The Argolis Peninsula in the paleogeographic and geodynamic frame of the Hellenides

THE ARGOLIS PENINSULA IN THE PALAEOGEOGRAPHIC AND GEODYNAMIC FRAME OF THE HELLENIDES

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ABSTRACT

Geological and biochronological studies on the Argolis Peninsula (Pelagonian - Subpelagonian Domain) -also based on petrological data on the ophiolitic rocks- allowed us to propose a new tectonic unit succession; from the bottom upwards: a- the Trapezona Unit (Early-Middle Triassic - Late Jurassic; Pelagonian continental margin); b- the Dhimaina Ophiolitic Unit (Middle Triassic-Late Jurassic/Early Cretaceous oceanic realm, covered by an Early Cretaceous-Eocene “Mesautochthon; c- the Iliokastron Mélange Unit (Middle-Late Jurassic - Early Cretaceous) in the northern Argolis and the Adheres Melange Unit (Cretaceous-Paleocene) in the southern Argolis; d- the Faniskos Unit (Late Jurassic-Eocene).

Based on a close examination of the paleogeography of the continental margin successions and of their possible relationships with the ocean floor successions, we propose a model for the evolution of the oceanic and continental domains of this section of the Hellenides during the Triassic-Eocene interval, and we try to frame it into the evolution of the whole Dinaric-Hellenic orogenic system. This model hypothesises the opening, during Middle-Late Triassic time, of a single ocean in the Dinaric-Hellenic realm (the Vardar Ocean), which continues its spreading phase until the Middle Jurassic when, an intra-oceanic subduction zone, testified by the presence of IAT volcanites and boninitic rocks developed contemporaneously with MOR basalts. During the Late Jurassic obduction of the ophiolitic units onto the continental margin began. During the Early Cretaceous, the complete thrusting of the Dhimaina Ophiolitic Unit onto the Trapezona Unit occurred. During Eocene, and particularly after the Ypresian, the different units reached their present tectonic setting.

INTRODUCTION

The Hellenides consist of NW-SE-trending parallel tectono-sedimentary belts, the ‘Isopic Zones’ of Aubouin (1959), modified by Aubouin et al. (1970); from west to east they are: the Ionian, Gavrovo, Pindos, Parnassos, Subpelagonian-Pelagonian, Vardar zones.

According to ancient authors the Pelagonian Zone (including the Subpelagonian), which crops out in the Argolis Peninsula, consists of a Palaeozoic metamorphic basement, covered by a Permian to Jurassic succession with volcanics (Pe-Piper, 1998) and sediments (Mercier, 1966; Celet and Ferrière, 1978; Mountrakis et al., 1983; Mountrakis, 1984; 1986; Papanikolaou, 1984; Katsikatsos et al., 1982; 1986). This succession, pertain to a continental margin and is overthrust by a stack of tectonic units with ophiolites and tectonic mélanges (Aubouin et al., 1970; Jacobshagen et al., 1976). Upper Jurassic to Upper Cretaceous calcareous successions and, at places, a Tertiary flysch overthrust these mélanges and shed debris in them.

In the past, different hypotheses on the Triassic-Eocene evolution of the Pelagonian continental margin and on the Dinaric-Hellenic oceanic basin or basins have been proposed

a- During the Triassic - Early Jurassic times the Pelagonian shallow water carbonate platform was the eastern portion of the External Hellenides isopic zones comprising the Ionian Zone (Celet et al., 1988; Katsikatsos et al, 1986; Feinberg et al., 1996); hence, it pertained to the Apulia domain. Only one oceanic basin existed, in the Vardar zone (Dercourt et al., 1993).

b- During the Dogger, the Pelagonian Domain was separated from the External Hellenides, due to the opening of a second ocean basin (the Pindos Ocean) to the west, and from the Serbo-Macedonian Domain, for the opening of Vardar Ocean, to the east. According to Robertson and Dixon (1984) the opening of the Pindos Ocean occurred during the Trias.

c- The Pelagonian zone was part of the Cimmerian Domain that was separated from the Gondwana supercontinent during Permo-Trias times (Mountrakis, 1984; 1986; 1994; Şengör et al., 1984; Papanikolaou, 1989; Channell and Kozur, 1997).

As to the Parnassos zone (present also in the Acrocorinth area, north from the Argolis Peninsula, Richter et al., 1992), the presence of Triassic to Eocene shallow water carbonate platform, with some Jurassic and Cretaceous bauxite levels, demonstrates that this zone did not suffered Jurassic tectonics (according to Celet and Ferrière, 1978, the lack of pre-Late Cretaceous tectonic phases excludes that this belongs to the Pelagonian Zone); in fact, it was not covered by ophiolitic units as is instead the Pelagonian Domain s.s., to the North and East. However, the detrital laterite levels which originated from the washing away of ophiolitic rocks (D’Argenio and Mindszenty, 1991) indicate that an emerged ophiolitic (tectonic) unit was not far away, probably to the east, according to our scheme (see below). Hence, the ophiolitic unit that overthrust the continental margin succession (Trapezona Unit succession) must come only from eastern areas.

In a preceding work, Bortolotti et al. (2002a) documented the presence, in the tectonic pile of the Argolis Peninsula, of a Triassic-?Jurassic basalt-chert assemblage, locally with serpentinite slivers at the base. The basalts have a MORB or

T-MORB affinity (Saccani et al., 2002; 2003 in press). This assemblage (Migdalitsa Ophiolitic Complex of the Dhimaina Ophiolitic Unit, see later) is tectonically sandwiched between an Upper Triassic-Lower Jurassic continental margin succession (Pantokrator Auctt.) at the base, and a polymictic mélange (Adheres Mélange, see below) or, directly, a second mélange unit with sheared serpentinites (Iliokastron Mélange, see below) at the top; this mélange is tectonically covered by large slices of Cretaceous carbonate successions (Faniskos Unit, see below).

Triassic basalt-chert associations, some of which with MOR characteristics (Greece: Pe-Piper, 1998, with bibl.. Pindos: Kostopoulos, 1989 and Jones and Robertson, 1991. Othrys: Lefèvre et al., 1993; Aeolia: Pe-Piper and Hadzipanagiotou, 1993. Euboea: Danelian and Robertson, 2001; Argolis, Bortolotti et al., 2002a and Saccani et al., 2002; Croatia: Halamić and Goričan 1995; Halamić et al., 1998) and Middle-Late Jurassic oceanic (MOR) and supra-subduction (IAT) basalt-chert associations (e.g. Albania, Bortolotti et al., 1996, with bibl.; Dinarids, Pamić et al., 1998; 2002, with bibl.; Greece, Robertson, 2002, with bibl., etc.) are widely reported all along the Dinaric-Hellenic orogenic belt. Many theoretic restorations of Triassic-Jurassic paleogeography and geodynamic evolution of the Argolis and more generally of the Hellenides - Dinarides internal domains have been recently proposed (Dercourt et al., 1993; Bortolotti et al., 1996; Pamić et al., 1998; 2002; Ricou et al., 1998; Robertson and Shallo, 2000; Robertson, 2002, etc.).

GEOLOGICAL SETTING

This paper is focused on the geology of the Argolis Peninsula, and proposes a new model for the evolution of the oceanic and continental domains of this section of the Hellenides during the Triassic-Tertiary interval, trying to fit it into the evolution of the whole Dinaric-Hellenic orogenic system.

The Argolis Peninsula (Fig. 1) is traditionally considered part of the Pelagonian (including the Subpelagonian) Zone (Aubouin, 1959; Aubouin et al., 1970; Mercier, 1966; Celet and Ferrière, 1978; Mountrakis, 1986: Photiades, 1986; Clift and Robertson, 1989). This isopic zone includes, according to ancient authors (Aubouin et al., 1970; Mercier, 1966; Celet and Ferrière, 1978; etc.), a Paleozoic metamorphic basement and Permo-Jurassic covers. In Argolis these latter are overlain by olistostromes and overthrust by a stack of tectonic units, including ophiolites, mélanges, Upper Jurassic to Upper Cretaceous calcareous successions and Tertiary flysch (Aubouin et al., 1970; Jacobshagen et al., 1976; Vrielynck, 1978a; 1978b; 1981-82; Baumgartner, 1985; Cift and Robertson, 1989; Photiades, 1986; 1987).

In more recent times, different tectono-sedimentary models were proposed. We take into consideration the principal reconstructions, starting from 1980. Fig. 2 resumes and correlates the tectono-stratigraphic schemes from: a- Vrielynck (1978b; 1980; 1981-82), b- Baumgartner (1985), c- and d- Photiades (1986; 1987; 1995), Dostal et al. (1991), Gaitanakis and Photiades (1991), Photiades and Skourtsis-Coroneou (1994), Capedri et al. (1996), Photiades and Keay (2000), Saccani et al. in press. Vrielynck (1978a; 1978b; 1980; 1981-82), (Fig. 2A) proposed a structural scheme in which, three tectonic units are piled up: 1- the Triassic-Jurassic Trapezona Nappe (shallow water carbonate Trapezona succession), 2- the coeval volcano-sedimentary and pelagic Epidaure Nappe (hemipelagic carbonate Epidavros succession), 3- the ophiolites. A transgression surface on top of 2 and 3 is overlain by shallow water limestones which ages vary from Barremian to Senonian. An Eocene flysch conformably and, at places, uncomformably covers the Cretaceous-Paleocene Limestones.

Baumgartner (1985) (Fig. 2B, 2C) subdivided the Pelagonian-Subpelagonian realm of the Argolis Peninsula into two stacks of tectonic units: a- the north-western area, more external and b- the south-eastern area, more internal, juxtaposed by a main strike-slip fault. From the bottom upwards the succession of the units is: i- in the external stack the Adhami Composite Unit, which comprises a- the Triassic-Upper Jurassic Basal Sequence, b- the coeval "main" Asklipion Unit, both pertaining to the Pelagonian continental margin and the Upper Jurassic Migdalitsa Ophiolite Unit; ii- in the internal stack, the Dhidhimi - Trapezona Composite Unit which comprises a- the Basal Sequence, b- the Asklipion Unit, and the Migdalitsa Ophiolite Unit, uncomformably covered by the Turonian-Eocene "Mesoautochthonous" and finally, c- the Faniskos Unit, which comprises a nappe of "sheared serpentinites", uncomformably covered by a "mid" Cretaceous-Eocene "Mesoautochthonous".

Photiades (1986; 1987; 1995), Dostal et al. (1991), Gaitanakis and Photiades (1991), Photiades and Skourtsis-Coroneou (1994), Capedri et al. (1996), Photiades and Keay (2000), Saccani et al. in press, proposed to subdivide the Argolis tectonic pile into three main units: from bottom to top they are (Fig. 2D, 2E) : 1- the Lower Unit, composed by Triassic-Upper Jurassic Pelagonian margin sediments; 2- the Middle Unit, made up of ophiolitic MOR basalts uncomformably covered (in the northern Argolis) by a Cretaceous-Eocene mesoautochthonous succession; 3- the Upper Unit, comprising a serpentinitic tectonic mélange uncomformably covered by an Upper Cretaceous-Eocene succession. Robertson et al. (1987) follow the scheme of Baumgartner (1985) relative to the external stack; only the Faniskos Unit does not have a precise tectonic position and the Mesoautochthon is locally thrust on the Migdalitsa Ophiolite.

Clift and Robertson (1990b) affirm "that major Mesozoic and Early Tertiary strike-slip fault do not in fact exist in Argolis and that all the Mesozoic platform carbonate units and their overriding thrust sheets form part of a single tectono-stratigraphic succession".

Clift (1996) modified the previous scheme as regards to the eastern portion of the Argolis (Adheres Peninsula): the carbonate basal unit (Pantokrator) with its ophiolitic Upper Jurassic Potami Mélange are "conformably and uncomformably" overlain by the Akros Formation platform and basin carbonate facies and then by the "turbiditic flysch of the Ermioni Complex" (also the Cretaceous slope limestones of the Poros Formation would be the base of the Ermioni Complex).

Finally, Bortolotti et al. (2002a) (Figs. 3 and 4) propose a new and more complex unit succession, slightly modifying the scheme of Baumgartner (1985) and Photiades (1986; 1987; 1995), Dostal et al. (1991), Gaitanakis and Photiades (1991), Photiades and Skourtsis-Coroneou (1994), Capedri et al. (1996), Photiades and Keay (2000), Saccani et al., in press. According to this scheme the tectonic pile of Argolis can be subdivided into five units; from the bottom upwards they are:

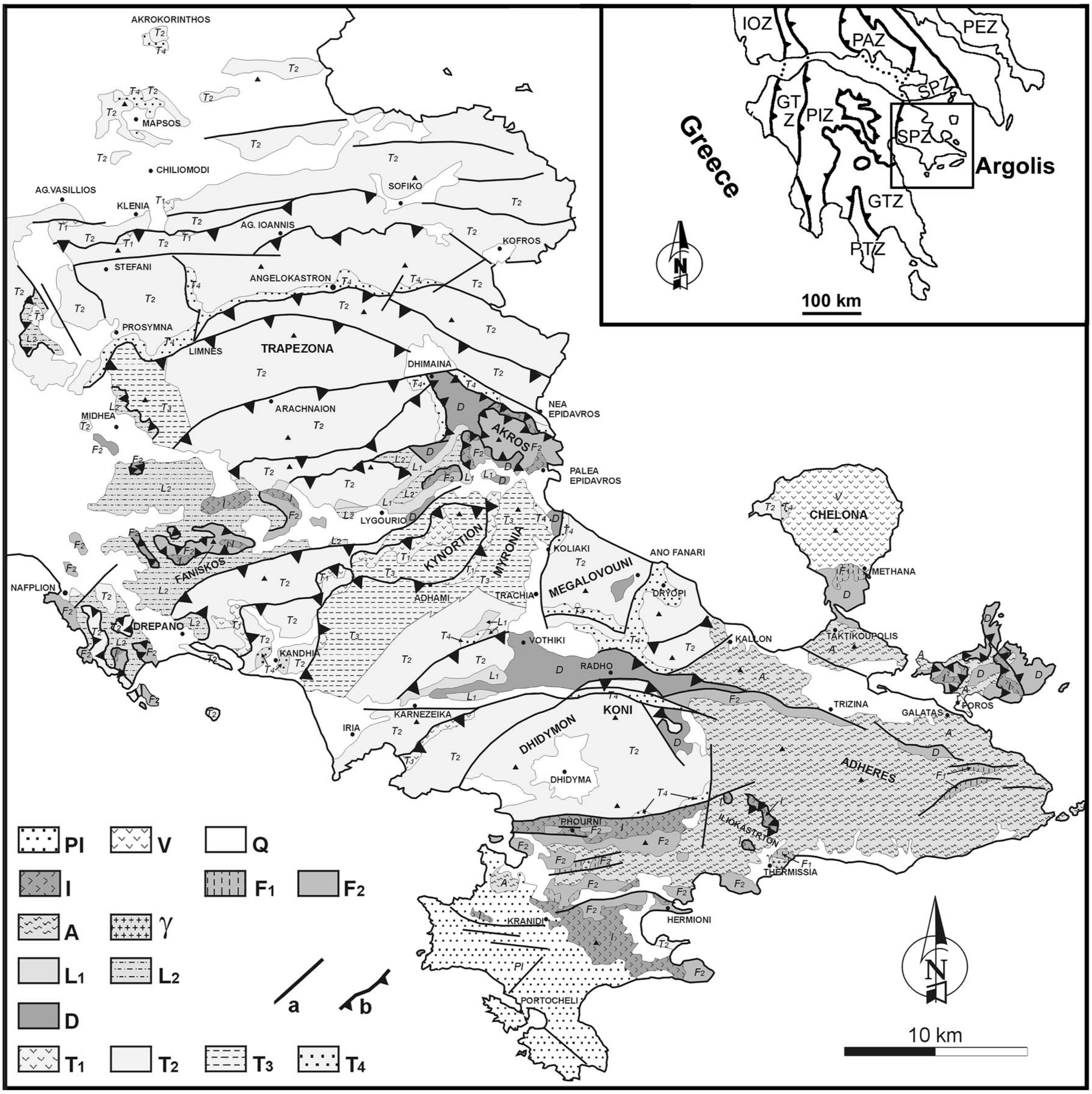

Fig. 1 - Schematic tectono-stratigraphic map of the Argolis Peninsula.

Trapezona Unit (T): T1- Lower Triassic andesitic lavas and tuffs; T2- Middle Triassic to Lower Jurassic neritic limestones; Lower-Middle Jurassic condensed "Ammonitico rosso"; Middle-Upper Jurassic red radiolarian-cherts; T3- Mid-upper Anisian red pelagic limestones with chert; Middle Triassic - Lower Jurassic cherty calciturbidites; T4- Ophiolite-derived sandstones, ophiolite-derived olistostromes and debris-flows, Kimmeridgian-Tithonian carbonate breccias

Dhimaina Ophiolitic Unit (D): D- Serpentinite thrust slices, Triassic basalts and radiolarian red-cherts.

Lighourio Meso-Autochthonous Unit (L): L1- Upper Albian-Cenomanian neritic limestones, Campanian-upper Maastrichtian pelagic limestones, Lower Eocene reef and pelagic limestones, Aptian to upper Maastrichtian cherty turbiditic limestones, Palaeocene red pelagic limestones. L2- "post-Ypresian" (post-Lower Eocene) flysch.

Adheres Mélange Unit (A): A- Arenaceous-shaly tectonosomes (tectonic mélange) including (and overlain by) tectonic slices of Middle-Upper Jurassic granodiorite megablocks (γ), uncomformably overlain by Kimmeridgian-Tithonian transgressive limestones, carbonate and arenaceous conglomerates and sandstones, ?Triassic basalts and Upper Triassic radiolarian red-cherts, Jurassic M.O.R. pillow basalts and radiolarian red-cherts, dolomites, quartz-sandstones and conglomerates "*incertae sedis*", Oxfordian-Portlandian neritic limestones, Barremian to Turonian neritic limestones, ?Vraconian to Cenomanian neritic limestone, Turonian/upper Maastrichtian to Palaeocene red pelagic limestones, Aptian to upper Maastrichtian platy and cherty limestones

Iliokastron Mélange Unit (I): I- sheared serpentinites, strictly associated with various blocks of volcanics, serpentinised harzburgites, dunites, boninitic rocks and metamorphites.

Faniskos Unit (F): F1- Kimmeridgian-Tithonian transgressive limestones; F2- Akros Limestones (middle-upper Cenomanian neritic limestones, middle Maastrichtian pelagic limestones, Palaeocene red pelagic limestones, "post-Ypresian" flysch.

Post-orogenic Units: Pl- Upper Miocene to Lower Pliocene marine deposits; V- lower Pleistocene to Holocene lavas and pyroclastics; Q- Quaternary deposits.
a- faults; b- thrusts.

Inset: IOZ- Ionian Zone; GTZ- Gavrovo-Tripolitsa Zone; PIZ- Pindos Zone; PAZ- Parnassos Zone; SPZ- Subpelagonian Zone; PEZ- Pelagonian Zone.

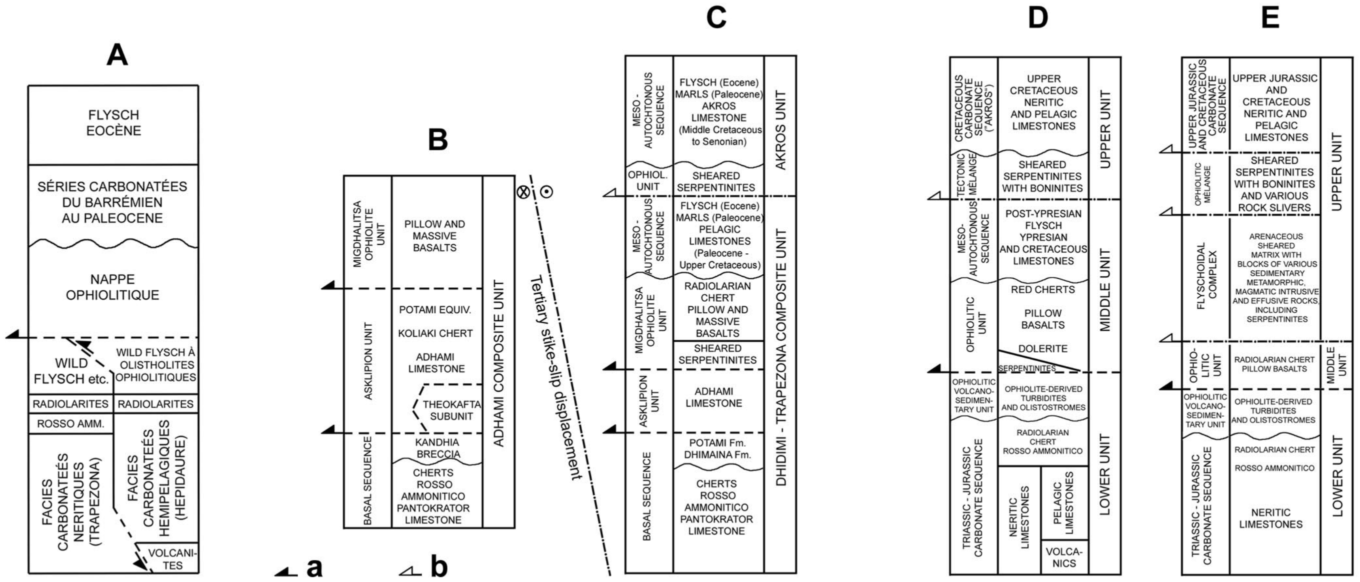

Fig. 2 - Tectono-stratigraphic logs according to previous authors: A- Vrielynck (1978, 1980, 1981-82). B- (North-western Argolis) and C- (South-eastern Argolis) Baumgartner (1985). D- (Northern and Central Argolis) and E- (Northern and Central Argolis) Photiades (1986; 1987; etc). a- Jurassic-Early Cretaceous thrust; b- Tertiary thrust.

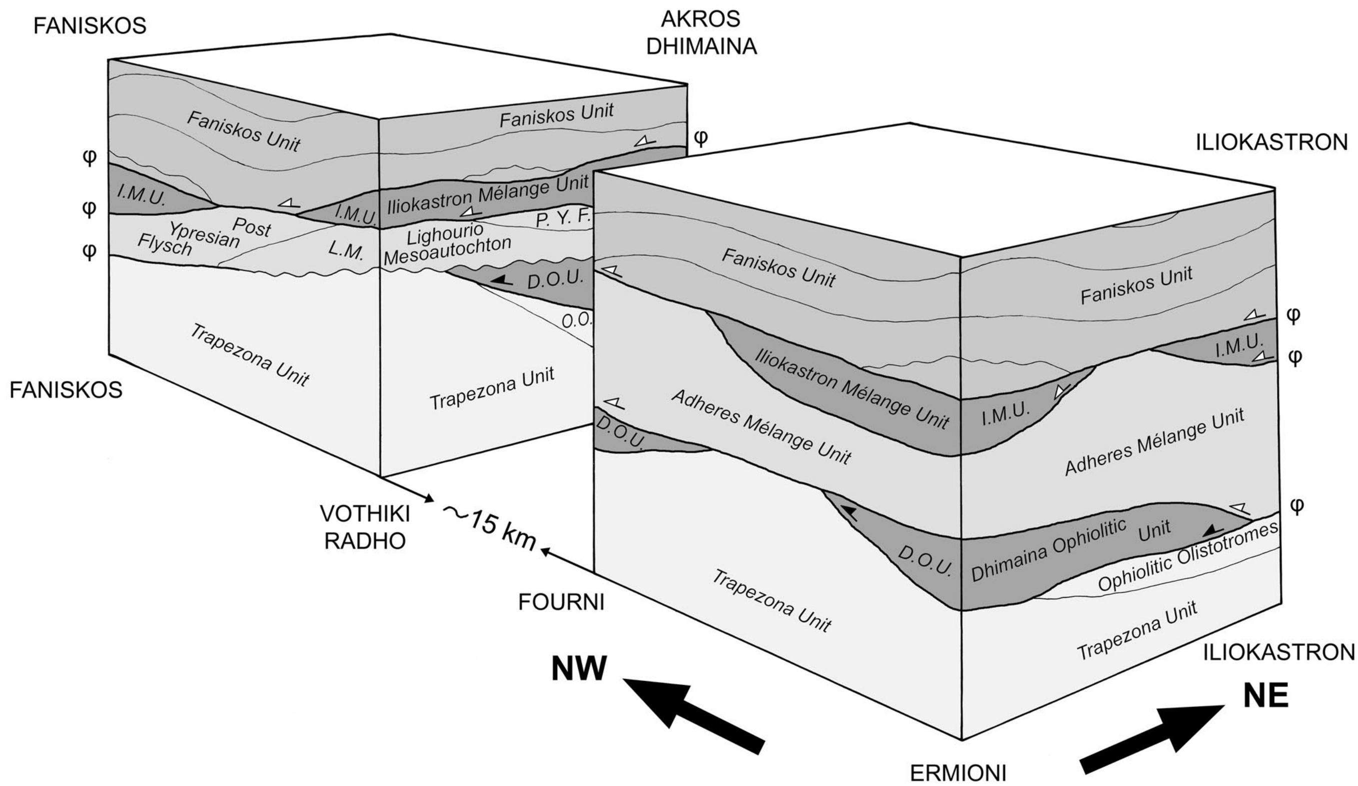

Fig. 3 - Block-diagrams of the relationships between the Argolis Tectonic Units. Black arrow- Jurassic thrust; white arrow- Tertiary thrust.

1- the Trapezona Unit (Early-Middle Triassic - Late Jurassic; Pelagonian continental margin, "TU");

2- the Dhimaina Ophiolitic Unit (Middle Triassic-Late Jurassic/Early Cretaceous oceanic realm, "DOU"; Early Cretaceous-Eocene "Mesautochthonous" cover "MC");

At the top of the Dhimaina Ophiolitic Unit two different tectonic units crop out in the northern and southern Argolis:

—Northern Argolis:

3- the Iliokastron Mélange Unit (Middle-Late Jurassic - Early Cretaceous, "IMU"), and upwards

4- the Faniskos Unit (Late Jurassic-Eocene, "FU");

—Southern Argolis:

3a- the Adheres Melange Unit (Cretaceous-Paleocene, "AMU");

4- the Faniskos Unit (Late Jurassic-Eocene, "FU");

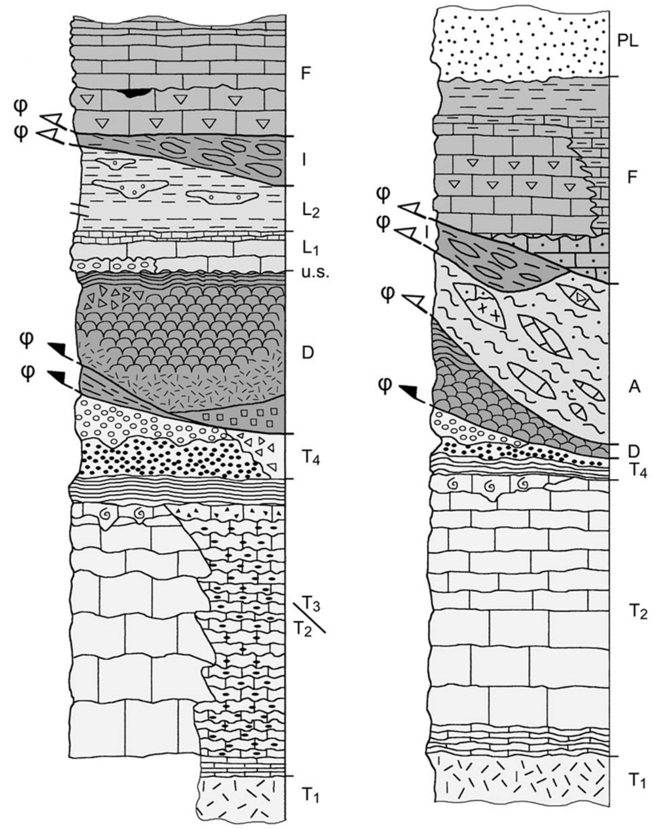

Fig. 4 - Tectono-stratigraphic logs of the Argolis Peninsula. A- northern Argolis; B- Southern Argolis. φ- thrust contacts: For other symbols see Fig. 1.

1- The Trapezona Unit
(“Basal Unit” of Baumgartner, 1985)

This Unit can be divided in some subunits piled up during the Upper Jurassic - Lower Cretaceous tectonic phase. The thrust vergence is towards W-SW. The main subunit, Koni Subunit (the “Basal Sequence” of Baumgartner, 1985) consists of: a- the Middle Triassic - Lower Jurassic shallow-water Pantokrator Limestones; b- Middle-Upper Jurassic deep-water limestones (“Ammonitico Rosso”) and radiolarian cherts. This succession is covered by c- ophiolitic sandstones, alternating with Upper Jurassic radiolarites (late Oxfordian-early Kimmeridgian in age, Baumgartner et al. 1980; 1995; Baumgartner, 1985), and d- with an unconformable contact, polymictic, mostly ophiolitic breccias and olistostromes (Potami Fm. and Kandhia Breccia) which contain fragments of arenites and rudites, cherts, chert-limestone sequences, pelagic and shallow water limestones, serpentinites, gabbros, basalts, boninitic and boninitic-type rocks (the latter group derived, according Dostal et al., 1991; Capedri et al., 1996, from an island arc).

This subunit is tectonically overlain by a coeval succession, mainly pelagic, the Asklipion Subunit (Baumgartner, 1985), which consists of a- Lower - Middle Triassic andesitic lavas and tuffs; b- Upper Triassic - Lower Jurassic shallow-water Pantokrator Limestones (laterally) substituted by prevailing cherty calciturbidites (Adhami Limestones, Middle Triassic - Liassic), c- Middle Jurassic Cherts and d- with an unconformable contact, ophiolitic sandstones, breccias and olistostromes, like in the underlying unit.

According to Baumgartner (1985), all the materials of the topmost levels of both units “represent slid masses or coherent olistostromes” derived from the topmost formations of the Trapezona Unit “emplaced synchronously with the ophiolitic material”.

Biostratigraphy

New biostratigraphic data are not provided, but some considerations regarding the age of the uppermost formations of this Unit (Aghios Nicolaos and Angelokastron Cherts, up to Potami Fm. and Kandhia Breccia), as pointed out by Baumgartner (1985) on the basis of radiolarian assemblages, can be stressed. The age of the top of the Trapezona Unit gives us the lower age limit for the thrust of the overlying Dhimaina Ophiolitic Unit. Radiolarians assemblages of late Oxfordian - early Kimmeridgian age have been found in the cherty formations (Baumgartner et al., 1980; Baumgartner, 1985, with the revision of 1995). The same age came from some siliceous marlstones in the Potami Fm., and Baumgartner (1985) suggests that these radiolarians are reworked from the underlying cherty formations. Thus, the late Oxfordian-early Kimmeridgian are the “maximum ages for the Potami formation”. The ages of the top formations of this Unit, have to be comprised between this age and the age of the base of the “Mesoautochthon”, which in some cases lies directly on the Pantokrator Limestones, i.e. between the late Oxfordian-early Kimmeridgian and the Cenomanian (a time interval of 50-60 million years!).

2- The Dhimaina Ophiolitic Unit (Baumgartner 1985)

This Unit includes the Migdalitsa Ophiolitic Complex and the overlying “Lygourio Mesoautochthon”.

a- *Migdalitsa Ophiolitic Complex.*

It consists of thrust sheets of MOR basalts (with scattered serpentinite slivers at the base), with thin intercalations of, and covered by radiolarian cherts. According to Saccani et al. (2002; in press) the Triassic basalts constitute two chemically distinct groups, which were never found together in the studied sequences The first group shows transitional-type MORB affinity, with a “moderate LREE enrichment, and incompatible element abundances very similar to those observed in present-day T-MORBs”; the second one has “characteristics typical of many normal-type MOR-basalts: that is, variable LREE depletion and flat N-MORB normalized patterns of incompatible element abundances”. The only Jurassic sample examined appears to be more differentiated (richer in Ti and P_2O_5 and Fe_{tot}). Normal MORB affinity for the basalts of this Unit were described also by Dostal et al. (1991).

Biostratigraphy

Thirteen sections of radiolarian cherts linked to the basalts, collected in the Migdalitsa Complex, all over the Argolis, yielded well preserved radiolarian assemblages (Plate 1), and gave three groups of ages: Middle and Late Triassic, Early Jurassic and Middle Jurassic. No stratigraphic relations have been until now found among the sections with different ages.

Middle - Late Triassic

The chert sections, found both as intercalations and as local geometrical top of the basalts, gave Middle and Late Triassic ages. In particular:

1- Moni Taxiarches. Along the road Lygourio - Dhimaina, south of Moni Taxiarches, in a metric tectonised intercalation, sample GR 51, 30 cm above the basalts gave a Late Triassic (early-late Norian) age for the presence of

Capnodoce anapetes, *Capnodoce serisa* and *Capnuchosphaera deweveri*.

2- Palea Epidavros. In an abandoned old mine, 1.3 km north of the main road Lygourio - Palea Epidavros, in a thin reversed succession, sample GR 49, 50 cm above the stratigraphic top of the basalts gave a Middle - Late Triassic age for the presence of *Pseudostylosphaera* sp. Sample GR 47, few metres above the same basalts gave a Middle - Late Triassic (late Ladinian - middle Carnian) age for the presence of *Pseudostylosphaera nazarovi*; sample GR 50, of uncertain stratigraphic position gave a Late Triassic (early Norian) age for the presence of *Capnuchosphaera constricta*, *Capnuchosphaera crassa*, *Capnuchosphaera lea* and *Capnuchosphaera triassica*.

3- Palea Epidavros. At the northern extremity of the haven, four samples (GR 67, 68, 69, 70) from a metric succession at the local top of the basalts, gave a Late Triassic (Rhaetian) age for the presence of *Livarella valida*.

4- Palea Epidavros. Along the road Palea Epidavros - Koliaki, sample GR 66, from a thin intercalation in the basalts, gave a Middle Triassic (Ladinian) age for the presence of *Baumgartneria* sp. cf. *B. retrospina*, *Oertlispongus inequispinosus*, *Pseudostylosphaera japonica*, *Triassocampe* sp., *Paroertlispongus* sp.

5- Vothiki. About 300 m south of a little quarry near the village, sample GR 181, from a chert intercalation in the basalts, some metres thick, gave a Late Triassic (late Carnian - middle Norian) age for the presence of *Xiphoteca longa*. Some metres upwards, on a secondary thrust, separating two basalt slivers, sample GR 184, collected in a thin chert intercalation, gave a Middle Triassic (Ladinian) age for the presence of *Baumgartneria* sp. cf. *B. retrospina*, *Cryptostephanidium cornigerum*, *Hozmadia reticulata*, *Oertlispongus inequispinosus*, *Paroertlispongus* sp.

6- Ermioni. South of the village, near Paloukia Hill, sample GR 221 collected in a small radiolarian cherts sliver tectonically imbricate in the serpentinites gave a Late Triassic (?Carnian) age for the presence of *Capnuchosphaera puncta*.

7 - Road Trachia-Kranidhi, near the pass to Radho. At the western side of the road, in a thin cherty intercalation, sample GR 246 gave a Late Triassic (late Carnian - late Norian) age for the presence of *Capnodoce* sp. It is noteworthy that at the eastern side of the same road, Baumgartner (1984; 1985) found a radiolarian assemblage of Late Jurassic age (see below, n. 2).

8 - Radho. West of this village, along the road to Tsoukalia, in a thin cherty tectonised intercalation, samples GR 297 and 298 gave a Late Triassic (late Carnian - late Norian) age for the presence of *Capnodoce* sp.

9 - Aghia Eleni. West of the village, along the road to Trachia, in a tectonised intercalation, sample GR 299 gave a Late Triassic (Carnian - Norian) age for the presence of *Capnuchosphaera* sp.

10 - Vothiki. 500 m north of the village, along the road to Karnezeika, in a very thin intercalation, sample GR 302 gave a Middle Triassic (late Ladinian) age for the presence of *Scudispongus rostratus rostratus*.

<u>*Early Jurassic*</u>

Early Jurassic have been found only in one section:

1- Vothiki. In a little quarry near the village, along the road Trachia - Karnezeika, in a thin tectonised cherty intercalation, sample GR 71 gave an Early Jurassic (?Sinemurian) age for the presence of *Bagotum* sp., *Pantanellium* sp. cf. *P. skedansense*, *Paronaella* sp. cf. *P. ravenensis*, *Paronaella jamesi*, *Paronaella* sp. cf. *P. corpulenta*, *Podocapsa* sp. cf. *P. abreojosensis*.

Early Jurassic (Sinemurian) ages were also found near Angelokastron (Chiari et al., 2003), in some manganiferous chert nodules (Photiades et al. 1995; Perseil et al. 1998) included in a very tectonised sliver of Bathonian-Callovian chert-shales on top of the Trapezona Unit. This sliver may belong to the upper levels of the Migdalitsa Complex (see Capedri et al., 1996) but it could also be a portion of the breccias and olistoliths at the top of the Trapezona U. In fact, manganiferous nodules, are never found in the Migdalitsa Complex, whereas they are found near Dhimaina at the top of the Trapezona Unit, associated to the boninitic fragments.

<u>*Middle Jurassic*</u>

Two sections near the geometrical top of the complex, plus a section collected by Baumgartner (1984; 1985) gave Middle Jurassic ages, they are:

1 -Moni Taxiarches, along the road Lygourio- Nea Epidavros. Sample GR 256 collected in the upper part of a cherty level, with a tectonised basal contact to the basalt, gave a late Bajocian to latest Bajocian-early Bathonian age for the presence of *Striatojaponicapsa plicarum* s.l., *Unuma latusicostata*, *Unuma* sp. A.

2- Along the road Tsoukalia - Radho, a little beyond the pass, the sample GR 295a, collected in a thin tectonised cherty intercalation gave a Middle Jurassic (latest Bajocian-early Bathonian to middle Callovian-early Oxfordian) age for the presence of *Theocapsomma cordis*.

On the eastern side of the road Trachia-Kranidhi, near the pass to Radho, Baumgartner (1984; 1985), in a cherty outcrop linked to the basalts, now covered by the asphalt (see above), found a radiolarian assemblage which gave a late Bajocian - early Bathonian age (according to the revision of Baumgartner, 1995 of the age given by the same author in 1984 and 1985)

b- *Lygourio Mesoautochthon*

Locally, (e.g. near Lygourio) Cretaceous limestones uncomformably cover the pillow lavas (or directly the Pantokrator Limestones); they are considered remnants of a meso-autochthonous sedimentary succession, including, from bottom to top, Cenomanian neritic limestones, breccias rich in basaltic and cherty clasts cemented by Campanian - Maastrichtian hemipelagic limestones, Paleocene - Lower-Middle Eocene pelagic to reefal limestones and, at the top, the flysch.

Biostratigraphy

We were particularly interested in analysing the age of the flysch, on which we collected new data.

Along the secondary road Palea Epidavros - Epano Epidavros, near Aghios Andreas, three samples (GR 304, GR 305 and GR 306) of reddish marls at the very base of the “Flysch” gave calcareous nannofossil associations of Late Paleocene age, for the presence of *Fasciculithus tympaniformis, F. richardii, F. involutus and F. tonii* (courtesy of Viviana Reale).

A marly sample (GR 307) collected at the beginning of the road to Kandhia, at the crossroad with the road Nafplio-Lygourio in the Flysch, at a not determinable stratigraphic position, gave a dubitative Late Paleocene age for the presence of ?*Fasciculithus tympaniformis* (courtesy of Viviana Reale).

These ages are in agreement with those by Bachmann and Risch (1979).

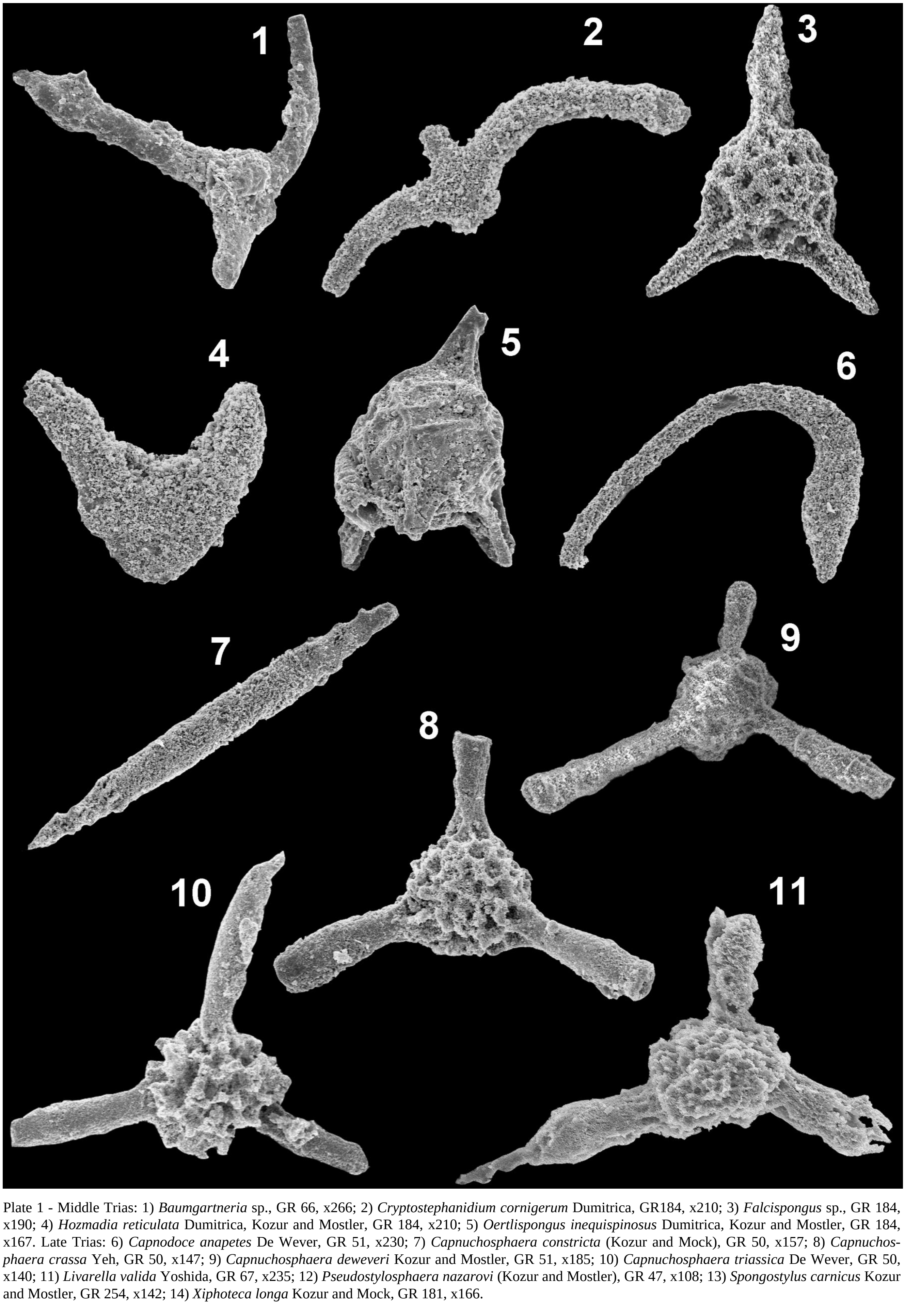

Plate 1 - Middle Trias: 1) *Baumgartneria* sp., GR 66, x266; 2) *Cryptostephanidium cornigerum* Dumitrica, GR184, x210; 3) *Falcispongus* sp., GR 184, x190; 4) *Hozmadia reticulata* Dumitrica, Kozur and Mostler, GR 184, x210; 5) *Oertlispongus inequispinosus* Dumitrica, Kozur and Mostler, GR 184, x167. Late Trias: 6) *Capnodoce anapetes* De Wever, GR 51, x230; 7) *Capnuchosphaera constricta* (Kozur and Mock), GR 50, x157; 8) *Capnuchosphaera crassa* Yeh, GR 50, x147; 9) *Capnuchosphaera deweveri* Kozur and Mostler, GR 51, x185; 10) *Capnuchosphaera triassica* De Wever, GR 50, x140; 11) *Livarella valida* Yoshida, GR 67, x235; 12) *Pseudostylosphaera nazarovi* (Kozur and Mostler), GR 47, x108; 13) *Spongostylus carnicus* Kozur and Mostler, GR 254, x142; 14) *Xiphoteca longa* Kozur and Mock, GR 181, x166.

3- Iliokastron Mélange Unit

This unit corresponds to the "Sheared Serpentinites" of Baumgartner (1985). It consists of brecciated and foliated blocks of harzburgites within a matrix of serpentinised harzburgite. It also includes blocks of dunites, basalts, coarse- and fine-grained boninitic rocks, cherts and limestones derived from the underlying units, metamorphic rocks (marble, metagraywacke, micaschist and amphibolite) (Gaitanakis and Photiades, 1993; Photiades and Economou 1993). The presence of boninitic rocks indicates that these clasts at least partly derive from a supra-subduction environment (Dostal et al. 1991)

3a- The Adheres Mélange Unit

We proposed (Bortolotti et al., 2002a) to call "Adheres Mélange Unit" the stack of tectonic slices and olistoliths of heterogeneous lithologies (the "Ermioni Complex" of Robertson et al., 1987 and Clift, 1996) which overlie the Dhimaina Ophiolitic Unit. The main lithology is a very disrupted turbidite succession made up of alternating silts, sandstones and marls, affected by very strong pervasive deformations, which constitutes the matrix of a tectonic mélange. This mélange tectonically encloses large blocks of variable composition (Triassic volcanites, radiolarites, Jurassic and Cretaceous limestones, Jurassic granodiorites (170-144 Ma, Photiades and Keay, 2000), pyroclastic rocks (personal observation), andesites (Sideris et al. 1987), Triassic dolomites and limestones (Aranitis, 1963 and references therein), quartzitic sandstones, serpentinites, basalts (MORB and IAT, according to Clift and Robertson, 1989).

Biostratigraphy

The age of the flysch is not well determined due to scarcity of fossils, and pervasive deformation. The first authors which tried to date accurately the flysch (Christodoulou, 1972; Bachmann and Risch, 1979) found the Paleogene (for the presence of *Globorotalia* sp. and *Discocyclina* sp.) and the Paleocene - Eocene (for the presence of macroforams Rotalids and Lithotamns). However, in Fig 12 of Bachmann and Risch (1979), the beginning of the flysch deposition in the eastern part of the Adheres Peninsula appears to be Late Cretaceous, on the basis of the Maastrichtian age found in the calcilutites immediately underlying the flysch in Poros Island.

According to Vrielynck (1981-82) the flysch appears to be Eocenic ("n'est pas daté précisement" but it is "vraisemblablement éocène").

A Maastrichtian - Paleogene age is proposed by Suesskoch et al., (1984) for the presence of *Globotruncana* sp., *Globorotalia* sp. and Nummulitidae. Clift (1996) agrees with the data of Bachmann and Risch (1979).

We studied four samples (GR290a, b, c, d) collected along the road Ermioni - Iliokastron. In a slice of silty marlstones from the very deformed siliciclastic turbidite succession which constitutes the mélange matrix, a calcareous nannofossil associations gave a Late Cretaceous (probably Campanian) age for the presence of *Arkhangelskiella cymbiformis* and *Aspidulithus parcus parcus* (courtesy of Viviana Reale).

Regarding the age of the basalt blocks, Clift and Robertson (1989) assert that the "field relations" of these basalts are "quite distinct" from those of the basalts of the Migdalitsa Complex because they are not linked to radiolarites but are covered by Campanian - Maastrichtian pelagic limestones. They conclude that these basalts are the remnants of a Cretaceous Neo-Tethyan ocean, perhaps a non-sutured portion of the "Mesozoic Neo-Tethys". This statement is not correct (see also Photiades and Skourtsis-Coroneou, 1994 and Photiades and Keay, 2000), in fact the basalt blocks are sometimes associated to chert levels, and they are Late Jurassic in age, like in the other units. In fact, a chert sample (GR 292) collected in a small mine, just above the basalts near Baroutospilia (road Iliokastro-Thermissia) gave a radiolarian assemblage attributable to the Middle - Late Jurassic (late Bajocian to late Kimmeridgian-early Tithonian) for the presence of *Emiluvia orea* s.l. The Upper Cretaceous pelagic limestones cited by Clift and Robertson (1989) are evidently the "Mesoautochthonous" cover on top of the basalt blocks.

4- Faniskos Unit

It corresponds to the Faniskos Unit p.p. of Baumgartner (1985) It comprises many slices of carbonate rocks of variable sizes and different environments (from shallow water to pelagic), ranging from Kimmeridgian to Maastrichtian (Dercourt, 1964; Charvet et al. 1976; Décrouez 1977; Vrielynck 1978b; Décrouez et al., 1983; Photiades 1987; Philip et al. 1989; Clift and Robertson, 1990b; Gaitanakis and Photiades 1993).

The slices are composed of: i- rare thin slivers of shallow-water limestone of Kimmeridgian - Portlandian age; ii- frequent thick shallow-water limestones ranging from Barremian and/or Aptian to Turonian, grading upwards to pink hemipelagic cherty limestones of Campanian-Maastrichtian age and, finally, to an Eocenic flysch; iii- a carbonate succession of shallow-water limestones ranging from middle Cenomanian to Turonian, overlain by hemipelagic cherty limestones of Campanian - Maastrichtian age; iv- pelagic detrital and/or cherty limestones of Aptian - Maastrichtian age, covered by an Eocenic flysch.

DISCUSSION

Before trying to propose a paleogeographic and geodynamic scheme we need to address the following problems:

1-The stratigraphic correlations and paleogeographic positions of the Trapezona Unit sequences;

2- The paleogeographic setting of the ophiolite succession,

3- The correspondence between the flysch of the Lygourio Mesoautochthon, the Faniskos Unit and the Adheres Mélange,

4- The tectonics of the Argolis Units and the age of the main tectonic phases.

The Trapezona Unit sequences and their position in the paleogeography of the Hellenic continental margin

The type section of the Upper Triassic - Lower Jurassic Pantokrator Limestone is located in the Korfu Island (Ionian Zone). The so called Pantokrator Fm. of Argolis and Hydra Island (just in front of Southern Argolis) is coeval and has similar shallow water sedimentological features and similar drowning events of the carbonate platform (Angiolini et al., 1992; Kube et al., 1998). The same features occur also in the coeval platform limestones of Epirus, as well as in other "Zones" of Hellenides and Albanides: the Hajmeli Subzone, which remnants are the large tectonic slabs included in the Rubik Complex and in the Simoni Mélange (Mirdita Zone, Kodra et al., 2000), the Parnassus Zone (Carras and Tselepidis, 2000), the Albanian Alps (Shehu et al., 1990), the Gavrovo Zone (Fleury, 1980; Aubouin et al., 1970) and the Pelagonian Zone of Continental Greece (e.g. Attica, Beotia, Locris, Euboea, Eastern Othrys and Pelion areas) (Ferrière, 1982 and references therein; Clément, 1983 and references therein).

The Triassic - Lower Jurassic Adhami Limestone, that has many analogies with the deep water facies of the Hydra Island (Kube et al., 1998) to the south, was deposited in a deep basin and, according to most authors, east of the Pantokrator platform. The Adhami Limestones overlie stratigraphically the Anisian Volcano-Sedimentary Formation. The presence of reworked material of Paleozoic age in this formation (Gaitanakis and Photiades, 1991) lead to suppose that this volcanism is linked with important extensional tectonics, even if not detectable in the local geology. In Argolis and in the nearby Hydra Island the volcanites are always overlain by pelagic limestones and only later (Carnian) in some places a transition to shallow water "Pantocrator Limestones" occurs. Thus, it is possible to suppose that during the Anisian a wide pelagic basin was present in the Argolis area.

According to some authors (Vrielynck, 1982; Baumgartner, 1985; Robertson et al., 1987) the pelagic deposits were sedimented on a deep scarp connecting the continent with an ocean basin. This hypothesis is tenable for the Hydra I., but in Central Argolis the Adhami Formation seems to be sited between two carbonate platforms, in an intracontinental environment (see Bachmann and Risch, 1979 and Clift and Robertson, 1990a). Also the Maliac-Othrys succession (Middle-Upper Triassic volcanic rocks overlain by deep-water limestones) is considered as derived from the eastern flank of the Pelagonian margin platform (Ferrière, 1985; Thiébault et al., 1994).

Similar deep sea facies occur also in the intra-platform basins, like the Pindos Zone (Aubouin et al., 1970; Fleury, 1980; Jacobshagen, 1986), and in its northwards prosecution, the Krasta - Cukali Zone of Albania (Shehu et al., 1990; Kodra et al., 2000; Robertson and Shallo, 2000, with bibl.). However, it is worth noting that: a- the Pindos Zone is bounded to the east and west respectively by the Pelagonian and the Gavrovo - Tripolitza platforms; b- the Pindos detrital successions never show ophiolitic material from the Triassic up to the Turonian (Wagreich et al., 1996; Neumann and Zacher, 1998), which would be a clear sign of the closure of a nearby oceanic basin. Likewise, in the Vardoussia Mountains between the Parnassos and Pindos zones, a detrital carbonate sequence continuous from Ladinian to Eocene, lacks any trace of ophiolite detritus (Ardaens, 1978).

Also the Jurassic pelagic succession: Middle Liassic-Middle Jurassic cherty limestones and/or "Ammonitico Rosso" with coarse-grained, gravity flow deposits, Middle-Upper Jurassic Radiolarian Cherts, is not typical only of the Argolis, but is present in some other basinal successions of the Hellenides and Albanides: Hydra Island (Angiolini, 1992; Kube et al., 1998), Hajmeli Subzone (in the Mirdita Zone, Kodra et al., 2000), the Pindos Zone and its prosecution Cukali Zone (Shehu et al., 1990; Kodra et al., 2000; Robertson and Shallo, 2000), Ionian Zone (Bernoulli and Renz, 1970; Karakitsios and Tsaila-Monopolis, 1988; Danelian, 1995), even if radiolarites occur only in the more subsiding areas and are generally substituted by shallow water cherty limestones.

In conclusion, the Triassic-Jurassic successions of the Trapezona Unit (of Pelagonian - Sub-Pelagonian pertinence) show many similarities with coeval successions pertaining to the internal, up to the more external Ionian Zone. During the Jurassic also the drowning of the platform occurred with the same pattern. Afterwards, only in the eastern, more internal zones the thrusting of the ophiolitic nappes, preceded by ophiolitic clastic deposits, interrupted (between Late Jurassic and Early Cretaceous times) the pelagic deposition on the continental margin. Elsewhere, the pelagic deposition continued until the Tertiary. According to the above exposed data, it seems possible that the arrival of the ophiolitic debris prograded from east to west, i.e. it was earlier in Argolis and later in the Pindos.

This general situation demonstrates that the Pelagonian - Subpelagonian Zone did never act as a micro-continent from the Late Triassic up to the Eocene. On the contrary, the Pelagonian carbonate platform was a portion of the platforms and related intra-platform basins of the Peri-Adriatic belt (presently, from west to east :1- Ionian Basin, 2- Gavrovo Platform, 3- Pindos Basin, 4- Parnassos Platform, Beotian Basin (Clément, 1983; Thiébault et al., 1994), Trapezona Platform, 5- Asklipion Scarp), and no space was available in between for an ocean basin.

The ophiolites and their paleogeographic significance

The ophiolites of the Argolis have twofold age and geodynamic significance: in fact both MORB and Suprasubduction (boninitic rocks and or IAT) rocks are present, but in different tectono-stratigraphic units.

Fragments of boninitic rocks and/or IAT basalts occur in the sedimentary Potami Mélange (Photiades, 1989; Photiades et al., 1989; Dostal et al., 1991; Capedri et al., 1996) at the top of the Trapezona Unit, in the Iliokastron Mélange Unit (Dostal et al., 1991; Gaitanakis and Photiades, 1993; Photiades and Economou, 1993) and in the Adheres Mélange Unit (Clift and Robertson, 1989), but have never been found in the Migdalitsa Ophiolitic Complex (as erroneously cited from Photiades, 1989, by Clift and Dixon, 1998), which contains only MOR basalts (Photiades, 1989; Photiades et al., 1989; Dostal et al., 1991; N- and T-MORB, according Saccani et al., 2002; 2003).

As previously pointed out, no chronological data are to date available for the boninitic rocks and IAT basalts, but they are both concordantly attributed to the Middle-Late Jurassic, as it is documented in the Mirdita zone (Albania, Bortolotti et al., 1996; 2002b) and in several areas of Greece (Pindos, Vourinos, Koziakas, Othrys; Beccaluva et al., 1984; Kostopoulos, 1988; Bortolotti et al., 2001a; Chiari, 2001; Saccani and Photiades, 2001; Saccani et al., 2003). Instead, the MOR basalts of the Migdalitsa U. are mainly Triassic, and subordinately also Early and Middle-Late Jurassic in age.

According to the commonly accepted geodynamic theories, MORB rocks are the results of ocean spreading whereas the IAT and boninitic rocks are the results of subduction processes. Accordingly, the problem shifts to the age and location of the ocean/s and to the dip-direction of the subduction zone (or zones) and of the related supra-subduction ocean crust.

Neither the Migdalitsa Complex basalts, nor the IAT and boninitic rocks show any orogenic metamorphism. This fact suggests a position of both these units above the embryonic accretionary prism of the Hellenic orogenic belt, (a supra-subduction zone setting) until their obduction onto the continental margin. It is possible to hypothesise for the Argolis region a paleogeodynamic situation similar to that described by Bortolotti et al., (1996; 2002b) for Albania (Mirdita). Here moreover, basaltic flows of both MOR and IAT type are locally intercalated into each other, suggesting an association of both MORB and the IAT spreading centres in a suprasubduction environment.

The "suprasubduction" (IAT) characteristics of most of the Middle Jurassic ophiolites from Argolis to central Albania, led us to suppose that they are the product of subduction of an older MORB type oceanic lithosphere, now almost completely subducted.

The strong cluster of Middle-Late Triassic ages in the MOR basalts of the Migdalitsa Ophiolitic Complex provides a tessera of the mosaic of Triassic basic rocks found along the Dinaric-Hellenic orogenic belt. Many authors (e.g., Kozur, 1991; Halamić and Goričan, 1995; Danelian and Robertson, 2001; Babić et al., 2002) interpreted the basic rocks scattered all along this belt as the evidence of a Triassic ocean crust, without presenting geochemical data supporting their MOR affinity. In fact, the same ages have been found in alkaline basalts, both included as blocks in mélanges and intercalated in continental margin successions, along the orogenic belt (see Pe-Piper, 1998), as well as along the Alpine-Apenninic chain (see Assereto and Casati, 1965; Channell et al., 1979, cum bibl.; Passeri, 1985; etc.). In the latter chain, these Triassic basalts are interpreted as products of intra-continental rifting, not necessarily evolving to ocean spreading.

Triassic oceans in different locations have been proposed by several authors, as follows:

a- The Meliata Ocean (Kozur and Réti, 1986; Kozur, 1991; Stampfli et al., 1991; Pamić et al., 2002). Stampfli and Mosar (1999) located this ocean between Pelagonia and Rhodope but not coincident with the future Vardar;

b- A paleo-Pindos (Robertson and Dixon, 1984,) or a paleo Pindos-Vardarian ocean (Danelian and Robertson, 2001)

c- A paleo-Vardar ocean (Şengör et al., 1984)

d- A paleo-Pindos ocean as south-western extension of the Paleo-Tethys (Dercourt et al., 1993).

Danelian and Robertson (2001), on the basis of radiolarite biostratigraphy reconstruct in the Euboea Island a continuous Middle Triassic- Middle Jurassic cherty sequence above the T-MOR basalts. They attribute these basalts to a vague "Neotethyan Ocean". However, the sampled outcrop does not show any stratigraphic continuity, because our detailed field observations showed that the outcrop exposes dismembered slices that are tectonically juxtaposed in the Euboea Pagondas Mélange.

Even if a sequence as proposed by Danelian and Robertson (2001) does not exist in Euboea, it is possible to reconstruct a continuous oceanic evolution in the Argolis Peninsula from the presence in the Migdalitsa Subunit of basalt-cherts associations scattered in time: most of them are Middle (Ladinian) - Late Triassic, but rare scattered records of Early and Middle Jurassic associations are also present. But here too without a direct link between Triassic and Jurassic rocks. Therefore, the oceanisation could have been continuous, at least in the southern section of the Dinaric-Hellenic realm, from Middle Triassic to Middle Jurassic as hypothesised also by Clift and Dixon (1998).

The Middle (Ladinian) - Upper Triassic Migdalitsa basalt (DOU) flows follow shortly after the Anisian volcano-sedimentary events of the rifting stage present at the base of the Trapezona Unit. These Triassic alkaline-acidic rocks are widespread all over the Pelagonian realm, and occur as far as the Dinarides and Southern Alps.

The presence of Early Jurassic ages in some radiolarite samples of the MOC, can represent sporadic records of the missing link between the Triassic and Middle-Late Jurassic MOR basalts, which form the main portion of the ophiolitic basalts of the Dinaric-Hellenic realm.

No biostratigraphic data are up to date available for the age of boninitic rocks and IAT related rocks which are present as fragments in the breccias at the top of Pantokrator (Trapezona unit) and in the Adheres and Iliokastron Mélanges. Up to now in the Albanides (Bortolotti et al, 1996; 2002b) and Hellenides (Danelian and Robertson, 2001; etc.) the boninitic rocks and IAT basalts are considered to be linked with Middle Jurassic radiolarites. Hence it is likely that also in the Argolis these rocks have the same age.

The flysches of the Lygourio Mesoautochthon, Faniskos Unit and Adheres Mélange

The Adheres Mélange, the Lygourio Mesoautochthon and the Faniskos Units include Cretaceous/ Eocene or Paleocene/Eocene flysches; in the two latter units the flysch is underlain by Cretaceous calcareous pelagites.

The stratigraphic relationships between the Dhimaina Ophiolitic Unit and the Lygourio Mesoautochthon are well documented near Anastassopouleika (North of Lygourio along the road to Athens) where the unconformable relationships between the Migdalitsa ophiolites and Cretaceous limestones occurs through ophiolitic breccias and sandstones that, upwards, are intercalated with Upper Cretaceous limestones, in turn grading to a Flysch. Nearby, (Aghios Andrea church), in a reverse stratigraphic section, the base of the flysch is Late Paleocene in age (see above).

The Faniskos Unit is made up of Cretaceous shallow- to deep-water limestones (Akros Formation) that, locally (especially in South Argolis), cover uncomformably the Jurassic shallow water limestones. This succession grades upwards into a Paleocene-Eocene Flysch.

The Lygourio Mesoautochthon and its flysch end abruptly against the Karnezeika - Trizina tectonic line (see later), and southwards the Adheres Mélange appears, made mainly of a not organised and intensively deformed arenaceous flysch which includes blocks of several lithologies. We have no evidence of the stratigraphic base of the Adheres Mélange. Our data (see above) attribute to a portion of the turbiditic matrix a Late Cretaceous age, but the abundant data from Bachmann and Risch (1979) and Suesskoch et al., (1984) document also the occurrence of Eocene fossils.

Two important differences between the flysch of the Adheres Mélange Unit and the others are: its anchizone metamorphic signature (Bachmann and Risch, 1979; Suesskoch et al., 1984; Clift and Robertson, 1989) and the presence inside of several slivers and blocks of various lithologies. According to Clift and Robertson (1989) these characteristics are considered consistent with the evolution in a subduction-accretion environment during the consumption of a supposed Upper Cretaceous - Lower Tertiary Neo-Tethys ocean. According to our interpretation, no Cretaceous - Tertiary ocean existed (see above) and the Adheres Mélange developed during the Eocene ensialic tectonic phases.

Despite the lack of a continuity between these flysches, they can be interpreted as the Cretaceous-Eocene "mesoautochthonous" cover of the tectonic pile comprising the Trapezona - Dhimaina -Faniskos Units (Fig. 3).

The pelagic deposition evolved to flysch in different times in different places, becoming younger westwards; in fact, the beginning of the detrital sedimentation is Late Cretaceous in the Adheres Unit, Paleocene up to ?post-Ypresian in the Lygourio Mesoautochthon. The flysch sedimentation ended everywhere within the Middle - Late Eocene interval.

The paleogeographic position of these “mesoautochthonous units” will be discussed below.

Tectonics and the age of tectonic phases

The field data on the tectonics and the age of the tectonic phases of the Argolis have not been peculiar purposes of our research. The tectonic interpretation that we present here is fundamentally the result of past field observations made by one of us (A.Ph., unpublished data).

The present tectonic frame of the Argolis Peninsula is dominated by E-W trending alignments. The more important ones (shown in the map of Fig. 1) are from north to south: Prosinna - Angelokastron Line; Dhrepanon - Palea Epidavros Line; Iria -Palea Epidavros Line; the Karnezeika - Trizina Line; Phourni - Iliokastron Line; Ermioni - Kranidhi Line and, finally a supposed Hydra Strait Line.

According to Vrielynck (1978; 1982) some of these lines are thrusts or reversed faults except for the Karnezeika - Trizina normal fault.

According to Baumgartner (1985) some of these lines (Dhrepanon - Palea Epidavros, Iria - Koliaki, Karnezeika - Trizina) are strike-slip faults.

Clift and Robertson (1990) agree with Vrielynck (1981-82) interpretation.

According to our interpretation, most of these main alignments must be considered as north verging thrusts or reverse faults of Eocene or post-Eocene age, crosscut in some places by more recent (neotectonic) normal faults (Fig. 1), except for the Karnezeika - Trizina line, which is a normal fault and, perhaps, the Iria-Koliaki one which, according to Clift and Robertson (1990a), could be only a synclinal axis.

The comparison between the magnetic data from Hydra Island (Muttoni et al., 1994; 1997) and still unpublished paleomagnetic data from the Argolis Peninsula (Aiello et al., 2003, submitted), show that the Hydra Triassic succession rotated clockwise (100°) during the Mesozoic-Early Tertiary with respect to the same succession of the Argolis continental margin. This rotation is coherent with a (dextral?) strike-slip movement along a Hydra Strait wrench line dividing the Trapezona Unit of the two sides of the strait.

Angiolini et al. (1992) correlate the basinal Triassic succession of Hydra Island with the Adhami Limestone of the Asklipion Subunit of the Argolis Peninsula. If we rotate the Hydra Island of 100° anticlockwise the Asklipion like Subunit of Hydra was originally located eastwards with respect to the Pantokrator platform, like in Argolis.

Other significant structures of the Argolis are the zigzag line going from Vivari to Epidavros, along which the Asklipion Subunit is thrust onto the Koni Subunit succession, and the structures (especially in the Dhimaina and Vothiki areas) along which the Dhimaina Ophiolitic Unit is thrust onto the Trapezona Unit.

The relationships among the tectonic units of Argolis Peninsula are reported in Fig 3. This simplified scheme reports only the thrusts implicating different tectonic units: they each consist of at least two Mesozoic and three Tertiary thrusting events.

The Mesozoic thrusts:

a)- The Vivari - Epidavros thrust along which the Asklipion Subunit was thrust onto the Koni Subunit (Pantokrator succession). This thrust occurred in a time span comprised between Late Jurassic and Cenomanian, and it was reactivated during the Eocene.

b)- The thrusts along which the Dhimaina Ophiolitic Unit was thrust onto the Trapezona Unit which is topped by polymictic, mostly ophiolitic breccias and olistostromes. No sediments younger than Late Jurassic (late Oxfordian - early Kimmeridgian) are found in the footwall. The Lygourio Mesoautochthon covers here and there both the units. Therefore, this basal thrust has to be attributed to the Late Jurassic - Early Cretaceous (Vrielynck, 1978; 1982; Photiades, 1986; 1987; Photiades and Skourtsis-Coroneou, 1994; Photiades and Karfakis, 1998).

An erosive stage followed this tectonic phase; later on, in the early Late Cretaceous a generalised pelagic carbonate sedimentation began.

The Tertiary thrusts:

They occurred in at least three stages: a- the Adheres Mélange Unit was thrust onto the Trapezona Unit with the overlying Dhimaina Ophiolitic Unit; b- the Iliokastron Mélange was thrust onto the former three units; c- the Faniskos Unit was thrust onto all the preceding units.

Sediments younger than the Ypresian were never found in the mesoautochthonous successions s.l.; hence, this could be approximately the age of these thrusts.

In particular, the three tectonic phases show the following characteristics

1- The post-Tithonian phase is characterised by overturned NW-trending folds, low angle shear planes and internal thrusts of similar direction, dipping towards the NE and with a constant southwestwards vergence.

2- An extensional phase with a NE-SW extensional stress-field affected the above mentioned units. It caused a successive transgression with hiatuses in sedimentation (from SE to NW) and then led to deposition of the mesoautochthonous carbonate succession (from Albian to Ypresian in age), followed by the post-Ypresian flysch.

3- The post-flysch Eocene tectonic phase, of significant geodynamic importance (connected also to the formation of the Cycladic blueschist belt), probably caused the formation of the Adheres Mélange, which was overridden by the Faniskos Unit and, finally, produced the reactivation of the (out of sequence?) thrust between the Trapezona and Migdalitsa Units. This compressional phase which reactivated the old NE-SW lines, caused low angle internal shearing and thrusting with compressional movement towards the northwest.

Two extensional phases followed, from Miocene-Pliocene to recent times; they caused the formation of the several graben structures of Argolis Peninsula.

CONCLUSIONS

The main constraints

The above discussion and our new data allow us to propose a scheme for the tectono-stratigraphic evolution of the Argolis Peninsula in the wider contest of the Hellenides geodynamics (Fig. 5).

The most important constraints useful for reconstructing this evolution are:

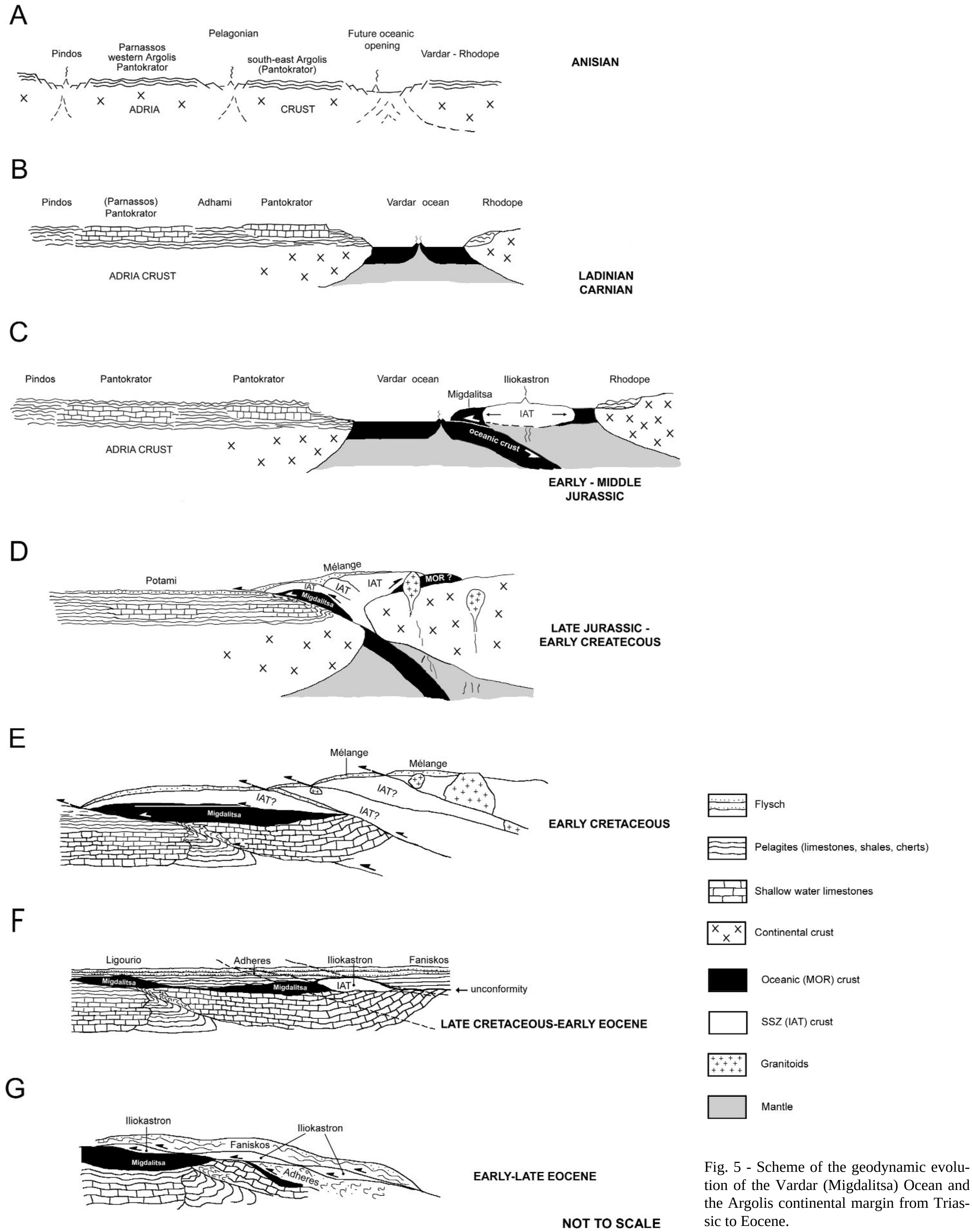

Fig. 5 - Scheme of the geodynamic evolution of the Vardar (Migdalitsa) Ocean and the Argolis continental margin from Triassic to Eocene.

1- An oceanic basin (Migdalitsa Ophiolitic Complex) existed since the Carnian.

2- The boninitic and IAT rocks testify that subduction occurred, probably during Middle Jurassic, for analogy with similar rocks all along the Hellenic - Dinaric belt.

3- The distribution of ophiolites in the tectonic units of the Argolis Peninsula, the regional correlations and paleogeographic considerations lead to place a single ocean basin eastwards (in present day geography) of the Pelagonia (Trapezona Unit) continental margin, in the Vardar Zone.

4- The whole Hellenic area suffered both clockwise (southern Hellenides) and anti-clockwise (northern Hellenides) rotations of significant extent; this makes the paleogeographic restorations difficult. e.g., the Triassic lineaments of the Argolis have to be imagined as rotated anticlockwise of more than 100° (Morris, 1995; Aiello et al., in press).

5- Among the three hypotheses put forward in a previous paper (Bortolotti et al., 2001b; 2002a) to explain the geodynamic evolution of the Argolis ophiolites and related continental margins which are:

a- a Triassic opening of the Vardar ocean;

b- Triassic oceanic scars along a rifting zone, rapidly aborted;

c- a westward Triassic progradation of the Paleotethys, we chose, according to all the previous considerations, we chose the first one, with only one ocean, which developed eastwards (today geographic references) between the Pelagonian and Rodope Massives, and that lived from the Middle Triassic to the Late Jurassic - earliest Cretaceous. The Jurassic evolution is inspired to the models of Bortolotti et al. (1996; 2002b) elaborated for the Mirdita ophiolites and related continental margin rocks.

A tentative evolution scheme from Triassic to Eocene

The seven drawings of Fig. 5 try to schematise the evolution of an E-W transect crossing the Hellenides in correspondence of the Argolis Peninsula.

Anisian

The literature data suggest that during this period, characterised by a widespread volcanic activity, most rock formations in the Argolis and also as far as the whole Pindos zone document a relatively deep sea environment, oriented roughly east - west, and bounded to the south and north by carbonate platforms (see Dercourt et al., 1993).The volcanites occurred all along this basin. Up to now, evidences of an oceanic sea floor is missing (Fig 5A).

Ladinian - Carnian

During this period, in the Argolis the carbonate platforms prograded onto the pelagic deposits; only locally, pelagic sedimentation continued. The paleogeography was so articulated in large platforms with smaller intra-platform basins. Eastwards, the continental margin probably deepened and made transition to an ocean floor. The opening of an ocean east of Argolis, in the Vardar zone, during the Ladinian, is testified by radiolarian faunas intercalated in MOR basalts of the Migdalitsa Ophiolite Unit. This oceanic basin could have been a prograding branch of the Paleotethys or may record the incipient opening of a new ocean (the Western Tethys or "Neotethys") separating the Adria Promontory from Eurasia (Fig 5B).

Early-Middle Jurassic

Drowning of the carbonate platforms of the Pelagonian continental margin, began in the Early Jurassic, it continued passing below the CCD, during the Bajocian with the sedimentation of radiolarites.

In the oceanic domain an intra-oceanic subduction zone, evidenced by the presence of IAT volcanites and boninitic rocks contemporaneous to MOR basalts. In the suprasubduction domain, in front of the IAT deposition area, the Triassic-Jurassic trapped crust (Migdalitsa Ophiolite Unit) survived in a fore - arc position (Fig. 5C).

Late Jurassic - Early Cretaceous

During the Late Jurassic, obduction of the ophiolitic units onto the continental margin began. This is documented by the occurrence of the ophiolite-derived Potami Formation and Kandhia Breccia at the top of the Trapezona Unit (continental margin). The presence of clasts of IAT and boninitic rocks in these formations let us to suppose that in the oceanic domain the IAT ophiolites and related mélanges (Iliokastron Unit?) overthrust and completely covered the Migdalitsa MOR ophiolites, shedding debris in the Potami and Kandhia Formations.

The presence of Jurassic granitoids in the Adheres Mélange and of amphibolised diorites and sialic metamorphites in the Iliokastron Mélange could be correlated to anatectic magmas from an uplifted continental margin (like in Fanos, Monopigadhon, etc.). The granitoid clasts and blocks in the Adheres Mélange could be reworked elements (as others blocks) of the Iliokastron Mélange (like the Simoni Mélange and/or Rubik Complex of the Mirdita Zone, Albania, Bortolotti et al., 1996) (Fig. 5D).

Early Cretaceous

The previous situation evolved with the complete thrusting of the Dhimaina Ophiolitic Unit onto the Trapezona Unit. Later on, emersion followed by erosion took place, possibly in connection with the beginning of underthrusting of the External Hellenides (Fig. 5E).

Late Cretaceous - Early Eocene

A marine transgression occurred above the eroded surface, and the neritic and pelagic carbonate sediments of the Lygourio Mesoautochthon and Faniskos Unit were deposited. These carbonates were followed by the sedimentation of a silty-arenaceous Flysch. Since the flysch deposition occurred during an important compressive tectonic phase, it probably took place in piggy-back basins (Fig. 5F).

Early-Late Eocene

During this period, and particularly after the Ypresian, the different units reached the present position. The Iliokastron and the Faniscos Units, thrusting over the flysch of the Adheres area, shed on it slivers and blocks of different composition. The week metamorphism recognised in the area can be related to this thrusting (Fig. 5G).

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