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Upper Cenozoic stratigraphy and paleogeographic evolution of Myrtoon and adjacent basins, Aegean Sea, Greece

George Anastasakis [a,*], David J.W. Piper [b], Michael D. Dermitzakis [a], Vassilios Karakitsios [a]

[a] *Faculty of Geology & Geoenvironment, University of Athens, Panepistimiopolis, 15784 Athens, Greece*
[b] *Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, NS, Canada B2Y 4A2*

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Abstract

The southern Aegean Sea has undergone major subsidence as a result of back-arc extension during the Neogene. The details of this subsidence and the resulting sedimentation patterns have been examined in the Myrtoon basin and adjacent areas, including the south Evoikos, Saronikos and Argolikos gulfs, by comparing seismic stratigraphy and facies interpretation from multichannel seismic profiles with the stratigraphic and sedimentologic history of adjacent land areas. A detailed seismostratigraphy has been developed for the whole area in the late Neogene. The Messinian erosion surface is an important regional marker. Pliocene and early Quaternary markers are dated by comparison of marine transgressions with dated sections along the coast and dated volcanic rocks on islands.

The region appears to have progressively subsided since the Miocene. Myrtoon basin and Saronikos Gulf were lake basins in the Messinian that were flooded to form deep-water marine basins during the basal Pliocene transgression. South Evoikos and Argolikos basins were progressively flooded during the Pliocene and early Quaternary. In most areas, deep-marine basins filled principally with hemipelagic sediment, but a submarine fan developed in the early Pliocene in the northern Myrtoon basin and fan deltas built into the basin from the east and southwest. Opening of marine ‘gateways’ as a result of subsidence led to enhanced oceanographic circulation and the formation of regional erosion surfaces at basin margins.

Keywords: Seismic stratigraphy; Paleogeography; Basin sedimentation; Faulting; Turbidite; Transgression

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1. Introduction

In continental margin settings, the early evolution of a back-arc region is commonly characterized by subduction-related extension and rifting. The south Aegean region (Fig. 1) is a zone of extensional tectonism within the overriding plate of a convergent plate margin, that is at the threshold of a continent-to-continent collision (Doutsos and Kokkalas, 2001). Aegean-style back-arc extension is a common and necessary feature of incipient collisions, serving to consume remnants within embayments of the colliding continents. An understanding of orogeny requires the understanding of the formation and development of such basins, which preserve a chronological record of extension. It is striking how the sedimentary infill of even adjacent back-arc basins can vary markedly both in terms of facies and thickness, as a result of their variable tectonic stage of evolution and variation in sediment supply resulting from drainage characteristics in the hinterland, distance to volcanic centres, and oceanographic and other environmental conditions.

The Myrtoon Sea occupies the northwest quarter of the south Aegean Sea. It lies west of the Cyclades islands, which form a shallow-water barrier between the deeper central and southern parts of the Aegean Sea (Fig. 1). The Myrtoon Sea is bounded by the Attiki and Argolis peninsulas to the north–northwest and is encircled by several small islands to the south, connected to the southwest Aegean Sea through wide seaways. The most important geotectonic element of the region is the western end of the active South Aegean Volcanic Arc (Fig. 1). Volcanic centers active during the Pliocene—Quaternary extend from Crommyonia in western Attiki through the island of Aegina and Methana peninsula to Milos and adjacent islands in the southwest Cyclades (Fig. 2). These volcanic centers are dominated by the presence of domes and lava flows with subordinate pyroclastic rocks (Fytikas et al., 1986) mainly of andesite and dacite composition (Pe-Piper and Piper, 2005).

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* Corresponding author. Tel.: +30 210 72 74 161; fax: +30 210 68 53 157.
E-mail addresses: anastasakis@geol.uoa.gr (G. Anastasakis), dpiper@nrcan.gc.ca (D.J.W. Piper).

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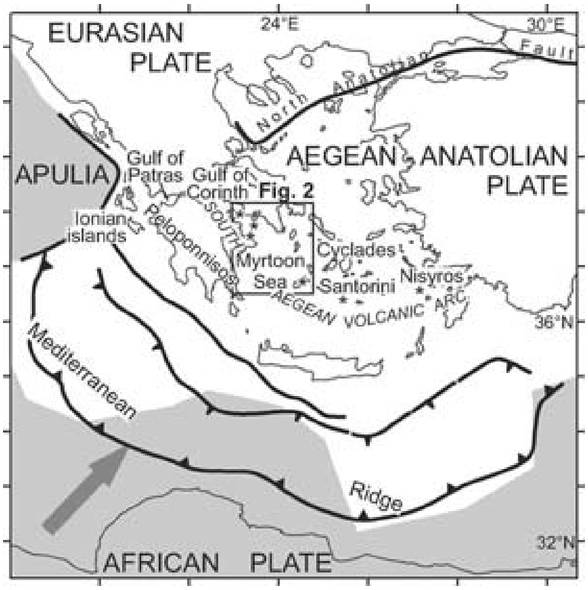


Fig. 1. General map of the Aegean Sea region showing the plate tectonic setting and the South Aegean Volcanic Arc.

The purpose of this paper is to interpret the manner in which subsidence and sedimentation has progressed in this part of the south Aegean back-arc region during the Neogene, as a guide to tectonic processes and to identify possible petroleum reservoir facies. This is achieved by establishing a seismostratigraphy of the Myrtoon basin and the adjacent south Evoikos, Saronikos, and Argolikos basins from industry multichannel seismic profiles, dated by comparison with sparse outcrops on adjacent land areas and the record of adjacent volcanism.

2. Upper Cenozoic sediments on land

There are scattered small occurrences of Neogene sediments on the islands of Milos and Kimolos southwest of the Myrtoon Sea (Fig. 2). The Neogene sequence unconformably overlies pre-Neogene metamorphic rocks and consists of bioclastic, partly reefal limestones associated with reddish conglomerates and followed upwards by clastic sediments that locally contain lenses of evaporites of Messinian age (Meulenkamp, 1979; 1985). The Messinian sediments are overlain by open marine gray silty clays belonging to the lower Pliocene (Bellas and Frydas, 1994; Frydas, 1996; van Hinsbergen et al., 2004) that are upwards succeeded by marls, diatomites and volcanic rocks.

The north–northwest borderland of the Saronikos Gulf is covered by extensive upper Cenozoic formations. The Megara Neogene and Pleistocene sediments were deposited in a WNW-ESE striking graben and generally dip towards the NNE. The Neogene sequence starts with a basal breccia above the Mesozoic basement that is followed by up to 150 m of light grey marls and intercalated sandstones that according to Theodoropoulos (1968) could be of late Miocene age. These marls that are unconformably overlain by several hundred metres of conglomerate, sandstone, marl, and lignite recording alternating marine, brackish and freshwater conditions. This sequence is unconformably covered by 150 m of fluviatile conglomerates and sandstones, which are locally cut by mid to upper Pleistocene marine terraces.

Along the west coast of Attiki peninsula, south of the city of Athens near the old Elliniko airport, Papp et al. (1978) have described an Upper Miocene sedimentary succession of the Trachones hills. The basal part consists of irregular alternations of fluviatile conglomerates, sands and marls that are unconformably overlain at places by reefal to stromatolitic limestones that contain an abundant fauna of mollusks and echinoderms; some species like the gasteropod *Pirenella caillandi* are indicative of elevated salinities. A marly limestone contains reworked blocks of reefal limestone at the base unconformably follows the coral limestones. The upper part of the sequence consists of a limestone with typical *Congeria* beds that are present together with *Dreissenia* and Limnocardiidae. These sediments are unconformable overlain by trangressive conglomerates and littoral sands with finer intercalations upwards that contain abundant foraminifera and calcareous nannoplankton not younger than the biozone NN15 (upper part of the Lower Pliocene). In addition, clastic sediments, marls and marine carbonates a few to several tens of metres thick, of early Pliocene age (Zanclean: Christodoulou, 1961) outcrop along the coast at Pireas and south of Trachones (Kalamaki to Kavouri), as well as in the south-central part of the city of Athens (Kallithea).

The plain in the eastern part of the Attiki peninsula has up to 700 m of reddish terrestrial, mostly coarse clastic, sediments (correlated regionally with the Pikermian mammalian fauna) overlain by fresh-water marl, carbonates, travertine and minor lignite. The Pikermian sediments contain a rich Late Miocene mammal fauna (Symeonidis et al., 1973), which have been related to seasonal evaporation in a paleo-lake basin associated with the Messinian salinity crisis (Bachmayer et al., 1982). Along the east coast of the Attiki peninsula, the Pikermian beds pass into or are unconformably overlain by up to 80 m of fluvial conglomerates at Rafina (Mettos, 1992). These conglomerates pass laterally into, or are overlain by, a marine Pliocene succession. Similar successions up to 50 m thick outcrop in places all along the eastern coast of the Attiki peninsula, unconformably overlying Pikermian strata or alpine basement rocks. The Pliocene strata have been dated from the lower part of the middle Pliocene (Markopoulou-Diakantoni et al., 1998). They consist of basal marine conglomerate and sandstone, passing upwards into carbonate-rich sandstones with a spectacular mollusc fauna, then deeper water marls with benthic foraminifera but no nannoplankton, and finally a regressive succession of alternating terrestrial and shallow marine clastic sediments.

Aegina island in the Saronikos Gulf has Neogene sediments at several localities. The most complete section at Souvala starts with a terrestrial conglomerate that passes upwards into a brackish succession of yellowish to whitish marls and marly limestones, which near the top contain foraminifera and nannoplankton characteristic of the late Messinian (Rogl et al., 1991). At the Agios Thomas section, there is a 70 m

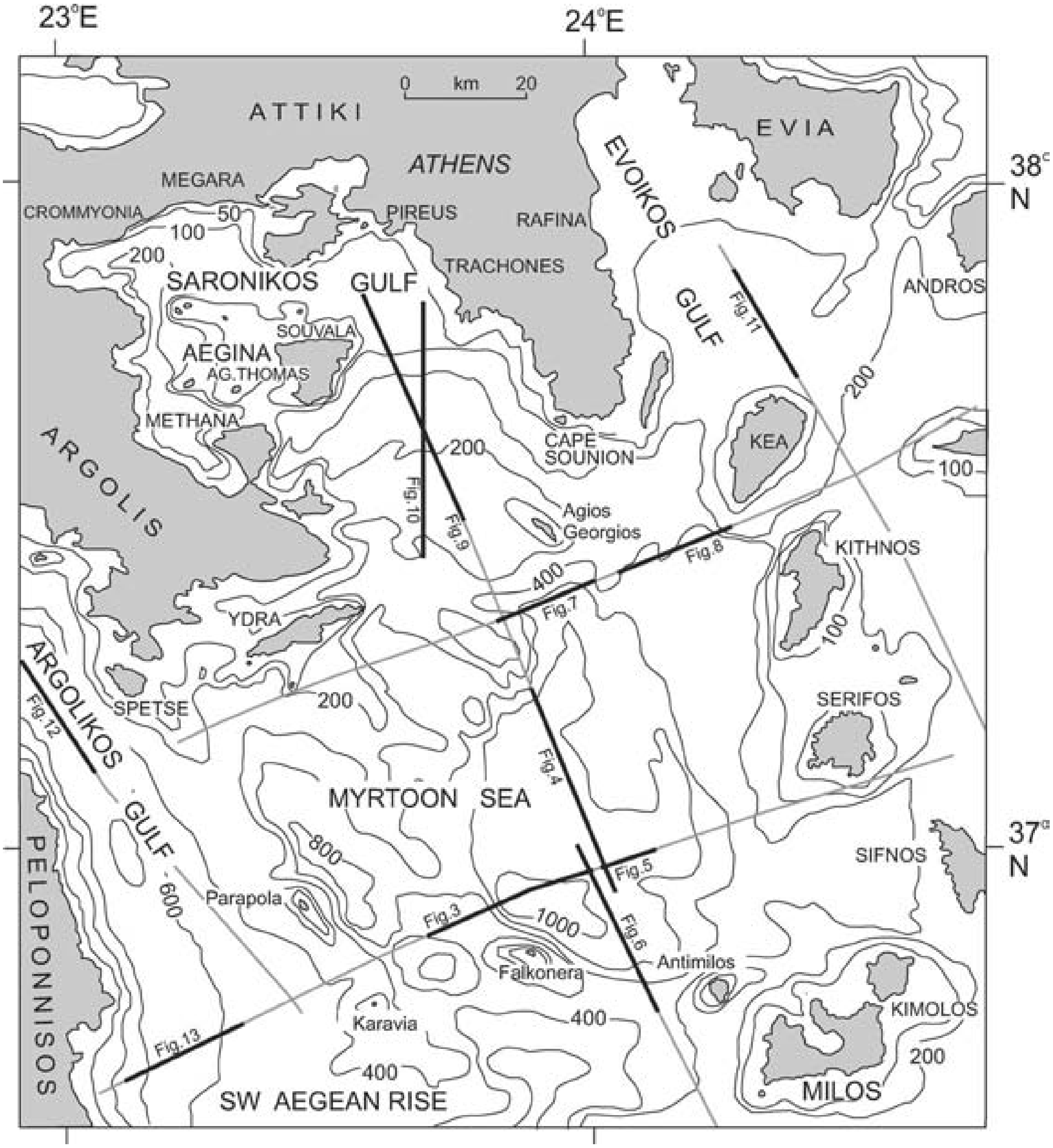


Fig. 2. Bathymetric map of the Myrtoon basin and adjacent areas, showing location of illustrated seismic-reflection profiles.

thick succession of sediments capped by an andesite breccia. The section starts with poorly exposed continental sediments that are overlain by fresh-water to brackish brown sands and silts with some limestone interbeds rich in ostracods and Planorbidae (Benda et al., 1979). The lower 40 m of the marine section consists of shallow water sands and silty clays, passing upwards into marls with silty argillaceous marls with thinly laminated gypsiferous claystone (Stamatakis and Magganas, 1988) that are overlain by 30 m of yellowish to white marls that include diatomite intervals, interpreted as representing subsidence of many hundred metres in the Early Pliocene by van Hinsbergen et al. (2004). The marls are overlain by andesite with a radiometric age of 3.87 Ma (Benda et al., 1979). The lower part of the section was placed by Caillère and Tsoli (1972) at the transition from the Miocene to the Pliocene. After the end of the volcanic period the northern part of the island was briefly submerged as indicated by a few meters thick sandy-marly white limestone.

Along the east coast of the Peloponnisos (Fig. 1), upper Cenozoic sediments are present in the Argive Plain, at the head of Argolikos Gulf (Fig. 2) and subsidence was interpreted by Schröder (1986) to be at least as old as Pliocene. Pliocene sediments fringe the plain and underlie >200 m of terrestrial Quaternary sediments. On the southern Argolis peninsula and on Spetses island, the lightly folded Pliocene is littoral and marine in origin and dips towards to Argolikos Gulf (van Andel et al., 1993).

3. Methods

This study is based on a series of multichannel seismic lines shot for Chevron in 1972 and kindly made available to us by the Greek National Petroleum Company (DEP). Mascle and Martin (1990) have reported on the same survey covering the entire Aegean Sea and the actual profiles were presented by Martin (1987). Illustrated time sections have a vertical exaggeration of approximately ×3 for the basin fill. We have also used selected parts of single-channel airgun seismic-reflection profiles shot from the R/V *Meteor* in 1974 and reported as line drawings by Jongsma et al. (1977). Illustrated Meteor lines have a vertical exaggeration of approximately ×6 for the basin fill. A series of 10 cu in airgun profiles were collected in 1986 and 1987 by the National Center for Marine Research from R/V *Aigaio* in the Myrtoon Sea and a network of high-resolution 100–200 J sparker records were collected in 2001 and 2002 by University of Athens in Saronikos Gulf. All these single-channel profiles provide information principally on the Quaternary part of the basin fill.

4. General Neogene stratigraphy from multichannel seismic profiles

4.1. Introduction

The overall Neogene stratigraphy in the Myrtoon basin and the basins to the north: the southern Evoikos Gulf, Saronikos Gulf and Argolikos Gulf, can be interpreted from the sparse multichannel seismic lines (Fig. 2), with single-channel data providing more information on the upper part of the sedimentary column. Regional reflectors have been picked based on previous work and the new profiles and are summarized in Table 1. Regional reflectors 1–5 are defined in this study from multichannel seismic profiles from central Myrtoon basin (Figs. 3–5). Shallower reflectors B–D were defined in the same area from a single-channel profile in the same area by Anastasakis and Piper (2005) and have been transferred to the multichannel seismic profiles. Anastasakis and Piper (2005) demonstrated that reflector C corresponds approximately to the uppermost part of the Pliocene.

Table 1
Summary of seismo-stratigraphic nomenclature

Marker	Stratigraphic pick (from Anastasakis and Piper, 2005)	Approximate correlatives in other basins	
MYRTOON BASIN		S. EVOIKOS	ARGOLIKOS
A	MIS 12		
B	Middle Pleistocene		
			UG1
C	Latest Pliocene	C	
D	Late Pliocene	X	
1	Early Pliocene		
2	Early Pliocene	Y	
3	Early Pliocene		
4	Early Pliocene		
5	Early Pliocene		
M	Top Messinian, may be younger on basin margins	M	M

The top Messinian surface (M) in the Mytoon basin has the characteristic high-amplitude seismic signature of evaporites and associated carbonates known from many Mediterranean basins (Biju-Duval and Montadert, 1977) and previously described by Schröder (1986); Mascle and Martin (1990). It passes laterally into a major erosional surface (e.g. Fig. 5), presumably largely of Messinian age, corresponding to the lowstand of sea level. Where it is onlapped by much younger strata, erosion may have continued later than Messinian.

4.2. Seismic stratigraphy of Myrtoon basin

The stratigraphy of the Myrtoon basin is illustrated in multichannel seismic profiles in Figs. 3–7. Regional reflections B–D and 1–5 overlie the Messinian surface M. In the central part of the basin, evenly stratified sediment 1.2 s thick overlies a more irregular sediment packet 0.4–0.8 s thick, capped by regional reflection 2 (Fig. 3). The Messinian erosion surface in the centre of the basin is at about 3 s below sea level. The margins of the basin appear faulted.

The top-Messinian surface (M) is a high amplitude, rather irregular, reflection, with a general lack of underlying coherent reflections. Locally, deeper discontinuous reflections are visible (Fig. 4b). Relief on the surface on the basin floor is less than 0.3 s, some of which may be the result of syn-sedimentary faulting (Fig. 5).

The first overlying acoustic facies, below reflection 5, occurs as wedge-shaped bodies returning short irregular reflections found only near the basin margin (Figs. 4 and 5). Between reflections 5 and 4 is a packet of high amplitude reflections that is up to 0.25 s thick at the basin margin that onlaps the Messinian surface and is thin in the basin centre. The oblique reflections have an original sedimentary dip and in places downlap onto the Messinian surface. Reflection 4 onlaps the basin margin at 1 s above its level in the basin floor (Fig. 4a). The packet between reflections 4 and 3 is 0.2 s thick and is the first packet to extend right across the basin, pinching out towards the basin margin (Fig. 4a). Downlapping reflections are common in this packet. The packet from reflection 3 to 2 also pinches out at the basin margin. Its reflection character is similar to the underlying packet, except that many reflections are more continuous and of lower amplitude.

Reflection 2 marks a period of scour at the basin margin (Figs. 4a and 5). Younger sediment is generally draped over this surface and is probably principally hemipelagic. Basin margin scour continued to be prominent to reflection 1. Above reflector C, there is considerable onlap at basin margins (Figs. 4a and 5).

At the basin margin, off Serifos (Fig. 5) and off Falconera ridge (Figs. 2 and 6), packets of obliquely dipping reflections truncated by sub-horizontal erosion surfaces appear to represent deltaic deposits. Seismic correlation from the basin is hampered by active faulting, but off Serifos the main delta phase predates reflection 1 and the youngest deltaic deposits are draped by reflection D. Strata below reflection 1 on line 4 (of which only the eastern end is illustrated in Fig. 5) thin from

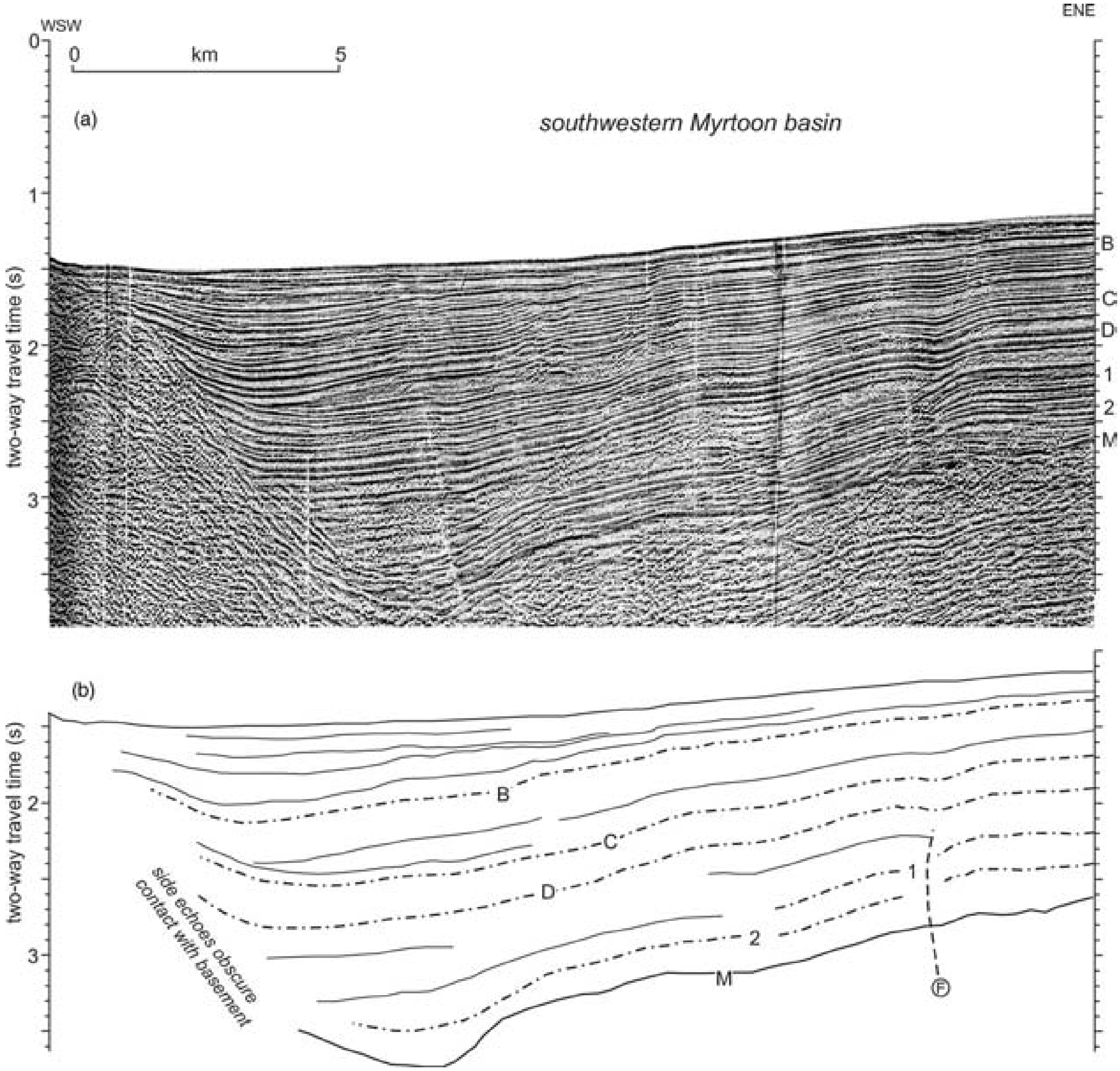


Fig. 3. Multichannel seismic line 4 from the southwestern margin of Myrtoon basin showing seismo-stratigraphic markers (M, 2–1, D–B) summarized in Table 1. (F) = fault.

>0.5 s off Serifos to only 0.2 s at the deepest western part of the basin. In contrast, the intervals from 1 to D and D to C are each 0.5 s thick adjacent to Falconera ridge, thinning to 50% off Serifos. Sediment above C is also twice as thick in the west as in the east.

At the northwestern end of the Myrtoon basin, in multichannel line 3 (Fig. 7), reflectors and facies character is similar to that at the northern end of Fig. 3. The M reflector is visible in the central part of the basin and is overlain by a succession of basin-filling reflections. The uppermost Pliocene reflection C is an erosional unconformity. On the flanks of the basin, an acoustic facies that is either incoherent or has short discontinuous reflections is developed and is onlapped by thin Quaternary basinal strata. No systematic reflection pattern is recognised in this facies, making its interpretation difficult. The strata immediately above the M erosion surface has sub-horizontal reflections and a few dipping reflections that might be clinoforms. It resembles the acoustic facies below reflection 5. In the west, the M erosion surface is overerlain by a transparent acoustic facies (facies uncertain in Fig. 7) that appears to pass westward into stratified sediment over a horst. South of Agios Georgios Island, a wedge of more reflective facies acoustically resembles submarine volcanic rocks described by Anastasakis and Piper (2005) around Milos, and overlies both the facies with sub-horizontal reflections and farther to the east directly overlies the M erosion surface. There is, however, no independent evidence for volcanic rocks here and this facies could represent shallow-water or basin-margin sediment.

In the northeastern part of the Myrtoon basin, just southwest of Kea, the seismic section (Fig. 8) is more complex. Erosion is pronounced at the modern sea floor and appears to have been initiated at a level well above reflector B. Reflectors B and C are confidently correlated with line 14 on the basis of sub-bottom depth and acoustic character, whereas the correlation of

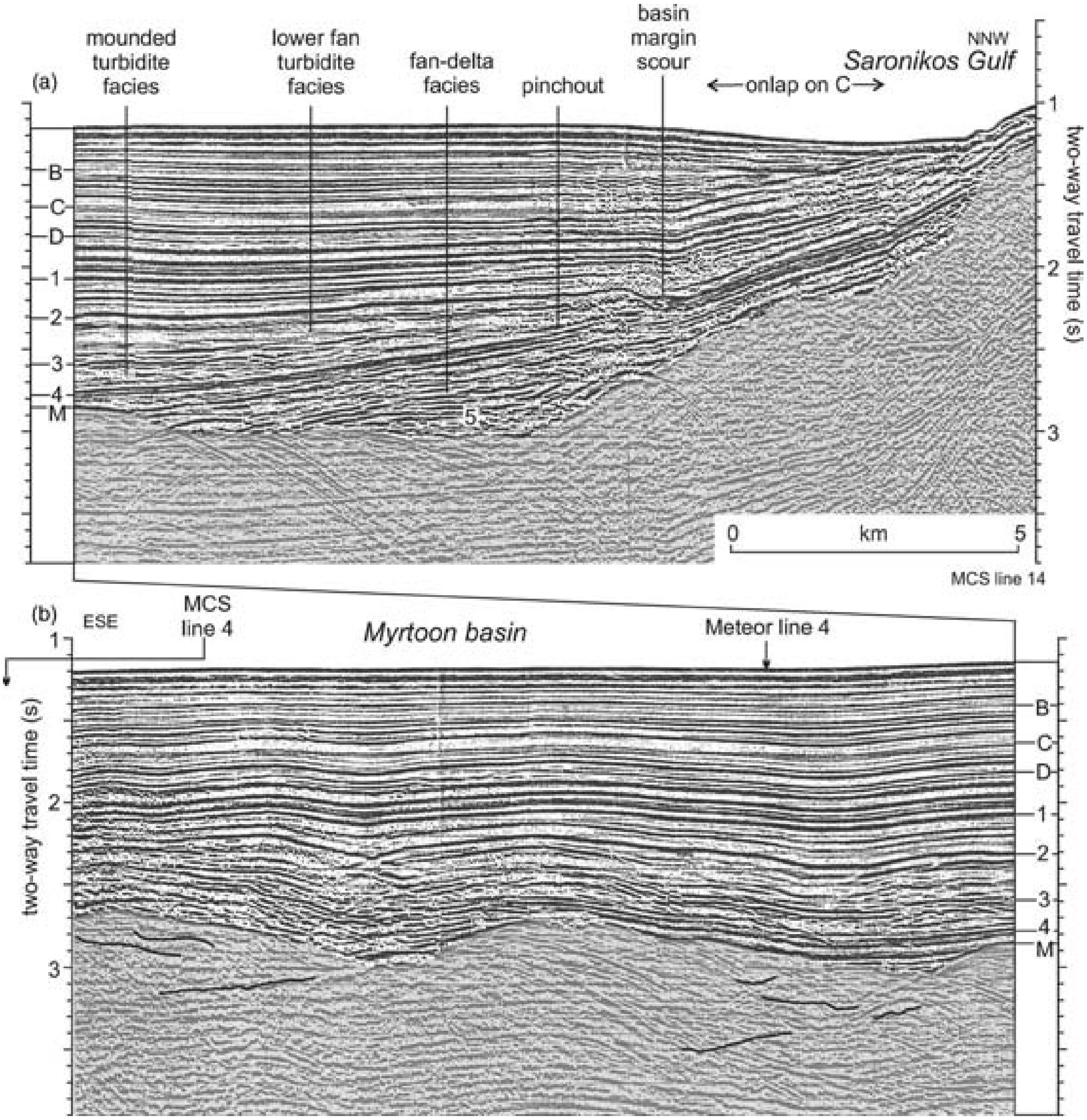


Fig. 4. Multichannel seismic line 14 from central and northern Myrtoon basin, showing stratigraphic and facies interpretation. Seismo-stratigraphic markers are summarized in Table 1.

deeper reflectors D and 1 is only approximate. Reflection 2 is recognised as a major erosional unconformity, corresponding to the basin-margin scour at this horizon recognised in line 14 (Fig. 5). Reflections below 2 are geometrically complex and vary laterally in amplitude. They show a general eastward progradation and the relief implies a basin depth of greater than 550 ms (450 m). A set of high-amplitude reflections resemble a channel-levee system with levee relief of 100 ms (80 m).

4.3. Seismic stratigraphy of Saronikos Gulf

The Saronikos Gulf appears much more faulted than Myrtoon basin and the resulting laterally discontinuous reflection packets are more difficult to interpret. The M erosion surface is tentatively recognised throughout Saronikos Gulf (Fig. 9) and only in the central basin is directly overlain by coherent parallel reflections. In general, it probably overlies alpine basement. Over much of the Gulf, the succession above the M erosion surface is relatively incoherent, but in the south passes up into an interval with sub-horizontal reflections and dipping reflections that appear to be prograded clinoforms (Fig. 9). This seismic facies likely represents prograded coastal units cut by transgressive erosion surfaces. This facies is absent in the central part of the Gulf, where sub-parallel reflections overlie the M surface. It is overlain throughout most of the Gulf by continuous sub-parallel reflections with similar acoustic character to the upper part of the succession in Myrtoon basin and likely representing principally hemipelagic sediment. A significant unconformity (C in Fig. 9) is correlated with a similar unconformity at a similar sub-bottom depth in the northern Myrtoon basin (Fig. 4b) and is confirmed by the higher resolution Meteor line 2 (Fig. 10). At the southern end of Saronikos Gulf, the sill to Myrtoon basin is highly faulted, making it difficult to interpret sediment facies. Nevertheless, the thickness of shallow-water facies appears greater here than in the main part of Saronikos Gulf.

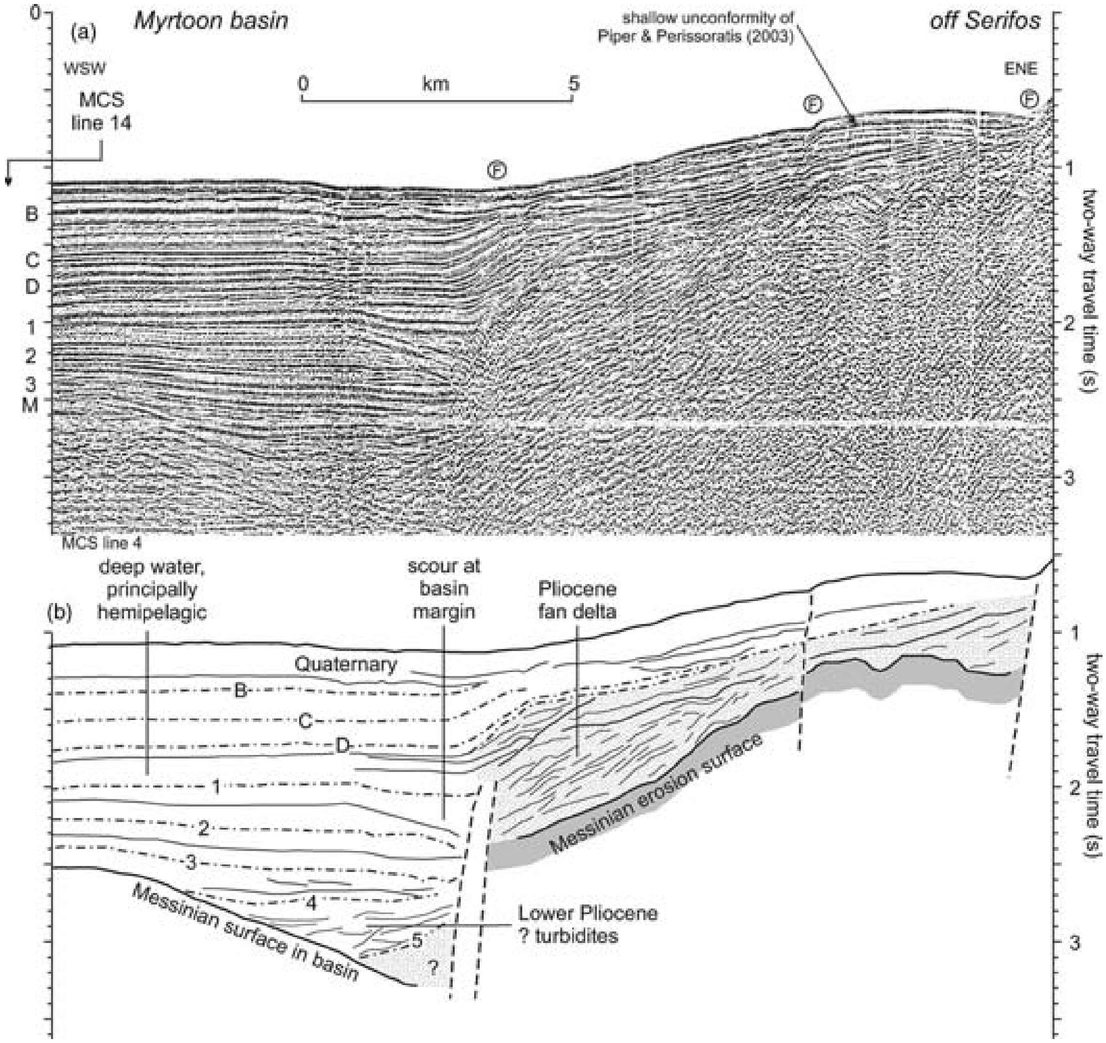


Fig. 5. Multichannel seismic line 4 from the eastern margin of Myrtoon basin showing stratigraphic and facies interpretation. Seismo-stratigraphic markers are summarized in Table 1.

In the northern part of the seismic profile of Fig. 9, a thick incoherent section overlies a tentative M reflection. At the extreme northern 1–2 km of the seismic profile, coherent dipping reflections resemble marine basin fill elsewhere. The incoherent section with numerous multiples lies about 4 km off the NE tip of Aegina, where Pliocene volcanic rocks outcrop. Prograding clinoforms appear absent and this incoherent packet is tentatively interpreted as volcanic flows or proximal volcaniclastic sediment. The nearby higher resolution Meteor profile (Fig. 10) shows a near-surface incoherent packet, which resembles volcanic rocks imaged by the same seismic system near Milos (Anastasakis and Piper, 2005), that pinches out at regional reflection C (transferred from Fig. 9). Part of this facies clearly overlies well-stratified basinal sediment (Fig. 10) and can be recognised as a thickening of reflector spacing in Fig. 9.

4.4. Seismic stratigraphy of south Evoikos Gulf

In south Evoikos Gulf, the M reflector is a high-amplitude reflector of rather low relief that can be traced over the entire basin (Fig. 11). A few reflectors below M are sub-parallel in the centre of the basin. Between reflectors M and Y, flat-lying parallel reflections are present in the centre of the basin. To the SSE, progradational packages are developed with erosional truncations at a few discontinuous flat-lying reflectors interpreted as coastal transgressive surfaces, but the overall character is rather incoherent. At the NNW end of the section, the 400 ms of section between M and Y has few coherent reflections, but passes southwards into more continuous inclined reflections with a progradational architecture, that thin towards the centre of the basin, where they interfinger with flat-lying, high amplitude reflections. Reflector Y marks a significant planar unconformity at the top of this incoherent packet and is also a widespread gently dipping planar surface in the southern part of the basin.

The section from Y to X shows somewhat similar features to the M to Y succession. Flat-lying parallel reflections are present in the centre of the basin, which pass both southward and northward into progradational packets with significant and extensive gently inclined reflections interpreted as major

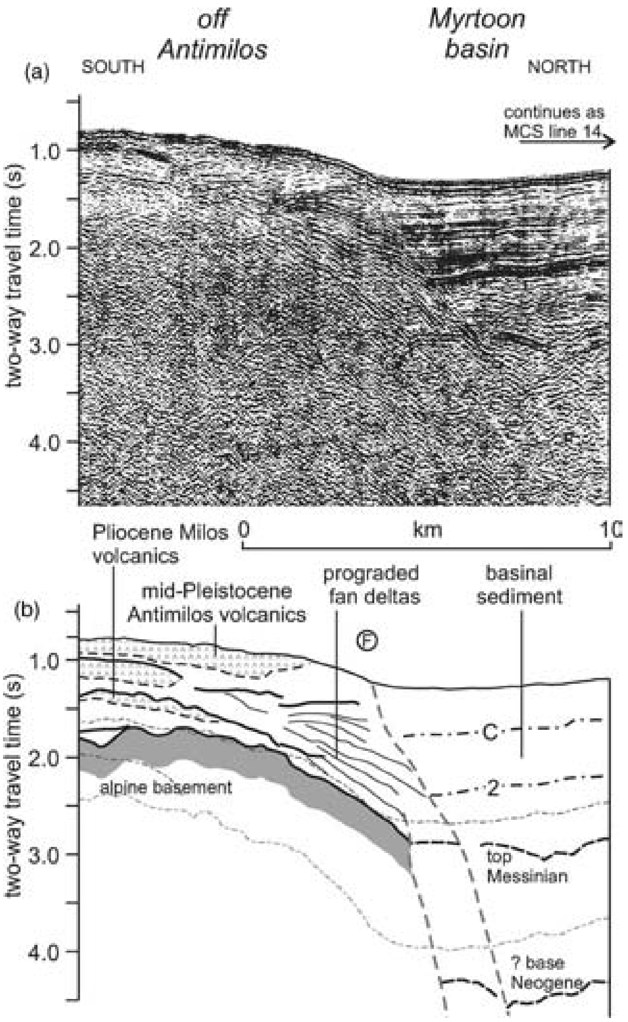


Fig. 6. Multichannel seismic line 33 northwest of Milos, showing stratigraphic and facies interpretation. Seismo-stratigraphic markers are summarized in Table 1.

coastal transgression surfaces. In the north, reflector Y is overlain by a wedge of shingled clinoforms that downlap from both the north and the south.

Reflector X marks a change in acoustic facies in the southern part of south Evoikos Gulf, from progradational packets and transgressive surfaces below, interpreted as shallow marine and coastal facies, to continuous parallel moderate to high amplitude reflections above, interpreted as continuous marine sedimentation below wave base (Fig. 11). Only in the northern part of the section are more irregular discontinuous reflections found, which appear to represent irregular erosional unconformities against which the marine sediments onlap (Fig. 11).

Reflector C is an unconformity at the northern end of the seismic section, shows ponded onlap in the central part of the basin, and is overlain by coastal progradational packets at the southern end of the seismic section. At about 100 ms above C, flat-lying continuous reflections extend to the northern end of the seismic section.

Stratigraphic correlation to the Myrtoon basin is indirect. Single-channel seismic reflection profiles (e.g. Meteor line 4 of Jongsma et al., 1977) south of Cape Sounion at the southernmost tip of Attiki show at least 1 s of stratified sediment, suggesting a sedimentary connection between the Myrtoon basin and the south Evoikos Gulf. In the south Evoikos Gulf, reflector C is recognised as a locally unconformable surface with considerable onlap, a feature similar to C in the northern Myrtoon basin (Fig. 7). Reflector X is a significant unconformity that marks the base of the section with widespread parallel stratification and therefore represents a significant deepening of the basin. Reflector Y appears to mark the first widespread coastal transgressive surface within the basin. The M-reflection is difficult to distinguish because it does not appear to be strongly erosional, presumably because the basin was bounded by a bedrock sill to the south during Messinian lowstand of sea level.

4.5. Seismic stratigraphy of Argolikos Gulf

Three seismo-stratigraphic units are recognised in the deep Argolikos basin. The lowermost unit is topped by the Messinian surface M, which in the north displays medium amplitude rather irregular reflections that show some relief (Fig. 12). To the south, some reflections are visible below the M unconformity (Figs. 12 and 13). The unit above the M unconformity is about 1 s thick in the north and west, but pinches out southeastward against the SW Aegean Rise. This unit has irregular discontinuous reflections that in the upper part of the unit show prograded clinoforms capped by planar erosion surfaces. Similarly with south Evoikos Gulf, this unit comprises terrestrial and shallow marine strata. The top of the unit is diachronous from northwest to southeast (Figs. 12 and 13). Some clinoforms are >200 ms high, confirming the evidence in Fig. 13 that there was progradation into a deep marine basin bounded by faults.

The uppermost unit consists of coherent parallel reflections. The unit thickens eastward (Fig. 13), showing progressive onlap onto the SW Aegean Rise in the southeast and onto the shallow marine unit to the west. This unit represents mostly Quaternary deep-water marine sedimentation, although its thickness at the eastern end of Fig. 13 suggests that marine conditions probably prevailed there since the late Pliocene. An unconformity developed in the north of the basin correlates with the UG1 horizon of Piper and Perissoratis (2003), for which they estimated an age of 0.8 Ma, but it was not correlated southwards to Fig. 13.

The faults in the central and western part of Fig. 13 appear almost orthogonal to the track line, whereas the major fault in the centre of Fig. 12 is subparallel to the seismic profile. The fault(s) bounding the SW Aegean Rise in Fig. 13 also appear to be subparallel to the seismic profile. The SW Aegean Rise appears to have been a positive block throughout the later Neogene, with onlap of both Pliocene (Fig. 12) and Quaternary (Figs. 12 and 13) sediments. Subsidence of the SW Aegean Rise in the Quaternary allowed the accumulation of deep-water marine facies, particularly above the UG1 unconformity. This is consistent with evidence from the Falconera margin of

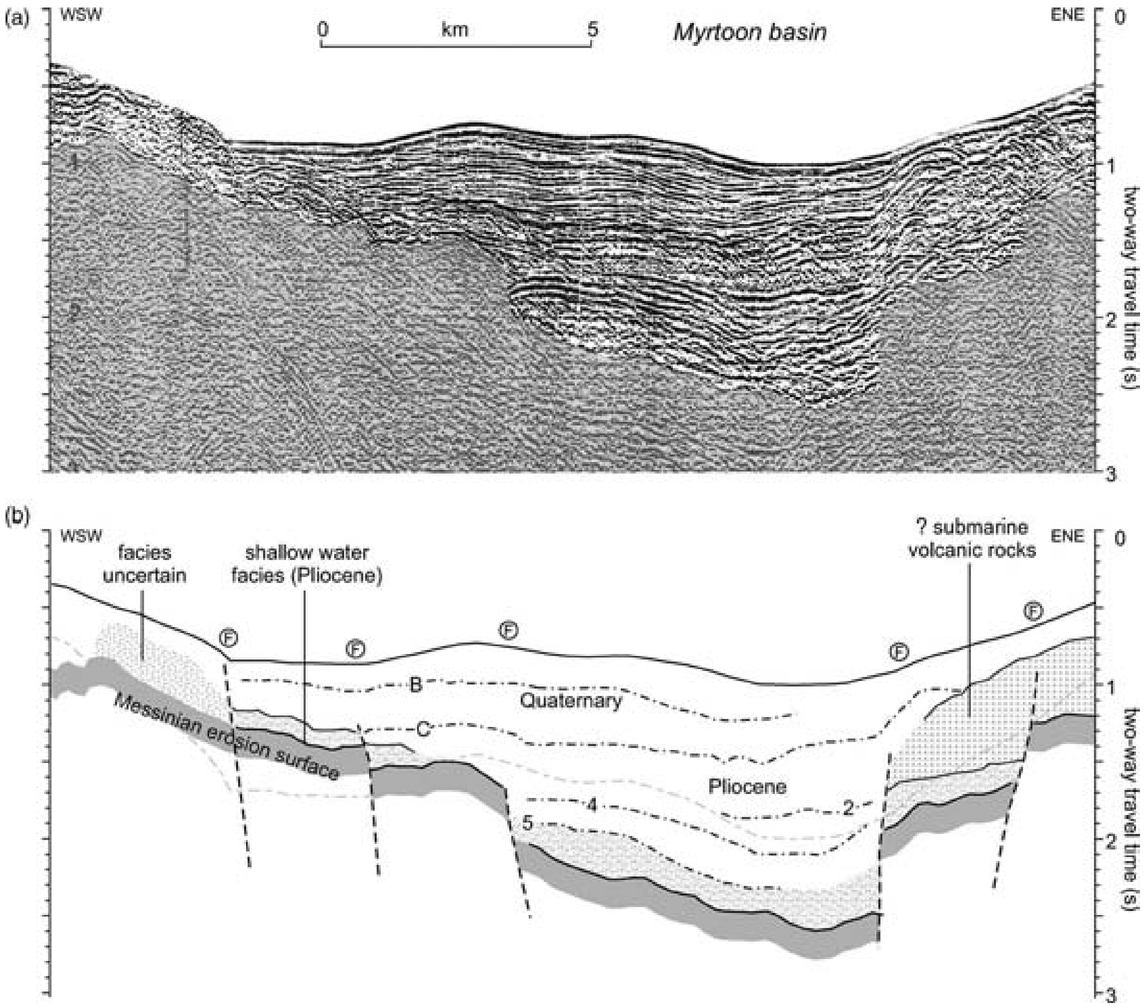


Fig. 7. Parts of multichannel seismic line 3 from the Northwestern margin of Myrtoon basin showing stratigraphic interpretation. Seismo-stratigraphic markers are summarized in Table 1.

Myrtoon basin (Fig. 6) for young faulting and subsidence in the southwest of the study area.

5. Discussion: Neogene evolution of Myrtoon basin and adjacent areas

5.1. An age model for the Miocene—Quaternary seismic stratigraphy

Where the 'Messinian' surface clearly includes halokinetic evaporites, as in the Cretan basin and in the eastern Milos basin (Bartoli et al., 1983), its age is defined as Messinian on the basis of this unique character and immediately overlying relatively acoustically transparent sediment represents Lower Pliocene deep-water hemipelagic sediment (Hsu et al., 1978; Anastasakis and Piper, 2005). In the Myrtoon basin and basins to the north, there is no independent evidence for the age of the basal erosion surface (M in Figs. 4 and 5): it might correspond to the Messinian erosion surface or might be younger. Several lines of evidence suggest that it is Messinian. Marine Messinian strata are known from Trachones in Attiki (Papp et al., 1978) and the Myrtoon basin is the most likely passage for ingress of the sea (Schröder, 1986). If the M surface were a younger surface that progressively subsided, a succession of shallow-water deposits would be expected, as in the Folegandros basin (Anastasakis and Piper, 2005). Rather, the packet between reflections 5–4 closely resembles marine fan-delta deposits in the Mesohellenic basin illustrated by Zelilidis et al. (2002) and the onlap of reflection 4 (Fig. 4a) implies a basin depth of at least 700 m by the end of deposition of the packet. The overlying packets, to reflector 2, have the classic characteristics of turbidite lobes, as discussed below. Evidence of a rapid transition to deep-water marine conditions above an erosion surface is characteristic of the Messinian surface elsewhere in the Mediterranean basin (Savoye and Piper, 1991). In both Saronikos and Evoikos gulfs, in the lower Pliocene the central basin shows parallel stratification, interpreted respectively as marine and lacustrine conditions, passing laterally into progradational units. The margin of these progradational units is relatively persistent through time, suggesting that subsidence kept pace with sedimentation. This is in strong contrast to the deep-water turbidite sedimentation in Myrtoon basin. It suggests that Saronikos and Evoikos gulfs formed shallow basins 'ponded' behind

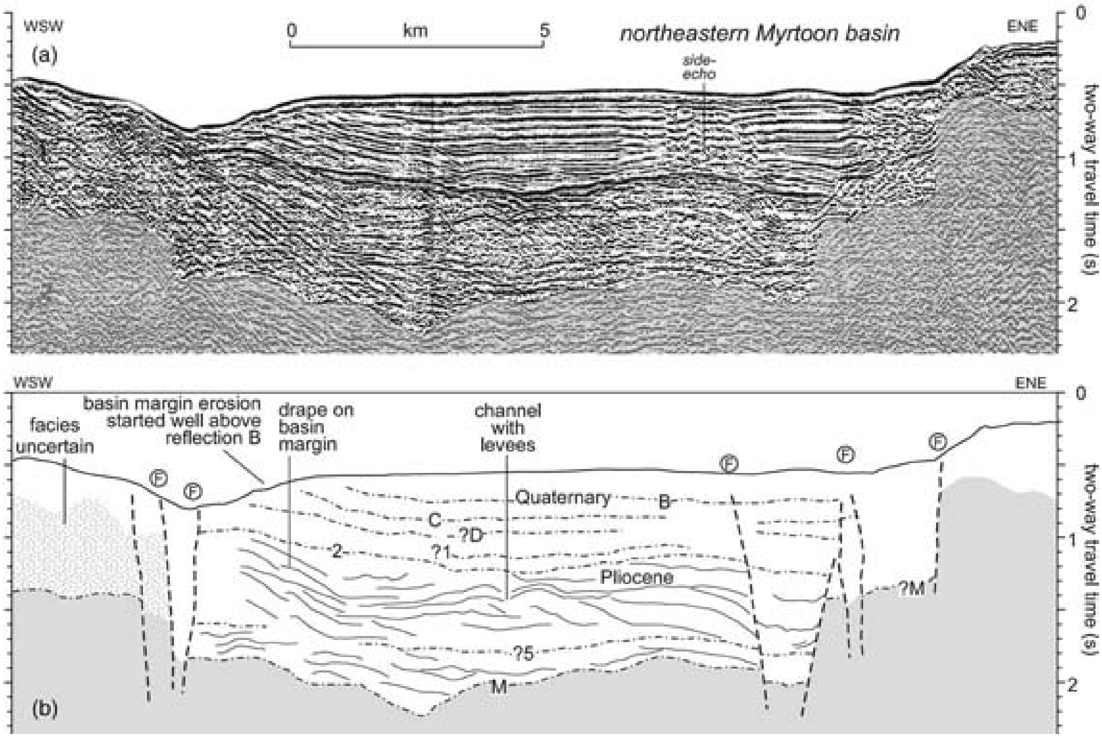


Fig. 8. Part of multichannel seismic line 3 from the Northeastern margin of Myrtoon basin, showing stratigraphic interpretation. Seismo-stratigraphic markers are summarized in Table 1.

bedrock sills in the Messinian so that there was no strong fluvial erosion on the basin margins at times of Messinian lowered sea level.

In Saronikos Gulf, the C reflector corresponds to the shallowest interpreted volcanic horizon. This likely correlates with the late Pliocene to early Pleistocene Oros eruptions, dated at 2.1 Ma by Pe-Piper et al. (1983) but reported as 1.6 Ma by Dietrich et al. (1988) and further constrained to the Matuyama polarity epoch (0.8–2.3 Ma) by Morris (2000). This confirms the interpretation of Anastasakis and Piper (2005) that the C reflection corresponds approximately to the base of the Quaternary. At the northern end of Fig. 9, the main mid-

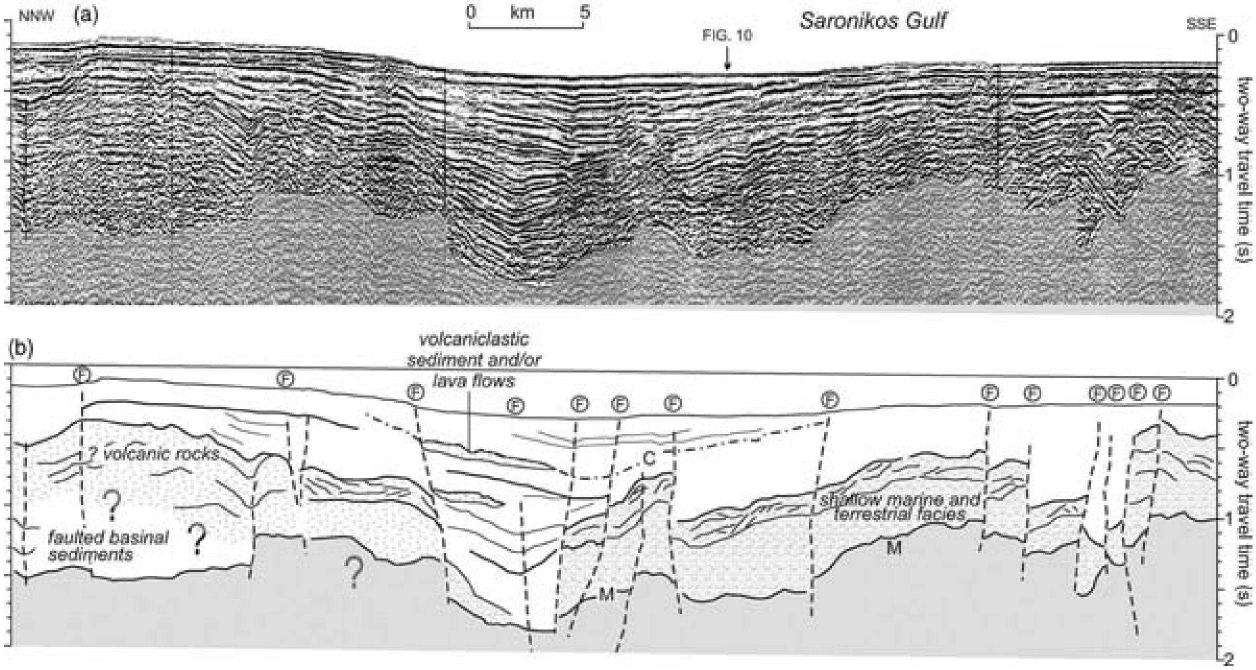


Fig. 9. Multichannel seismic line 14 from Saronikos Gulf showing stratigraphic and facies interpretation. Seismo-stratigraphic markers are summarized in Table 1.

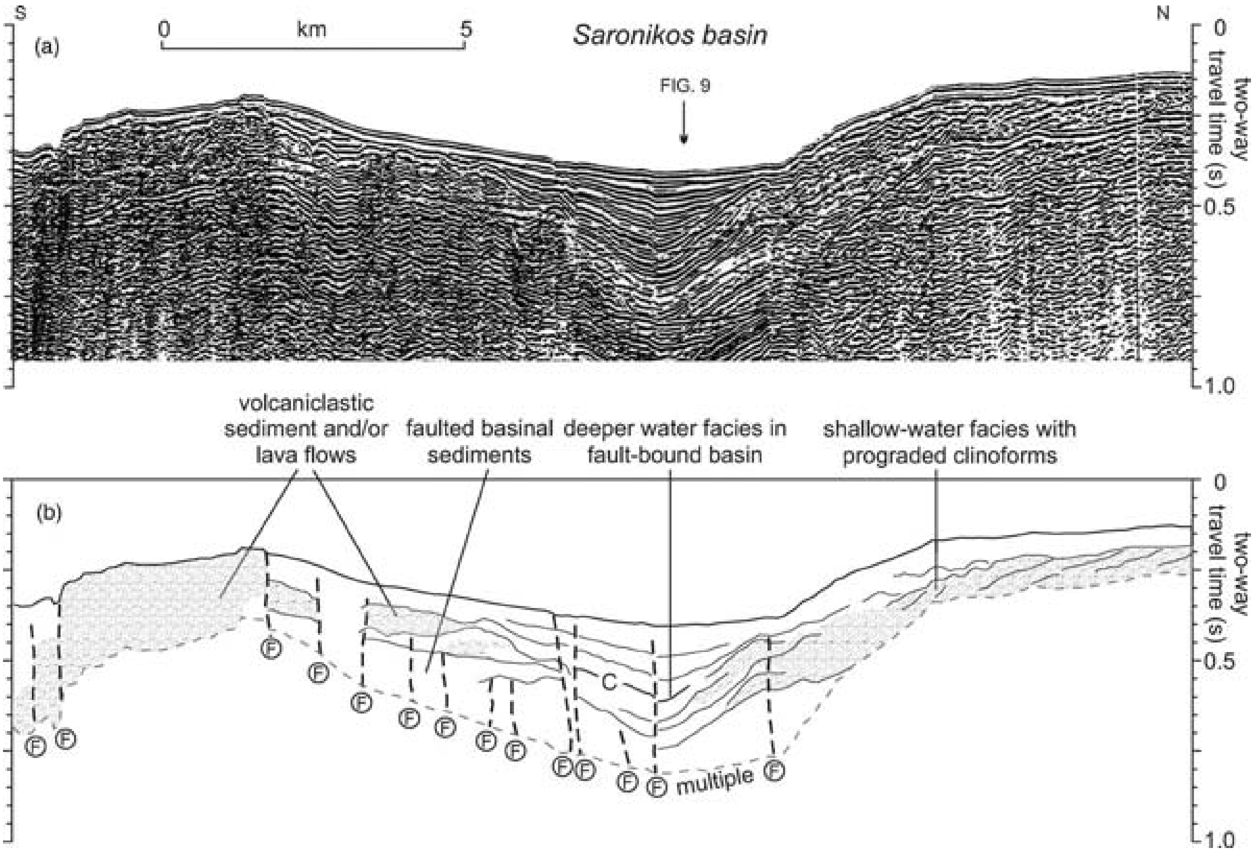


Fig. 10. Meteor air-gun seismic reflection profile of Saronikos Gulf showing higher resolution interpretation of the Quaternary and upper Pliocene section. Seismo-stratigraphic markers are summarized in Table 1.

Pliocene volcanic succession of Aegina is interpreted to overlie early Pliocene basinal sediments.

In south Evoikos Gulf, reflector Y is the first widespread coastal transgression surface and as argued in more detail below, it therefore probably corresponds to the base of the marine Pliocene section seen along the eastern coastline of Attiki that is dated from the lower part of the middle Pliocene (Markopoulou-Diakantoni et al., 1998).

In Argolikos Gulf, the UG1 unconformity was dated by extrapolation from sedimentation rates and sea-level variations at about 0.8 Ma by Piper and Perissoratis (2003). South of Milos, Anastasakis and Piper (2005) demonstrated that reflection B dated from approximately 1 Ma and reflection A from approximately 0.5 Ma, on the basis of correlation with volcanic rocks and sea level variations. Otherwise, the age of reflections must be interpreted by interpolation between dated reflections (Fig. 14).

5.2. Basin formation and sedimentation

5.2.1. Myrtoon basin

In the Myrtoon basin, as argued above, the basal erosion surface (M in Figs. 4 and 5) likely dates from the Messinian lowstand of sea level, followed by a rapid transition to deep-water conditions in the Early Pliocene. The seismic packet between reflections 5 and 4 represents marine fan-delta deposits in a basin depth at least 700 m deep. The overlying packets, to reflector 2, have the typical characteristics of turbidite lobes and thin rapidly at the basin margin (Fig. 4). The interval from 4 to 3 has high-amplitude reflections and clear bi-directional downlap of mounded features 1–2 km wide (Fig. 3b). These resemble small sandy deep-sea fans described from the North Sea by McGovney and Radovich (1985). Similar features, but with lower amplitude reflections, are seen in the 3–2 interval (e.g. right hand end of Fig. 4b). The northeastern margin of the basin preserves a more proximal facies, showing complex progradational architecture and near the level of reflection 3 a channel-levee system with 80 m of relief. Analogous architecture is illustrated from small submarine fans of the California continental borderland by Normark et al. (1998). There is an abrupt change to generally draped sediment architecture at reflection 2.

The source of the main turbidite fill of Myrtoon basin appears to be from the northeast, as indicated by the thickening in this direction (Figs. 4a and 8). A source from Saronikos Gulf would be unlikely, given the evidence from the Souvala and Agios Thomas sections from deep-water hemipelagic sediments in the early Pliocene. Rather, we infer a river draining from the northern Cyclades and the south Evoikos Gulf as the source of turbidite sediment (Fig. 15b), consistent with the interpretation of Evoikos Gulf discussed below.

From reflection 2 to C, the strata are draped over the northern margin of the basin, before the reappearance of onlap and basin-margin scour from C to the seabed. The interval from

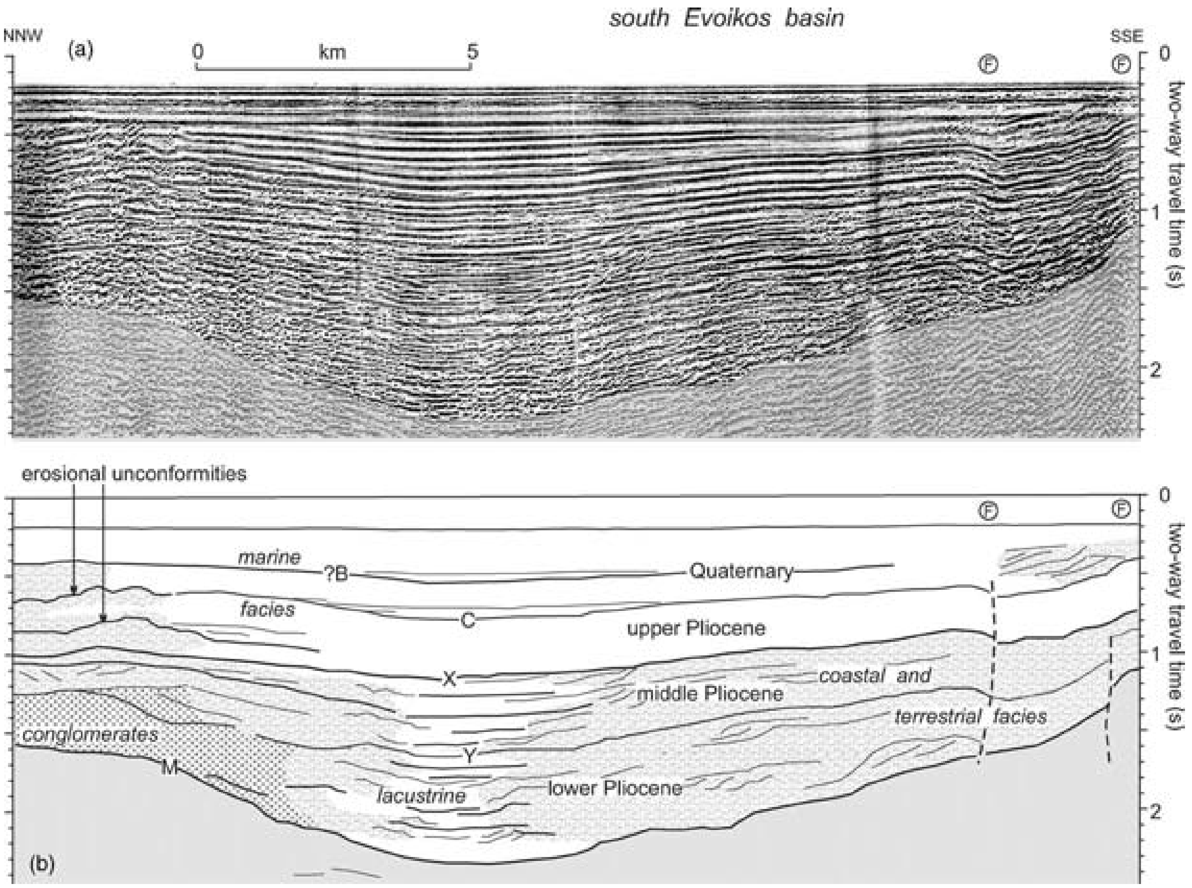


Fig. 11. Multichannel seismic reflection profile 13 from the south Evoikos Gulf showing stratigraphic and facies interpretation. Seismo-stratigraphic markers are summarized in Table 1.

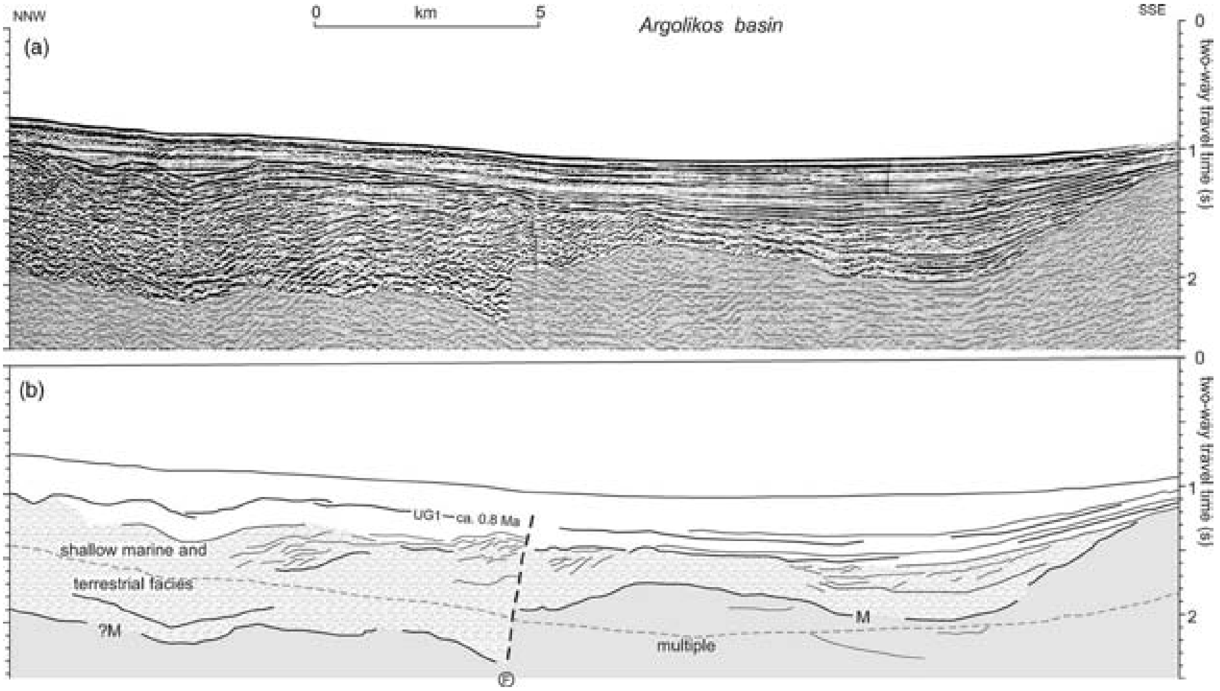


Fig. 12. Multichannel seismic reflection profile 15 from Argolikos Gulf showing stratigraphic and facies interpretation. Seismo-stratigraphic markers are summarized in Table 1.

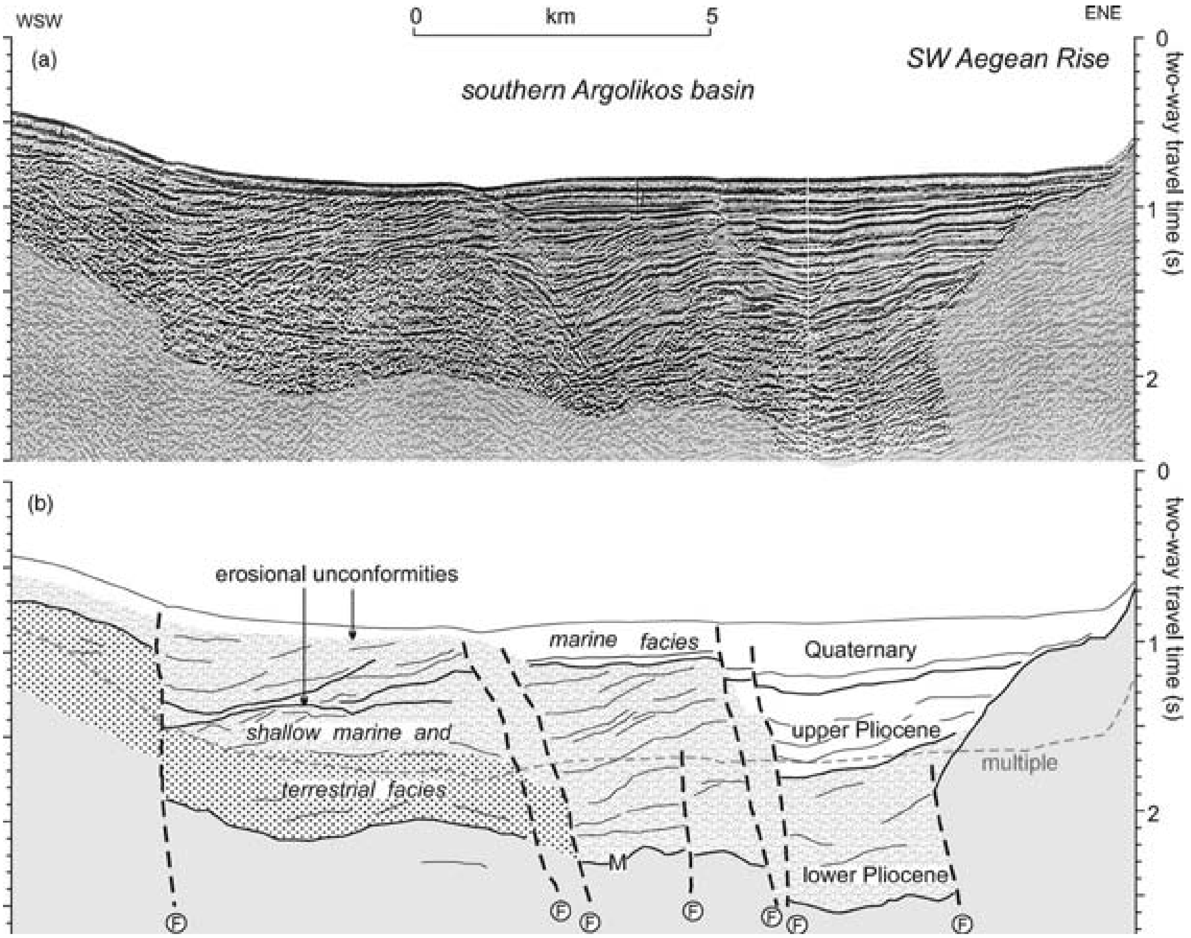


Fig. 13. Multichannel seismic reflection profile 4 from off the Peloponnisos coast to the SW Aegean Rise, showing stratigraphic and facies interpretation. Seismo-stratigraphic markers are summarized in Table 1.

reflection 2 to at least D corresponds to a time of fan-delta progradation off Serifos, with sediment thickening in the southwestern part of the margin near the Falconera ridge. This may have been a time of substantial fine-grained sediment supply to the Myrtoon basin, both from rivers draining the emergent areas of the Falconera ridge and the Cyclades and from erosion of volcanic rocks in Milos. In contrast, in the interval above C, there is no evidence for significant fan-delta supply of sediment to the basin and sedimentation may be more hemipelagic. With a lower sedimentation rate, basin-margin scour would be more effective.

5.2.2. Saronikos Gulf

In central Saronikos Gulf (Fig. 8), the basement surface with Messinian terrestrial erosion is onlapped by 0.5 ms of well-stratified apparently Pliocene deep-water sediment. Early Pliocene deep-water sediment is known on land where it is overlain by mid-Pliocene submarine, and later subaerial, volcanic rocks. Volcanic lava flows or proximal volcaniclastic sediment locally interfingers with basinal sediment. The deep-water link between Myrtoon and Saronikos basins appears to have been between Agios Georgios island and the coast of Attiki (Fig. 15c). Shallow marine and terrestrial facies were deposited between Agios Georgios and the Argolis peninsula in the Pliocene, but were eventually transgressed at about the base of the Quaternary (reflection C).

Prior to the mid Pleistocene (ca. 0.7 Ma), the Gulfs of Patras and Corinth (Fig. 1) opened eastward into Saronikos Gulf (Piper et al., 1991). When the channels through the Ionian islands began to develop, resulting tidal flows from the Ionian to the Aegean seas may have produced the widespread near-surface erosion in Saronikos Gulf (Figs. 9 and 10) and the northern Myrtoon basin (Fig. 8), where it is dated to be substantially younger than reflection B (1 Ma). The link to the Ionian Sea was closed at Isthmos, between Saronikos Gulf and the Gulf of Corinth, at lowstands of sea level and was finally closed tectonically after MIS 5 (0.12 Ma) (Piper et al., 1991).

5.2.3. Evoikos Gulf

In south Evoikos Gulf, correlation can be made with the geological sections in eastern Attiki. Reflector X marks a significant change in style of sedimentation in the Gulf, with a significant deepening of the southern part of the basin. Reflector Y is the first widespread coastal transgression surface and it therefore probably corresponds to the base of the marine Pliocene section seen along the eastern coastline of Attiki and dated from the lower part of the middle Pliocene (Markopoulou-Diakantoni et al., 1998). Reflector Y is thus approximately

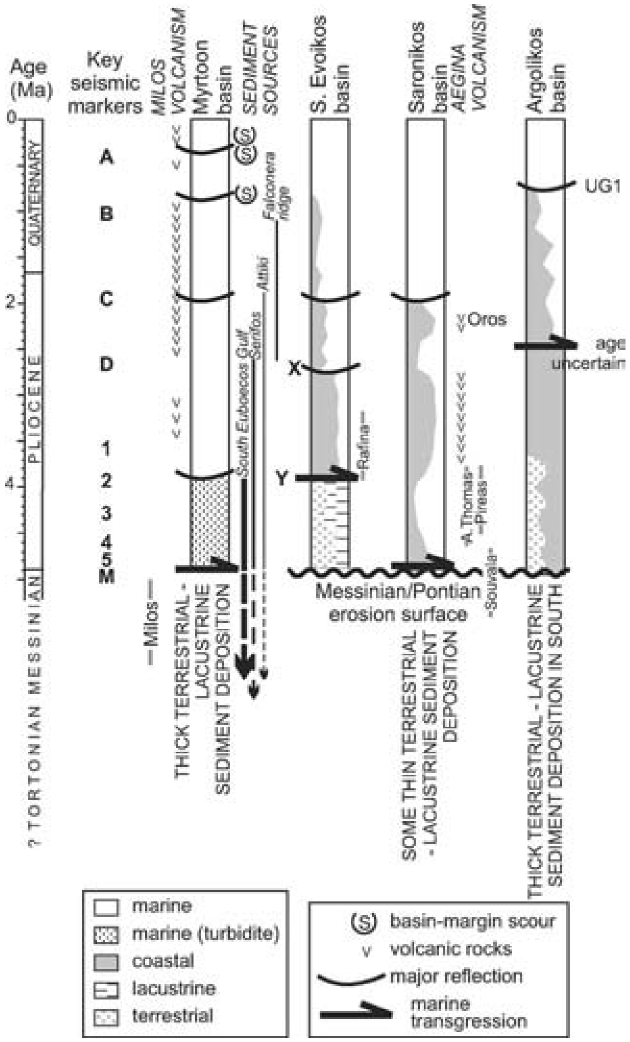


Fig. 14. Late Cenozoic chronology of Myrtoon basin and adjacent areas.

equivalent to reflector 2 in the Myrtoon basin. The strongly incoherent packet between the Y and M reflectors at the northern end of Fig. 11 is interpreted to correspond to the Rafina conglomerates in eastern Attiki. The section from M at least to Y is probably lacustrine in origin: the persistence of a central basin with flat-lying reflections despite the lack of bounding faults suggests a fluctuating lake level bounded by a bedrock sill to the south, as also inferred for the Messinian lowstand of sea level. Where prograded clinoforms are visible between M and Y, the capping coastal transgressive surfaces are not basin-wide. This interpretation is also consistent with the evidence for a fluvial supply to turbidites at the North-eastern margin of Myrtoon basin discussed above.

Above Y (reflection 2), the central basin shows a progressive expansion in size up to the major deepening at reflection X and coastal transgressive surfaces extend across the entire basin, suggesting that since reflection Y, the seaway past Cape Sounion would have been open. The seaway between Kea and Evia appears to have opened considerably later, on the basis of multichannel seismic line 13. In the southern Evoikos Gulf, reflector C is recognised as a locally unconformable surface with considerable onlap, a feature similar to C in the northern Myrtoon basin.

5.2.4. Argolikos Gulf

Around the northern Argolikos Gulf, shallow marine and littoral Pliocene sediments are present and the Pliocene section above the Messinian reflector in present marine areas consist principally of shallow marine and coastal facies. In the west, some terrestrial sediments are probably present. Subsidence to form a deep marine basin began in the southeast at some time in the mid to late Pliocene, perhaps synchronous with the tilting of the Falconera Ridge to shed sediment to Myrtoon basin after reflection D (Figs. 14 and 15).

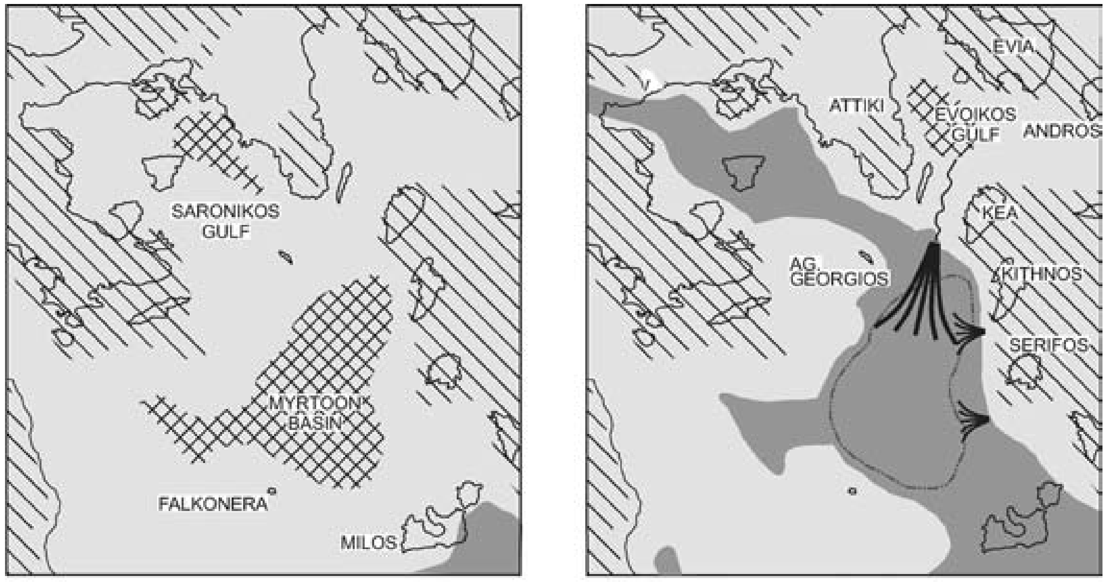
5.3. Changing tectonics

The density of seismic-reflection profiles is insufficient to develop a comprehensive tectonic model for the region under study in the late Neogene. The Myrtoon basin and probably parts of the Saronikos Gulf were deep fault-bound basins by the Messinian, whereas fault-controlled subsidence affected the Cyclades (Hjeil et al., 2000), south Evoikos Gulf, Argolikos Gulf and the SW Aegean Rise principally in the Pliocene and Quaternary (cf. Papanikolaou et al., 1988; Perissoratis and van Andel, 1991). There is some evidence for a regional change in tectonic style in the late Pliocene. The NW-trending margin of the Myrtoon basin north of Falconera ridge was actively faulted in the Quaternary, but basin margin sedimentological effects are not recognised below reflector C (Figs. 3 and 6) and there is little thickness change at this margin in the Pliocene (Fig. 6). In contrast, active faulting on the margin off Serifos (Fig. 5) ended in the late Pliocene. At about the same time, deep-water conditions became established in Saronikos and south Evoikos gulfs.

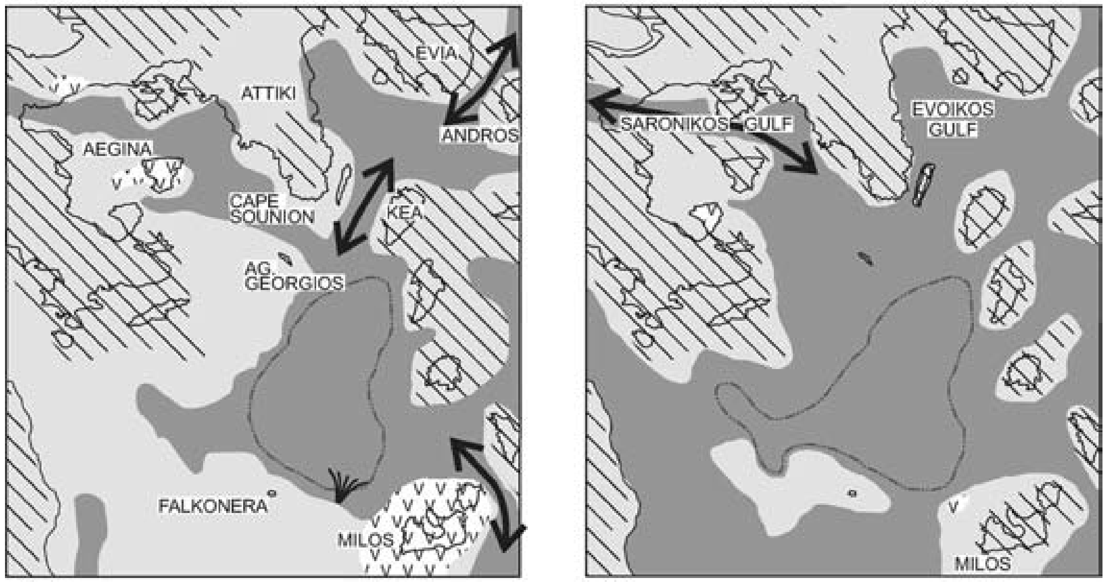
5.4. Paleogeographic synthesis

Beneath the M surface in the Myrtoon basin, there is more than 1 s of sediment over basement (Figs. 4 and 6) that is presumably of Miocene age, and likely terrestrial or lacustrine. In the Messinian, there is no evidence of significant halokinetics in Myrtoon basin and the Falconera—Ananes—Milos ridge appears to have been present in the late Miocene. It is therefore likely that Messinian sea-level lowering isolated the Myrtoon basin from the eastern Mediterranean Sea and that it formed an enclosed evaporitic lake basin, which probably extended northwestward into parts of the Saronikos Gulf (Fig. 15a).

In the earliest Pliocene (Fig. 15b), marine transgression took place in the Myrtoon basin, submerging the basin to at least 700 m water depth. Marine transgression also took place in Saronikos Gulf, based on the biostratigraphic evidence on land. In the Myrtoon basin, submarine fan deposition took place, with sediment supplied from the NE part of the basin from early Pliocene up to reflector 2 (Fig. 15b). This implies river supply through south Evoikos Gulf, which was a terrestrial-lacustrine basin not transgressed until the mid Early Pliocene (reflector 2). At the same time, fan deltas supplied sediment to



(a) **MESSINIAN** (b) **EARLY PLIOCENE** 3 to 2



(c) **LATE PLIOCENE** 1 to C (d) **MID QUATERNARY** B to A

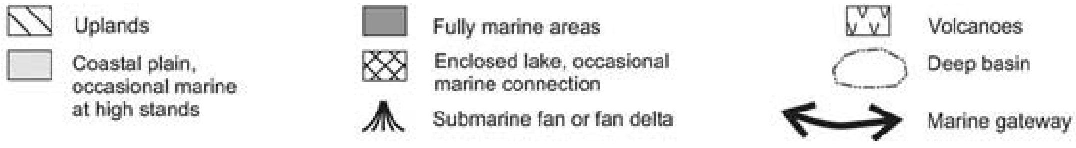


Fig. 15. Paleogeographic reconstructions for (a) Messinian; (b) Early Pliocene; (c) Late Pliocene; (d) mid Quaternary.

Myrtoon basin from Serifos (Fig. 5) and likely other parts of the eastern margin of the basin (Fig. 15b). Terrestrial and later coastal and shallow marine sediments accumulated in Argolikos Gulf in the Early Pliocene.

Middle Early Pliocene marine transgression in south Evoikos Gulf terminated the sediment supply to the submarine fan at the northern end of Myrtoon basin (Fig. 15b). At this time, at about reflector 2, there was some seabed erosion near constrictions (Figs. 4, 5, 8). This might indicate that by this time the Evia—Andros strait was open, so that opening of the Kea—Attiki strait to marine waters substantially altered tidally-driven flows in the western Aegean Sea (Fig. 15c). At about the same time, volcanism began in Aegina and Milos, the latter constricting the marine passageway between Myrtoon basin and the Cretan Sea.

In the Late Pliocene, sediment supply from Serifos (Fig. 5) terminated likely at reflector D or at the latest at reflector C, indicating progressive subsidence of the Cyclades and consequent diminution in its importance as a sediment source. At the same time, sediment supply from Falconera ridge is evident only above reflector D (Fig. 3) and may mark the onset of faulting at that basin margin at that time (Fig. 15c). The first development of deep-water sedimentation in the southern Argolikos Gulf dates from about this time, as does the subsidence of the SW Aegean Rise.

In the early Quaternary, in northern Myrtoon basin, there is onlap above reflector C at the basin margin (Fig. 4). This corresponds to the termination of volcanic activity on Aegina and wider development of deep-water facies in Saronikos Gulf (Fig. 9) and south Evoikos Gulf (Fig. 15d). It probably indicates the end of major sediment supply from the north to Myrtoon basin. There is younger scour at horizon B (Figs. 3 and 6) and at or near the modern seafloor (Fig. 7). The latter may have been facilitated by the opening of the Gulf of Corinth to the Ionian Sea between MIS 8 and MIS 11 (Piper et al., 1991), or by further subsidence of the Evia—Kea sill (Fig. 15 d).

6. Conclusions

(1) A dated seismo-stratigraphy is established for the post-Messinian of the Myrtoon basin and adjacent gulfs, based on correlations to transgressions in sections on land and the chronology of volcanic rocks.

(2) Myrtoon basin and Saronikos Gulf were lake basins in the Messinian that were flooded to form deep-water marine basins during the basal Pliocene transgression. A submarine fan developed in the early Pliocene in northern Myrtoon basin and fan deltas built into the basin from the east and southwest. These are potential reservoir rocks for hydrocarbons.

(3) South Evoikos and Argolikos basins were progressively flooded during the Pliocene and early Quaternary. A change in tectonic style in the Late Pliocene led to more rapid subsidence in both gulfs and the establishment of deeper marine conditions. This event initiated the rapid subsidence of the Cyclades and the SW Aegean rise.

(4) Opening of marine ‘gateways’ as a result of subsidence, in the mid Pliocene between the Myrtoon basin and the central Aegean Sea and in the mid Pleistocene between the Gulf of Corinth and the Ionian Sea led to enhanced oceanographic circulation and the formation of regional erosion surfaces at basin margins.

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References

Anastasakis, G., Piper, D.J.W., 2005. Late Neogene evolution of the western South Aegean volcanic arc: sedimentary imprint of volcanicity around Milos. Marine Geology 215, 135–158.

Bachmeyer, F., Symeonidis, N., Zapfe, H., 1982. Die Ausgrabungen in Pikermi-Chomateri bei Athen. Eine Dokumentation. Annalen des Naturhistorischen Museums in Wien 84A, 7–12.

Bartoli, R., Catani, G., Lenardon, G., Vinci, A., 1983. Tectonic and sedimentation of the southern Aegean Sea. Bollettino Oceanologia Teorica ed Applicata 1, 319–340.

Bellas, S., Frydas, D., 1994. Calcareous and siliceous phytoplankton stratigraphy from Neogene deposits of Milos island (Cyclades, Greece). Bulletin of the Geological Society of Greece 30 (2), 363–372.

Benda, L., Jonkers, H.A., Meulenkamp, J.E., Steffens, P., 1979. Marine microfossils, sporomorphs and radiometric data from the Lower Pliocene of Ag. Thomas, Aegina, Greece. Newsletters in Stratigraphy 8, 61–69.

Biju-Duval, B., Montadert, L., 1977. The Messinian event and recent sedimentation. In: Biju-Duval, B., Montadert, L. (Eds.), Structural History of the Mediterranean Basins, pp. 377–380.

Caillère, S., Tsoli, P., 1972. Contribution à l’histoire géologique de l’ile d’Egine. Comptes Rendus des Seances de l’Academie des Sciences, Paris 274, 3515–3518.

Christodoulou, G., 1961. The foraminifera of the marine Neogene of Attiki. Geological Geophysical Research 7, 1–47.

Dietrich, V.J., Mercolli, I., Oberhänsli, R., 1988. Dazite, High-Alumina-Basalte und Andesite als Produkte amphiboldominierter Differentation (Aegina und Methan, Ägäischer Inselbogen). Schweizische Mineralogische und Petrographische Mitteilungen 68, 21–39.

Doutsos, T., Kokkalas, S., 2001. Stress and deformation patterns in the Aegean region. Journal of Stuctural Geology 23, 455–472.

Frydas, D., 1996. Upper Zanclean silicoflagellates from Milos island (Cyclades, Greece). Journal of Nannoplankton Research 18 (2), 61–67.

Fytikas, M., Innocenti, F., Kolios, N., Manetti, P., Mazzuoli, R., 1986. The Plio-Quaternary volcanism of Saronikos area (western part of the active Aegean volcanic arc). Annales géologiques des pays helléniques 33, 23–45.

Hjeil, E., Riedl, H., Soulakelis, N., Van den Haute, P., Weingartner, H., 2000. Young Neogene tectonics and relief development on the Aegean islands of Naxos, Paros and Ios. Mitteilungen der Osterreichischen Geologischen Gesellschaft 93, 105–127.

Hsu, K.J., Montadert, L., Bernouilli, D., Bizon, G., Cita, M., Ericson, A., Fabricius, F., Garrison, R.E., Kidd, R.B., Mellières, F., Müller, C., Wright, R.C., 1978. Site 378, Cretan Basin. Initial Reports of the Deep Sea Drilling Project 42 (1), 321–357.

Jongsma, D., Wissman, G., Hinz, K., Gardé, S., 1977. Seismic studies in the Cretan Sea. Meteor Forschungs-Ergebnisse C 27, 3–30.

Markopoulou-Diakantoni, A., Ntouropi, A., Kosta, I., 1998. The Cirripedia of the Pliocene deposits of Rafina (Attica, Greece). Bulletin of the Geological Society of Greece 32 (2), 73–83.

Martin, L., 1987. Structure et evolution recent de la mer Egée: rapports d’une étude par sismique reflexion. PhD thesis, University Paris 6, 305 + xix p.

Mascle, J., Martin, L., 1990. Shallow structure and recent evolution of the Aegean Sea: a synthesis based on continuous seismic reflection profiles. Marine Geology 94, 271–299.

McGovney, J.E., Radovich, B.J., 1985. Seismic stratigraphy and facies of the Frigg Fan Complex. In: Berg, O.R., Wolverton, D.G. (Eds.), Seismic Stratigraphy 2: An Integrated Approach to Hydrocarbon Exploration. American Association of Petroleum Geologists Memoir vol. 39, pp. 139–156.

Mettos, A., 1992. Geological and paleogeographical investigation of the continental Neogene and Quaternary formations of NE Attiki and SE Beotia. PhD thesis, University of Athens, 259 p. [in Greek].

Meulenkamp, J.E., 1979. The Aegean and the Messinian salinity crisis. Proceedings of the VI Colloquium on the Geology of the Aegean Region, Athens 3, 1253–1263.

Meulenkamp, J.E., 1985. Aspects of the Late Cenozoic evolution of the Aegean region. In: Stanley, D.J., Wezel, F.C. (Eds.), Geological Evolution of the Mediterranean Basin. Springer, New York, pp. 307–321.

Morris, A., 2000. Magnetic fabric and palaeomagnetic analyses of the Plio-Quaternary calc-alkaline series of Aegina Island, South Aegean volcanic arc, Greece. Earth and Planetary Science Letters 176, 91–105.

Normark, W.R., Piper, D.J.W., Hiscott, R.N., 1998. Sea level effects on the depositional architecture of the Hueneme and associated submarine fan systems, Santa Monica Basin, California. Sedimentology 45, 3–70.

Papanikolaou, D., Lykousis, V., Chronis, G., Pavlakis, P., 1988. A comparative study of neotectonic basins across the Hellenic arc: the Messiniakos, Argolikos, Saronikos and Southern Evoikos Gulfs. Basin Research 1, 167–176.

Papp, A., Steininger, F.F., Georgiades-Dikeoulia, E., 1978. Biostratigraphie und Korrelation des Neogens von Trakhones südlich von Athen (Attica, Griechenland). Annales géologiques des pays helleniques 29, 603–629.

Pe-Piper, G., Piper, D.J.W., 2005. New perspectives on the active South Aegean volcanic arc. Developments in Volcanology, in press.

Pe-Piper, G., Piper, D.J.W., Reynolds, P.H., 1983. Paleomagnetic stratigraphy and radiometric dating of the Pliocene volcanic rocks of Aegina, Greece. Bulletin Volcanologique 46, 1–7.

Perissoratis, C., van Andel, T.H., 1991. Sea level changes and tectonics in the Quaternary extensional basin of the South Evoikos Gulf, Greece. Terra Nova 3, 294–302.

Piper, D.J.W., Perissoratis, C., 2003. Quaternary neotectonics of the South Aegean arc. Marine Geology 198, 259–288.

Piper, D.J.W., Stamatopoulos, L., Poulimenos, G., Doutsos, T., Kontopoulos, N., 1991. Quaternary history of the Gulfs of Patras and Corinth. Zeitschrift fur Geomorphologie 34, 451–458.

Rögl, F., Bernor, R.L., Dermitzakis, M.D., Muller, C., Stancheva, M., 1991. On the Pontian Correlation in the Aegean Aegina Island. Newsletter on Stratigraphy 24 (3), 137–158.

Savoye, B., Piper, D.J.W., 1991. The Messinian event on the margin of the Mediterranean Sea in the Nice area, southern France. Marine Geology 97, 279–304.

Schröder, B., 1986. Das postorogene Känozoikum in Griechenland/Ägäis. In: Jacobshagen, V. (Ed.), Geologie von Griechenland. Borntraeger, Berlin, pp. 209–240.

Stamatakis, M.G., Magganas, A.C., 1988. Thermally induced silica transformations in Pliocene diatomaceous layers from Aegina island, Greece. In: Hein, J., Obradovic, J. (Eds.), Siliceous deposits of Tethys and Pacific regions. Springer, New York, pp. 141–150.

Symeonidis, N., Bachmayer, F., Zapfe, H., 1973. Ausgrabungen in Pikermi bei Athen, Griechenland. Annalen des Naturhistorischen Museums in Wien 77A, 125–132.

Theodoropoulos, D., 1968. Stratigraphie und Tektonik des Isthmus von Megara (Griechenland). Erlanger Geologische Abhandlungen, Hft 73, 3–23.

van Andel, T.H., Perissoratis, C., Rondoyanni, T., 1993. Quaternary tectonics of the Argolikos Gulf and adjacent basins, Greece. Journal of the Geological Society of London 150, 529–539.

van Hinsbergen, D.J.J., Snel, E., Garstman, S.A., Mărunteanu, M., Langereis, C.G., Wortel, M.J.R., Meulenkamp, J.E., 2004. Vertical motions in the Aegean volcanic arc: evidence for rapid subsidence preceding volcanic activity on Milos and Aegina. Marine Geology 209, 329–345.

Zelilidis, A., Piper, D.J.W., Kontopoulos, N., 2002. Sedimentation and basin evolution of the Oligocene–Miocene Mesohellenic basin, Greece. American Association of Petroleum Geologists Bulletin 86, 161–182.