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The Ophiolitic Molasse Unit of Ikaria Island (Greece)

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Abstract: Ikaria Island can be divided generally into two composite tectonic units, namely the lower and upper. The lower unit comprises paragneiss basement with local orthogneiss bodies that is overlain by a platform-type marble sequence, passing upward into a sequence of intercalated schist and marble that is intruded by Miocene granites. The upper unit has not experienced Alpine high-pressure metamorphism, and is restricted to the central (Kefala unit) and northeastern (Faros area) parts of the island, which host ophiolitic associations similar to those found in the upper unit of several Cycladic islands. The Faros area consists of an Oligocene-Early Miocene age ophiolitic molasse unit (conglomerates and olistostromes), rich in ophiolitic clasts, which are similar to diorite and amphibolite rocks of the Kefala unit, and probably were derived from Late Cretaceous oceanic crust. Furthermore, olistolites and/or rifted recrystallised carbonate blocks that are similar to those of the Kefala unit overlie the upper parts of the molasse unit, which elsewhere is discordantly succeeded by Lower Pliocene marine formations. Therefore, the tectonic emplacement of the upper unit is assigned to the Late Miocene. The origin and provenance of the molasse unit is probably the present Cretan Basin. Thus, in its northwestern part, the molasse unit is related to the Eocene-Miocene molasse of the Meso-Hellenic trough of continental Greece, to the northeast passes into the SW Anatolian Late Oligocene-Early Miocene molasse basin of Turkey.

Key Words: Olistostrome, ophiolite, Cretaceous, molasse, Miocene, Ikaria, Cyclades, Greece

Ikaria Adası Ofiyolitik Molas Birimi (Yunanistan)

Özet: Ikaria adası (Yunanistan) alt ve üst olmak üzere başlıca iki kompozit tektonik birimden oluşmaktadır. Alt birim, yerel ortognays oluşumları içeren paragnayasik bir temel üzerine gelen platform tipi mermerlerden ihtiva bir istiften oluşur ve en üstte de Miyosen yaşlı granitler tarafından kesilen şist-mermer ardalanmasını içerir. Buna karşın, alt birim Alpin tipli yüksek basınç metamorfizması yaşamamıştır. Birim, genellikle Ikaria adasının merkezi kesimleri (Kefala birimi) ile adanın kuzey doğusunda (Faros bölgesi) geniş yüzlekler verir ve tipik olarak diğer Kitlat adalarında olduğu gibi ofiyolitik litolojilerden oluşur. Faros bölgesinde alt birim, Kefala birimindeki diyorit ve amfibolitlere benzeyen, ve olasılıkla Geç Kretase yaşlı okyanus kabuğundan türemiş bol miktarda ofiyolit parçaları içeren Oligosen-Erken Miyosen yaşlı ofiyolit molastan oluşmaktadır (çakıltaşları ve olistostromlar). Bundan başka, yine Kefala biriminde olduğu gibi molasik istif üst kesimlerde olistolit ve/veya riftleşmiş rekristalize karbonat blokları tarafından üzerlenirken, alt birim adanın diğer alanlarında Erken Miyosen yaşlı denizel istifler tarafından uyumsuz olarak üzerlenirler. Bundan dolayı, üst birimin tektonik yerleşme yaşı Geç Miyosen olarak kabul edilmiştir. Molas biriminin köken ve kaynağı olasılıkla bugunkü Girit basenidir. Bu nedenle, molas biriminin kuzeybatı bölümleri Yunan ana karasındaki Mezo-Helenik çukurluğundaki Eosen-Miyosen molasları ile ilişkilendirilirken, birim kuzeydoğuda Türkiye'deki Geç Oligosen-Erken Miyosen yaşlı güneybatı Anadolu molas havzalarına geçişlidir.

Anahtar Sözcükler: Olistostrome, ofiyolit, Kretase, molas, Miyosen, Ikaria, Kitlatlar, Yunanistan

Introduction

Ikaria Island lies in the east-central part of the Aegean Sea and occupies the northeastern part of the Cycladic Archipelago. The dominant morphological feature is an oblong NE-SW–trending crest with fusiform-shape.

Ikaria occupies a transitional geotectonic position between the Attic-Cycladic Crystalline Complex and the Pelagonian Zone (*sensu lato*) to the west, and the Menderes Massif to the east (Renz 1940; Brunn 1956; Ktenas 1969; Aubouin *et al.* 1976; Robertson & Dixon 1984; Bozkurt & Oberhänsli 2001). Furthermore, the island belongs to the median tectono-metamorphic belt of the Hellenides (Dürr *et al.* 1978; Papanikolaou 1978, 1984, 1988), which is characterised by Alpine and pre-Alpine tectonic units.

The island consists of a gneissic basement that is overlain by a sequence of multiple intercalations of schist and marble, which is intruded by granite. It was mapped, for the first time, by Ktenas (1969), and its geological and tectonic structure completed by Papanikolaou (1978). Thereafter, a Miocene age was ascribed to the granite intrusion (Altherr *et al.* 1982; Schliestedt *et al.* 1987).

The upper tectonic unit, which is found on several Cycladic islands (Jansen 1973, 1977; Angélier *et al.* 1978; Dürr *et al.* 1978; Röesler 1978; Papanikolaou 1979; Dermitzakis & Papanikolaou 1980; Robert 1982; Reinecke *et al.* 1982; Altherr *et al.* 1994; Patzak *et al.* 1994) as well as on Crete (Seidel *et al.* 1981), comprises unmetamorphosed or weakly metamorphosed rocks (ultramafic, gabbroic, basaltic relicts, associated with various Mesozoic and Tertiary age limestones) and also occurs on Ikaria Island. It concerns the Kefala locality, with an Upper Triassic limestone (Papanikolaou 1978) overlying a Upper Cretaceous diorite-bearing amphibolite (Altherr *et al.* 1994), and the Faros area, which is composed by an ophiolitic molasse unit that is overlain by recrystallised carbonate rocks.

The aim of this research was to study (1) the upper tectonic unit of the island, which consists of an ophiolitic molasse with overlying carbonate formations, and (2) their separation from the post-Miocene deposits of the Plio-Quaternary deposits. This ophiolitic olistostrome of the molassic formation, which herein is examined for the first time, was hitherto confused as being, on the whole, Plio-Quaternary sediments transgressively deposited on the metamorphic basement of the island.

The term "ophiolitic molasse" used in this study refers a sedimentary formation that comprises conglomerates and olistostromes. These rocks were deposited in a terrestrial and/or shallow-marine environment and resulted from post-orogenic uplift and reworking of mainly ophiolites and medium- to low-grade metasediments. Since this unit is devoid of Cycladic metamorphic and granitoid rocks, Röesler (1978) ascribed an age corresponding to the Oligo-Miocene conglomerates. This formation, as a superficial nappe, tectonically overlay the Cycladic metamorphic rocks and the Miocene granitic bodies during the Late Miocene (Jansen 1973, 1977; Angélier 1977, 1979; Dermitzakis & Papanikolaou 1980; Faure *et al.* 1991), as is the case of several outcrops belonging to the upper unit of the Cyclades that have not experienced Alpine high-pressure metamorphism. The upper unit was emplaced from south to north by gravity sliding due to ductile or brittle and ductile extensional event, which is explained by collapse of the Aegean crust during Miocene granitoid intrusions (Faure & Bonneau 1988; Faure *et al.* 1991; Lee & Lister 1992; Boronkay & Doutsos 1994; Jolivet *et al.* 1994).

Geological setting

Taking into account the existing geological data (Ktenas 1969; Papanikolaou 1978), as well as those of recent geological re-mapping at a scale of 1:50,000 (Photiades 2002), the island of Ikaria consists of two units (Figure1). These units are characterised by the absence of any preservable relicts of Eocene high-pressure (HP)/low-temperature (LT) metamorphic event that are well known from several other islands of the Aegean Sea (Altherr *et al.* 1979, 1982; Andriessen *et al.* 1979; Maluski *et al.* 1981, 1987; Henjes-Kunst & Kreuzer 1982; Wijbrans & McDougall 1988).

The Lower Unit

The lower unit is characterised by a gneissic basement that is overlain by a platform-type marble sequence which hosts emery deposits, and passes upward into a sequence of intercalated schist and marble.

The gneissic basement has a northeastern-plunging anticlinal core and underlies the eastern half of the island. Biotite- and/or muscovite-bearing banded gneiss usually is widespread and alternates with amphibolitic schist; and its deeper members pass into amphibolitic gneiss which locally encloses amphibolite bodies. The biotite-bearing gneiss contains porphyroblasts of staurolite, kyanite, garnet with feldspar, and quartz. In the upper stratigraphic members, the paragneiss sequence is intercalated with irregular bodies of leucocratic augen gneiss, most probably originating from acid magmatic rocks, and associated with quartzite and biotite-garnet schist.

The paragneiss, with deformed orthogneiss bodies of probable Palaeozoic age, constitute the basement of the Cyclades, the Menderes Massif and the Pelagonian zone, which are thought to be homologous and are closely related spatially (Dürr *et al.* 1978; Jacobshagen *et al.* 1978; Blake *et al.* 1981; Mountrakis 1984; Robertson & Dixon 1984; Okay 1989; Schermer *et al.* 1990; Pe-Piper *et al.* 1993). Carboniferous magmatic activity, which is widespread over large parts of the Aegean region (Keay 1998; Engel & Reischmann 1998; Reischmann 1998), is unknown in the Menderes Massif due to its ascribed older age (Hetzel & Reischmann 1997; Bozkurt & Oberhänsli 2001).

The basement passes upward into calcschist, which in turn is overlain by a platform-type marble sequence (up to 250-m-thick) that hosts emery deposits at its highest level. This marble is of similar Triassic age as its corresponding members on Naxos and Paros islands. The emery deposits represent original karst bauxite, considered to have been formed during the Jurassic when the carbonate platform was emergent (Feenstra 1985). Meta-bauxite and karst bauxite also occur on the Cyclades and in the Menderes Massif and the Pelagonian zone (Dürr *et al.* 1978; Blake *et al.* 1981; Feenstra 1985; Yalçın 1987; Özer *et al.* 2001).

The Triassic (inferred) marble passes upward into a sequence of intercalated schist and marble, up to 300-m-thick. The lower stratigraphic members consist of intercalations of amphibolitic and micaceous schists, which contain epidote-bearing greenschist lenses within microcrystalline bedded marble. Toward the upper part of this unit, calcshist, phyllitic schist and phyllite with marble intercalations, locally containing quartzitic nodules predominate. Locally, this unit is unconformably overlain by a restricted dolomitic horizon.

Furthermore, the platform-type marble and the overlying schist-marble sequence are considered to be homologous with the Mesozoic series rocks of the Cyclades that have been dated on the basis of sparse palaeontological evidence (Cayeux 1911; Négris 1915; Anastopoulos 1963; Dürr *et al.* 1978; Dürr & Flugel 1979; Maluski *et al.* 1987; Melidonis 1980). Additionally, zircon ages obtained from several Mesozoic-series rocks of the Cyclades are dominantly of Triassic-Jurassic age (Keay 1998).

The whole lower unit has been affected by amphibolite-facies metamorphic conditions of Barrovian-type, with a maximum temperature of 500° C, during the Late Oligocene (Altherr *et al.* 1982). Subsequently, this unit was variably affected by retrogressive greenschist-facies metamorphism during the intrusion, in the Miocene, of the Raches and Xylosyrtis granites, which crop out in the western and eastern parts of the island, respectively.

In particular, the Raches granite is mainly by I-type leucogranite, and occupies the western half of the island. Potassium-Ar and Rb-Sr dates on biotite (between 8 and 9 Ma), as well as a fission-track date of 7 Ma on apatite, are interpreted by Altherr *et al.* (1982) as cooling ages related to uplift. The age of the Raches granite is estimated to be about 18 Ma (Schliestedt *et al.* 1987). This granite is intensely deformed in the form of orthogneiss and is characterized by typical S-C mylonitic fabrics, indicating top-to-the-north to top-to-the-NE shear extensional movement (Faure & Bonneau 1988; Faure *et al.* 1991; Papanikolaou *et al.* 1991), which has been associated with continuous brittle deformation from the Early Miocene to the present (Boronkay & Doutsos 1994; Jolivet *et al.* 1994).

In the eastern part of the island, the small S-type Xylosyrtis granite of Miocene age (21-10 Ma) (Altherr *et al.* 1982; Schliestedt *et al.* 1987) has northeast-verging structure. Furthermore, between the gneiss basement and the overlying formations, evidence for the metamorphic hiatus postulated by Papanikolaou (1978), and ascribed to the so-called tectonic Messaria unit, was not observed. Consequently, it is inferred that this unit is a unified lithological succession, and was affected by the same metamorphic events.

The Upper Unit

The upper tectonic unit consists of an ophiolitic molasse member, characterised by a conglomeratic and olistostromal ophiolitic formation, which has been tectonically transported, and is overlain by a recrystallised white-grey limestone and dolomite member. These carbonate rocks occur at Kefala hillock (central part of the island), and in the area of Faros (northeastern peninsula of the island). The carbonate rocks are olistolites and/or slices tectonically imbricated with the ophiolitic molasses unit. Particularly, at the Kefala hillock, Papanikolaou (1978) accepts that the recrystallised limestone and dolomite are of Late Triassic age, while the tectonically underlying formation, with dioritic and amphibolitic rocks, has yielded radiometric dates corresponding to 80.5-67 Ma and 84.4.±2.4 Ma (Late Cretaceous) (Altherr *et al.* 1994).

Finally in the northern part of Raches granite at the Yaliskari locality (Figure 1), as well as along the southeastern coast of the island, sandstone, marly sandstone and marlstone deposits, with fauna rich in *Cardiides* of Early Pliocene age, have been observed (Ktenas 1927). Compact breccia-conglomerate and pudding-stone terrace deposits of Quaternary age unconformably overlie the Pliocene formations (Ktenas 1927; Georgalas 1953).

Lithostratigraphy of the Upper Tectonic Unit

The molassic deposits occur, apart from the Kefala locality, on the Raches granite at Yaliskari, and on the schist-marble sequence on the northeastern peninsula of the island at the Daimonopetra, Panagia and Faros localities (Figures 1 & 2).

Daimonopetra, Panagia and Faros Localities

At the Daimonopetra, Panagia and Faros localities, a polygenic conglomerate up to 100-m-thick is present. This conglomerate formation is rich in ophiolitic boulders, cobbles and pebbles and constitutes an olistostromal ophiolitic molasse unit. Towards the upper part of this unit in the Faros area it is progressively enriched and dominated by carbonate conglomerate, which is characterised by cobbles and pebbles of fine- to coarse-grained white-grey recrystallised limestone and dolomite elements, and admixed with smaller quantities of phyllite fragments. Finally, the whole clastic unit is overlain by olistolites and/or rifted recrystallised carbonate blocks.

The boulders, cobbles and pebbles that make up the olistostrome are rounded and angular to subangular (diameter up to 50 cm) and mainly comprise gabbro (80%) and volcanic rocks, amphibolite and pyroxenite (5%) of ophiolitic origin. Marble, amphibole-bearing schist, mica-bearing schist and calcschist, as well as red chert, mudstone, green phyllite and calcareous sandstone, make up the remaining percentage. In addition to these components, at the Faros locality there are also few scattered pebble-sized rocks of white nummulitic limestone (*Nummulites* sp.), typically of Early Tertiary age.

The matrix of the molasse unit consists of well-cemented to loose, sandy, pelitic to argillaceous and calcareous fine- to coarse-grained sandstone. The clastic grains are rounded to subangular, with diameters up to 5 mm, and comprise quartz, alkali feldspar, plagioclase, biotite, muscovite, chlorite, chromite, and opaque minerals, as well as various ophiolitic rock fragments.

The ophiolitic clasts are characterised by hydrothermal metamorphism at greenschist-facies conditions, typified by minerals such as prehnite, actinolite, tremolite, chlorite, albite and magnetite. All of these sea-floor hydrothermal alterations took place during the circulation of high-temperature fluids in the oceanic crust. The banded amphibolite blocks are probably derived from the metamorphic “sole”, which locally underlie ophiolite slices and originate by overthrusting of the still-hot ophiolite.

At the Faros locality (Figures 2 & 3) in particular, the basal parts of the ophiolitic molasse, apart from calcite and quartz veins, comprise a broken conglomeratic deposit with a pervasively sheared matrix and, therefore, exhibit a mélange character. The multiply bounded fracture and shear surfaces of conglomerate are especially due to Middle to Late Miocene (ductile and brittle) extensional deformations (Angélier 1977, 1979; Boronkay & Doutsos 1994). Moreover, the broken formation acquired a northward-preferred orientation, and the whole ophiolitic molasse is interpreted as an allochthonous unit, characterised by an ophiolite olistostrome, rich mainly in ophiolitic constituents of various dimensions. In addition, there also occur, in lower proportions, medium- to low-grade metasediments.

In the Yaliskari area on the northern side of the island (Figure 1), a very limited ophiolitic molasse outcrop overlies deformed granite that occupies a graben bordered by NNE–trending high-angle normal faults. The

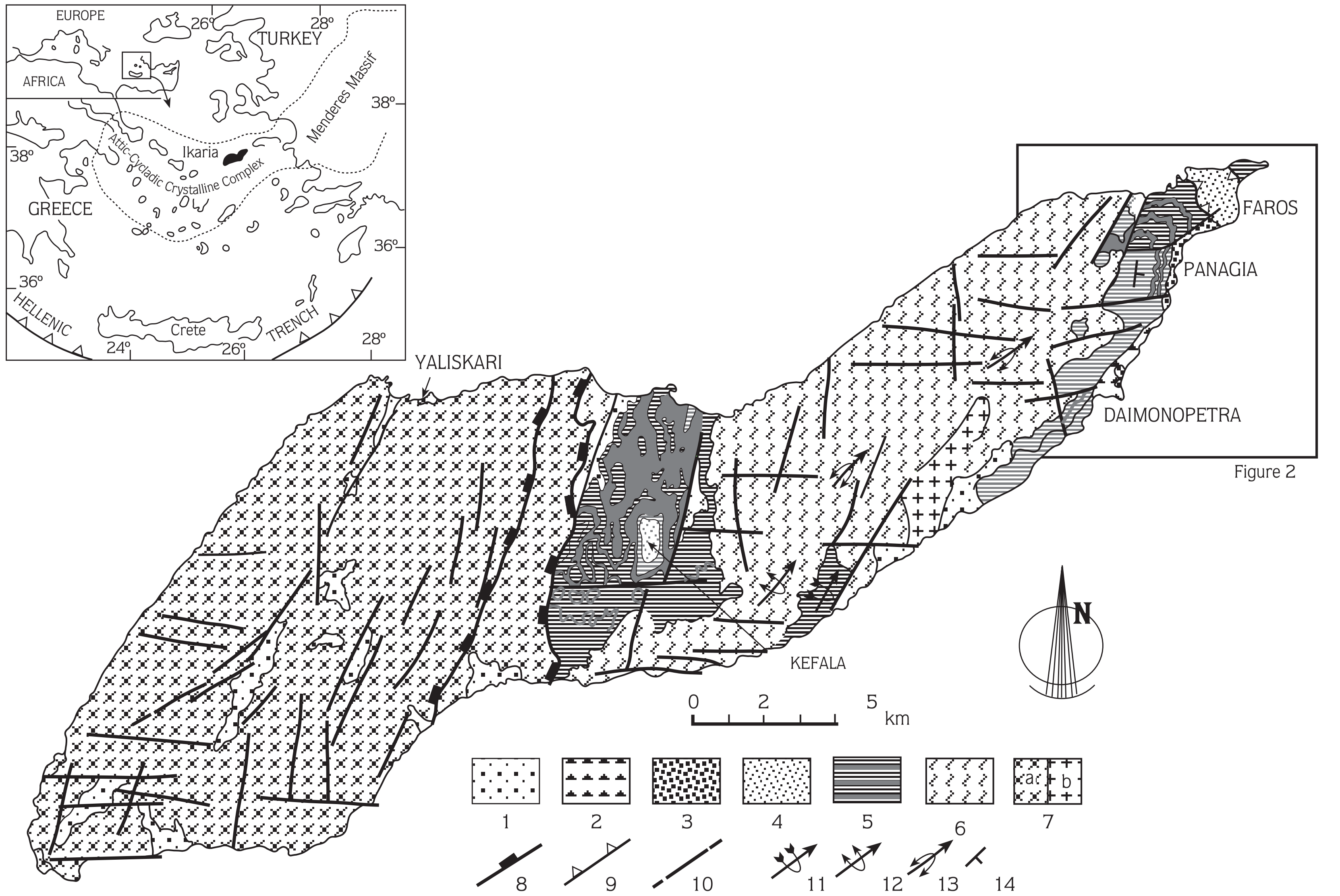

Figure 1. Geotectonic position of the Cyclades archipelago with a simplified geological map of Ikaria island (modified from Photiades, in press). 1– Quaternary deposits; 2– Pleistocene deposits; 3– Lower Pliocene marine deposits; 4– upper tectonic unit ("ophiolitic molasse" and recrystallised carbonates). *Lower unit:* 5– schist-marble formation and marble type-platform sequence; 6– gneiss; 7a– Miocene Raches granite, 7b– Miocene Xylosyrtis granite; 8– thrust; 9– tectonic contact (thrust and/or low-angle normal fault); 10– high-angle normal fault; 11– recumbent synclinal axis; 12– recumbent anticlinal axis; 13– anticlinal axis; 14– strike and dip of beds and schistosity planes.

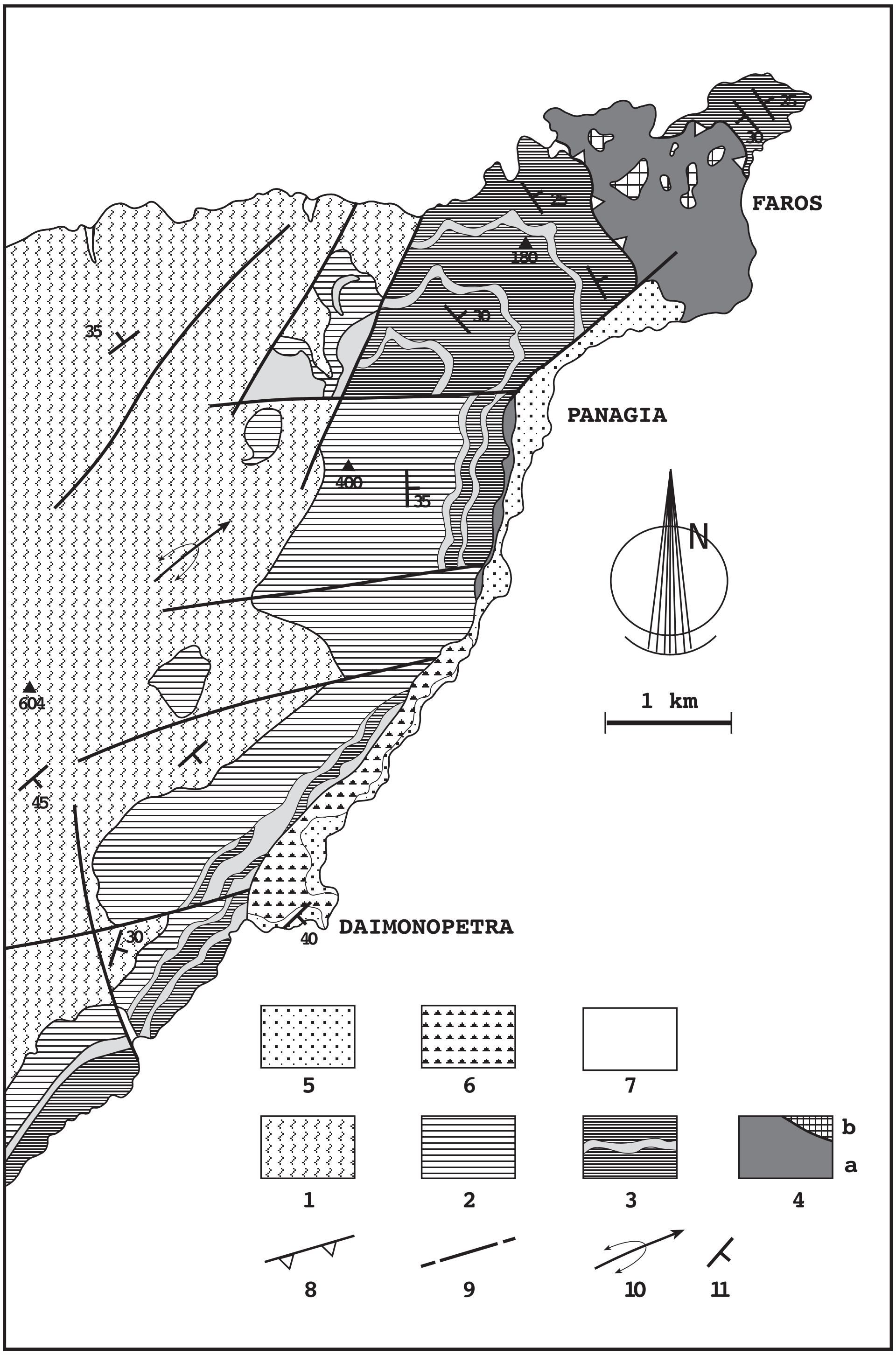

Figure 2. Detailed geological map of Faros peninsula in Ikaria island (see Figure 1 for location of the studied area). *Lower unit:* 1– gneissic basement, 2– marble type-platform sequence, 3– schist and marble formations; *Upper unit:* 4a– "ophiolitic molasse", 4b– olistolites and/or rifted recrystallised carbonate blocks; 5– Lower Pliocene marine deposits; 6– Pleistocene massive breccia-conglomerate terrace deposits; 7– alluvial and coastal deposits; 8– tectonic contact (thrust and/or low-angle normal fault); 9– high-angle normal fault; 10– anticlinal axis; 11– strike and dip of beds and schistosity planes.

contact between the deformed granite and the ophiolitic conglomerate separates a domain which has been affected by ductile and then brittle deformation. This relationship can be observed, both in the top-to-the-north sense of shear in the ductile domain on the granite below the ophiolitic conglomerate, and by the north-dipping normal fault with tilted ophiolitic conglomerate, which is covered by Lower Pliocene sediments. This contact is also characterised by hydrothermal quartz, carbonate and iron precipitations within extensional veins, shear bands and fractures. Such hydrothermal precipitations are also found in the granite, where iron-rich concentrations are limited to ductile shear bands.

As can be seen in Figure 3, these clastic sequences tectonically overlie the Mesozoic metamorphic series of the lower unit, and also the intensely deformed Miocene granite. Despite subsequent tectonic emplacement, rather significant sedimentary features were observed at different levels of the Faros sequence. The lower part of the olistostrome is dominated by a clast-supported conglomerate, and the upper part is matrix-supported conglomerate, interbedded with coarse- and fine-grained sandstone, some of which is very shallow-channeled and locally characterized by fining-upwards sequences. These sedimentary features can be attributed to a depositional environment between proximal debris gravity-flow (Lowe 1982) and very proximal braided-stream (Miall 1978).

Kefala Area

In the Kefala area, however, the ophiolitic rocks appear as tectonically wedged amphibolite and hornblende-bearing diorite rocks associated with schistose volcanic rocks and red mudstone. The radiometric ages reported for the hornblende-bearing diorite and amphibolite are 80.5–67.4 Ma and 84.4±2.4 Ma, respectively, representing a Late Cretaceous age (Altherr *et al.* 1994). It is evident that these hydrothermally altered and tectonically imbricated rocks are similar to those of the Faros area.

Finally, the recrystallised white-grey limestone and dolomite that overlie the ophiolitic molasse unit in the Faros area occur also at the Kefala hillock, but there the contact is tectonic. There, Papanikolaou (1978) mentions the existence of *Megalontidae*, accepts that these carbonate rocks have a Late Triassic age, and that they are similar to those found on Thymaena Island (Papanikolaou 1980), which is located to the east of Ikaria island.

Moreover, at the Faros, Panagia and Daimonopetra localities (Figures 2 & 3), as well as in the Yaliskari area (on the Raches granite in the northwestern part of the island), the ophiolitic olistostromal formations are overlain discordantly by an alternating sequence of calcareous sandstone, marly sandstone and limestone (sparite, biosparite and oolitic limestone), up to 25 m in thickness, which is rich in macrofossils, such as bivalves, gastropods, ostracods, algae, echinoderm spicules and bryozoans. Ktenas (1927) also mentions the presence of *Cardiidae, such as Cardium (Limnocardium) bollenense MAYER, Syndosmya alba WOOD and Venus ovata PENN.* Furthermore, in all of the aforementioned formations, significant percentages of tree pollen have been observed; in addition, there occur pollen grains of herbaceous plants as well as marine phytoplankton, i.e., *Hystrichosphaeridium sp., Achomospaera sp., Tuberculodinium vancampoae, Cyclonephelium sp., Hystrichokolpoma sp., Spiniferites div fsp.* Furthermore, a few pteridophyte spores have also been observed (Chrysanthi Ioakim, pers. comm. 1998).

The presence of the Cardiidae and pollen associations suggests that the sequence was deposited in a shallow littoral marine environment during the Early Pliocene. Finally, at the Daimonopetra locality, above the Neogene formations, massive breccia-conglomerate terrace deposits of Pleistocene age (Georgalas 1953) have developed discordantly and contain lithic elements derived from the metamorphic basement.

Discussion and Conclusions

The ophiolitic molasse unit and the carbonate formation that constitute the upper tectonic unit of Ikaria are characterised by high temperature/low-pressure (HT/LP) rocks, and are related to metamorphic episodes of the Late Cretaceous (Altherr *et al.* 1994). Therefore, these rocks have escaped high-pressure deformational events that affected the Aegean domain during the Eocene. A paragenesis (HT/LP) similar to that of Ikaria island has also been reported from the upper unit of the Cyclades, which also records Cretaceous ages for an amphibolite-facies metamorphic event, such as on Anafi (Reinecke *et al.* 1982), Donousa, Nikouria, Amorgos (Dürr *et al.* 1978; Altherr *et al.* 1994) and Tinos (Patzak *et al.* 1994;

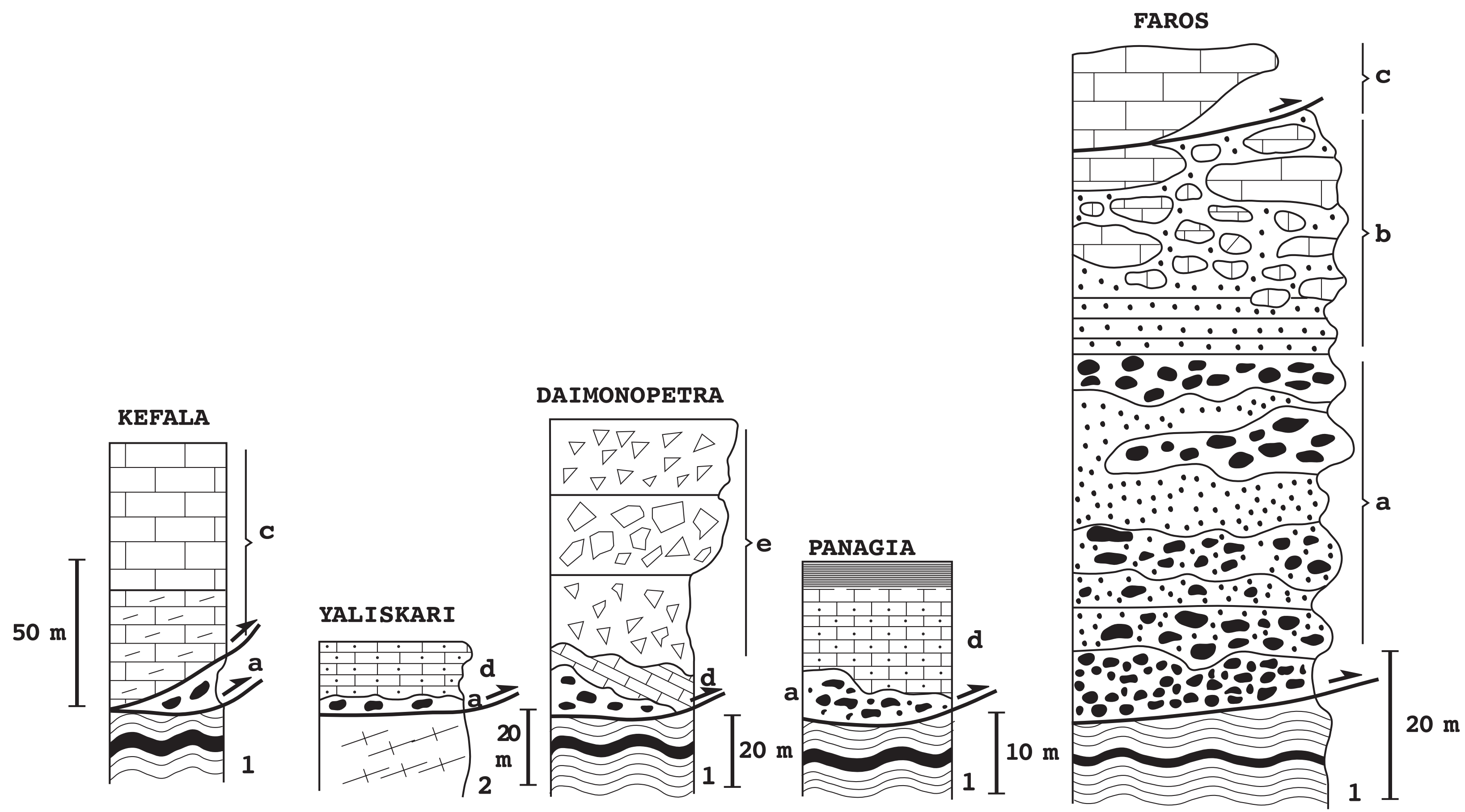

Figure 3. Lithostratigraphic schematic sections of upper unit in Ikaria island. 1– schist and marble formation of the lower unit; 2– Miocene Raches granite; Upper unit: a– "ophiolitic molasse" with conglomerates and olistostromes, b– conglomerate and olistolite of recrystallised limestone and dolomite, c– outlier or/and rifted recrystallised carbonate blocks, d– Lower Pliocene marine deposits, e– Pleistocene massive breccio-conglomerate terrace deposits.

Katzir *et al.* 1996) as well as on Crete (Seidel *et al.* 1981). Moreover, these ages are considered to coincide with the emplacement of the ophiolite onto continental crust, and also post-date the ophiolite formation (Reinecke *et al.* 1982; Robertson & Dixon 1984; Patzak *et al.* 1994).

Furthermore, the ophiolitic molasse unit tectonically overlies the Cycladic Mesozoic metamorphic series of the lower unit (Kefala and Faros areas), and the deformed Miocene granite (Yaliskari locality) of the island. Since the ophiolitic molasse is devoid of the Mesozoic Cycladic metamorphic series and Miocene granitic rocks, it is considered to be of an age similar to that of the Oligo-Miocene conglomerates (Röesler 1978). Therefore, the age of the Ikaria ophiolitic molasse is pre-granitic, and also older than discordantly overlying marine sediments, rich in *Cardiidae* and phytofossils of Early Pliocene age.

However, the upper tectonic unit of Ikaria, in comparison to the overall upper-unit Cycladic lithostratigraphic successions, is characterised by an ophiolitic molasse unit, which is tectonically overlain by Upper Triassic limestone at the Kefala hillock (if this age is correct) and by clastic recrystallised-carbonate deposits in the Faros area. Eventually, this apparent succession was related to an initial depositional feeder process (ophiolitic debris followed upward by olistolite and/or rifted carbonate-block deposits), and then the unit was engaged in subsequent tectonic emplacement.

The existence of molasse indicates that the following processes have operated: (a) uplift, erosion and transport of mainly ophiolitic clasts, probably derived from Late Cretaceous oceanic lithosphere, which have been partially reworked during their transport with rocks of various provenance, such as nummulitic limestone, marble and schist, and subsequently all were deposited in a continental and/or shallow-marine environment during Oligo-Miocene time; (b) the thrusting and/or sedimentary sliding of Upper Triassic limestone and recrystallised carbonate rocks onto top of the molasse formation; (c) tectonic emplacement of the sequence (ophiolitic molasse and carbonate formation) onto the metamorphic series and the coevally deformed Miocene granite during the Late Miocene; and lastly (d) deposition of shallow-water transgressive sediments of Early Pliocene age.

In addition, this ophiolitic molasse unit is analogous to Cycladic molasse of Oligocene-Early Miocene age on the islands of Paros, Naxos, Koufonisia, Makares and Mykonos (Jansen 1973, 1977; Angélier *et al.* 1978; Dürr & Altherr 1979; Röesler 1978; Dermitzakis & Papanikolaou 1980; Robert 1982; Faure & Bonneau 1988; Papanikolaou 1996). Due to the tectonic nature and the predominantly exotic pebble content of this unit, Jansen (1973, 1977) postulated an allochthonous origin for this Miocene formation. This unit was considered to have been moving by gravity sliding, due to a local uplift of the Aegean domain, during Langhian-Tortonian (Angélier 1977, 1979; Dermitzakis & Papanikolaou 1980).

Consequently, the emplacement of the upper unit must have occurred in the Late Miocene, and its sense of movement was from south to north, similar to that postulated for Thymaena and Mykonos islands (Papanikolaou 1980; Faure & Bonneau 1988; Dürr & Altherr 1979; Faure *et al.* 1991). The origin and provenance of this unit was probably the present Cretan Basin (Dermitzakis & Papanikolaou 1980; Papanikolaou 1988); in its northwestern part, it is related to the Eocene-Miocene Meso-Hellenic trough of continental Greece (Brunn 1956), and to the northeast passes into the Late Oligocene-Early Miocene SW Anatolian molasse basin of Kale-Tavas and Denizli in Turkey (Akgün & Sözbilir 2001). Brunn *et al.* (1976) previously noted their geodynamic resemblance.

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