Tectonic development of the Eastern Mediterranean region: an introduction

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Abstract: The Eastern Mediterranean is one of the key regions for the understanding of fundamental tectonic processes, including continental rifting, passive margins, ophiolites, subduction, accretion, collision and post-collisional exhumation. It is also ideal for understanding the interaction of tectonic, sedimentary, igneous and metamorphic processes through time that eventually lead to the development of an orogenic belt. Below, we will outline some milestones in the development of tectonic-related research in the Eastern Mediterranean region. We will mention how studies of the Eastern Mediterranean contribute to our understanding of fundamental tectonic processes and indicate how papers in this volume contribute to this aim. Current and emerging research themes will be highlighted. We will also outline the main alternative tectonic reconstructions of the region (see Fig. 1), and mention which of these the different contributors favour. Tethyan nomenclature remains controversial and we will suggest an appropriate informal terminology for the various oceanic basins that existed. An entrée to some of the key literature sources is also provided. Citations here are mainly to edited volumes, which provide access to this large subject area.

Many of the papers in this book integrate and synthesize large amounts of geological information for extended periods of geological time. The papers are ordered in a general time sequence with a view to linking those that consider comparable tectonic setting and processes. The locations of the areas are shown in Figures 2 and 3. Figure 2 also shows the main sutures, and Figure 3 illustrates the main neotectonic elements of the region.

Development of research

1970s to mid-1980s

The Eastern Mediterranean region figured in pre-plate tectonic geosynclinal models (e.g. Aubouin *et al.* 1970). The plate tectonic framework for the modern tectonic setting was established in seminal papers by McKenzie (1972, 1978) and Le Pichon & Angelier (1979). Modern interpretations of this region in terms of plate tectonics effectively began with the pioneering work of Smith (1971) and of Dewey *et al.* (1973). During the 1970s field-based information was amassed by the French-led Tethys project, culminating in sets of palaeogeographical maps that evolved through several editions (Dercourt *et al.* 1986, 1993, 2000). The Tethys group initially envisaged the existence of a Mesozoic–Early Tertiary Tethyan ocean dating from Triassic time, bordered by the African and Eurasian continents. They interpreted the Mesozoic ophiolites as forming at mid-ocean ridges. The Tethyan ocean was subducted northwards beneath Eurasia in this interpretation.

Others developed alternative tectonic models for parts of the region. By the early 1980s the existence of an Early Mesozoic oceanic basin in the easternmost Mediterranean region had been proposed (Robertson & Woodcock 1979; Garfunkel & Derin 1984). In western Greece a belt of ophiolites was interpreted as evidence for the existence of a Mesozoic ocean basin, separate from a second belt of ophiolites further east (Smith *et al.* 1975; see also Smith 1993). Ophiolites and deep-sea sediments were distributed throughout many areas of Turkey, suggesting that several Mesozoic oceanic basins, rather than one, might have existed there. In 1981 Şengör & Yılmaz published a seminal plate tectonic synthesis of Turkey, which depicted the interaction of microcontinents and small ocean basins. In addition, based initially on information from the Eastern Pontides (northern Turkey), Şengör *et al.* (1980) introduced a tectonic model for Late Palaeozoic–Early Mesozoic time, later applied to Eurasia as a whole (Şengör 1984). This envisaged southward subduction of a Late Palaeozoic–Early Mesozoic ocean (Palaeo-Tethys) and the related opening of several marginal basins along the northern margin of Gondwana. Closure of this ocean culminated in continental collision by the latest Triassic–Early

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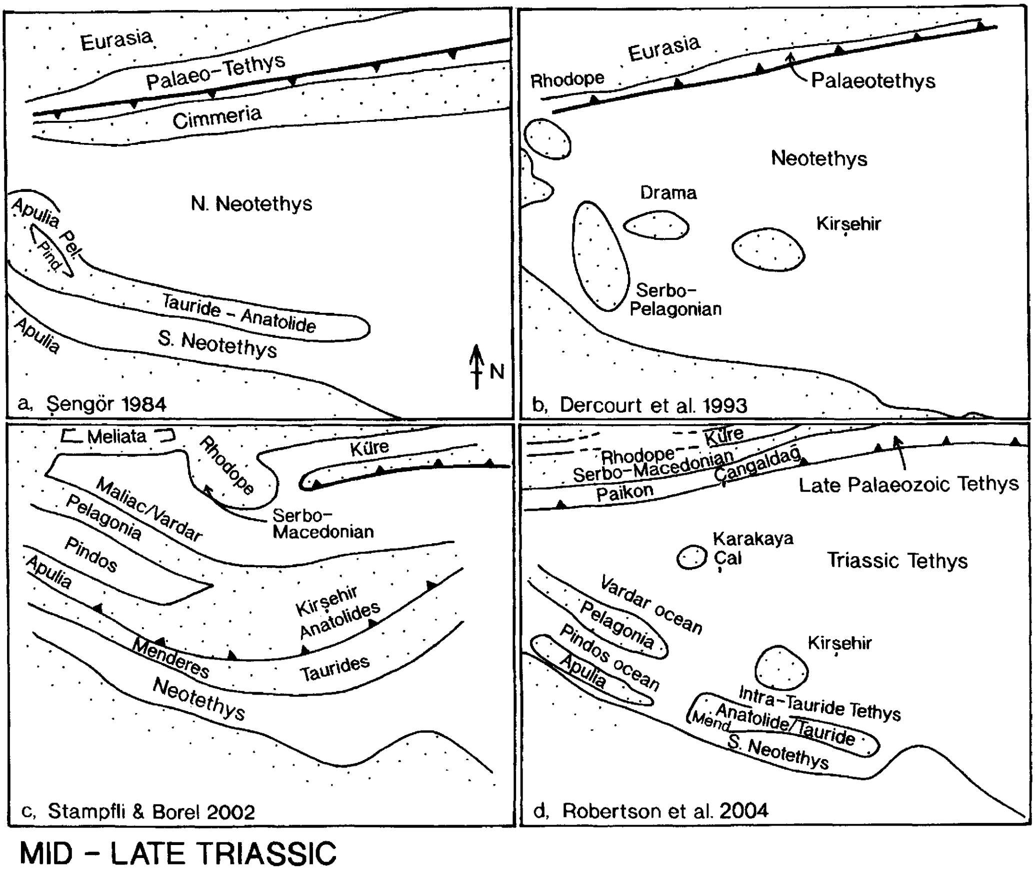

Fig. 1. Alternative tectonic models of Tethys in the Eastern Mediterranean region. (See text for explanation.)

Jurassic time, and was followed by opening of a new, Jurassic ocean basin (Northern Neotethys). The nomenclature of Tethyan oceanic basins is, however, rather confusing and an attempt to clarify this aspect is made at the end of this introduction.

At an international conference on the Eastern Mediterranean region, held in Edinburgh in October 1982, several different tectonic interpretations and much supporting evidence were presented and later published as Special Publication of the Geological Society of London No. 17, *Tectonic Evolution of the Eastern Mediterranean* (Dixon & Robertson 1984). A plate tectonic model of the Eastern Mediterranean by Robertson & Dixon (1984) in that book combined the concept of the area as a mosaic of micro-continents and ocean basins with the hypothesis that many of the Mesozoic ophiolites formed above intra-oceanic subduction zones. Two key elements: northward subduction and supra-subduction ophiolite genesis, were retained in many of the more recent reconstructions.

Mid-1980s onwards

A critical mass of information had by then become available for many areas and geological units including the Mesozoic–Early Cenozoic land geology of Greece, former Yugoslavia, Cyprus and parts of Turkey, whereas many other areas and units remained poorly understood. Chief amongst these were the regional metamorphic complexes, which by then could no longer be seen simply as 'basement units', but still remained poorly dated and little understood. Neotectonics (broadly post-Miocene) were known to affect many areas but also remained obscure. In addition, the marine geological setting remained largely unknown, despite the pioneering work of the Deep Sea Drilling Project (e.g. Hsü *et al.* 1978).

A major advance in recent years has been the testing and confirmation of the early plate tectonic model of McKenzie (1972, 1978) using a combination of field evidence, geophysical modelling (e.g. Jackson & McKenzie 1984) and,

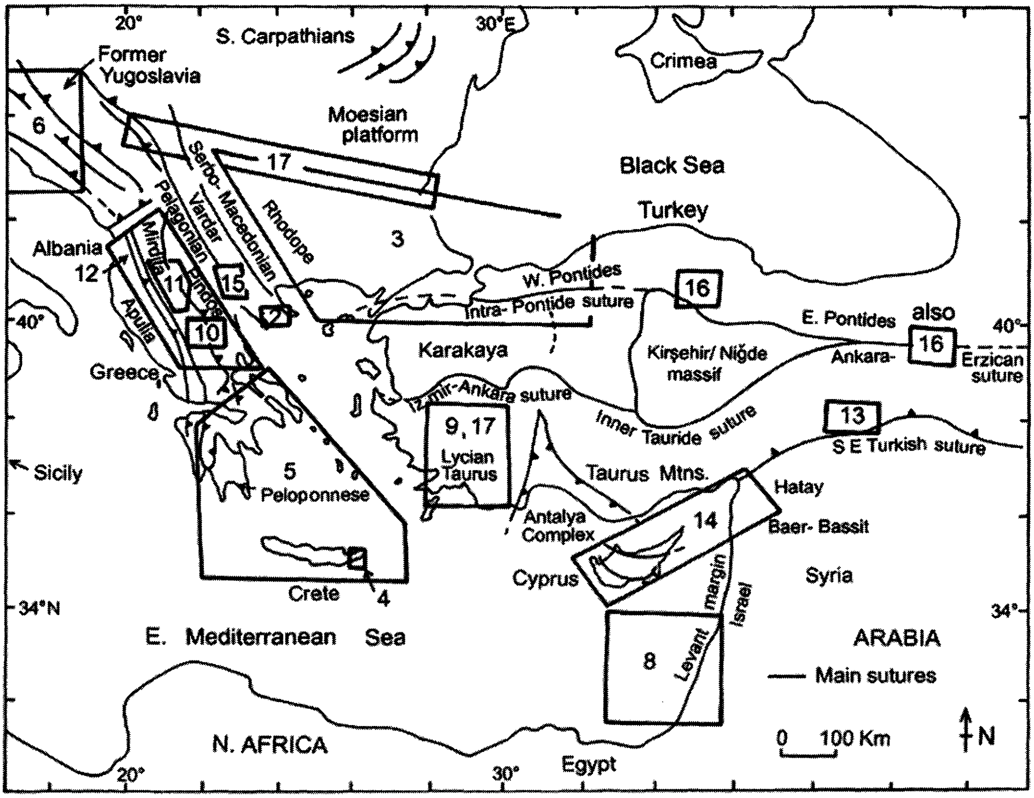

Fig. 2. Outline map of the main sutures showing the locations of studies mainly concerning the Palaeozoic and Mesozoic tectonic development of the Eastern Mediterranean region. 1, Smith; 2, Himmerkus *et al.*; 3, Yanev *et al.*; 4, Romano *et al.*; 5, Robertson; 6, Karamata; 7, Kazmin & Tikhonova; 8, Gardosh & Druckman; 9, Danelian *et al.*; 10, Rassios & Moores; 11, Koller *et al.*; 12, Garfunkel; 13, Rizaoğlu *et al.*; 14, Morris *et al.*; 15, Sharp & Robertson; 16, Rice *et al.*; 17, Rimmelé *et al.* Studies 1 and 7 cover whole area.

more recently, direct measurements by the global positioning system method (Reilinger *et al.* 1997).

Large datasets have continued to be amassed that can now be used to test and develop tectonic hypotheses. Several international research programmes have aided this effort. Amongst these was the International Geological Correlation Project (IGCP) No. 276, 'Terrane Maps and Terrane Descriptions' (Papanikolaou 1996–1997); this analysed the region as tectonostratigraphic terranes supported by regional correlation maps and terrane descriptions. Another was IGCP No. 369, 'Comparative evolution of Peri-Tethyan Rift Basins', which focused on the rift basins of the Tethyan periphery (Ziegler *et al.* 2001). Recently, EUROPROBE GeoRift 3, 'Intraplate Tectonics and Basin Dynamics' (Stephenson 2004) has provided much information on the SE European craton and its margins. Palaeomagnetic studies have played an important role in regional interpretation (e.g. Morris & Tarling 1996). Ophiolites in the region have received particular attention (e.g. Hoeck *et al.* 2002). Several geological compilations have recently focused on parts of the Eastern Mediterranean region, notably Turkey (Bozkurt *et al.* 2000) and Greece (Pe-Piper & Piper 2002).

There has also been an increasing focus on the neotectonic development of the region (Robertson & Comas 1998; Durand *et al.* 1999; Taymaz *et al.* 2004) Neotectonics refers to the strain resulting from a stress regime that essentially remains active at the present time, broadly from Miocene to Recent in the Eastern Mediterranean region. Conversely, palaeotectonics refers to stress regimes that are no longer active. One of the most important discoveries, especially from the study of the South Aegean region, is that many tectonic contacts that were traditionally interpreted as thrusts related to the emplacement of nappes are instead extensional faults (i.e. extensional detachments) related to Tethyan exhumation (e.g. Durand *et al.* 1999).

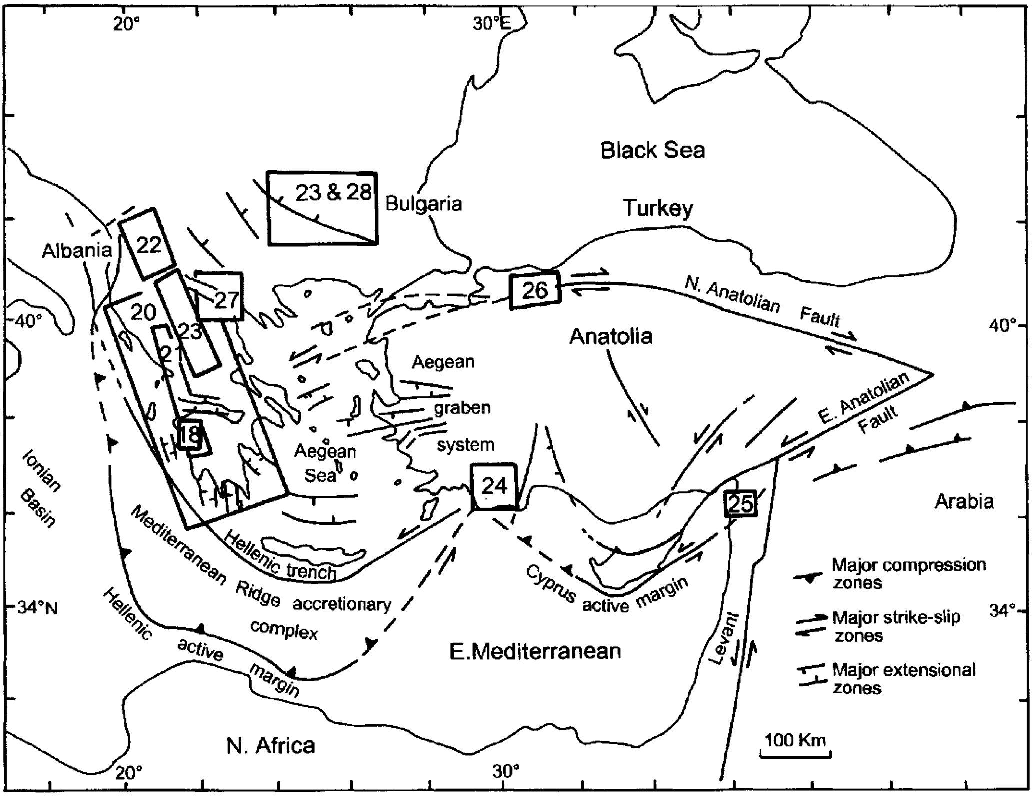

Fig. 3. Outline map of the main neotectonic features showing the locations of studies mainly concerning the Cenozoic–Recent tectonic development of the Eastern Mediterranean region. 18, Degnan & Robertson; 19, Piper; 20, Doutsos *et al.*; 21, Vamvaka *et al.*; 22, Muceku *et al.*; 23, Westaway; 24, Alçiçek *et al.*; 25, Boulton *et al.*; 26, Pavlides *et al.*; 27, Mountrakis *et al.*; 28, Tranos *et al.*; 29, Papzachos *et al.* covers whole area.

Other advances include the results of ocean drilling in the Eastern Mediterranean Sea that allowed a closer integration of tectonic processes operating on land and under the sea (Robertson *et al.* 1998). Also, sedimentary basin evolution is increasingly seen as a response to kinematically linked tectonic processes, as shown by studies of the Mediterranean as a whole (e.g. Robertson & Grasso 1995), and most recently in southern Turkey (Kelling *et al.* 2005).

Sets of papers resulting from the Third and Fourth International Meetings on Eastern Mediterranean Geology, held in Nicosia (Cyprus) and Isparta (Turkey) were edited by Panayides *et al.* (2000) and by Akıncı *et al.* (2003), respectively. The integrated set of papers on the classic Isparta Angle of SW Turkey (Akıncı *et al.* 2003) exemplifies the complex geology of interacting microplates.

An outcome of these studies is that it is now possible to trace the well-known modern plate tectonic setting backwards through time (i.e. neotectonics) and link this with the previous tectonic evolution of the region (i.e. palaeotectonics) to provide a more complete picture of the evolution of the orogen.

Tectonic processes

The Eastern Mediterranean region is an ideal test-bed for the development of hypotheses for fundamental tectonic processes. Such work is also important to the well-being of those living in this highly populated region (>100 million people) as it can contribute to an evaluation of the resource potential, notably hydrocarbons, and is critical to the assessment of hazards, most obviously earthquakes.

Process-oriented tectonic studies are outlined below. Many of these are developed in this book, as indicated.

Processes of rifting and continental break-up, especially of Triassic age, are well documented by volcanic and sedimentary rocks throughout the region. Processes of rifting are discussed here by **Gardosh & Druckman** for the easternmost Mediterranean area, and by **Robertson** and **Degnan & Robertson** for the Aegean area.

The region includes some of the best examples of emplaced deep-water passive margin successions (e.g. Pindos zone, Greece), as summarized for the Peloponnese in southern Greece by **Piper** and **Degnan & Robertson**.

The Mesozoic ophiolites include the classic Troodos ophiolite (Cyprus), the Pindos and Vourinos ophiolites (Greece) and the Mirdita ophiolite (Albania) that contribute much to our understanding of oceanic lithosphere genesis and emplacement. New results and interpretations are presented by **Rassios & Moores** and **Koller *et al.*** concerning Mesozoic ophiolites in Greece and Albania. Evidence for previously little known Late Cretaceous ophiolites in northern Turkey is given by **Rice *et al.***

The region includes some excellent examples of accretionary prisms (e.g. Cretaceous Ankara mélange) related to subduction. For example, biostratigraphical studies of radiolarian cherts in mélange blocks can shed light on Tethyan evolution, as discussed here for SW Turkey by **Danelian *et al.***

High-pressure–low-temperature (HP/LT) metamorphic rocks are widely distributed (e.g. NW Turkey) and are critical to our understanding of deep-seated subduction processes. Here, important new evidence of carpholite-bearing HP/LT rocks related to subduction and exhumation in SW Turkey is presented by **Rimmelé *et al.***

The region provides good examples of arc volcanism and the formation of back-arc basins in active margin settings, as discussed by **Rizaoğlu *et al.*** for eastern Turkey and by **Rice *et al.*** for northern Turkey. In general, evidence of subduction-related magmatism has increasingly been found in different areas, especially in eastern Turkey.

As would be expected, the region is ideal for the study of collisional processes, allowing new models for continental collision to be developed, as presented here by **Doutsos *et al.***

The region is one of the key areas for studies of post-collisional processes, notably extensional detachment faulting and crustal exhumation (e.g. southern Aegean). Here, new fission-track thermochronology results are presented by **Muceku *et al.***, which elucidate the exhumation of the Neotethyan suture in Albania.

Syn- to post-collisional sedimentary basins are well exposed and yield important insights into a range of tectonic processes, as exemplified by the Neogene Hatay Graben, southern Turkey (**Boulton *et al.***), the Cameli Basin, SW Turkey (**Alçiçek *et al.***) and the Mesohellenic Trough, Greece and Albania (**Vamvaka *et al.***).

The potential of the Eastern Mediterranean region increases still further when the wider regional setting is taken into account, including the Western Mediterranean and Central–North Atlantic regions, as discussed by **Smith**, and also Eurasia to the north and NE of the Eastern Mediterranean region, as summarized by **Kazmin & Tikhonova**.

Traditional plate tectonic analysis is effective where large oceans and continental areas existed (e.g. related to subduction of Palaeotethys; see **Kazmin & Tikhonova**) but becomes difficult to apply in regions where numerous microplates existed. Alternative reconstructions, using terrane analysis, are presented here for parts of the Balkan Peninsula and adjacent areas (see **Yanev *et al.*** and **Karamata**).

Particular difficulties are encountered with regions dominated by microplate interaction like the Eastern Mediterranean. For example, rift processes may be regionally variable and affect several microcontinental blocks simultaneously (see **Robertson**). Rifts may be constructed on several pre-existing orogens (Hercynian, or Pan-African) and this may affect the geometry of rifting or the geochemistry of rift-related igneous rocks (see **Romano *et al.*** and also **Robertson**). The nature and timing of sea-floor spreading may be difficult to determine where ophiolites are distributed through several adjacent sutures (see **Garfunkel** and **Smith**). Collision affecting several microcontinents is necessarily complex and diachronous (see **Sharp & Robertson**).

Regional-scale crustal rotations may play an important role, and these, in favourable settings, may be restored and interpreted using palaeomagnetic techniques, as documented by **Morris *et al.*** for ophiolites and related units in Cyprus, southern Turkey and northern Syria. Strike-slip may also be important but is often difficult to recognize and restore in deformed regions (see **Karamata**).

In addition, many parts of the Eastern Mediterranean region are seismically active and subject to earthquakes. Such hazards to the large populations living in this region can be investigated by studies of active faults and modern-day seismicity, as discussed by **Mountrakis *et al.*** and **Tranos *et al.*** The resulting data can be used to develop predictive models of earthquakes, as presented here by **Papazachos *et al.***

Tectonic processes operate successively or interact through time to produce complex tectonic assemblages that are ultimately unique. However, recognizable patterns recur in different suture zones at different times. One important example is flexural foredeep development related to ophiolite emplacement, as for both the Mid–Late Jurassic of Greece and the Late Cretaceous of Turkey. Another is post-collisional extensional basin development related to exhumation, both for the Late Carboniferous–Permian of the Balkans and for the Neogene of the Eastern Mediterranean region as a whole. A number of papers in this book exemplify the successive activity and interaction of different tectonic processes through time, an excellent example being the tectonic development of the Vardar zone in northern Greece (see **Sharp & Robertson**).

Tectonic settings

Most workers now accept that the Eastern Mediterranean region hosted a wide ocean separating Africa and Eurasia (Palaeotethys), at least by Late Palaeozoic time (see **Kazmin & Tikhonova**), but there is little agreement as to how, when and where this ocean formed and was ultimately consumed. There is an emerging consensus that some of the large allochthonous units ('terranes') of Late Palaeozoic, or earlier, age originated along the northern margin of Gondwana and were later accreted to Eurasia at different times (i.e. Carboniferous; Late Triassic; Late Cretaceous; see **Yanev *et al.*** and **Karamata**). However, it is also suggested that some exotic terranes including igneous and metamorphic rocks formed and remained along the north margin of Gondwana during their entire history (see **Romano *et al.*** and **Karamata**). A further uncertainty is the timing, location and amount of lateral displacement related to strike-slip faulting (i.e. terrane displacement), especially during Late Carboniferous–Late Triassic time.

The record of basement units of Pan-African age is sparse (e.g. western and NW Turkey) and thus their tectonic settings remain obscure. Hercynian-aged terranes are more widespread (e.g. Bulgaria; northern Turkey; southern Aegean) but were commonly deformed, metamorphosed and dispersed during later orogenesis, such that their tectonic settings have remained unclear. New evidence of Palaeozoic tectonic settings, supported by new radiometric dating, is given here for northern Greece by **Himmerkus *et al.***, and for southern Greece by **Romano *et al.***

Different tectonic interpretations also exist for the Mesozoic–Early Cenozoic tectonic evolution. Deep-water basins rifted along the North Africa–Levant margin during Late Palaeozoic–Early Mesozoic time, but there is no agreement as to whether these represent intra-continental rifts (i.e. Red Sea-type rifts), or back-arc basins related to subduction. Here, **Gardosh & Druckman** argue in favour of an origin of the Levant Basin in the easternmost Mediterranean Sea as an early Mesozoic rift basin unrelated to subduction.

The main Mesozoic ophiolites are, nowadays, widely viewed as forming above intra-subduction zones, as explained in papers by **Smith**, **Rassios & Moores** and **Garfunkel**. However, some geologists continue to believe that most ophiolites formed at mid-ocean ridges, unrelated to subduction. Assuming most of the ophiolites did indeed form in subduction-related settings, questions still exist concerning the timing of spreading, subduction initiation, and the number and location of subduction zones involved. In addition, because continental collision is progressive and diachronous it is difficult to determine when, where and how collision has taken place. For example, in northwestern Greece the initial closure of the Vardar ocean is seen by some as Late Jurassic in age but by others as latest Cretaceous–Early Cenozoic. In central Turkey, within the Izmir–Ankara–Erzincan zone, collision is seen as either latest Cretaceous or Eocene (see **Rice *et al.***). In SE Turkey suturing of a southern Neotethyan ocean is variously thought to be latest Cretaceous, Late Eocene or Mid-Miocene (see **Rizaoğlu *et al.*** and **Boulton *et al.***).

Miocene–Recent tectonic settings are better understood as they can be directly related to the well-established modern plate tectonic setting of the region. There is a consensus that a Tethyan ocean in the south Aegean region (e.g. Ionian basin) was subducted northwards accompanied by back-arc extension, extending across the Aegean into western Turkey (e.g. Le Pichon & Angelier 1979). Evidence of related extension extending as far as northern Greece and Bulgaria is presented here by **Mountrakis *et al.***, **Tranos *et al.*** and **Westaway**. However, questions remain, including when and where subduction-related extension began (e.g. in western Turkey) and the extent to which Mesozoic Tethyan oceanic crust remains in the easternmost Mediterranean Sea, e.g. within the Herodotus Basin SW of Cyprus. Was the driving force of neotectonics in the south Aegean region southward migration (i.e. roll-back) of the Aegean subduction zone or westward tectonic escape of Anatolia, or a combination of both? For SW Turkey this question is addressed by **Alçiçek *et al.*** In the easternmost Mediterranean region, around Cyprus, did subduction continue until the present time along the

'Cyprus arc', or end with collision during the Miocene or even earlier in this region (see **Boulton *et al.***)?

Tectonic reconstructions

The Eastern Mediterranean is a favourite region for tectonic reconstruction, especially as the bounding North African (Gondwana) and Eurasian (Laurasia) continents are clearly defined. Several of the papers in this book present reconstructions for certain regions or time intervals (e.g. **Smith**), and the alternatives are critically discussed (see **Robertson**).

Palaeomagnetic studies show how the continental separation between Gondwana and Eurasia has evolved through time (e.g. see Morris & Tarling 1996). However, there are drastically different views of where the intervening pieces of the jigsaw puzzle should be placed and how they moved through time (see Robertson *et al.* 1996 for alternatives). There is still no consensus as to the most appropriate regional tectonic reconstruction. Controversial aspects include the timing and location of continental rifting and break-up to form one or more oceanic basins, the direction and timing of subduction, and the mode and timing of continental collision.

The most currently discussed tectonic models are outlined in Figure 1. In one class of reconstruction (Şengör 1984) a 'Palaeo-Tethyan' ocean was subducted southwards associated with the opening of 'Southern Neotethyan' marginal basins to the south. In most other reconstructions subduction was instead northwards (e.g. Garfunkel 1998, 2004). The reconstructions of Robertson *et al.* (1991, 1996, 2004), Dercourt *et al.* (1993, 1998, 2000) and Ricou (1996) envisage the rifting of several microcontinents from Gondwana. These fragments drifted northwards until they were accreted to Eurasia at various times. Even within this class of model (i.e. involving northward subduction), individual reconstructions vary considerably; for example, in the inferred location and age of oceanic crust in the Eastern Mediterranean region and whether the ophiolites mainly formed at mid-ocean ridges or above a subduction zone. In a third, different type of model, a 'Palaeotethyan ocean' was located in a more southerly position and completely closed by Early Jurassic time within the South Aegean region, whereas back-arc basins opened further north and did not then close until latest Cretaceous–Early Cenozoic time (Stampfli *et al.* 2001; Stampfli & Borel 2002).

The alternatives come sharply into focus for the Late Palaeozoic–Early Mesozoic evolution of the South Aegean region, which is interpreted differently according to whether the Palaeotethyan suture is located within this area or much further north, close to the Eurasian margin (see **Himmerkus *et al.***). One option is that subduction was dominantly northwards beneath the Eurasian margin (see **Robertson**), but that subduction also took place southwards beneath Gondwana at least during Late Devonian–Carboniferous related to the Hercynian orogeny (see **Romano *et al.***). **Robertson** presents evidence from the South Mediterranean region (Sicily, Crete, Peloponnese and Evia) that supports a model of rifting of microcontinents from Gondwana during the Triassic, followed by their northward drift during a time when northward subduction was active beneath Eurasia. However, southward subduction during the preceding Hercynian orogeny is not precluded.

Tethyan nomenclature

At present, Tethyan nomenclature is confusing mainly because different researchers apply the same names (e.g. Neotethys) to entirely different oceanic basins in different areas. Here, we advocate a relatively loose, non-exclusive terminology for the various Tethyan ocean basins in the Eastern Mediterranean region. We take Palaeotethys to refer to oceanic crust of mainly Late Palaeozoic–Early Mesozoic age that was formed, subducted or emplaced regardless of its geographical location. We use the term Neotethys for oceanic basins that rifted and then opened during Early Mesozoic time, again regardless of their location or mode of formation. In principle, Neotethyan rift basins could have formed in several different settings, including cratonic areas or pre-existing orogens (either within their interiors or along their margins). Neotethys may also include oceanic lithosphere that was formed within a pre-existing (i.e. Palaeotethyan) ocean; for example, as a subduction-related marginal basin or a strike-slip controlled basin. Neotethys was clearly multi-stranded and in principle coexisted with Palaeotethys, in a manner similar to the multiple relatively young ocean basins that formed in the SW Pacific region while older oceans in the region coexisted.

In Greece, Neotethys includes two belts of ophiolitic and related rocks (Pindos and Vardar), whereas Neotethys in Turkey includes the Southern Neotethys, south of the Tauride–Anatolide platform and the Northern Neotethys to the north of this continental unit. Several other smaller Neotethyan oceanic strands have been proposed (e.g. Inner Tauride ocean; intra-Pontide ocean).

This rather informal, non-prescriptive nomenclature that we advocate contrasts with some other approaches in which Tethyan oceans are named as specific basins in specific geographical regions that are indivisible from particular tectonic reconstructions. This is unsatisfactory, as in different reconstructions the same names (e.g. Palaeotethys; Neotethys) are applied to entirely different oceanic basins in different areas by different workers. A genetic terminology needs to be avoided in principle, as it leads to circular reasoning and inhibits the testing of alternatives. It seems increasingly likely there was, in any case, no sharp distinction between Palaeotethys and Neotethys, but rather one oceanic system existed and continued to develop throughout Palaeozoic–Recent time, akin to the tectonic development of the SW Pacific region.

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References

AKINCI, O., ROBERTSON, A. H. F., POISSON, A. & BOZKURT, E. (eds) 2003. Special issue on the Isparta Angle, SW Turkey. *Geological Journal*, **38**, 195–234.

AUBOUIN, J., BONNEAU, M., CELET, P. *et al.* 1970. Contribution à la géologie des Héllenides: le Gavrovo, le Pinde et la Zone Ophiolitique Subpélagonian. *Annales de la Societé Géologique du Nord*, **90**, 277–306.

BOZKURT, E., WINCHESTER, J. A. & PIPER, J. D. (eds) 2000. *Tectonics and Magmatism in Turkey and the Surrounding Area*. Geological Society, London, Special Publications, **173**.

DERCOURT, J., ZONENSHAIN, L. P., RICOU, L. E. *et al.* 1986. Geological evolution of the Tethys belt from the Atlantic to the Pamirs since the Lias. *Tectonophysics*, **123**, 241–315.

DERCOURT, J. RICOU, L. E. & VRIELYNCK, B. (eds) 1993. *Atlas Peri-Tethys Palaeogeographical Maps*. CCGM/CGMW, Paris.

DERCOURT, J., GAETANI, M., VRIELYNCK, B. *et al.* (eds) 2000. *Peri-Tethys Palaeogeographical Atlas*. Gauthier-Villars, Paris.

DEWEY, J. F., PITMAN, W. C., III, RYAN, W. B. F. & BONNIN, J. 1973. Plate tectonics and the evolution of the Alpine System. *Geological Society of America Bulletin*, **84**, 3137–3180.

DIXON, J. E., ROBERTSON, A. H. F. (eds) 1984. *The Geological Evolution of the Eastern Mediterranean*. Geological Society, London, Special Publications, **17**.

DURAND, D., JOLIVET, L., HORVÁTH, F. & SÉRANNE, M. 1999. *The Mediterranean Basins: Tertiary Extension within the Alpine Orogen*. Geological Society, London, Special Publications, **156**.

GARFUNKEL, Z. 1998. Constraints on the origin and history of the Eastern Mediterranean basin. *Tectonophysics*, **298**, 5–37.

GARFUNKEL, Z. 2004. Origin of the Eastern Mediterranean basin: a re-evaluation. *Tectonophysics*, **391**, 11–34.

GARFUNKEL, Z. & DERIN, B. 1984. Permian–early Mesozoic tectonism and continental margin formation and its implications for the history of the Eastern Mediterranean. *In*: DIXON, J. E. & ROBERTSON, A. H. F. (eds) *The Geological Evolution of the Eastern Mediterranean*. Geological Society, London, Special Publications, **17**, 177–186.

HOECK, V., TOMEK, C., ROBERTSON, A. H. F. & KOLLER, F. (eds) 2002. Eastern Mediterranean ophiolites: magmatic processes and geodynamic implications. *Lithos, Special Issue* **65**.

HSÜ, K. J., MONTADERT, L., *et al.* (eds) 1978. *Initial Reports of the Deep Sea Drilling Project, 32A*. US Government Printing Office, Washington, DC.

JACKSON, J. & MCKENZIE, D. P. 1984. Active tectonics of the Alpine–Himalayan belt between western Turkey and Pakistan. *Geophysical Journal of the Royal Astronomical Society*, **77**, 185–264.

KELLING, G., ROBERTSON, A. H. F. & VAN BUCHEM, F. H. P. (eds) 2005. *Cenozoic Sedimentary Basins of South Central Turkey. Sedimentary Geology, Special Issue*, **173**.

LE PICHON, X & ANGELIER, J. 1979. The Hellenic arc and trench system: a key to the neotectonic evolution of the Eastern Mediterranean area. *Tectonophysics*, **60**, 1–42.

MCKENZIE, D. P. 1972. Active tectonics of the Mediterranean region. *Geophysical Journal of the Royal Astronomical Society*, **30**, 109–185.

MCKENZIE, D. P. 1978. Active tectonics of the Alpine–Himalayan belt: the Aegean Sea and surrounding regions. *Geophysical Journal of the Royal Astronomical Society*, **55**, 217–354.

MORRIS, A. & TARLING, D. H. (eds) 1996. *Palaeomagnetism and Tectonics of the Mediterranean Region*. Geological Society, London, Special Publications, **105**.

PANAYIDES, I., XENOPHONTOS, C. & MALPAS, J. (eds) 2000. *Proceedings of the Third International Conference on the Geology of The Eastern Mediterranean*. Geological Survey Department, Nicosia.

PAPANIKOLAOU, D. J. (ed.) 1996–1997. *International Geological Correlation Project 276. Terrane Maps and Terrane Descriptions*. Annales Géologiques des Pays Helléniques.

PE-PIPER, G. & PIPER, D. W. J. 2002. *The Igneous Rocks of Greece. The Anatomy of an Orogen*. Beitrage zur regionalen Geologie der Erde, **30**.

REILINGER, R. E., MCCLUSKY, S. C., ORAL, M. B., KING, R. W. & TÖKSÖZ, M. N. 1997. Global Positioning System measurements in the Arabia–Africa–Eurasia plate collision zone. *Journal of Geophysical Research*, **102**, 9983–9999.

RICOU, L.-E. 1996. The plate tectonic history of the past Tethys ocean. *In*: NAIRN, A. E. M., RICOU, L.-E., VRIELYNCK, B. & DERCOURT, J. (eds) *The Ocean Basins and Margins, 8, The Tethys Ocean.* Plenum, New York, 3–62.

ROBERTSON, A. H. F. & COMAS, M. C. (eds) 1998. *Collision-related Processes in the Mediterranean Region. Tectonophysics, Special Issue*, **298**.

ROBERTSON, A. H. F. & DIXON, J. E. 1984. Introduction: aspects of the geological evolution of the Eastern Mediterranean. *In*: DIXON, J. E. & ROBERTSON, A. H. F. (eds) *The Geological Evolution of the Eastern Mediterranean*, Geological Society, London, Special Publications, **17**, 1–74.

ROBERTSON, A. H. F. & GRASSO, M. (eds) 1995. Late Tertiary Mediterranean tectonics and palaeoenvironments. *Terra Nova*, **7**, 254–264.

ROBERTSON, A. H. F. & WOODCOCK, N. H. 1979. The Mamonia Complex, SW Cyprus: the evolution and emplacement of a Mesozoic continental margin. *Geological Society of America Bulletin*, **90**, 651–665.

ROBERTSON, A. H. F., CLIFT, P. D., DEGNAN, P. J. & JONES, G. 1991. Palaeogeographic and palaeotectonic evolution of the Eastern Mediterranean Neotethys. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **87**, 289–344.

ROBERTSON, A. H. F., DIXON, J. E., BROWN, S., *et al.* 1996. Alternative tectonic models for the Late Palaeozoic–Early Tertiary development of Tethys in the Eastern Mediterranean region. *In*: MORRIS, A. & TARLING, D. H. (eds) *Palaeomagnetism and Tectonics of the Mediterranean Region.* Geological Society, London, Special Publications, **105**, 239–263.

ROBERTSON, A. H. F., EMEIS, K. C., RICHTER, K.-C. & CAMERLENGHI, A. (eds) 1998. *Proceeding of the Ocean Drilling Program, Scientific Results, 160.* Ocean Drilling Program, College Station, TX, 723–782.

ROBERTSON, A. H. F., USTAÖMER, T., PICKETT, E. A., COLLINS, A., ANDREW, T. & DIXON, J. E. 2004. Testing models of Late Palaeozoic–early Mesozoic orogeny: support for an evolving one-Tethys model. *Journal of the Geological Society, London*, **161**, 501–511.

ŞENGÖR, A. M. C. 1984. *The Cimmeride Orogenic System and the Tectonics of Eurasia. Geological Society of America, Special Papers*, **195**.

ŞENGÖR, A. M. C. & YILMAZ, Y. 1981. Tethyan evolution of Turkey: a plate tectonic approach. *Tectonophysics*, **75**, 81–241.

ŞENGÖR, A. M. C., YILMAZ, Y. & KETIN, I. 1980. Remnants of a pre-Late Jurassic ocean in northern Turkey: fragments of Permian–Triassic Paleo-Tethys. *Geological Society of America Bulletin*, **91**, 599–609.

SMITH, A. G. 1971. Alpine deformation and the alpine areas of Tethys, Mediterranean and Atlantic. *Geological Society of America Bulletin*, **82**, 2039–2070.

SMITH, A. G. 1993. Tectonic significance of the Hellenic–Dinaric ophiolites. *In*: PRICHARD, H. M., ALABASTER, T., HARRIS, N. B. W. & NANCE, D. R. (eds) *Magmatic Processes and Plate Tectonics.* Geological Society, London, Special Publications, **76**, 213–243.

SMITH, A. G., HYNES, A. J., MENZIES, M., NISBET, E. G., PRICE, I., WELLAND, M. J. & FERRIÈRE, J. 1975. The stratigraphy of the Othris Mountains, Eastern Central Greece: a deformed Mesozoic continental margin sequence. *Eclogae Geologicae Helvetiae*, **68**, 463–481.

STAMPFLI, G. M. & BOREL, G. D. 2002. A plate tectonic model for the Palaeozoic and Mesozoic constrained by dynamic plate boundaries and restored synthetic oceanic isochrones. *Earth and Planetary Science Letters*, **169**, 17–33.

STAMPFLI, G., MOSAR, J., FAURÉ, P., PILLEVUIT, A. & VANNAY, J.-C. 2001. Permo-Mesozoic evolution of the western Tethys realm: the Neotethys East Mediterranean basin connection. *In*: ZIEGLER, P., CAVAZZA, W., ROBERTSON, A. H. F. & CRASQUIN-SOLEAU, S. (eds) *Peri-Tethys Memoir 5. Peri-Tethyan Rift/Wrench Basins and Passive Margins.* Mémoires du Muséum National D'Histoire Naturelle, 51–108.

STEPHENSON, R. A. (ed.) 2004. *EUROPROBE, GeoRift 3: Intraplate Tectonics and Basin Dynamics. Tectonophysics, Special Issue*, **381**.

TAYMAZ, T., WESTAWAY, R. & REILINGER, R. (eds) 2004. Active Faulting and Crustal Deformation in the Eastern Mediterranean Region. *Tectonophysics, Special Issue*, **391**.

ZIEGLER, P., CAVAZZA, W., ROBERTSON, A. H. F. & CRASQUIN-SOLEAU, S. (eds) 2001. *Peri-Tethys Memoir 5. Peri-Tethyan Rift/Wrench Basins and Passive Margins.* Mémoires du Muséum National D'Histoire Naturelle.