3. NEOTETHYS: Turkey

The papers in this section are all concerned with aspects of the Mesozoic evolution of Turkey, which has seen an upsurge in international research interest in recent years. The dominant themes are the processes of *initiation*, *growth* and *destruction* of Mesozoic ocean basins documented in the development of rift-related sedimentary and volcanic sequences and in the internal character and 'organisation' of Mesozoic ophiolites, and the ocean *closure* indicators—the calc-alkaline volcanic belts, blueschist zones and nappe emplacement sequences involving ophiolites.

If regional plate-kinematic synthesis is the ultimate aim then an obvious precursor stage is the building of a network of reasonably well understood transects where ocean creation and destruction are recorded, coupled with more summary attention to variations along-strike and with time in relevant linear belts. This is the stage represented by the papers in this section. Mapping and detailed interpretation of the many vast tracts that lie between the discontinuous ophiolite belts will probably continue to take a minor role compared to 'suture documentation', and models will remain largely two-dimensional until the areal density of information is much greater.

Figures 1 & 2 show the areas covered by contributors to this section. The scale of the map should be noted. There are two papers not so directly ophiolite or continental-margin oriented. The paper by **POISSON** would be a good starting point for anyone seeking a sample of the stratigraphic complexities and interpretation problems in one tract of nappes—the Lycian Nappes of SW Turkey. The other exception is the paper by **LAUER** reporting palaeomagnetic data bearing on the number and location of Turkey's component blocks during the Mesozoic. It is a fair reflection of the gap between what are presently realistic interpretation objectives on the ground and what might actually have happened, that **LAUER**'s far-reaching inferences of large-scale independent block-motion are only discussed in one of the other contributions, **RICOU *et al.*** (see also the introductory chapter). One important reason is that he concludes that no significant displacement is detectable between allochthonous sequences and the local autochthon with which they are associated so justifying for the moment local two-dimensional interpretations.

Returning to the main theme of the majority of the contributions, the reader should recognize that a fundamental and resilient dichotomy of interpretation exists among the contributors, which will probably take a future Eastern Mediterranean conference to resolve. On the one hand **RICOU *et al.*** argue that so remarkable are the parallels and systematic variations in the histories of rifting, sea-floor spreading, and emplacement in the two discontinuous ophiolite belts north and south of the Tauride carbonate axis, that the belts must have a common origin in a *single* basin, in this case a northern one. The opposing view, implicit for example in the model of **ROBERTSON & WOODCOCK** for the Antalya area is that parallel evolution in different belts reflects the parallel generation and destruction of *more than one* Neotethyan ocean basin, with common timing and common stratigraphic evolution being a natural consequence of the common crustal structure, large-scale plate-configuration, climate, etc., in the region as a whole. These opposing views are discussed at length in the introductory chapter. The reader seeking first-hand statements should perhaps start with **RICOU *et al.*** for the basic philosophy and support it with **WHITECHURCH *et al.*** in which ophiolites in the two belts are reviewed in some detail. **ROBERTSON & WOODCOCK** review the history of the models proposed for the Antalya area and focus specifically on areas and field relations which constitute critical tests of the **RICOU *et al.*** concept.

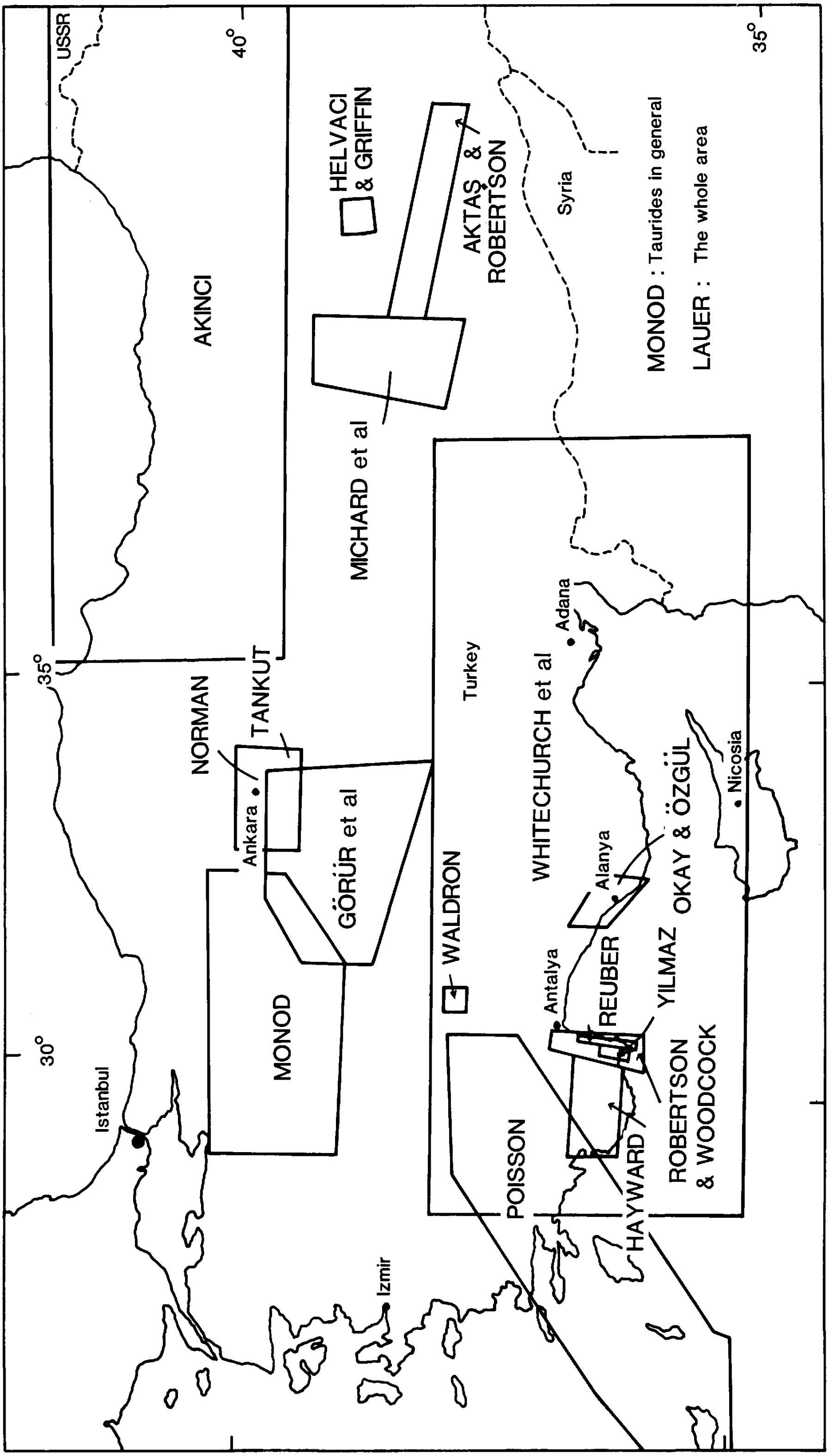

FIG. 1. The areas of Turkey discussed by various authors in this section.

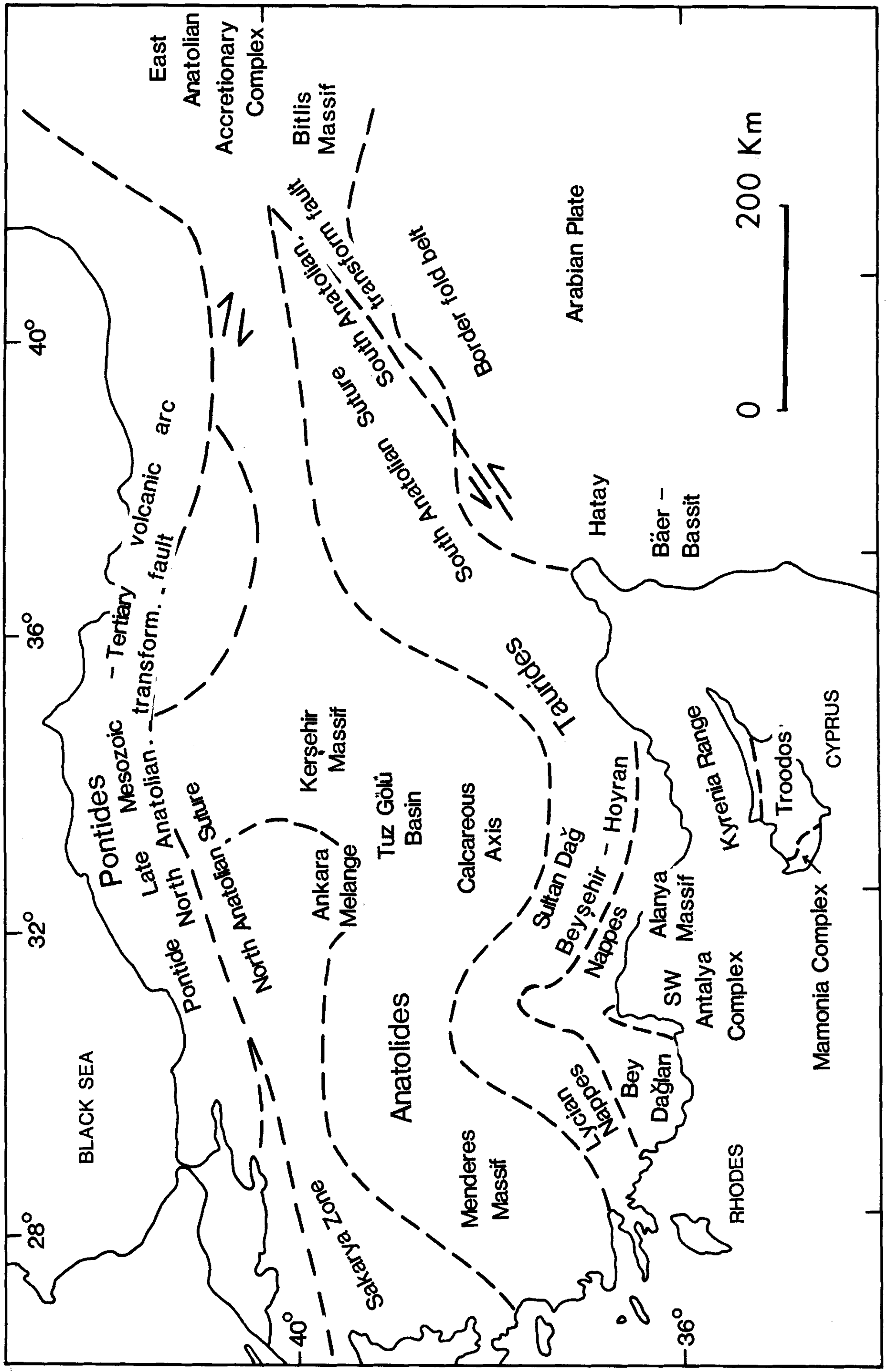

FIG. 2. The main tectonic elements of the Turkish area.

The two opposing views are discussed further in the papers by **MICHARD *et al.*** and **AKTAŞ & ROBERTSON** which consider segments of the southern suture belt in Eastern Anatolia, and these two contributions well illustrate the enormous diversity in structure, stratigraphy, magmatism and the timing of major events to be found even along what is apparently a 'single' belt, so great is the scale of Turkish geology.

The papers are arranged geographically, which means that the information they contain on the often synchronous phases of rifting, ocean growth, subduction and collision is rather scattered. Here we provide a brief guide to where contributions under these headings may be found.

Most of the discussion on rifted and passive margin development in the existing literature has centred on the Antalya–Isparta area of SW Turkey. **POISSON**, working in the Lycian nappes, to the west correlates stratigraphic sequences as far as the Aegean Sea in the far west. He draws attention to the Kızılıca–Corak gol trough which originated by Early Jurassic faulting with deposition of pelagic carbonates throughout much of the Mesozoic to Early Tertiary. He points out that this trough could well be an extension of the Ionian Zone as the Aegean arc runs from western Greece, through Crete and Rhodes (see **BONNEAU**, Section 4 and the introductory chapter). The appearance of ophiolite-derived clastics in the trough as late as Upper Eocene fits with an origin south of the Menderes massif, rather than north as has been assumed previously for the Lycian nappes. Since the ophiolites themselves in the Lycian nappes were not apparently rooted in this trough, **POISSON** still prefers to derive them from a basin north of the Menderes massif. This has profound implications for the scale of nappe transport and the curvature of the Aegean arc, which **POISSON** then goes on to discuss.

The Tauride 'Calcareous Axis' is the critical zone either across which ophiolite nappes were transported from the north or, alternatively, which separated northern and southern basins, according to one's view in the great debate. **WALDRON**, describing a key area near Eğridir in the Isparta angle, on the edge of this axis, uses detailed mapping, facies analysis and balanced cross-sections to reconstruct the Mesozoic palaeogeography. The result is a series of irregularly shaped carbonate banks separated by deep basins with pelagic sediments, similar to the modern Bahamas. Latest Cretaceous thrusting to the north or east is clear from thrust duplex geometry, followed by SW or W-directed refolding and thrusting in the north-east of the area, probably in the Eocene. The structural analysis lends no support to the case for ophiolite nappe transport from a northern basin as in **RICOU *et al.***'s concept.

ROBERTSON & WOODCOCK review the sedimentary and structural evidence for the rifting and passive margin development (and subsequent tectonic emplacement) of the segment of the Antalya allochthon, located on the SW limb of the Isparta angle. The competing models share a common view of the Triassic rifting history, but still contentious issues are the former existence of off-margin carbonate banks, the timing and significance of mafic volcanism and ophiolite genesis and the extent and timing of strike-slip faulting. **ROBERTSON & WOODCOCK** outline their conception of the Mesozoic palaeogeography which involves progressive subsidence of a braided Triassic rift during much of the Jurassic followed by genesis of ophiolites in a new strike-slip-controlled tectonic regime. Strike-slip faulting along a N–S margin dominated the active margin phase from latest Cretaceous to Mid-Tertiary.

Evidence from the volcanics and sediments related to Triassic rifting in the various allochthonous units, including the Lycian Nappes, the Beyşehır-Hoyran Nappes (Turkey), Baër-Bassit (N. Syria) and the Mamonia 'nappes' (SW Cyprus) is summarized by **RICOU *et al.*** and **WHITECHURCH *et al.*** Ricou states that the Mid-Triassic units of the 'Calcareous Axis' show a northwards slope to basin transition.

Ophiolites

WHITECHURCH *et al.* and **RICOU *et al.*** review between them much new data on the age, petrology and 'organization' of the Tauride ophiolites and those of Antalya (Tekirova), Cyprus and Hatay/Baër-Bassit. The internal fabric of the Tekirova ophiolite and its age of creation and slicing are discussed by **REUBER** and **YILMAZ** respectively. **DELALOYE & WAGNER**'s geochemical and age data on Hatay and Baër-Bassit, presented in the previous section, augment this information.

On age of creation, firm data are still sparse where the sedimentary cover is missing, as in the 'Tauride-type' of eroded, dismembered ophiolite with thick cumulate sequences: the Antalya (Tekirova), Lycian, Baër-Bassit and Pozantı-Kersantı ophiolites (**RICOU/WHITECHURCH**). Isotopic ages from plutonics in the Antalya (Tekirova) (**YILMAZ**) and Baër-Bassit (**DELALOYE & WAGNER**) ophiolites are *Upper Cretaceous*, in accord with the sedimentary ages from the thinner intact, cumulate-poor 'Troodos-type' ophiolites of Hatay and Troodos itself. **RICOU/WHITECHURCH** using in part the detailed fabric analysis of **REUBER** argue that sheeted-dyke orientations and internal structure in those ophiolites so far studied, are all consistent with original E–W spreading axes cut by N–S transform faults.

This consistency of creation age and orientation extends to the 'slicing' ages considered below and constitutes the basis of the **RICOU/WHITECHURCH *et al.*** single-basin argument.

Destructive margin processes

From the Upper Cretaceous onwards there is abundant evidence from many parts of Turkey of destructive margin processes until continental collision in the Miocene. Looking at the two southern ophiolite belts first, **WHITECHURCH *et al.*** and **RICOU *et al.*** consider that intra-oceanic slicing and the generation of amphibolite soles beneath the ophiolites (other than Troodos and Hatay) are the first evidence of compressional tectonics. A progression from west to east in the ages of the soles, from 104 Ma in the Lycian ophiolites to 88 Ma for Baër-Bassit in the east, is attributed to the northward motion of African affecting a single ocean basin.

There is general agreement that ophiolites were emplaced onto the Arabian margin in the Upper Cretaceous (e.g. see **DELAUNE-MAYERE**, section 2). **RICOU *et al.*** see this as the result of complete closure of the single northern Neotethyan basin, with expulsion of the ophiolites, following the precursor intra-oceanic slicing. Further collision-related nappe-telescoping then followed in the Tertiary. As the carbonate platform in the Antalya area, and the unseen basement of Troodos, are envisaged as the continuation of the African margin west of Hatay, the emplacement of these ophiolites is considered to be the same event.

The alternative two-ocean-basin concept admits the possibility of ophiolite emplacement from a southern basin south onto the Arabian margin, as well as north onto the southern edge of the 'calcareous axis' or an intervening arc. The papers of **ROBERTSON & WOODCOCK** on Antalya, **MICHARD *et al.*** on the Malatya transect of the Arabian margin suture, **AKTAŞ & ROBERTSON** on the adjacent Maden area, east of Malatya, **HAYWARD** west, and **WALDRON** north of Antalya all deal with these basic questions of transport polarity in the southern belt of ophiolites.

ROBERTSON & WOODCOCK's Antalya review, as noted earlier, presents a case for Upper Cretaceous strike-slip-dominated emplacement of the passive margin sequences and Upper Cretaceous Tekirova ophiolite, from the south and east onto the adjacent Bey Dağları platform. **REUBER**'s independent documentation of N–S transform fabrics in the Tekirova ophiolite is of note in this respect. Further north near Eğridir **WALDRON**'s first and major Upper Cretaceous thrust phase is directed towards the NE quadrant. **HAYWARD**, describing the incoming of ophiolitic debris in continuous Miocene sedimentary sequences on the Bey Dağları autochthon, documents the final mutual approach from opposite directions of the Lycian and Antalya ophiolitic nappes but sees no evidence for an earlier emplacement event across the platform. **ROBERTSON & WOODCOCK** discuss at length how **RICOU *et al.***'s model attempts to explain these observations.

East of Hatay and Baër-Bassit, along the suture zone, the structural succession is markedly different and complex and many interpretation problems remain. The two papers by **MICHARD *et al.*** and **AKTAŞ & ROBERTSON** which deal with areas with several structural units in common produce between them three fundamentally different alternative models. The major Upper Cretaceous volcanic arc north of the suture and clear evidence of ophiolite generation south of this arc are important common components. **MICHARD *et al.***'s one-basin model has to invoke a subduction-generated back-arc basin to generate this southern Elaziğ ophiolite and both north- and south-dipping subduction to explain the present structural sequence. Their alternative two-basin model shares with **AKTAŞ & ROBERTSON**'s favoured alternative interpretation, the conclusion that the southern basin remained in existence into Tertiary times. However, **AKTAŞ & ROBERTSON** conclude that northward subduction generated the arc, that an Upper Cretaceous ophiolite was emplaced northwards over the fore-arc complex and southwards elsewhere onto the Arabian margin, and that further northward subduction led to imbrication of the remaining basin and ultimately collision.

HELVACI & GRIFFIN illuminate the structural metamorphic and magmatic history of one component in the Eastern Anatolia structural stack—the Bitlis massif, which forms the uppermost unit in the east and in part the basement on which the Upper Cretaceous volcanic arc was constructed. They present new radiometric age data and argue that in the Avnic area a Lower Ordovician–Devonian meta-volcanic unit was intruded by granitoids and then covered unconformably by Carboniferous to ?Permian shales and limestones, which were deformed and metamorphosed in the Cretaceous (90 Ma) and Eocene (40 Ma).

Still problematic is the significance of important new discoveries by **OKAY & ÖZGÜL** of a blueschist nappe in the Alanya massif along the Turkish Mediterranean coast. Eclogites and blueschists occur in one of three nappes thrust over the Antalya Complex, in which a fine Ordovician to Late Mesozoic succession is exposed in the Alanya window.

In contrast to the North Turkish blueschists described by **OKAY**, those in the Alanya massif show evidence of two distinct metamorphic events prior to exposure and transgression in the Middle Eocene.

For the remaining papers, the coverage of destructive margin processes switches further north to the North Anatolian suture zone south of the Pontides. In these areas, clear evidence of a previous rifting phase is often obscure and there is also evidence of active margin processes earlier than the Upper Cretaceous.

NORMAN and **TANKUT** summarize the evidence of accretionary sedimentation, tectonics and magmatism along the south Pontide active margin. The famous ca. 100 km wide Ankara melange consist of 7 parallel belts, including a 'metamorphic belt' melange, a 'limestone block' melange and an ophiolitic melange. **NORMAN** views the Ankara melange as the result of subduction under a continental block then located to the east (Sakarya or Cimmerian continent of **ŞENGÖR *et al.***) possibly from as early as mid-Jurassic onwards. He attributes major debris-flow units to oblique subduction, uplift of trench sediments and flow roughly at right angles to the direction of subduction. **TANKUT** summarizes the limited data on the field relations, mineralogy and geochemistry of mafic igneous rocks in the Ankara melange. Only rare basic or ultramafic rocks are known from the 'metamorphic block' and the 'limestone block' melange. All the mafic rocks are altered but initial data from 'immobile' trace elements points to a low-Ti type chemistry typical of many of the Eastern Mediterranean Upper Cretaceous ophiolites.

OKAY discusses the major developments of blueschists located in the Western Pontides in a regional depression between the 'Sakarya zone' of the Pontides and the carbonate cover of the Menderes metamorphic massif to the south. The HP/LT belt is tectonically overlain by a major undated, little-metamorphosed peridotite nappe. **OKAY** shows that both the blueschist nappe and the structurally underlying volcano–sedimentary unit were derived from similar protoliths, including abundant pyroclastics, ranging in age from at least Late Jurassic to Upper Cretaceous. Influenced by a downward transition of the blueschist nappe into a basal marble unit, **OKAY** suggests that the blueschists originated as the northern passive margin of the 'Anatolide-Tauride platform' which was subducted from the Turonian, followed by continental collision. The blueschists were exposed as early as Upper Campanian and problems inherent in this remarkably rapid uplift are discussed.

The possible complexities involving closure of a multi-strand Mesozoic Tethys are discussed by **GÖRÜR *et al.*** The contrasting deposition in the Haymana and Tuz Gölü basins of central Anatolia is summarized, from isopachyte maps. After ophiolite emplacement, flysch troughs formed then filled in Palaeocene and Eocene time. **GÖRÜR *et al.*** unfold a scenario in which by the late Maastrichtian northward subduction had pinned the tip of the Kerşehir micro-continent against the Pontide active margin to the north, while subduction continued during the early Tertiary to the north west and along the western margin of the Kirşehir massif. By the late Eocene, closure was complete and a 90° rotation preserved the Haymana and Tuz Gölü basins in a strain-free area between the colliding continental blocks.