SHORT NOTE

NEW GEOLOGICAL OBSERVATIONS AND BIOSTRATIGRAPHIC DATA ON THE ARGOLIS PENINSULA: PALAEOGEOGRAPHIC AND GEODYNAMIC IMPLICATIONS

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INTRODUCTION

The ophiolites of the Dinaric-Hellenic belt still pose intriguing questions. In fact their ages, the oceanic domains of pertinence, the mechanisms of formation, the paleogeographic positions with respect to the nearby continents, have been and still are matter of very hot debates.

We here present the preliminary results of our researches on the geology of the Argolis Peninsula. We studied the stratigraphic and structural organisation of the pile of the tectonic units and in particular focused our attention on the age of the radiolarian cherts at the top of the ophiolitic sequence, and on the tectonic-sedimentary features of the so-called ophiolite-bearing Ermioni Complex (Robertson et al., 1987). The petrography of the basalts has been object of a co-ordinate work by Saccani et al. (2002). The new data allowed to suggest a new tectonic interpretation of the Argolis Peninsula and of the Mesozoic geodynamic evolution of this sector of the Hellenides.

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

The Pelagonian Zone (comprising also the Subpelagonian), includes the Argolis Peninsula and, according to ancient authors it consists of a Paleozoic metamorphic basement, covered by Permo - Jurassic sediments (see Mercier, 1966). The formations pertaining to a continental margin are overthrust by a stack of tectonic units with ophiolites and tectonic mélanges (Aubouin et al., 1970; Jacobshagen et al., 1976). These latter include and are overthrust by Upper Jurassic to Upper Cretaceous calcareous successions and by a Tertiary flysch.

More recently, Baumgartner (1985) subdivided the Pelagonian realm of the Argolis Peninsula into two stacks of tectonic units juxtaposed by a strike-slip fault. From the bottom upwards they are: **i**- the external stack (Adhami Composite Unit), which comprises the Basal Sequence and the Asklipion Unit, both pertaining to the Pelagonian continental margin, and the Migdhalitsa Ophiolite Unit (middle Jurassic); **ii**- the internal stack (Dhidhimi - Trapezona Composite Unit), which comprises the Basal Sequence, the Asklipion Unit, and the Migdhalitsa Ophiolite Unit, unconformably covered by the "Mesoautochthonous" of Turonian to Eocene age. Afterwards, during the Eocene this stack was overthrust by: **iii**- a nappe of "sheared serpentinites", these too unconformably covered by the "Mesautochthonous".

Clift and Robertson (1990) simplified this scheme: they concluded "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) studying the eastern portion of Argolis (Adheres Peninsula), slightly modified the previous scheme, and considered the presence of a carbonate (shallow water and pelagic) basal unit covered by an "Ophiolitic Mélange" (Late Jurassic). The carbonates and the mélange are "conformably and unconformably" overlain by the "turbiditic flysch of the Ermioni Complex".

TECTONIC INTERPRETATION

According to our observations, the structure of the Argolis Peninsula consists of a stack of five tectonic units, from the bottom upwards: Trapezona Unit, Dhimaina Ophiolitic Unit, Adheres Mélange Unit, Iliokastron Mélange Unit and Faniskos Unit (Fig. 1).

The Trapezona Unit

The Trapezona Unit corresponds to the Basal Unit of Baumgartner (1985), modified by Clift and Robertson (1990). It consists of Mesozoic formations; from bottom to top they are: **i**- Lower - Middle Triassic andesitic lavas and tuffs (Gaitanakis and Photiades, 1991), overlain by the Middle Triassic - Lower Jurassic shallow-water Pantokrator Limestones and/or by deep-water limestones deposited in intraplatform basins; **ii**- Toarcian - Dogger p.p Ammonitico Rosso or, directly, radiolarian cherts of middle Callovian - Oxfordian age. This succession is unconformably covered by **iii**- ophiolitic sandstones, alternating with Upper Jurassic radiolarites, and locally by carbonate breccias; **iv**- ophiolitic olistostromes with fragments of serpentinitic rocks, slightly metamorphic boninitic lavas and coarse-grained boninitic-type rocks which testify the presence of a (Jurassic?) subduction zone (island arc?; Dostal et al., 1991; Capedri et al., 1996) in an arenitic matrix containing ophiolitic, amphibolitic, calcareous and cherty clasts. These ophiolitic sediments, widespread in northern and central Argolis, and very rare in southern Argolis are the record heralding the thrust of the Migdhalitsa Unit.

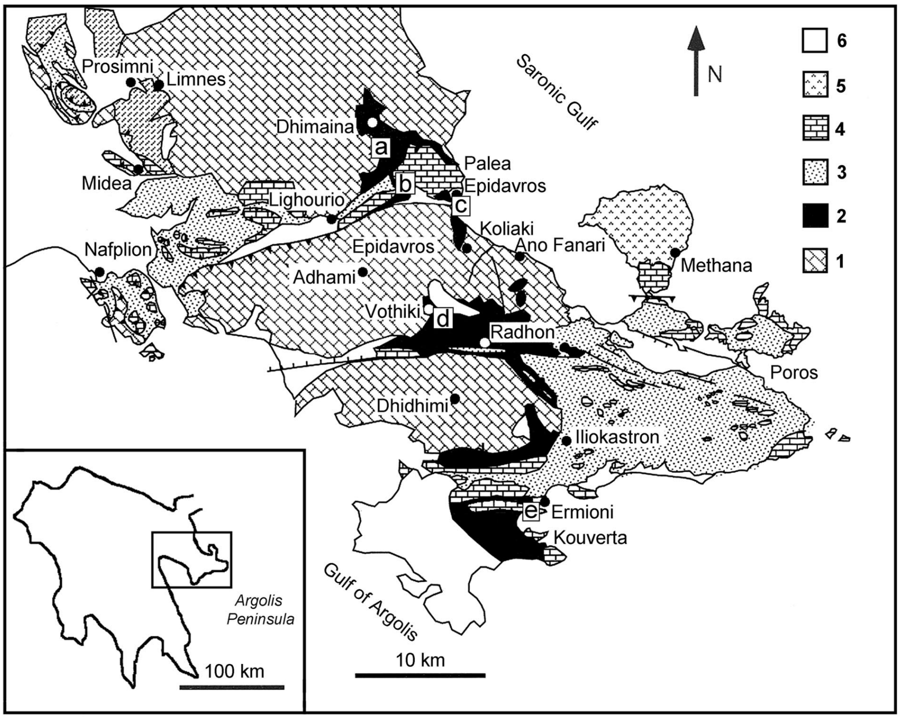

Fig. 1 - Sketch map of the Argolis peninsula. 1- Trapezona Unit; 2- Dhimaina Ophiolitic Unit; 3- Adheres Mélange Unit ; 4- Iliokastron Mélange Unit and Faniskos Unit; 5- Quaternary volcanites ; 6- Quaternary clastic deposits. Sampled sections: a- Moni Taxiarches; b- Palea Epidavros old mine; c- Palea Epidavros; d- Vothiki; e- Ermioni. (Modified after Clift and Dixon, 1998).

The Dhimaina Ophiolitic Unit

This unit includes both the "Migdhalitsa Ophiolite Unit" and the overlying "Mesoautochthonous Sequence" of Baumgartner (1985). We propose to call the "Migdhalitsa Ophiolite Unit" "Migdhalitsa Ophiolitic Complex" and the "Mesoautochthonous Sequence" "Lighourio Mesoautochthon".

The Dhimaina Ophiolitic Unit was emplaced onto the Trapezona Unit during the Late Jurassic - Early Cretaceous (Aubouin et al. 1970, Photiades, 1986) compressional tectonic phase. Successively it was unconformably covered by the Lighourio Mesoautochthon.

Migdhalitsa Ophiolitic Complex

In northern and central Argolis, it consists of thrust sheets, sometimes imbricate, of massive MOR dolerites and pillow lavas, often with serpentinite slivers at the base, cut by rare mafic dykes and covered by radiolarian cherts. Southwards this unit becomes similar to a tectonic mélange. We focused the study on the petrography of the basalts (Saccani et al., 2002) and on the ages of the radiolarites.

Petrographic data.

According to Saccani et al. (2002) the basalts constitute two distinct groups with unclear relations. The first group shows transitional-type MORB characteristics, very similar to present-day T-MORB; the second one typical normal-type MORB. Normal MORB characteristics for these basalts were described also by Dostal et al. (1991) which, *fide* Baumgartner (1985) considered these rocks of Jurassic age.

Biostratigraphic data (by M. Chiari and M. Marcucci).

We collected many samples of radiolarian cherts near their contact with the basalts. All gave similar results: the radiolarian cherts, and hence the underlying basalts, are of Middle - Late Triassic age. Five sections (Fig. 1) are the more meaningful ones, for the good preservation of the radiolarians, three in northern, one in central and one in southern Argolis:

Northern Argolis

a. *Moni Taxiarches*, along the road from Lighourio to Dhimaina, south of Moni Taxiarches. One sample (GR 51), 30 cm above the basalts gave a Late Triassic (latest Carnian - earliest Norian) age for the presence of *Capnodoce anapetes*, *Capnodoce extenta*, *Capnodoce serisa* and *Capnuchosphaera deweveri*.
b. *Palea Epidavros old mine*, near the main road from Lighourio to Palea Epidavros. A sample 50 cm above the basalts (GR 49) gave a Middle - Late Triassic age for the presence of *Pseudostylosphaera* sp.; a sample few metres above the basalts (GR 47) gave a Middle - Late Triassic (late Ladinian - middle Carnian) age for the presence of *Pseudostylosphaera nazarovi*; finally, a sample of uncertain stratigraphic position (GR 50), gave a Late Triassic (early Norian) age for the presence of *Capnuchosphaera constricta*, *Capnuchosphaera crassa*, *Capnuchosphaera lea* and *Capnuchosphaera triassica*.
c. *Palea Epidavros*. Four samples from an outcrop of radiolarian cherts with the contact with the basalts is not directly visible (GR 67, 68, 69, GR 70) gave a Late Triassic (Rhaetian) age for the presence of *Livarella valida.*

Central Argolis

d. *Vothiki*, in a little quarry near the village, along the road from Trachia to Karnezéika. A sample included in the basalts (GR 71) gave a probably Triassic badly preserved radiolarian assemblage; a sample 70 cm above the basalts (GR 181) gave a Late Triassic age (latest Carnian - ?late middle Norian) for the presence of *Xiphoteca longa*; finally, a sample of uncertain stratigraphic position gave a Middle - Late Triassic age for the presence of *Pseudostylosphaera* sp. and *Vinassaspongus* sp.

Southern Argolis

e. *Ermioni*, near Paloukia Hill (south of Ermioni). A sample collected in a small radiolarian cherts sliver that is imbricated tectonically in the serpentinites (GR 221) gave a Late Triassic age for the presence of *Capnodoce* sp. This radiolarian cherts is probably associated to the nearby basalts.

These ages of the radiolarian cherts and, consequently, of the underlying basalts rise an intriguing problem. In fact, in the area of Migdalitsa (not far from Votiki) they were dated as late Bajocian - early Callovian by Baumgartner (1985; 1995) but all our determinations indicate always Middle-Late Triassic ages. These different, but reliable, ages found at short distances from each other, can suggest imbrication of thrust sheets of Triassic and Jurassic ophiolitic sequences.

Lighourio Mesoautochthon

Above the pillow lavas, or locally directly on the Pantokrator limestones, Cretaceous limestones occur considered (according to Baumgartner, 1985) as a meso-autochthonous sedimentary sequence. They include: Albian to Cenomanian neritic limestones; breccias rich in basaltic and cherty clasts cemented by Campanian - Maastrichtian hemipelagic limestones; Palaeocene - Lower-Middle Eocene pelagic to reefal limestone; well organised “post-Ypresian flysch”.

The Adheres Mélange Unit

The Migdhalitsa Unit is tectonically overlain by a stack constituted by several tectonic slices of heterogeneous lithologies that we here propose to call “Adheres Mélange”. The characteristics of this Unit vary notably from south-eastern to north-western Argolis Peninsula, possibly due to a decrease of tectonic deformation.

Stratigraphical and structural observations on the Adheres Mélange Unit

According to Suesskoch et al. (1984) the Adheres Peninsula (south-eastern Argolis), is characterised by a strongly deformed, mainly arenaceous Paleocene-Eocene flysch. According to Clift (1996), the flysch, up to 8 km thick, is strongly deformed and sheared and includes blocks of ophiolites and limestones; together they constitute a stack of thrust sheets, called from the author “Ermioni Complex”, and corresponding to a subduction/accretion complex. The same author recognised, through analysis of the deformation features (fracture cleavage, block-in matrix fabric and brittle pull-apart deformations) a main thrusting event towards the north-east, with minor back-thrusts.

According to our observations, the “flysch” of the previous Authors is generally not organised and it is affected by strongly pervasive deformations; the contacts of the arenaceous rocks with the enclosed blocks are tectonic. These blocks consist of: **i**- neritic and pelagic limestones of Triassic and Jurassic age, probably derived from the Trapezona unit; **ii**- Triassic basic rocks and radiolarites; **iii**- Upper Jurassic conglomeratic limestones, locally associated with Middle - Upper Jurassic granodiorites (Photiades and Keay, 2000); **iv**- dolomites and quartz sandstones and conglomerates; **v**- pyroclastic rocks including andesitic blocks; **vi**- serpentinites; **vii**- pelagic limestones of Campanian - Maastrichtian age; **viii**- MOR basalts with sulphide and manganiferous mineralisation; **ix**- neritic limestones of Campanian - Maastrichtian age, locally overlain by pelagic detritic limestones of Maastrichtian - Aptian-age. At the top they grade into a turbiditic flysch of Paleocene - Eocene age (see Clift, 1996); **x**- pelagic detritic limestones of Aptian - Maastrichtian age.

These features suggest to interpret the “Ermioni Complex” as an association of several tectonosomes (Pini, 1999), in which the flysch sediments constitute the matrix of a tectonic Mélange, that we propose to name “Adheres Mélange”.

In north-western Argolis ,the same geometrical position of the Adheres Unit is occupied by the above mentioned “post-Ypresian flysch”.

Iliokastron Mélange Unit

This tectonic unit corresponds to the “Sheared Serpentinites” of Baumgartner (1985).

The Iliokastron Mélange consists mainly of brecciated and schistose serpentinised harzburgite as matrix and includes blocks of harzburgite, dunite, rodingites, basalt, boninite, with a suprasubduction-related geochemical signature (Dostal et al. 1991, with references) cherts and limestones coming from the underlying units and metamorphic rocks (marble, metagraywacke, micaschist and amphìbolite).

Faniskos Unit

The tectonic Faniskos Unit corresponds to “Mesoautochthonous Sequence” of the “Akros Unit” of Baumgartner (1985).

The sheared serpentinites of Iliokastron Mélange Unit are tectonically overlain in northern and in southern Argolis by large slices of calcareous rocks (Photiades, 1986), including: **i**- thin limestone slivers of Kimmeridgian - Portlandian age; **ii**- thick neritic limestone successions ranging from Barremian and/or Aptian to Turonian, overlain by pink hemipelagic limestone of Campanian-Maastrichtian age; **iii**- a carbonate sequence of middle Cenomanian - middle Maastrichtian age with a recession of sedimentation (hiatus) during the late Cenomanian - early Turonian (“Akros Formation”, according to Decrouez, 1976); **iv**- deep-water limestones of Aptian - Maastrichtian age.

DISCUSSION AND CONCLUSION

The geological interpretation of the Argolis Peninsula that we propose does not differ much from that of Baumgartner (1985), modified by Cliff and Robertson (1990). The main differences consist in considering the Flysch Units of Cliff and Robertson (1990) and the “Sheared Serpentinites” of Baumgartner (1985) as tectonic mélanges (the Adheres and the Iliokastron Mélanges, respectively), and in subdividing the tectonic pile into five units.

The widespread findings of (Middle?) - Triassic ages of the radiolarian cherts and related MOR basalts of the Dhimaina Ophiolitic Unit are the more important result of our study. They suggest that this ophiolitic unit represents a tessera of a mosaic of Triassic “ophiolites” reported by several authors (Halamić and Goričan, 1995; Channell and Kozur, 1997; Danelian and Robertson 2001) along the Dinaric-Hellenic orogenic belt[1].

The existence of Triassic oceans demised along the Dinaric-Hellenic belt has been proposed by some authors: e.g. the Triassic Meliata Ocean (see Channell and Kozur, 1997) or the Triassic opening of the Vardar ocean invoked by Ha-

[1] The same ages are shown by alkaline basalts along the same orogenic belts, as well as along the Alpine-Appenninic chains, both in blocks included in the mélanges and in intercalations in the continental margin successions.

lamić and Goričan (1995) and Danelian and Robertson (2001). These latter authors in a work on Eubea interpret a pile of thrust sheets of Transitional MOR basalts, Middle Triassic cherts, Middle Jurassic cherts and limestones, included in a mainly tectonic mélange, as a continuous ophiolitic sequence from Middle Triassic to Middle Jurassic. They assign these ophiolites to a vaguely defined "Neotethyan Ocean" , which would have been almost completely consumed during subduction.

The time gap between the (Middle) - Late Triassic and the Middle Jurassic shown by the age data obtained up to now on the "ophiolites" of the Dinaric-Hellenic belt is a problem that still has to be solved. We can consider the following hypotheses about a linkage between the Triassic and Jurassic ophiolites of the Argolis and of the Dinaric-Hellenic domain in general:

1. A Triassic opening of a proto Vardar ocean and its more or less complete disappearance during the Jurassic subduction when oceanic crust (east-Mirdita, Pindos, Vourinos ophiolites) was formed in a suprasubduction domain. In fact, the "subduction" characteristics of the major outcrops of the Middle Jurassic ophiolites of this belt lead to think that they formed as a consequence of the subduction of an older oceanic lithosphere whose scattered remains could be represented by the scarce Triassic outcrops.
2. A rifting to embrional oceanic break-up during the (Middle) - Late Triassic in the proto-Pelagonian continental margin which rapidly aborted. Successively, a new Middle Jurassic ocean opened and it was more or less contemporaneously subducted eastwards under the Rhodope continental block.
3. A westwards prograding opening of the Paleotethys, at least as far as the Argolis (Bortolotti et al., 2001), to which a Jurassic evolution followed, as described for hypothesis n.1.

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