western Turkey and the north Aegean Sea, J. Geophys. Res. 103 (1998) 24469–24486.
- [438] Kissel C., Laj C., Tertiary geodynamical evolution of the Aegean arc: a paleomagnetic reconstruction, Tectonophysics 146 (1988) 183–201.
- [439] Becker-Platen J.D., Lithostratigraphische untersuchungen im Kanozoikum südwest-Anatoliens (Turkei), Beih. Geol. Jahrb. 97 (1970) 244 p.
- [440] Benda L., Principles of palynologic subdivision of the Turkish Neogene, Newslett. Stratig. 1 (1971) 23–26.
- [441] Benda L., Meulenkamp J.E., Biostratigraphic correlations in the eastern Mediterranean Neogene. 5. Calibration of sporomorph associations, marine microfossils and mammal zones, marine and continental stages and the radiometric scale, Ann. Géol. Pays Hellén. 1 (1979) 61–71 (hors série).
- [442] Benda L., Meulenkamp J.E., Schmidt R.R., Steffens P., Zachariasse J.W., Biostratigraphic correlations in the Eastern Mediterranean Neogene. 2. Correlation between sporomorph associations and marine microfossils from the Upper Oligocene-Lower Miocene of Turkey, Newslett. Stratig. 6 (1977) 1–22.
- [443] Benda L., Meulenkamp J.E., Biostratigraphic correlations in the Eastern Mediterranean Neogene 9. sporomorph associations and event stratigraphy of the Eastern Mediterranean Neogene, Newslett. Stratig. 23 (1990) 1–10.
- [444] Sözbilir H., Akgün F., Akkiraz S., Stratigraphy of the unconformity-bounded Tertiary sedimentary sequences between Denizli and İzmir. Abstract of the Geological Congress of Turkey, Ankara, 21–25 February, 2000, pp. 179–181.
- [445] Bozkurt E., Satır M., The Southern Menderes Massif (western Turkey): geochronology and exhumation history, Geol. J. 35 (2000) 285–296.
- [446] Şaroğlu F., Yılmaz Y., Doğu Anadolu'da neotektonik dönemdeki jeolojik evrim ve havza modelleri, Min. Res. Expl. Inst. Turkey Bull. 107 (1993) 73–94 (in Turkish with English abstract).
- [447] Yılmaz Y., Şaroğlu F., Güner Y., Initiation of neomagmatism in East Anatolia, Tectonophysics 134 (1987) 177–199.
- [448] Koçyiğit A., Ünay E., Saraç G., Episodic graben formation and extensional neotectonic regime in west Central Anatolia and the Isparta Angle: a case study in the Akşehir-Afyon graben, Turkey, in: Bozkurt E., Winchester J.A., Piper J.D.A. (Eds.), Tectonics and magmatism in Turkey and the surrounding area, Geological Society Special Publication no. 173, Geological Society, London, 2000, pp. 405–421.
- [449] Akgün F., Akyol E., Palynostratigraphy of the coal-bearing Neogene deposits in Büyük Menderes Graben, Western Anatolia, Geobios 32 (1999) 367–383.
- [450] Bingöl, E., Geological map of Turkey at 1:2000000 scale. Mineral Research and Exploration Institute of Turkey Publications, Ankara.