The Sedimentary Basins from the Miocene to the Present in Greece: Examples for the Most Studied Basins from North Greece

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1 Introduction

There are many post-Oligocene basins in Greece, where both terrestrial, lacustrine-lagoonal, or marine deposits have been accumulated (Fig. 1). These correspond to the main areas of targeted field research to find fossil vertebrates, although in some exceptional cases, such fossils could be found in older rocks as well. For the purpose of this book, which concerns the fossil vertebrates from Greece ranging mainly from the Miocene to present time, we present an introduction on three major basins, situated in central and north Greece: Mesohellenic, Axios-Thermaikos, and Strymonikos basins, and their associated minor ones. These are some of the basins where many vertebrate fossils have been discovered and include also more detailed studies on the stratigraphy and paleoenvironment (Fig. 1).

These basins are situated in central and north Greece and have been developed on the Internal Hellenic Units (Fig. 2). The Mesohellenic basin is situated in the contact between External and Internal Hellenides, the Axios-Thermaikos basin on Axios-Vardar unit, whereas the Strymonikos basin on the contact between Serbomacedonian with Rhodope Massif.

It seems that these three major basins were active from late Eocene to the present, during which clastic deposits were accumulated. However, all of them were

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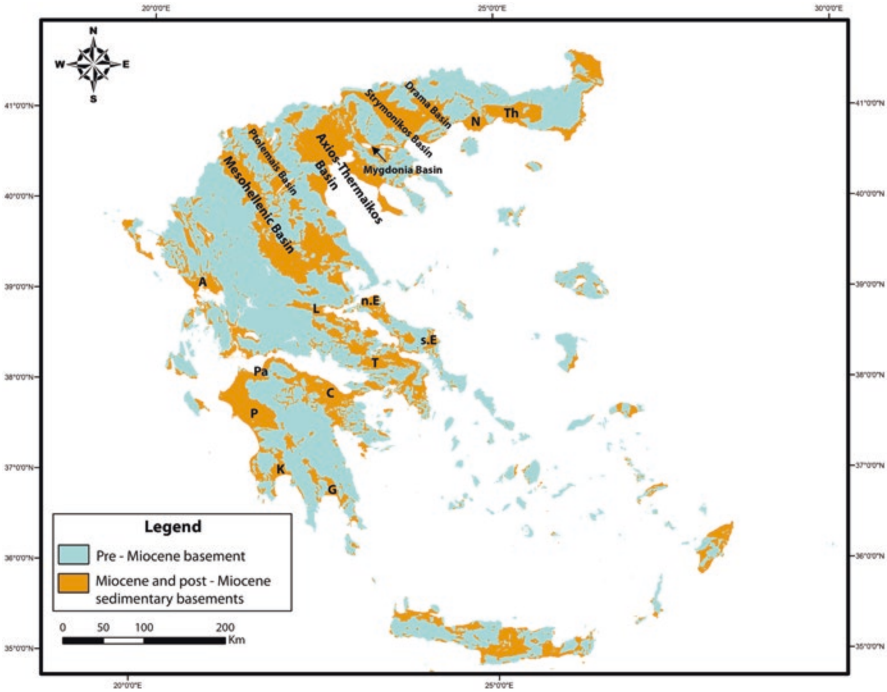

Fig. 1 The post-Oligocene basins of Greece, where the studied Mesohellenic, Ptolemais, Axios-Thermaikos, Mygdonia, and Strymonikos basins were showed. Additional, smaller, basins not presented in detail in the text: K, Kalamata; G, Gytheion; P, Pyrgos; Pa, Patras; C, Corinth; T, Thiva; L, Lamia; n.E, North Evia; s.E, South Evia; A, Amvrakikos Gulf; N, Nestos; and Th, Thrace

accompanied by three minor, and younger, basins, which were developed east of the major basins from the Miocene onwards. The Mesohellenic major basin is accompanied by the Ptolemais minor basin, the Axios-Thermaikos major basin is accompanied by the Mygdonia minor basin, and finally, the Strymonikos major basin is accompanied by the Drama minor basin (see Figs. 3, 4, and 5).

The remaining post-Alpine deposits from Greece are located in other, smaller basins, which nevertheless show important fossil vertebrate potential. These basins were strongly influenced by normal faults producing asymmetrical grabens.

At least four basins can be distinguished in Crete Island (Kasteli-Chania, Rethymnon, Irakleion-Messara, Ag. Nikolaos-Siteia basins), being characterized by strong synsedimentary tectonic influence with normal faults, where sedimentation started during late Miocene time (Tortonian) and continues with some interruptions as far as during the Pleistocene (Kontopoulos et al. 1996; Pasadakis et al. 2012; Moforis et al. 2013; Zidianakis et al. 2015; Maravelis et al. 2016; Zelilidis et al. 2016). Compared to other post-Oligocene basins from Greece that are predominantly terrestrial, the Neogene deposits from Crete contain several marine sediments. As such, they play an important role to our knowledge of the fossil record of

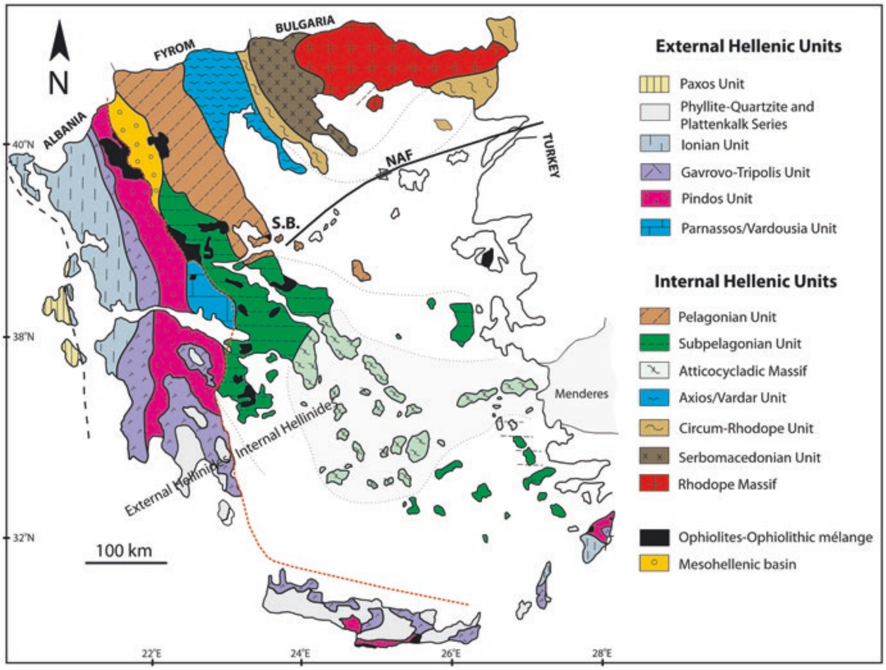

Fig. 2 Geological map of Greece showing the External and Internal Hellenides with their Units, Series, and Massifs; S.B., Sporades Basin (modified from Koukouvelas 2019)

vertebrates adapted to marine niches, including a diverse record of ray-finned fishes (see Argyriou volume 1, and references therein) and the entire Greek fossil record of sea cows (see Iliopoulos et al. volume 1, and references therein).

The remaining Aegean islands also contain smaller scale Neogene deposits. The most interesting are situated in Rhodes Island, where sedimentation during the Neogene covered a very high percentage of the present-day island. These deposits have not been extensively explored for fossil vertebrates, but they most certainly show an important potential, as evidenced by the rich diverse micromammalian faunas of the island (see Vasileiadou and Sylvestrou volume 1, Vasileiadou and Doukas this volume; and references therein).

In Peloponnesus, also there are many quite large basins, like these of Kalamata, Gytheion, Pyrgos, Patras, and Corinth (see Fig. 1), where mostly sedimentation took place in deltaic environments from early Pliocene to present, with many cycles of sedimentation, introducing regression and transgression events, owed mostly to tectonic activity and less to eustatic sea-level changes (Kontopoulos and Zelilidis 1992; Poulimenos et al. 1993; Zelilidis and Kontopoulos 1994; Zelilidis 2000; Zelilidis and Kontopoulos 2001). Many fossil vertebrates have been discovered in these deposits, including mainly large mammals like elephants and hippos (Athanassiou volume 1, this volume) or turtles (Vlachos volume 1).

There are also smaller basins, characterized by Neogene deposits, like these of Thiva, Lamia, north Evia, central Evia in eastern part of central Greece, Amvrakikos gulf in the western Greece, and Nestos and Thrace basins in North Greece (see Fig. 1). With the exception of Evia island, the other basins mentioned above contain only some few known localities with fossil vertebrates.

Although there are many basins with great interest, as mentioned above (Fig. 1), we focused in three synthetic basins (a major with an accompanied minor) as their complicated evolution seems to present the higher interest. Moreover, as this chapter represent the introductory chapter for all other chapters, with these three-basin analyses, a detailed description for post-Oligocene evolution in Greece is presented. Finally, all detailed maps were organized with unified basement, different lithologies and environments with chronologically divisions and not per formation, in order readers to understand and follow the remaining chapters.

2 The Mesohellenic Basin (MHB)

Geological Setting

The Mesohellenic Basin (MHB) corresponds to a Late Eocene/Oligocene–Middle Miocene thrust-top basin that was developed because of the westwards progradation of the Pindos Orogen (Avramidis et al. 2000; Zelilidis et al. 2002). The MHB is approximately 150 km long and 30 km wide (Figs. 1 and 3) and is positioned at the boundary between the Apulian Platform to the west and the Pelagonian Microplate to the east (Doutsos et al. 1994).

The basement of the MHB is represented by the ophiolite complex, remnants of the older subducted oceanic crust (of the so-called Pindos Ocean) that was subsequently emplaced over the margin of the continental crust (Apulian Platform) during compression (Moores 1969), along with Upper Cretaceous limestones of the western Pelagonian margin (Killias et al. 2015). The dip directions of the sedimentary succession at the western margin of the MHB (toward the ENE), and the eastern margin (toward the WSW) define a large-scale asymmetrical syncline (Killias et al. 2015), whereas to the north, the basin is further subdivided into two narrower synclines, separated by a region of uplift (Doutsos et al. 1994). Structural analyses reveal that during the Middle Eocene to Quaternary, the MHB displays a complex tectonic pattern (Vamvaka et al. 2010) that occurred in semi-ductile to brittle conditions (Killias et al. 2015).

Contrasting scenarios have been proposed to account for the origin of the MHB, with the most possible being: (1) a multi-story strike-slip and piggy-back-type basin from Middle Eocene to the present, above the westward emplacing Neotethyan ophiolites and Pelagonian units on the cold Hellenic accretionary prism (Killias et al. 2015); (2) a foreland-type basin developed in response to eastwards back-

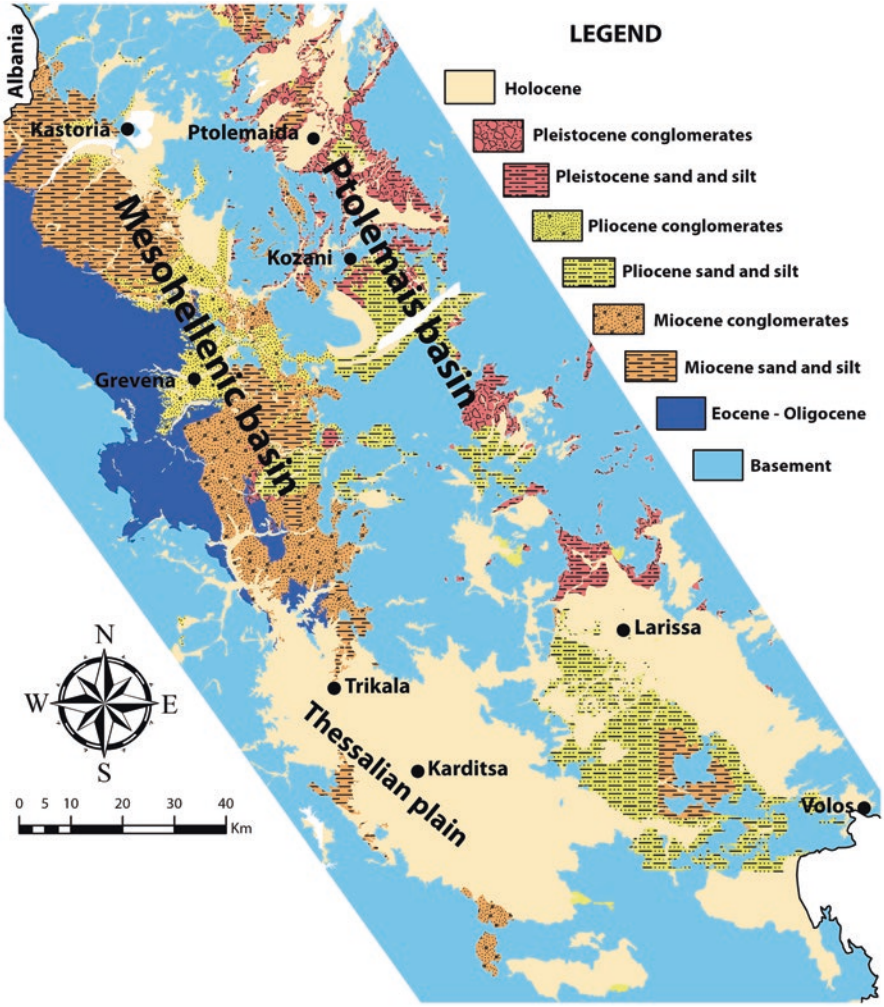

Fig. 3 Geological map of the Mesohellenic and accompanied Ptolemais basins

thrusting from Eocene to Miocene, because of the growth of the Pindos Orogen (Doutsos et al. 1994); (3) a forearc-type basin that developed during the early stages of a Mid–Late Eocene subduction (Pindos Ocean) and turned into a piggy-back basin as a result of Oligocene underthrusting of the Gavrovo-Tripolis domain (Ferriere et al. 2004).

Since the Late Miocene, the MHB exhibits gentle strike-slip deformation along major faults, uplift, and erosion, with the oldest rocks being exposed along the western basin margin (Doutsos et al. 1994).

Stratigraphic Evolution

The MHB receives sediments that have been accumulated in a variety of depositional environments from the Early Oligocene to the Middle Miocene. The stratigraphic record of the MHB initiates with the Eptahori Formation (1000-m thick, Lower Oligocene) that comprises conglomerates and interbedded sandstones that accumulated on a fan-delta depositional environment (Zelilidis and Kontopoulos 1996; Zelilidis et al. 2002; Avramidis et al. 2002). These deposits evolve abruptly upward into fine-grained submarine fan sediments. At the southwestern margin of the MHB, the Eptahori Formation unconformably overlays the Middle to Upper Eocene shales and sandstones of the Kranea Formation (Bizon et al. 1968). The Kranea Formation (<2 km thick) evolves up-sequence from fan-delta conglomerates and shales to turbidite sandstones and shales, and finally to deltaic and flood plain deposits (Zelilidis and Kontopoulos 1996; Zelilidis et al. 2002). During the Late Oligocene to Middle Miocene, the depositional environments are represented by fan-delta deposits that evolve into shelf deposits around the uplifted areas to the north and south of the MHB. Submarine fan deposits were continuously deposited in the central part of the MHB. Over the Eptahori Formation, the Pentalofos Formation (2500 m thick, Upper Oligocene–Lower Miocene) comprises submarine fan deposits that evolve to the southeast into shelf deposits. The overlying Tsotili Formation (1500 m thick, Lower to Middle Miocene) is also composed of submarine fan deposits, which in the northern part of the basin are overlain by Middle Miocene sandy shelf deposits (Ondria beds, 350 m thick). Finally, in the eastern parts of the basin, fluvial deposits have been accumulated. South of the MHB, the Thessalian plain is characterized by coarse-grained shallow water deltaic deposits that formed after the separation of the MHB into three-distinct sub-basins (according to Zelilidis 2003), during early Miocene.

Vertebrate Fossils in the MHB Basin

The majority of the vertebrate fossils from the MHB basin area are known actually from the more recent, Plio–Pleistocene deposits. These sediments contain perhaps the most important records of derived proboscidean specimens, including elephants and mammoths (see Athanassiou volume 1, and references therein), and mastodons (see Konidaris and Tsoukala volume 1, and references therein). The Miocene deposits are much poorer in fossil vertebrate remains, given that they mostly represent more coastal or littoral depositional environments; they are, however, quite rich in invertebrate fossil remains. As such, Miocene vertebrate localities from the MHB basin are few, including some aquatic turtle remains (see Vlachos volume 1, and references therein). These few occurrences, however, are of great importance for their respective clades and highlight the important potential of vertebrate fossil findings in the Miocene and older deposits of the MHB.

3 The Ptolemais Basin (PTB)

Geological Setting

The Ptolemais Basin (PTB) is a northwest-southeast trending sedimentary basin and is located in the Pelagonian Zone (Figs. 1 and 3). The study region was affected by at least six deformational stages from the Carboniferous to the Miocene (Mountrakis 1983). This tectonic activity triggered uplift and deformation of the basement rocks, along with the development of large-scale synclines and anticlines (Mountrakis 1983). The PTB basin was developed along a preexisting syncline, located within the regional mountain ranges. The study area is regarded as a rift-type basin developed because of extensional tectonic activity, which followed the Alpine orogenesis in Greece (Anastasopoulos and Koukouzas 1972; Koukouzas et al. 1979, 1981, 1984, 1985). During the Pliocene, NE-SW to NNE-SSW directed normal faults affected the Neogene sedimentary succession of the PTB and controlled topography, forming grabens and horsts. Tectonic analysis studies suggest at the early stages of basin development, the PTB was controlled by NW-SE directed normal faults, whereas the later stages are impacted by NE-SW normal faults (Pavlides 1985; Pavlides and Mountrakis 1987). The fault activity is subdivided into two stages that were active during the Late Miocene-Pleistocene and post-Early Pleistocene, respectively (Pavlides and Mountrakis 1987).

Stratigraphic Evolution

In the PTB, Neogene in age sediments (Miocene to Pliocene) are deposited, which come from the erosion of the preexisting basement rocks. These basement rocks belong to the Pelagonian Zone and consist of Pre-Cambrian to Paleozoic metamorphic rocks, Carboniferous granites, Triassic to Lower Jurassic limestones, and Middle Jurassic ophiolites that are unconformably overlaid by Upper Cretaceous limestones and submarine fan deposits (Mountrakis 1983). The Neogene (Late Miocene to Early Pleistocene) deposits have been interpreted as lagoonal in origin and are divided into two discrete members, based on the age, composition, and type of lignite-bearing deposits (Koukouzas et al. 1979; Steenbrink 2001). The lower member was accumulated during the Late Miocene to possibly earliest Pliocene age. It is composed of yellow to green, fine-grained silty sandstone and sandy claystone. The upper member was deposited during the Pleistocene and is composed of repetitions of silty sandstone and sandy claystone, along with sandstone and mudstone. During the Early to Middle Pleistocene, fluvial in origin sediments consisting of loose conglomerate, sandstone, and red in color mudstone accumulate in the PTB. The fluvial deposits overlay the preexisting lagoonal deposits, and their boundary is represented by an erosional unconformity.

Vertebrate Fossils in the PTB Basin

The PTB basin hold important occurrences of vertebrate fossils, many of which have been discovered during prospecting or mining activities related to the lignite exploration and research in the basin. The most important vertebrate fossils from the PTB basin belong to two different categories. On the one hand, there are plenty and diverse localities with numerous micromammalian fossils (e.g., see Vasileiadou and Sylvestrou volume 1; Vasileiadou and Doukas this volume; and references therein). These occurrences mostly come from the lower member, as described above. On the other hand, there are several occurrences of elephants and mammoths, including some partial skeletons with exceptional preservation (see Athanassiou volume 1). Most elephant fossils come from the Pleistocene deposits of the basin.

4 The Axios-Thermaikos Basin (ATB)

Geological Setting

The Axios-Thermaikos Basin (ATB) (Figs. 1, 2, and 4) corresponds to a fault-bounded sedimentary basin (Ferentinos et al. 1981) and forms part of the North Aegean region, an area with complex geological history (Kilias et al. 2013; Maravelis et al. 2015). The ATB overlies the eastern margin of the Pelagonian Zone (the so-called Vardar-Axios Zone), a fault-related crystalline massif and part of the Internal Hellenides (Brooks and Ferentinos 1980). The Vardar-Axios Zone is NNW-SSE directed and extends through Bulgaria, Northern Crete, and Western Turkey. An important regional feature is the North Aegean Trough (NAT), a 300-km-long trough along the Tethyan Ocean suture zone (Mountrakis 2006). The western margin of the NAT is the Sporades Basin, which in turn corresponds to the offshore extension of the ATB (Brooks and Ferentinos 1980). The development of the NAT is ascribed to late collisional processes that occurred between the Apulian and Eurasian continental lithosphere during the Late Oligocene to Middle Miocene (Tranos 2009), probably combined by the westward progradation of the North Anatolia Fault (McKenzie 1972; Pavlides et al. 1990).

The study area exhibits a complex tectonic regime characterized by periods of extensional, compressional, and strike-slip tectonics since the Oligocene (Pavlides et al. 1990; Sokoutis et al. 1993; Kilias et al. 1999; Tranos 2009; Koukouvelas and Aydin 2002). Tectonic analyses suggest that the NE-SW Sporades Basin was initiated either during the (1) Early–Middle Miocene under regional contraction and strike-slip to transpressional deformation and subsequently involved into extensional basin (Tranos 2009) or (2) Middle–Late Miocene WNW-ESE extension (Tranos 2009). In both scenarios, the Sporades Basin was initiated because of late collisional processes, rather than the westward propagation of the North Anatolia Fault into the North Aegean Sea (Tranos

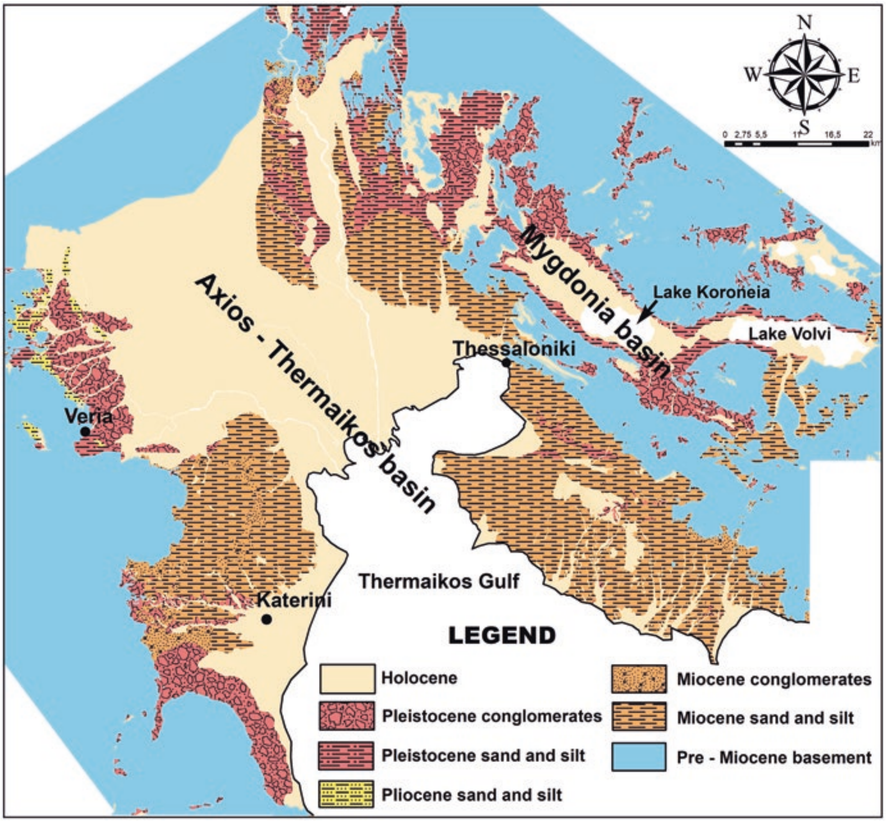

Fig. 4 Geological map of the Axios-Thermaikos basin and the accompanied Mygdonia basin

2009). Strike-slip tectonic activity played a key role in the development of the study area since the seismic reflection data suggest that basin-bounding faults display strike-slip architecture (Ferentinos et al. 1981; Roussos and Lyssimachou 1991). Normal and strike-slip interaction is also supported by fault pattern analyses, bathymetric data, and onshore and offshore seismic profiles (Koukouvelas and Aydin 2002). Since the Early Pleistocene, the deformation of the NAT is related to a NNE-SSW back-arc extension of the present-day Hellenic subduction zone (Tranos 2009).

Stratigraphic Evolution

The Neogene sedimentary succession in the ATB is ~1000 m thick (Kalkreuth et al. 1991). The ATB stratigraphy is subdivided into three major units with sediments that belong to a terrestrial to low salinity lacustrine depositional environment (Benda and Steffens 1981; Kalkreuth et al. 1991; Kotis and Papanikolaou 1999).

The lower unit is ~400 m thick and is exposed in the northern margin of the ATB because of extensive erosion of the overlying strata. It includes conglomerates of terrestrial origin and sandstone beds (up to 10 m thick). Silt and sandy clay beds are also present. The middle part is over 200 m thick and is composed of sandstone, mudstone and thick coal beds. The age of this unit, as determined by palynological data, is Lower Miocene (Benda and Steffens 1981), and it has been interpreted as being deposited in a swamp to limnic lower delta environment (Kalkreuth et al. 1991). Unconsolidated sandstones, silt and clay follow the thick-bedded coals (up to 1 m thick). The upper unit consists of sandstone and mudstone beds that accumulated during the Late Miocene age ("Pontian"). In this unit, lignite beds occur, but they are of no economic importance (Kalkreuth et al. 1991). The sediment flow direction is generally to the south and east further feeding the Sporades Basin. During the Late Quaternary, deposition is controlled primarily by prodeltaic and delta plain dynamics and, secondarily, by relative sea level changes (Lykousis et al. 2005). Three major river systems (Axios, Aliakmon, and Pinios), along with minor ones (Loudias and Gallikos), contribute freshwater and sediment to the sea. All but Pinios debouch in the north part of the Thermaikos Gulf (Lykousis et al. 2005). The excess in river-borne sediment is responsible for the development of an extensive bird-foot-type delta (Poulos et al. 1994). In the eastern margins of the ATB (western Chalkidiki), the basin was formed during early Miocene and was filled with Neogene–Quaternary deposits that are over 5 km in total thickness (Syrides 1990). The deposits are grouped into six formations: (a) Antonios Formation was deposited during the Early to Middle Miocene and Late Miocene (fluvial deposits), (b) Triglia Formation was deposited during the Late Miocene (Vallesian-Lowermost Turolian, continental deposits and red-beds), (c) Trilophos Formation was deposited during the Latest Miocene (Pontian or Turolian, brackish-lacustrine deposits), (d) Gonia Formation was deposited during the Pliocene (Ruscinian, fluvio-lacustrine deposits), and (e) Moudania Formation was deposited during from the Villafranchian onwards (continental sediments). To the west (Katerini sub-basin), the Neogene sedimentation is represented by eight Formations (Sylvestrou 2002): (1) Elatochori (alluvial fans, Early Miocene), (2) Moschopotamos (continental to lagoonal-lacustrine, Early to Middle Miocene), (3) Sykea (meandering fluvial, Middle Miocene), (4) Ryakia (meandering fluvial, Middle Miocene), (5) Lagorachi (braided fluvial, Late Miocene), (6) Sfendami (lagoonal, Late Miocene), (7) Makrygialos (braided fluvial, Late Miocene to Early Pleistocene), and (8) Lofos Formation (fluvial and lagoonal, Pleistocene to Quaternary).

Vertebrate Fossils in the ATB Basin

The ATB Basin is one of the most important regions that contain vertebrate fossils. The first collections of vertebrate fossils in the area took place in the beginning of the twentieth century by C. Arambourg (Arambourg and Piveteau 1929) and continue until present with new collections and extensive exploration. In the northern part of the basin, on each margin of the Axios river, numerous and famous localities with vertebrate fossils have concentrated enormous interest during the last 100 years. The majority of these localities are quite diverse, containing important primate (Koufos volume 1), bovid (Kostopoulos this volume), equid (Vlachou et al. this volume), carnivoran (Koufos this volume-a, -b, -c, -d), and proboscidean (Konidaris and Tsoukala volume 1) fossils. The western Chalkidiki sub-basin contains several vertebrate localities as well, mostly discovered along the coastline of the eastern border of Thermaikos gulf. These localities contain important non-mammalian fossils, including snakes (Georgalis and Delfino volume 1), turtles, and giant tortoises (Vlachos volume 1). The Katerini sub-basin is just as promising as the western Chalkidiki one, but focused fieldwork and exploration targeting vertebrate remains only recently took place (Sylvestrou 2002).

5 The Mygdonia Basin (MB)

Geological Setting

The Mygdonia basin (MB) (Fig. 4) is situated in central Macedonia, to the northeast of Thessaloniki city and is characterized by active seismic activity (Papazachos et al. 1979; Martinod et al. 1997). The MB is an E-W directed sedimentary basin (graben) that was developed during the Early-Middle Miocene because of extensional tectonic activity (Le Pichon and Angelier 1981). The MB is nowadays characterized by N-S extension (Martinod et al. 1997) that has been interpreted as the result of the spreading of the Aegean region over the subducted oceanic Mediterranean plate (Le Pichon and Angelier 1981). The extension principally influences a narrow (less than 2 km), E-W oriented zone at the southern edge of the basin (Martinod et al. 1997). The integration of seismological and neotectonic data indicates that normal faults prevail the tectonic features in the MB (Papazachos et al. 2001). Despite the variety in fault azimuths observed in some small faults, the majority of the faults and the major-magnitude seismic events are in agreement with the average N-S extension (Papazachos et al. 2001). The MB exhibits S-shape geometry, with its edges being NW-SE oriented, and the central parts being E-W oriented (Papazachos et al. 2001). The central part has drown the scientific attention because of the seismic activity of the Mw = 6.5 magnitude that affected the city of Thessaloniki (Papazachos et al. 1979; Pavlides et al. 1988). The basin is situated within the Serbomacedonian massif and is surrounded by a several sediment depocenters (Axios Basin, Strymon Basin, and North Aegean Trough). The MB receives sediments from Neogene to Quaternary that uncomformably overlay the pre-Neogene basement. Gneisses, schists, represent the basement rocks and amphibolites, metamorphic rocks that form parts of the Serbomacedonian Massif (in the central and eastern part of the MB, Kockel et al. 1977). The basement rocks in the western part of the basin correspond to phyllites, limestone, and sandstone that belong to the Circum-Rhodope Belt and have experienced low-grade metamorphism (Kockel et al. 1977).

Stratigraphic Evolution

The sedimentary pile in the MB is divided into two units: (1) the Pre-Mygdonian Group and (2) the Mygdonian Group. The Pre-Mygdonian Group encompasses Neogene and Early Pleistocene in age sediments, whereas the Mygdonian Group was deposited during the Middle Pleistocene to the Holocene and overlies uncomformably the Pre-Mygdonian Group (Koufos et al. 1995; Konidaris et al. 2015). The Pre-Mygdonian Group is further subdivided into three formations. The oldest Chrysavgi Formation (Middle Miocene, 40–50 m thick) uncomformably overlies the basement and is composed of laterally discontinuous conglomerates interbedded with sandstones. The conglomerate is unconsolidated and consists of well-rounded gravels (up to 40 cm in diameter). The gravels consist of mica-schist, gneiss, granite, quartzite, and pegmatite. Finer-grained deposits are rare and form thin-bedded lenses of silt and clay. The conglomeratic deposits mainly occupy the lower parts of the Chrysavgi Formation and exhibit an upward decrease in the gravel diameter within the formation. The upper parts of the Formation are sand-dominated and the finer-grained deposits (siltstones, silty sandstones, and silty claystones) are sporadically present. The overlying Gerakarou Formation (Early Pleistocene, over 100 m thick) is represented by red-beds consisting of repetitions of unconsolidated gravels, sand, silt, and clay. The gravelly beds are lenticular in shape and laterally discontinuous, and they have been interpreted as being accumulated in a fluvio-terrestrial environment of deposition. These red-beds erode significantly the underlying deposits and develop steep, valley-type landforms. The overlying Platanochori Formation (Early Pleistocene, 10–20 m thick) consists of sandstones and conglomerates, interbedded with silty sandstones, silty claystones, marlstones, and marly limestones. The limit between the Gerakarou and Platanochori Formations is transitional, consisting of laterally discontinuous sandstones, sandy marlstones, and red beds. The Platanochori Formation is thought as being accumulated in fluvial, fluvio-lacustrine depositional environment. This Formation represents the early stages of evolution between the continental Gerakarou Formation and the overlaying lacustrine sediments of the Mygdonian Group.

Vertebrate Fossils in the MB

Targeted exploration in the MB focusing on fossil vertebrates has contributed greatly to our knowledge of the stratigraphy of the basin; it is not a coincidence that some of the most important localities share the same name with the formations mentioned above. Vertebrate fossils are found mainly in the Pre-Mygdonian Group and are encountered in all formations. Occurrences from the great majority of mammalian families covered in volume 1 are found in the MB (e.g., Koufos 2006; Koufos et al. 1995; Tsoukala and Chatzopoulou 2005; Konidaris et al. 2015; and references therein).

6 The Strymonikos Basin (SB)

Geological Setting

The Strymonikos Basin (SB) is positioned over the boundary between the Rhodope massif and Serbo-Macedonian massif (Fig. 5). The boundary between the basement massifs is documented by the overthrusting of biotitic gneiss and marbles (Serbo-Macedonian) over the marbles of the Pangaion Mt. (Rhodope). The SB is thought as a NNW-SSE oriented graben-type basin and is arcuate in shape (Psilovikos 1994). The SB is interpreted to have been developed in response of a low-angle normal boundary fault (Dinter and Royden 1993). The fault action triggered collapse of the material and slumping toward the southwest. This tectonic event is the result of the extensional regime that controlled the basin evolution during the Neogene and extends from the Aegean Sea to Bulgaria (Dinter and Royden 1993).

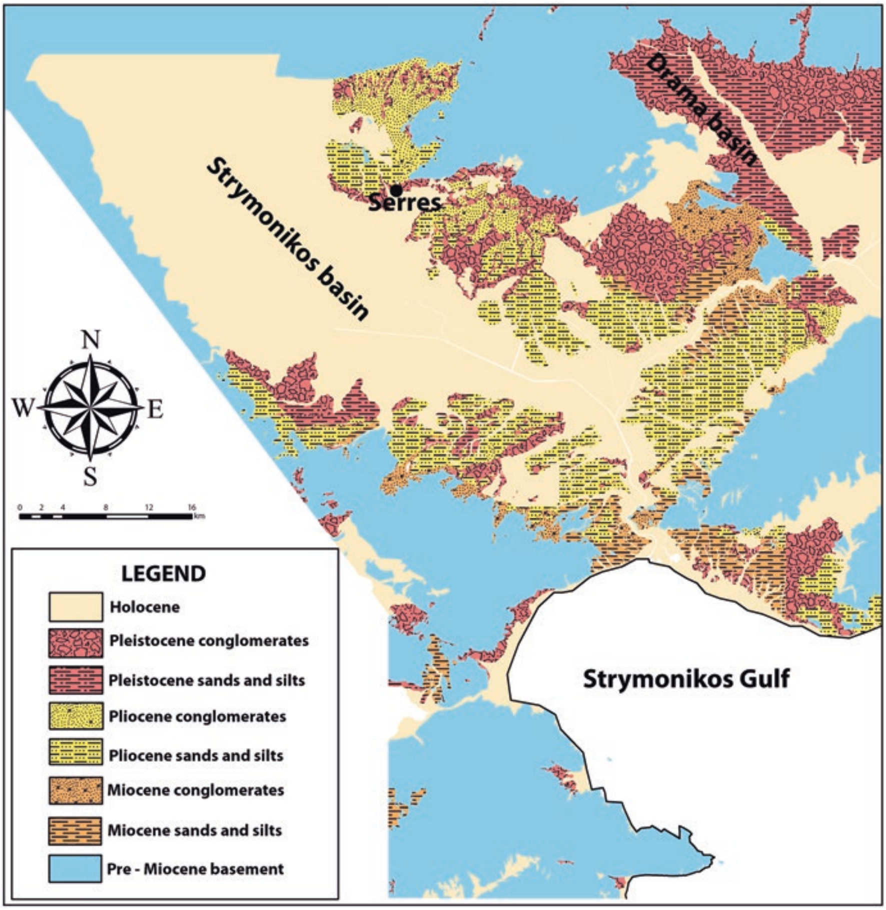

Fig. 5 Geological map of the Strymonikos basin and the accompanied Drama basin

Gravity faults affected the development of the SB, particularly the central parts, triggering post-depositional sediment deformation and anticline formation (Lalechos 1986). The uplift of the surrounding regions leads to the erosion of the basement rocks that provided the detritus for the sediment in the SB. The basin includes evidence of relative sea-level fluctuations, with stages of lagoonal-lacustrine sedimentation and stages of marine sedimentation (Lalechos 1986). At the latest stages of evolution, sedimentation in the SB is entirely continental.

Stratigraphic Evolution

The SB receives Neogene in age sediments (Miocene to Pleistocene), stemming from the erosion of the preexisting basement rocks that belong to the Rhodope massif and Serbo-Macedonian massif (Lalechos 1986). Sub-surface data indicate that the Miocene deposits correspond to both marine and lacustrine depositional environments and are subdivided into three units (Lalechos 1986). The basal unit comprises brecciated deposits, with the internal clasts being composed of fine-grained sandstones and conglomerates.

The overlying unit is interpreted as lacustrine deposits and is composed of repetitions of sandstones, mudstones, and dark brown marlstones that evolve up-section into petroliferous limestones. The younger deposits represent marine deposits and develop repetitions of sandstones, siltstones, and claystones that accumulate along with micro-brecciated deposits and lignite layers. The Pliocene sediments are interpreted to represent both brackish and continental environments of deposition (Lalechos 1986). The brackish sediments include sandstones, mudstones, siltstones, along with travertines and lignites. The continental deposits are composed of alternations of reddish sandstones and mudstones. Intercalations of sandstones, siltstones, and micro-conglomerates are common. These sediments also include travertines, lignite-bearing limestones, and chalk limestones. The Pleistocene deposits are composed of quartz gravels, coarse-grained sandstones, siltstones, and claystones. The sedimentary succession suggests that the sedimentation in the SB was dominated by lacustrine conditions and low energy sedimentation on continental deposits (Lalechos 1986). The travertinic and lignitic deposits represent materials accumulated at the basin margin, adjacent to the basement rocks (Lalechos 1986).

Vertebrate Fossils in the SB

The majority of the vertebrate fossil-bearing localities of the SB are located in the northern parts of the basin. These localities are mainly quite rich and diverse in micromammalian (e.g., see Vasileiadou and Sylvestrou volume 1; Vasileiadou and Doukas this volume; and references therein) and squamate (Georgalis and Delfino volume 1) remains, including some of the most diverse vertebrate localities in

Greece (Schmidt-Kittler 1995). These localities document the transition from the Miocene to the Pliocene in great detail. Large vertebrate remains are fewer, but include important chalicothere specimens together with associated Late Miocene remains (Tsoukala this volume and references therein). Stratigraphically younger vertebrates are known from the central and southern parts of the SB and the associated Drama basin, including mainly proboscidean remains (Athanassiou volume 1; Konidaris and Tsoukala volume 1).

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